COURSE OF TECHNICAL INSTRUCTION

TELEPHONY 3.

Engineering Training Section, Headquarters, Postmaster-General's Department, Melbourne C.2.

THE AUSTRALIAN POST OFFICE

COURSE OF TECHNICAL INSTRUCTION

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TELEPHONY III.

REISSUED, 1951.

Because of the limited use of this system in Australia Paper No. 9 is not included in this book. It is, however, available as a separate Paper upon application to this office.

INDEX.

/ Impulsing

/ Nickel

/ Magnetic

/ S. T. and C.

/ Two

COMMONWEALTH OF AUSTRALIA.

Engineering Services,
Postmaster-General's Department,
Treasury Gardens,
Melbourne, C.2.

COURSE OF TECHNICAL INSTRUCTION.

RELAYS.

CONTENTS.

1. INTRODUCTION.

1.1 In Telephony I, relays were introduced and some of the methods used for introducing time lags into the operation and release of relays have been discussed in Telephony II. The vast majority of relays used in telephony function electromagnetically, but it might be noted at this stage that other principles may be used. The thermionic valve is a relay in the general sense of the word, and has the exclusive advantage of a zero time lag. The thermostat relay is used for special applications and will be described later in this Paper. In fact, any of the effects of an electric current or potential difference could be used to relay changes of current or potential from one circuit to another.

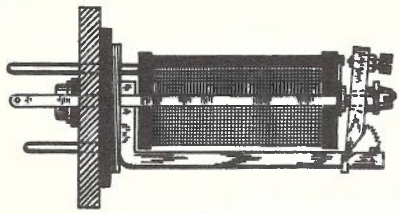
1.2 This Paper deals with details of construction and characteristics of the more common types of relays in use in the Commonwealth. Relays for telephone working operate on comparatively small values of power and have many special requirements, the main ones being listed below -

(i) Sensitive.
(ii) Reliable.
(iii) Small in size.
(iv) Inexpensive.
(v) Easy to adjust and maintain.
(vi) Free from dust trouble.
(vii) Immune from effects of external fields.

2. EARLY MANUAL TYPES.

2.1 Many types of relays have been used in early Manual exchanges, and the fact that many of these are still functioning indicates that the design of the relays, although crude by present-day standards, was fundamentally sound.

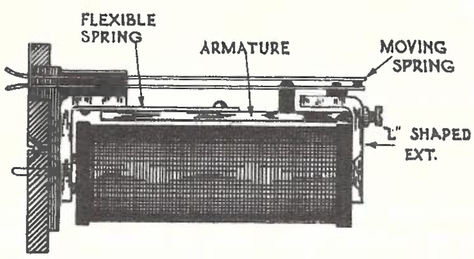
2.2 Knife-Edge Relay. (Fig. 1.) This type has a gravity controlled type armature. The magnetic circuit is completed between the core and the armature by a soft-iron "yoke". The armature has a bevel on the lower edge which rests in a groove at the front end of the yoke. A contact is placed at the top edge of the armature, giving adequate clearance between contacts with a short stroke, consequently the sensitivity of the relay is quite good. The distance between core and armature, when the armature is operated, is adjusted by means of the screw contact on the armature, and the position of rest is determined by an adjustable stop screw. When this type of relay carries speech currents, a screw-on individual dust cover is provided which also serves as an electrostatic shield preventing crosstalk between adjacent relays. An example of this application is in the cord circuit supervisory relays of a C.B. No. 1 exchange. In these exchanges, this type of relay is often used as a line relay and individual covers are not required. Strips of ten line relays and their associated cut-off relays are protected with a common dust cover. A disadvantage of this type of relay is that it is not possible to mount more than one pair of contacts on it.



KNIFE-EDGE RELAY.

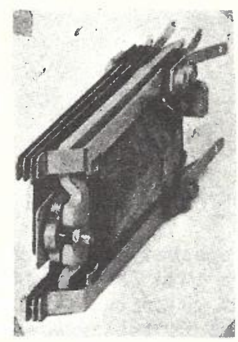
FIG. 1.

2.3 Multi-Contact Relays. A cut-off relay carrying two pairs of break contacts is shown in Fig. 2. The armature is loosely suspended by means of a flexible spring underneath two L-shaped extensions of the core, and operates the nickel-silver moving springs by means of short ebonite pips. An adjustable back-stop screw is provided. Three "piles" of contact springs may be mounted side by side on this type of relay.



CUT-OFF RELAY.

FIG. 2.



FLAT TYPE RELAY.

FIG. 3.

2.4 Flat Type Relays. This type of relay is shown in Fig. 3 and is representative of modern manual type relays. It is a "minor" relay, that is, it has no special facilities, but is economical in mounting space and in cost.

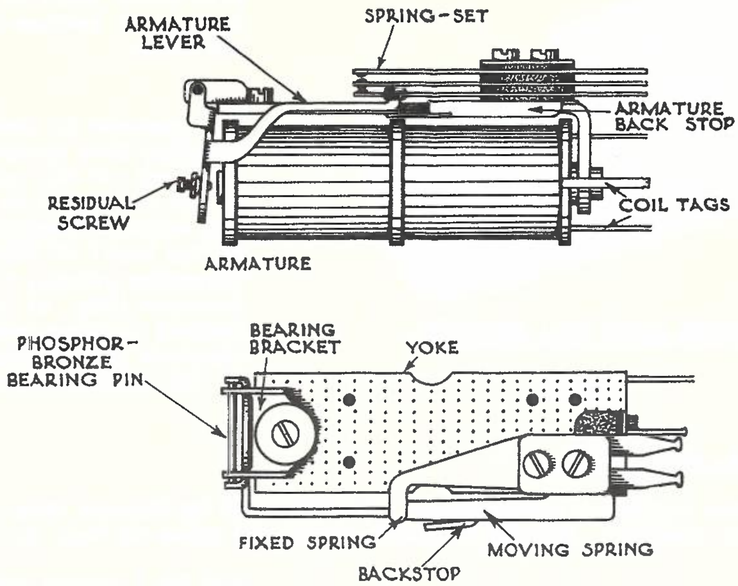
The armature is U-shaped, and is hinged on flat springs at the heel end of the relay. The core is flat in cross-section, and this is not so economical as a round section as regards the length of wire per turn of winding. However, it allows the parts to be pressed out, reducing manufacturing costs. An individual cover is provided to prevent interaction between adjacent relays.

2.5 The magnetic circuit of the multi-contact type relay, previously described, is not as efficient as the knife-edge type because of the comparatively large air-gap at the hinge end of the armature, and development in relay design has tended towards eliminating air-gaps while still retaining the spring type of contacts. The L-shaped armature achieves this object and this type of construction has been used almost exclusively for Automatic telephony. Detailed descriptions of the various types are given below.

/ 3.

3. HORIZONTAL SWITCH TYPE (STROWGER TYPE).

3.1 Fig. 4 shows the details of construction of a typical relay of this type. They were manufactured by various companies and used extensively in Automatic exchanges of the Strowger Type.

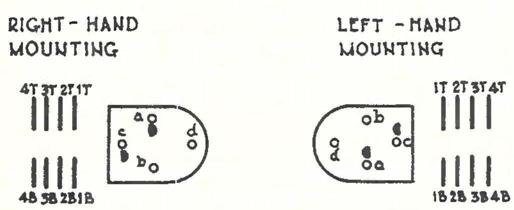


HORIZONTAL SWITCH TYPE RELAY.

FIG. 4.

3.2 The armature is pivoted on a phosphor-bronze pin, held by a brass bearing bracket which is clamped to the iron yoke. This clamp is adjusted to give a minimum clearance (1-1/2 mils) between the yoke and armature in its operated position, to prevent mechanical binding of the armature. An adjustable brass residual screw and lock-nut is fitted to the armature. The nickel-silver springs operated by the armature lever, overhang the side of the yoke and this allows the moving springs to be coupled together by means of ebonite collets. A back-stop for the armature is fastened at the base of the spring assembly, which is clamped together and attached to the yoke by insulated screws.

3.3 The coil is wound on to the core between fibre end cheeks, empire cloth being used for insulation and protection of the winding. There are a maximum of four coil tags, numbered as shown in Fig. 5. The first winding is connected to tags a-b, and where a second winding is provided it is wired to c-d. On relays with balanced windings a centre coil cheek is fitted and the winding on the armature end is connected to a-b.



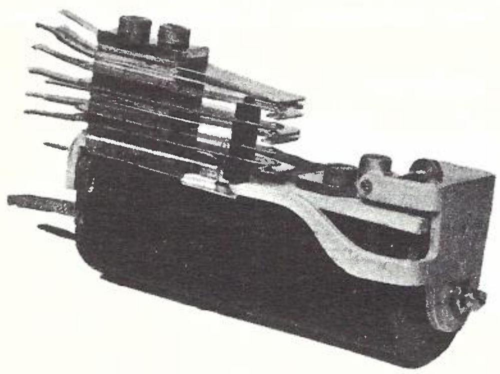
SPRING AND COIL NUMBERING (FROM REAR).

FIG. 5.

3.4 In all cases these relays are mounted on their sides so that dust will not settle on the contacts. As the springs are usually mounted in one pile on the upper side of the yoke, both left-hand and right-hand relay assemblies are used on relay sets. Where the number of contacts is large, a double armature may be used. These, however, take up more mounting space than single arm types.

/ The

The maximum number of contacts that can be fitted is 11 per spring pile on a left-hand relay and 14 per spring pile on a right-hand relay. This is because the pairs of relays are mounted eccentrically on the mounting plate. Some relays are fitted with guide posts to prevent the fouling of springs when replacing the cover.



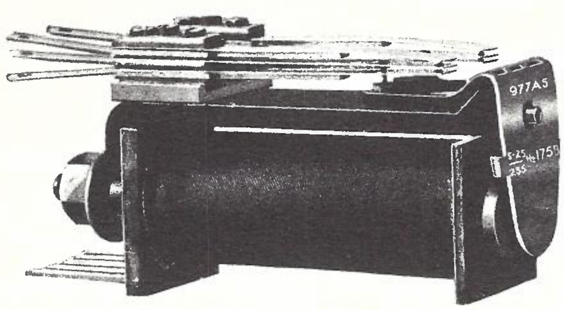
STROWGER RELAY (2:1 ARMATURE).

FIG. 6.

The armature in common use on ordinary fast relays has a ratio of travel of the springs (measured at the contacts) to the travel of the armature (measured at the centre of the core) of three to one. On slow releasing relays, a 2:1 ratio armature (Fig. 6) is used; the reduced leverage assisting the armature to withstand the pressure of the springs during release.

4. SIEMENS AND B.G.E. AUTO. TYPES.

4.1 The relay shown in Fig. 7 was designed and introduced by Siemens Bros. and later used by the B.G.E. Company. Details of construction are given in Fig. 8.



SIEMENS RELAY.

FIG. 7.

4.2 The L-shaped armature rests on a machined knife-edge at the end of the yoke. A notch in the centre of the knife-edge engages with a small pip on the inside of the V-bend in the armature, and this prevents lateral displacement of the armature. Lifting of the armature is prevented by a stud, passing through a hole in the armature and screwed into the vertical face of the knife-edge. The relays are generally mounted on their side and in such cases a nickel-silver carriage, forming a loosely fitting hinge over the armature, holds it in place.

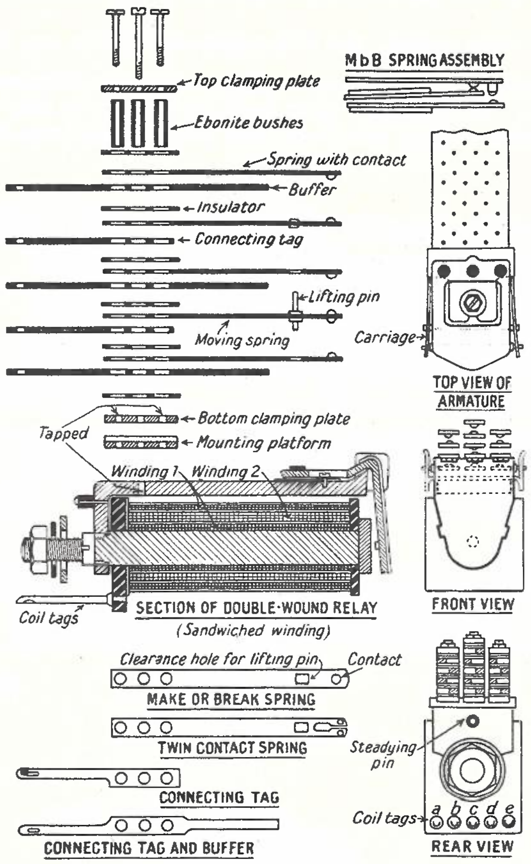
4.3 A residual air-gap may be provided by an adjustable brass screw and lock-nut, but where the residual value is not critical, phosphor-bronze residual studs are riveted on the inner face of the armature. Fixed residuals of 20 or 12 mils are provided by a single stud, but if a gap as small as 4 mils is required, three residual studs are considered necessary to ensure that the core and armature do not touch during operation.

4.4 The cylindrical soft-iron core is a forced fit in the heelpiece of the yoke, and a circular brass nut holds it rigidly in position. At the armature end of the core is an enlarged pole face, and this reduces the reluctance of the armature air-gap, so improving the magnetic efficiency.

4.5 Relay coils are wound directly on to the core between bakelite cheeks. A maximum of five coil tags may be provided, numbered as shown in Fig. 8. A single coil is terminated on tags a-e, but where two coils are required the inner winding is

/ connected

connected to a-b, the outer one to d-e. Where balanced windings are required, a "sandwiched" winding is employed, as shown in Fig. 8. The centre winding is connected to tags d-e in this case. In all cases the inner end of any winding is connected to the left-hand tag, and usually painted red, indicating that the earthed positive pole of the exchange battery should be connected to that side.



SIEMENS AUTO RELAY ASSEMBLY.

FIG. 8.

4.6 Up to 18 springs may be mounted in three piles, which are each held together by two screws, a third screw passing through into the yoke. Thus, a spring-set may be removed as a whole simply by removing the centre screw. The first moving spring in each pile is lifted directly by one of the three ebonite pips on the armature, a brass "lifting pin" is provided, if necessary. A second spring-set above this is operated by a lifting pin passing through holes in intermediate make and break springs, with an ebonite insulating pip where the brass pin touches.

4.7 Buffer springs are fitted parallel with certain contact springs and are extended to the back of the relay to form substantial soldering tags. The contact springs are tensioned against their buffer spring ensuring adequate contact pressure during operation. The buffer springs also tend to reduce contact "bounce". However, they make it rather difficult to adjust the contact springs.

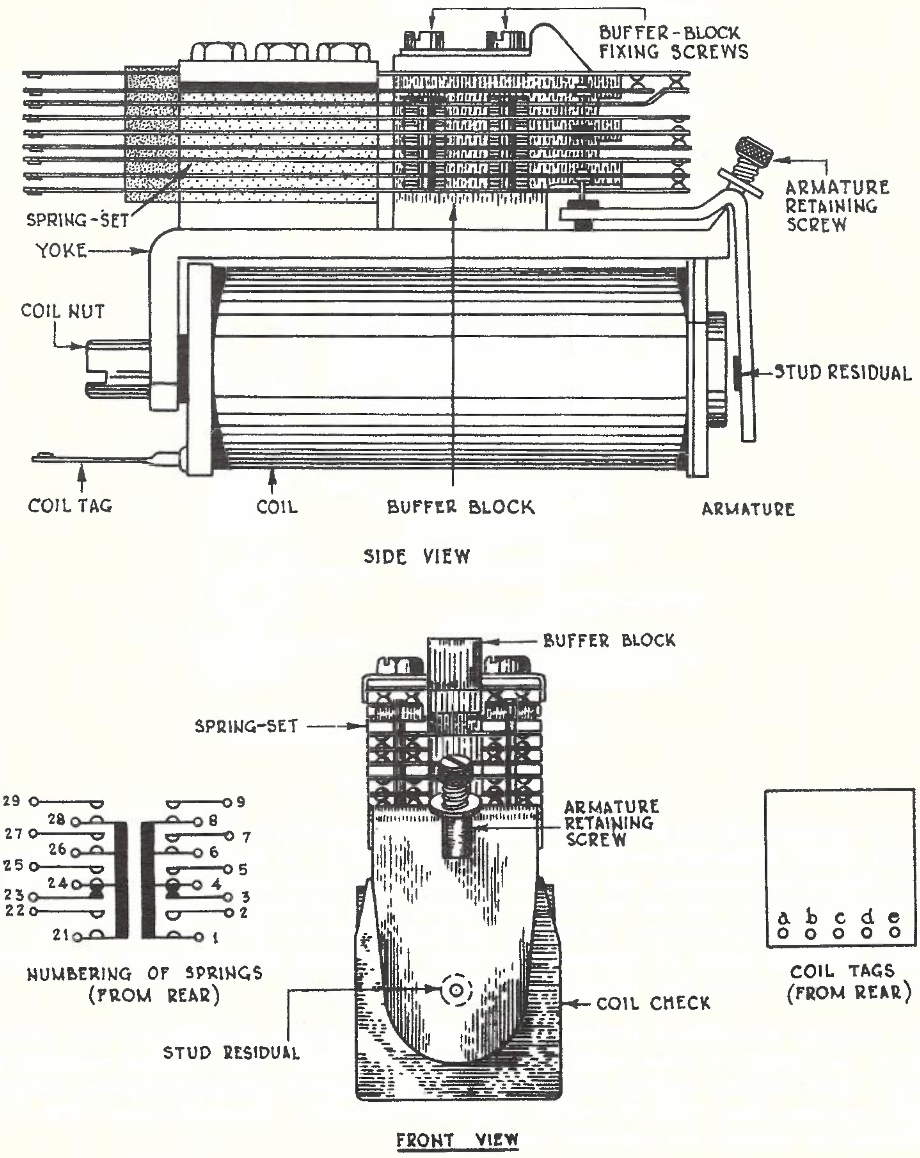
4.8 On the Siemens type of relay, the iron parts are protected from rust by either nickel plating subsequent to copper plating, or, alternatively "coslettising", which is a chemical process producing a surface layer of phosphate or iron giving a dull, black finish.

5. 3,000 TYPE.

5.1 About the year 1932 the British Post Office developed a standard telephone relay, utilising many features of existing types, notably Siemens, as well as introducing some entirely new features. Known as the 3,000 type relay, the design was subsequently adopted by the A.P.O. as a standard major relay.

5.2 Fig. 9 shows the 3,000 type relay, and its component parts are depicted in Fig. 10.

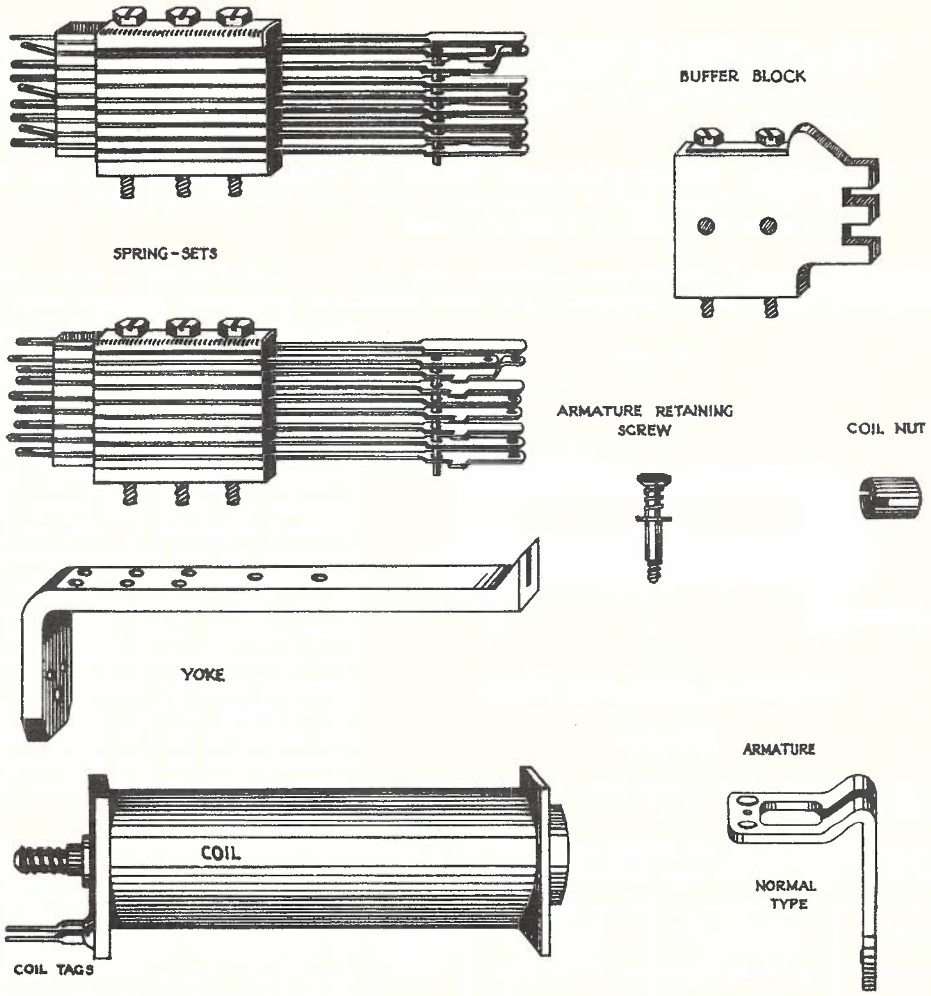
The core is of soft iron, and with its windings, can be withdrawn as a unit by removing the coil nut. An enlarged pole face is fitted to the core. The windings are terminated on tags fixed to the bakelite rear coil cheek (see Fig. 9).



THE 3,000 TYPE RELAY.

FIG. 9.

A single winding is connected to tags a-e, and when two windings are used the inner winding terminates on a-b, the outer winding on d-e. Sandwich winding is used for balanced windings. A maximum of four windings can be provided on a coil, one side of each winding being commoned in that case.



3,000 TYPE RELAY PARTS.

FIG. 10.

The tag to which the inner end of a winding is connected is usually painted red, indicating that it should be connected to earth side of the circuit. Apart from various windings, five types of coil are in normal use -

(i) Plain. This type of coil is fitted with a copper front cheek, and is used in most cases, except when operating time is critical. The cheek acts as a small armature end slug, and, while not considerably affecting the operating and releasing times, minimises armature oscillation and consequent contact bounce.

(ii) Nickel-Iron Sleeved. These coils are fitted with three 12 mil split sleeves of nickel-iron sheet (36 per cent. nickel) and are used where the maximum impedance to speech currents is required. Both cheeks of the coils are of S.R.V.P. (synthetic resin varnished paper) board.

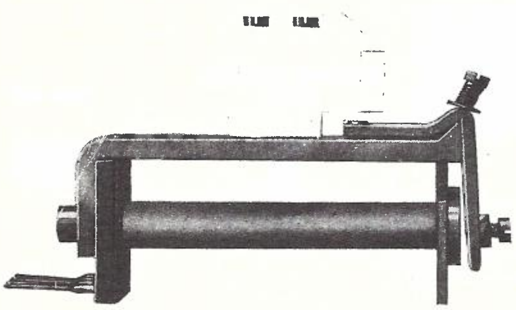
/ (iii)

(iii) Slugged. As explained in Telephony II, coils with armature end or heel end slugs are used where appreciable operate or release lags are required. Three standard lengths of slugs are employed - 1/2 in., 1 in. and 1-1/2 ins. With the largest slug, it is possible to obtain up to 100 mS operate lag, and 600 mS release lag under favourable conditions.

(iv) Plain (with Bakelite Front Cheek). In this coil, the copper front cheek is replaced with one of S.R.V.P. board. It is used where the relay must be critically fast in operation and where the slight slugging effect of the copper front cheek is undesirable.

(v) Nickel-Iron. Relays which must operate or release very fast (in the order of 5 mS) are fitted with a nickel-iron core, and the enlarged pole face is omitted. Coil cheeks are both of S.R.V.P. board.

5.3 The magnetic circuit may be seen clearly from Fig. 11, which shows a relay stripped of the winding and contact springs. All iron parts are protected against rust by nickel plating, and, as nickel is slightly magnetic, this form of protection introduces less reluctance into the magnetic circuit than other methods. The yoke is L-shaped and a machined knife-edge is formed at its front extremity. A close magnetic joint is effected between the yoke and core, which are clamped together by the coil nut. The armature is of light construction to minimise mechanical inertia and rides on the yoke knife-edge, lateral displacement being prevented by a spring-loaded retaining screw. The magnetic circuit is similar to that of the Siemens relay, and is very efficient, the majority of its reluctance being concentrated in the armature-core air-gap. Because of this, the 3,000 type relay is quite sensitive and heavy contact pressures can be used.



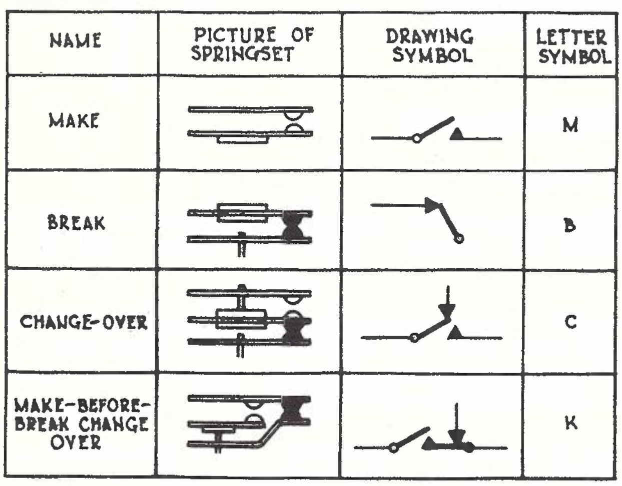
SKELETON OF 3,000 TYPE RELAY.

FIG. 11.

5.4 The residual air-gap is normally given by a phosphor-bronze stud riveted to the armature (see Fig. 9). These may have a nominal height of 4, 12 or 20 mils. Where intermediate values are required, or where adjustment is required to meet timing or other tests, an adjustable brass residual screw is provided. For reliable performance, the residual air-gap of this type of relay should never be reduced below 4 mils.

5.5 Springs and Contacts. The springs are of nickel-silver, and a maximum of eighteen may be fitted, arranged in two spring-sets. The loads on each spring-set are adjusted to be as equal as possible, and where there is only one spring-set it is arranged on the left side of the buffer block. Numbering of springs is shown in Fig. 9.

There are four standard contact actions employed and these are shown in Fig. 12. Standard spring thickness is 14 mils, but 12 mil springs are used in some relays, and in special cases thicker springs may be used. Twin dome contacts are standard and were first tested in the Siemens / type

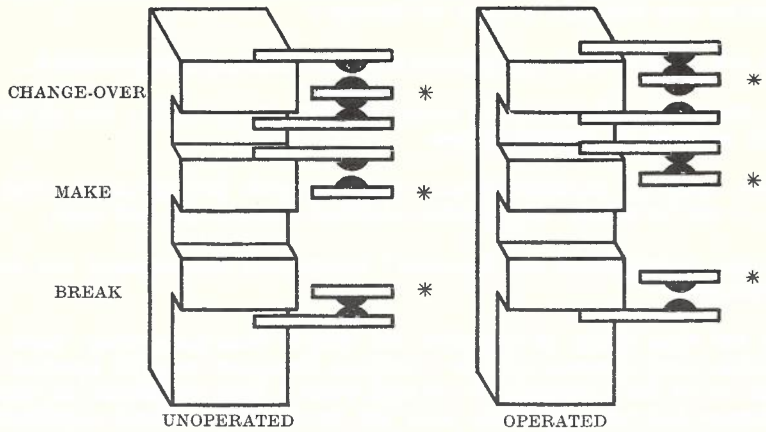


CONTACT SPRING UNITS.

FIG. 12.

type relay. Experiments show that contact dust troubles are reduced to approximately 2 per cent. by changing to twin contacts. The springs are split for a distance to allow each contact to function independently. Contact materials used will be dealt with later in this Paper.

5.6 Buffer Block. An outstanding feature of the 3,000 type relay is the use of a buffer block, serving to position the contact springs correctly. It is moulded from a white synthetic material, and a number of steps are accurately formed which engage on small lugs on the sides of make or break springs, so limiting their travel. (See Fig. 13.)

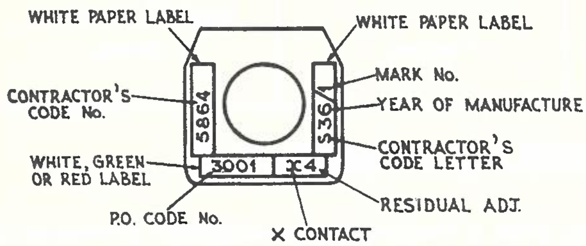


BUFFER BLOCK METHOD OF SUPPORTING SPRINGS.

FIG. 13.

The make and break springs are adjusted to bear against their buffer block step with a certain pressure, so that when the armature is operated or unoperated and the spring is lifted clear of the block, the required contact pressure is automatically obtained. This ensures a definite standard of contact pressure, and is an important point, as it has been proved that where low pressures are used fault liability is greatly increased. The white surface of the buffer block facilitates adjustment of the relay by providing a light coloured background against which the contacts stand out in sharp relief. The curved upper surface is arranged to guide a relay set cover safely over the contact springs.

5.7 Adjustments. Maintenance has been considerably simplified by the adoption of standard spring tensions and armature travel. Relays with standard 14 mil springs, and which can be maintained by the application of the standard adjustments. are fitted with a white label on the coil front cheek (Fig. 14). Relays with 12 mil springs are given a green label, and the spring tensions are reduced. Current tests are not required on these relays, and the residual value is marked on the paper label. When it is not possible to meet the circuit conditions with a relay in standard adjustment, it is fitted with a red label, which indicates that reference must be made to the relay adjustment card for details of adjustments and current tests.



LABELLING SYSTEM 3,000 TYPE RELAY.

FIG. 14.

The buffer block ensures that, provided the springs are straight, the correct contact clearances are automatically obtained.

/ 6.

6. 600 TYPE.

6.1 This type of relay is a "minor" relay modelled on the lines of the 3,000 type and designed for economy in capital cost and mounting space. It meets the simpler requirements of a straight relay with a small contact load, that is, a relay which is just required to operate and is equipped with not more than 12 springs. Its principal uses are as L and K relays, and in intercommunication telephones and cord type P.B.X's. The following are the main points of design -

(i) All 600 type relays are maintained by mechanical adjustments.

(ii) One thickness of spring is usually employed, 14 mils, but 12 mil springs may be used in special cases.

(iii) Three types of phosphor-bronze residual stud are employed, that is, 4, 8 and 12 mils. Adjustable residual screws are not used.

(iv) Current adjustments and "special" mechanical adjustments are not required.

(v) The 600 type relay is intended for simple functions only, that is, without nickel-iron sleeves or other devices designed to give special characteristics. The relay may, however, be fitted with a slug to obtain an operate or a release lag but such lags must not be critical, since adjustable residual screws are not used.

6.2 Its main features are compared with those of the 3,000 relay in the following table.

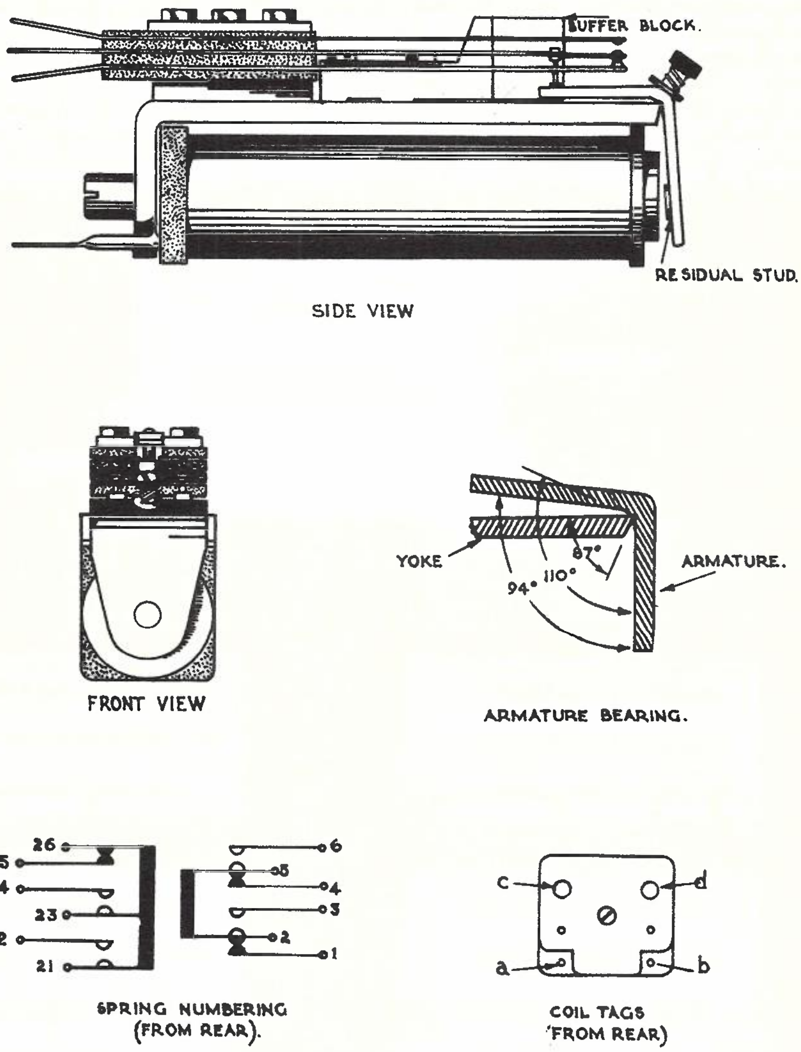
Features	3,000 Type	600 Type
Width	1"	3/4"
Height	1-7/8"	1-1/2"
Over-all Length	3-7/8"	3-3/8"
Maximum No. of springs	18	12
Thickness of springs	12 or 14 mils.	12 or 14 mils.
Residual Stud	4, 12 or 20 mils or residual screw.	4, 8 or 12 mils, no adjustable residual screw.
Maximum Permissible Power Dissipation.	7 watts.	4 watts.

COMPARISON BETWEEN 3,000 AND 600 TYPE RELAYS.

6.3 The core, its windings and coil tags, form a complete and independent sub-assembly, known as a "coil assembly," which may be removed (without unmounting the relay) by detaching the wiring from the coil tags, removing the armature and then unscrewing the coil nut. The spool, which is insulated and wound for voltages not exceeding 75, should not dissipate more than four watts in free air. The coil assembly with S.R.V.P. board cheeks, at front and rear, may have two or four coil tags which are identified by letters, as shown in Fig. 15. The coil should be viewed from the rear with springs uppermost or, if the spool is unmounted, with the notches in the rear spool cheek uppermost.

/ 6.4

6.4 The yoke has no knife-edge projecting as in the 3,000 type relay but the front edge is sheered at an angle of 87° and the armature is shaped to conform thereto making a bearing on this edge, as shown in Fig. 15. The buffer block may be a cylinder of white insulating plastic with concentric grooves, fastened by a metal bracket, or it may be a moulded block with projecting lugs. The block is fastened directly to the yoke by two screws. The latter type is superseding the circular type, both types being interchangeable.



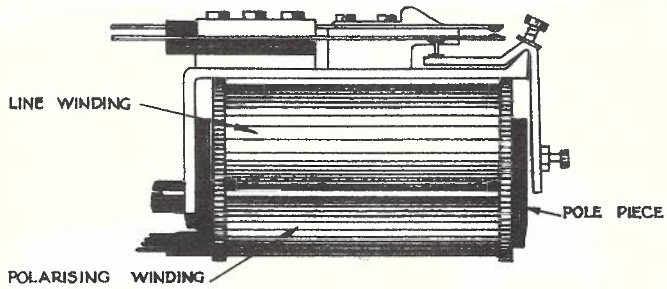
600 TYPE RELAY

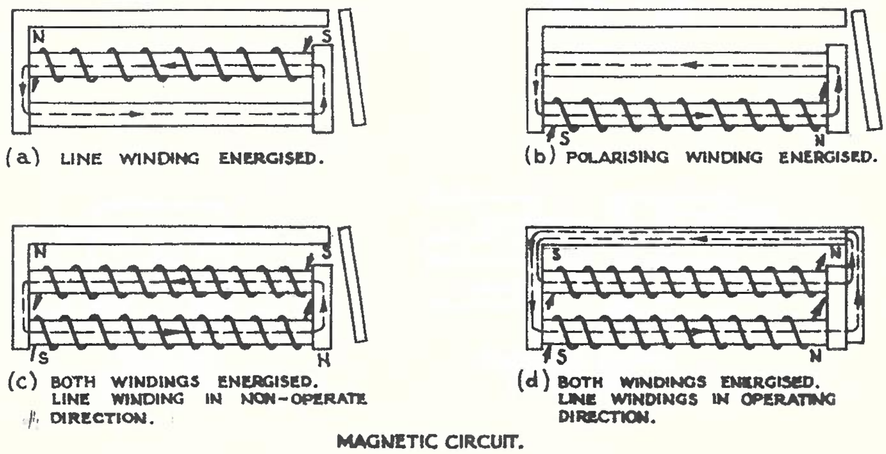
FIG. 15.

7. SPECIAL TYPES.

7.1 The relays described in the previous paragraphs of this Paper are all known as "ordinary" relays, that is, they operate on D.C., irrespective of the direction of current flow through the coil, and have no special features. Most of the relays used in telephony fall into this category, but occasions often arise where an ordinary relay is not suitable for a particular purpose, and special types of relays have to be introduced. In this Paper, some of the more common types of special relays will be described.

7.2 Shunt-Field and Polarised Relays. A polarised relay is one in which the relay operates only when the energising current flows through the coil in a specified direction. A shunt-field relay is a special form of polarised relay having two coils, and will not operate when one coil only is energised or when the two coils are energised in opposite directions, but will operate when both are energised in the same direction. A 3,000 type shunt-field relay and the principle of operation is shown in Fig. 16. In this relay the two coils are coupled together at each end by small yokes. The armature is slightly longer than that normally used on 3,000 type relays. Owing to the greater size of the shunt-field relay, it is necessary to limit the contact load to two units in order that the relay can be accommodated in the standard mounting space.

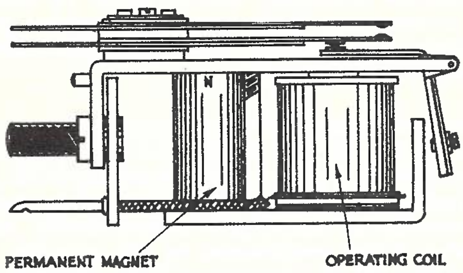




THE SHUNT FIELD RELAY.

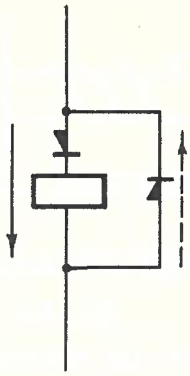
FIG. 16.

The polarised relay operates on a similar principle to the shunt-field relay, except that the polarising coil is replaced by a permanent magnet. An example of its use is in the automatic public telephone. (See Fig. 17.)



POLARISED RELAY.

FIG. 17.

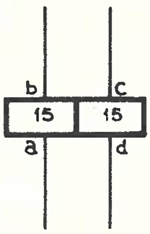


RECTIFIER-POLARISED RELAY.

FIG. 18.

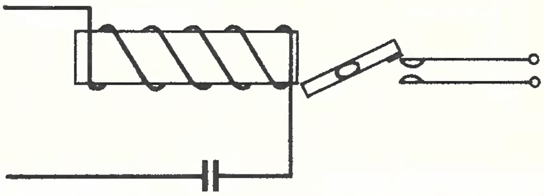
In the latest circuits both shunt-field and polarised types of relay are being superseded by ordinary non-polarised relays in conjunction with metal rectifiers, as in Fig. 18. With the current flowing in the non-operate direction, the shunt rectifier offers a low resistance and the series rectifier a high resistance. The current path is shown by the dotted arrow. When the current reverses, the series rectifier conducts readily and the shunt rectifier opposes any flow of current. The full arrow denotes the current path and the relay will be energised.

7.3 Differential Relay. (See Fig. 19.) This relay has two windings so arranged that when both are energised with current in appropriate directions, the magnetic effect of one winding is neutralised by that of the other, with the result that the armature will not operate. Any disturbance of this balanced condition resulting from an increase, decrease or reversal of current in either winding will, if the unbalance is sufficient, cause the relay to operate. This unbalanced condition can be caused in many ways, for example, by shunting one winding or placing resistance in series with it.



DIFFERENTIAL RELAY.

FIG. 19.



SIMPLE FORM OF A.C. RELAY.

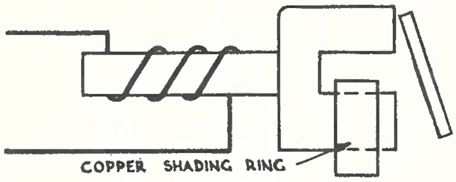
FIG. 20.

7.4 A.C. Relays. Relays are often required which will operate on low frequency A.C. The ordinary fast relay is unsuitable for this purpose owing to the release of the armature at each reversal of current. Special types of A.C. relays have been developed and the principle of operation of a typical design is shown in Fig. 20.

The armature is of considerable mass, and has a long travel. The inertia of the armature prevents it from restoring sufficiently during reversal periods to open the contacts.

/ Another

Another type is shown in Fig. 21. Known as a "Shaded Core" relay, it has a U-shaped pole face, one portion of which is encircled with a copper slug, acting to delay the flux changes on that part. Thus, that section of the pole face holds the armature operated while the reversals of flux are taking place in the other part. Still another type uses two separate windings, one of which is shunted by a condenser. Thus, the flux changes in the two windings are out of phase and the armature is held firmly operated.



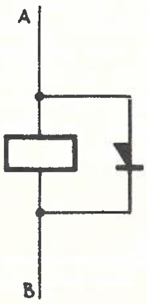
SHADED CORE A.C. RELAY.

FIG. 21.

The development of metal rectifiers in small sizes has led to the use of ordinary fast relays for use on A.C., and has made special types no longer necessary. Metal rectifiers possess the property of unilateral conductivity, that is, they offer a low resistance to the passage of a current in one direction (the forward direction), and a very high resistance in the reverse direction.

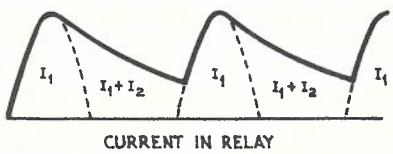
When a relay and rectifier are connected with A negative to B, as in Fig. 22, a current will pass through the relay coil, and not through the rectifier, operating the armature. When the current reverses, the rectifier shunts most of the current from the relay. The rectifier in shunt with the relay makes it slow to release and the armature is thus held during each alternate half-cycle, the coil receiving current pulses every other half-cycle. The action is shown graphically in Fig. 23, I_1 being the half-cycle pulses, I_2 the currents due to the slugging effect of the rectifier.

The circuit shown offers a low impedance on each alternate half-cycle and usually has a condenser or some other form of impedance connected in series to limit the current.



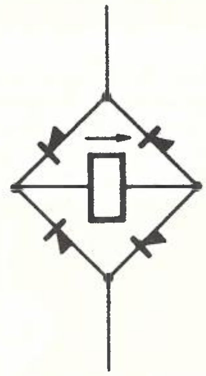
RECTIFIER SHUNTED RELAY.

FIG. 22.



CURRENT IN RELAY.

FIG. 23.



BRIDGE-CONNECTED A.C. RELAY.

FIG. 24.

Another method of adapting an ordinary relay to A.C. use is shown in Fig. 24. Both half-cycles of the A.C. are directed through the relay in the same direction as indicated by the arrow.

7.5 Relays Insensitive to A.C. A relay will not respond to A.C. if it is sufficiently slow in operating and releasing, therefore, relays which are not required to respond to A.C. are fitted with armature end slugs, and, in some cases, a copper sleeve in addition.

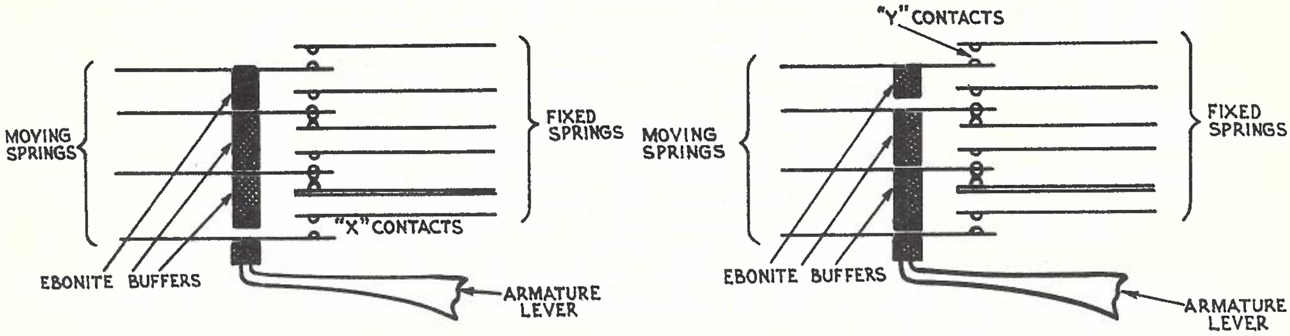
7.6 Two-Step Relay. This relay is characterised by a special arrangement of the contact springs. The armature has a half operated position in which it may come to rest as well as a fully operated position. Such relays are not viewed with favour on account of the critical marginal adjustment necessary.

/ In

In its broader sense, a two-step relay is one in which certain contacts operate before or after the remaining contacts. There are two available sequences -

"X" contact, a contact which operates before any of the other contacts on the relay. (See Fig. 25a.)

"Y" contact, a contact which operates subsequent to all other contact operations. (See Fig. 25b.) Only one "x" or "y" spring-set may be mounted on a relay, and a longer stroke has to be used.



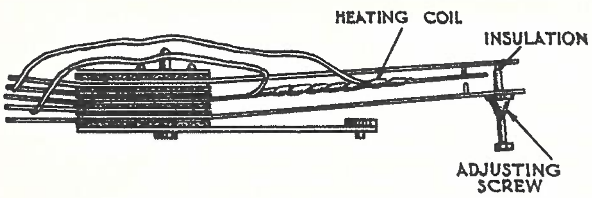
(a) "X" Contact. (b) "Y" Contact.

2-STEP SPRING ASSEMBLY.

FIG. 25.

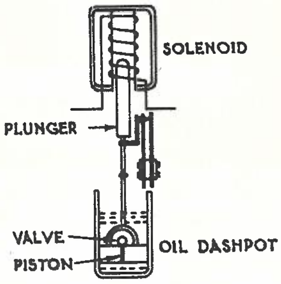
7.7 Slow Acting Relays. Where a very long operating lag is required, an ordinary relay fitted with a copper slug will not suffice and many special types have been used, some of the more common ones being described -

Thermostat Relay. This relay (Fig. 26) differs in the principle of operation from those previously discussed. It is operated by heat and not by magnetic flux, consisting essentially of a moving spring of a bi-metallic strip around which a heating coil is wound. The bi-metallic strip consists of a strip of iron and a strip of brass welded together. The coefficient of linear expansion of brass is greater than that of iron, and thus, if the brass side of the spring is placed upwards and current passing through the coil generates heat, the heat will cause the strip to bend in a downwards direction. The upper spring is prevented from following the bi-metallic spring by the insulated screw. This type of relay with suitable winding and adjustments can provide a delay of from 150 mS to 2 minutes. Later types of thermostat relays include a toggle arrangement to provide a more positive contact action.



THERMOSTAT RELAY.

FIG. 26.



DASH-POT RELAY.

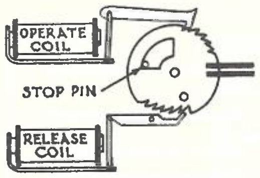
FIG. 27.

Dash-Pot Relay. This relay (Fig. 27) consists of a solenoid, the plunger of which is connected to a piston which is drawn through a cylinder (called a dash-pot) filled with oil. The solenoid is mounted above the dash-pot. When current is applied to the solenoid, the plunger will be drawn into it. The time taken for plunger to be completely drawn into the solenoid may be varied by means of a screw which regulates the flow of oil through the piston. The dash-pot is not completely filled with oil, thus the end of the stroke is

/ rapid

rapid in order to effect a quick make or break of the contacts. On release, a one way valve in the piston permits it to restore quickly. The delay period may be from 2 seconds to five minutes.

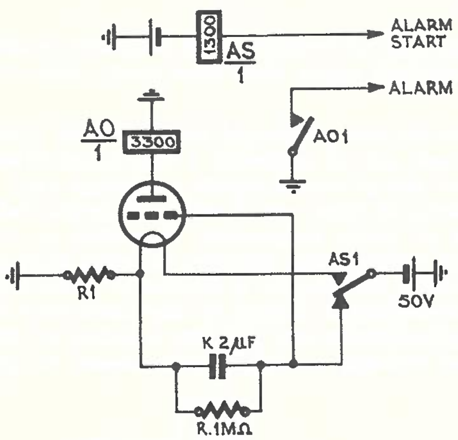
Pawl and Ratchet Relay. This type of relay is shown in Fig. 28, and consists of two electromagnets each causing the operation of a pawl by a movement of the armature. The two pawls engage with a ratchet wheel having two sets of teeth. A portion of the ratchet wheel is cut away, and thus its equilibrium is destroyed. The wheel has a tendency to rotate in a clockwise direction in an endeavour to restore equilibrium. This movement is prevented by a stop pin and the wheel is held in its normal position. When current impulses are sent through the operate coil, the pawl of this coil operates in unison with the current impulses. The wheel restores to normal after each impulse unless the releasing coil is energised, and then moves round the space of one tooth and remains held by the pawl of the release coil. On the sixth step the wheel operates the spring-set. When the release coil circuit is opened, the wheel restores to normal. The time for which the operation of the spring-set may be delayed depends on the frequency of the impulses through the operating coil.



RATCHET AND PAWL RELAY.

FIG. 28.

Modern practice favours the use of uniselector switches in conjunction with ordinary relays for obtaining very long operating or releasing lags. In some cases a valve circuit using a charged condenser and timing resistance have been used. A typical circuit is shown in Fig. 29. The charge on the condenser maintains a negative potential to the grid of the valve, thus preventing the flow of current to the anode. As the condenser discharges, the negative grid potential decreases and finally reaches a point where anode current flows to operate the alarm control relay AO. On the release of the alarm start relay AS, the condenser is recharged ready for the next operation. Using a capacitance of 2 µF and a resistance of 1 megohm, a delay period of 4-5 seconds may be anticipated. The delay period may be varied by choosing suitable values of capacitance and resistance for the timing circuit.



VALVE DELAY CIRCUIT.

FIG. 29.

7.8 Impulsing Relays. In automatic telephony, as explained later, the operation of selector electromagnets is controlled by means of a dial connected across the subscriber's end of the line. When the dial is operated, the continuity of the line is rapidly broken and re-made a number of times in succession, the number of "breaks" being the same as the digit dialled. At the exchange, a relay coil is joined across the line and the contacts of this relay are employed to repeat the dialled impulses to the selector electromagnet. Such a relay is called an impulsing relay.

To ensure correct functioning of the selector electromagnets, it is important that the interval of time for which the line circuit is opened by the dial shall be repeated with minimum distortion by the relay contact. This necessitates a relay with equal operate and release lags. When a relay is connected to a line, however, the operate and release lags are both influenced by line conditions, but not necessarily to an equal extent. Lines differ widely in characteristics and the problem is to design an impulsing relay which will have equal operate and release lags when joined to any line. This ideal cannot be achieved in practice as, in general, a variation in line conditions

/ which

which gives an increase in the operate lag will reduce the release lag and vice versa: therefore, a relay with short operate and release lags is the best compromise.

It is important that the impulsing relay shall have short releasing and operating lags in order that the variations of time, which are bound to occur under the wide range of circuit conditions, shall not have too great an effect on the impulses. The ordinary fast relay is taken as the basis of design, and the normal time lags are of the order of 8 to 12 mS.

The coil is designed to give balanced impedances in the two windings, and to this end the windings are either sandwiched, or else two separate coils are used with a centre cheek between them.

The contact springs of normal selector impulsing relays are three in number, and form either a change-over or make-before-break assembly. The time interval between make and break, that is, the "change-over time" or "transit time", is wasted in a change-over combination but is added to both break and make periods in the case of "K" contacts. Thus, if the transit time were 2 mS and the total impulse took 100 mS, a 67 per cent. break impulse repeated without distortion would appear as 65 mS break and 31 mS make in the one case, and 69 mS break and 35 mS make in the other case.

A short travel of armature is necessary for fast operation, typical figures being 10 mils for the Strowger relay, and 25 mils for the 3,000 type.

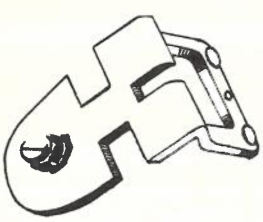
Residual magnetism can have a detrimental effect on an impulsing relay, and, to minimise this effect, the residual air-gap is kept relatively large. In some types of relay the hinge air-gap assists in this respect. The Siemens impulsing relay has a pin-type armature suspension in lieu of the normal knife-edge.

On 3,000 type relays an "isthmus" type armature is used. (See Fig. 30.) The effect is to produce magnetic saturation at the narrow neck or isthmus, and this has a stabilising effect on the flux when the relay is operated at high or low voltages, long or short lines, and so release lag is also to some extent stabilised. It gives a reduction of about 4 per cent. in the amount of distortion produced when the loop resistance is increased from zero to 1,500 ohms.

It has been found that the shape and position of the cut-away portion of the armature has an important influence on the performance of a relay, and that an armature designed for one particular impulsing relay may not be entirely satisfactory on a relay of different design.

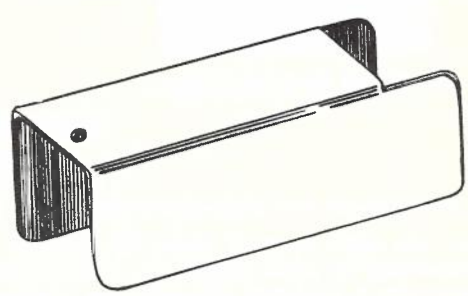
Two types of isthmus armature have been standardised for use with the 3,000 type relay. In one type, the isthmus is produced by parallel-sided slots cut into the armature, as shown in Fig. 30, whilst in the second type the slots are V-shaped. On Siemens type relays, the isthmus effect was often obtained by providing two or three holes in the armature.

Where an impulsing relay of the 3,000 type is mounted adjacent to slugged relays, a three-sided magnetic shield (see Fig. 31) is fitted over the coil to prevent interference effects due to magnetic leakage.



ISTHMUS TYPE ARMATURE.

FIG. 30.



MAGNETIC SHIELD.

FIG. 31.

7.9 Fast Relays. Most general purpose relays are known as fast relays, but the terms "fast" or "slow", as applied to relays, are purely relative. A relay in which special features have not been introduced, to affect its natural speed of operation and release, may be regarded as a fast relay. In practice, the operate and release lags of ordinary fast relays lie between 10 and 30 mS.

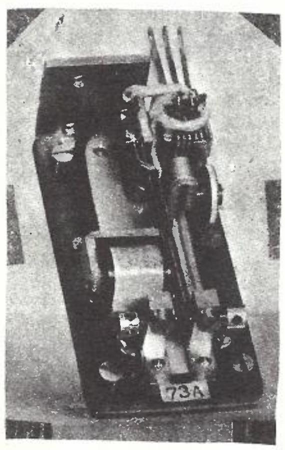
/ Relays

Relays with a nickel-iron core may be used for special applications where operate and release times are required to be faster than this, and lags under 5 mS may be obtained. Nickel-iron (36 per cent. nickel) has a resistivity equal to about ten times that of soft iron, thus reducing considerably the magnitude of the eddy currents produced.

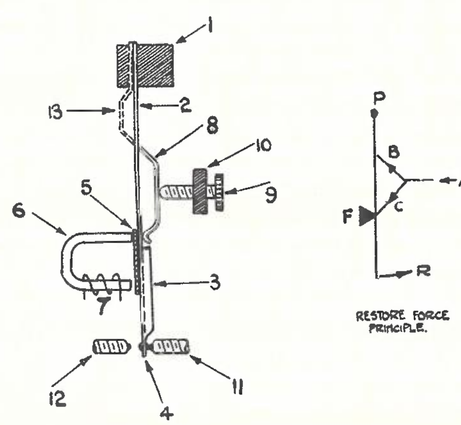
When an extremely high operating speed is required, special relays are used having a very light moving system. Relays designed for use in telegraphy may sometimes be used for this purpose, and descriptions and characteristics of these are given in Telegraphy I.

7.10 Siemens High-Speed Relay (Type 73). This relay has been designed to operate and release very fast, in the order of one millisecond. Its chief characteristics are a very efficient magnetic circuit, a low inductance winding, a short armature travel and a moving system of small mass.

The mechanical arrangements of the relay are shown in Fig. 32. Fixed detail (1) carries a phosphor-bronze spring (2) which is channelled for stiffness at (3) and carries platinum contacts (4). Welded to this spring is a soft-iron armature (5) which butts against the unwound limb of the soft-iron yoke (6). The armature and yoke are plated to prevent rusting, and at the same time this precludes iron-to-iron contact. The winding (7) is carried on a moulded insulating bobbin which is slipped on to the yoke and retained by a brass wedging strip. Spring (2) passes through a slot in the buffer spring (8), the upper end of which is clamped with spring (2) to detail (1). Screw (9), which is for adjusting the tension, passes through tapped lug (10), and engages the buffer spring towards its free end. Referring to the diagram on the right of Fig. 32b, force A splits into components B and C. Force C holds the armature securely against the yoke while force B, pivoting about fulcrum F, imparts contact pressure in the direction R, thus contact (4) normally presses against break contact screw (11). When the relay is energised, the contact (4) changes over to press against contact screw (12).



(a) Relay Without Cover.



(b) Mechanical Principles.

HIGH-SPEED RELAY.

FIG. 32.

The adjustments of the high-speed relay are simple and are carried out as follows -

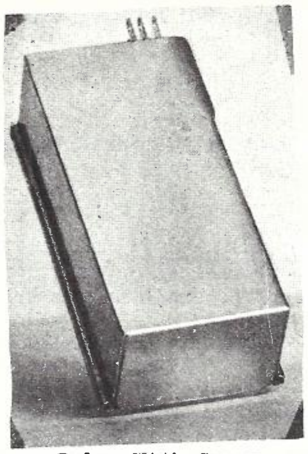
(i) Set the make contact screw so that it just touches the moving contact when the armature is held operated. Then turn the screw a further quarter of a turn to provide a residual air-gap and tighten the locking screw.

(ii) Adjust the break contact so that a 4 mil gauge will just pass between the make and moving contacts.

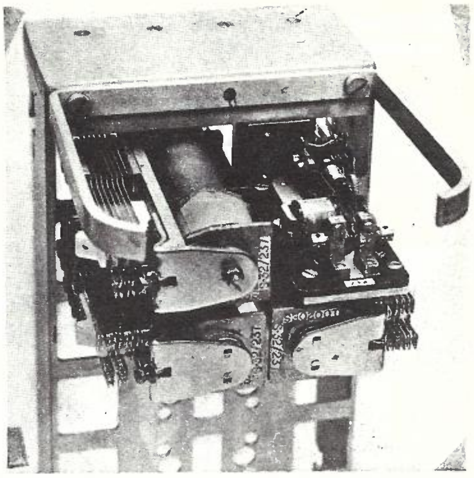
(iii) Turn the tension screw until the break contacts can be opened with from 15 to 20 grams pressure when applied to the tip of the armature spring. In view of the very short armature travel, it is of advantage, when adjusting the relay, to use a voltmeter or test lamp to indicate when the contacts open or close.

/ The

The relay can withstand considerable handling without adverse effect. It can be supplied with an individual cover, which is not required when the relay is mounted with other apparatus under a common cover, as shown in Fig. 33.



Relay With Cover.



MOUNTING OF HIGH-SPEED RELAY.

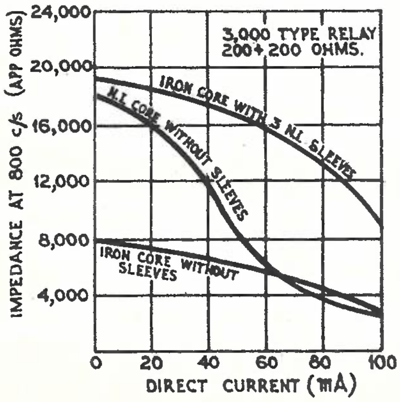
FIG. 33.

7.11 High Impedance Relays. Relays are often required to have a high value of impedance at voice frequencies, in addition to their normal D.C. characteristics. This can be effected by the reduction of eddy currents, which circulate in the core of the relay when speech currents pass through the coil.

It has been found that A.C. fluxes are confined to the surface layer of the core due to a "skin effect". The depth of penetration of frequencies above 300 c/s is no more than 10 mils.

The A.C. inductance of a relay, and, therefore, its impedance, can be increased by employing a medium at the core surface which has a high permeability, a low eddy current loss, and a low hysteresis loss. Such a material is the 36 per cent. nickel-iron alloy used for the cores of fast relays, but it suffers from the disadvantage that it becomes saturated at the magnetising forces used for relays, and so its permeability drops. This is shown in Fig. 34, where the impedance for a nickel-iron core is shown to be lower than an iron core at current values in excess of 60 mA.

By fitting three 12-mil sleeves of nickel-iron over the normal soft-iron core, as shown in Fig. 35, the effect of saturation is eliminated, the iron core carrying the D.C. flux, the D.C. characteristics of the relay are practically unaltered, and its impedance to voice frequency currents greatly increased.



EFFECT OF CORE MATERIAL
ON THE IMPEDANCE OF A RELAY.

FIG. 34.

SECTION OF CORE WITH NICKEL-IRON SLEEVES.

FIG. 35.

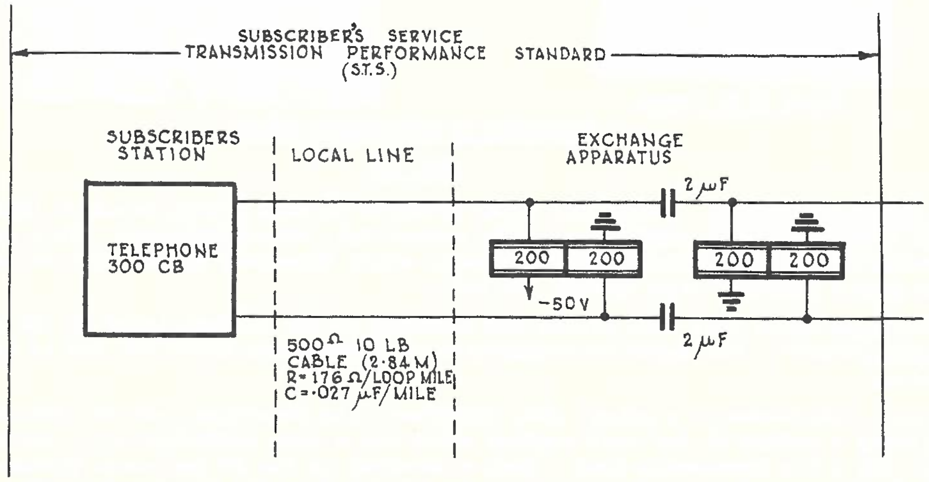
8. BALLAST RESISTORS.

8.1 On lines connected to C.B. (manual or automatic) exchanges two factors affect the transmission level -

(i) Voice frequency losses in the conductors, and

(ii) Reduced sending level, due to reduction of transmitter current with increase of line resistance.

8.2 Subscribers' Service Transmission Performance Standard (S.T.S.) is the limiting condition laid down for the transmission performance between the subscriber and the local exchange, as indicated in Fig. 36, and includes the losses in the transmission bridge at the subscriber's exchange.



SUBSCRIBERS' SERVICE TRANSMISSION PERFORMANCE STANDARD.

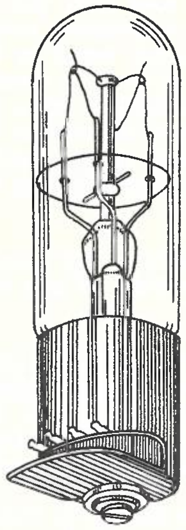
FIG. 36.

8.3 In order to comply with the standard transmission performance limits, the maximum line resistance of 10 lb. cable, using a 200/200 ohm feed relay in the transmission bridge and the standard C.B. telephone, is 500 ohms. To increase the loop resistance over which satisfactory transmission is possible, the resistance of the feed relay could be reduced, but this would result in an excessive current flowing when short lines were connected to the circuit. Although the level of transmission increases with an increase of current, a point is reached where hissing and frying would take place, and arcing would cause deterioration of the transmitter electrodes. In practice, the upper limit of current through the transmitter is taken to be 100 mA.

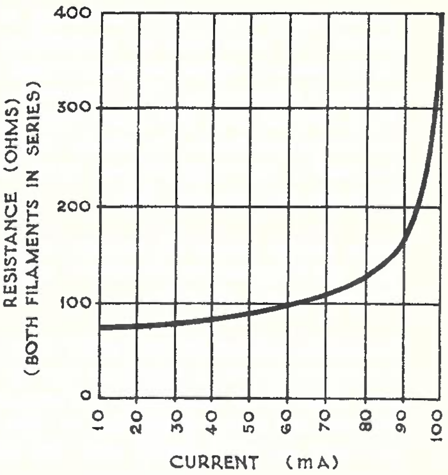
8.4 Ballast Resistor. In recent years, a form of ballast resistor or barretter has been introduced with a view to increasing the transmitter current on long lines, but at the same time preventing excessive current on short lines. A ballast resistor is so designed that its resistance value varies with change of current and is so connected that the change of resistance assists to maintain a constant current in the circuit. Thus, they are made of a material which has a high positive temperature coefficient.

/ Fig. 37

Fig. 37 shows the standard twin-filament ballast resistor and its characteristic curve. The two filaments are of fine tungsten wire enclosed in a hydrogen-filled bulb, the connections being made by means of soldering tags.



(a) Twin-Filament Ballast Resistance.



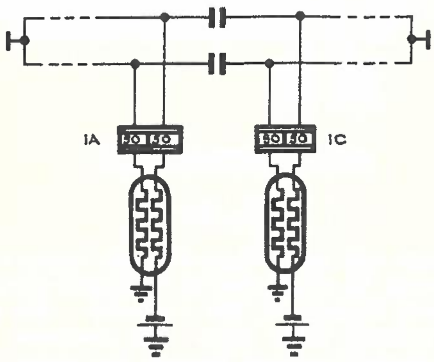
(b) Characteristic Curve.

BALLAST RESISTOR.

FIG. 37.

The curve shows clearly the rapid increase in resistance as the current rises above 80 mA.

Fig. 38 shows a Stone transmission bridge with twin-filament ballast resistors inserted in the battery and earth supply to the impedance coils. These are of low resistance, the ballast resistor giving ample protection against overheating on short lines and under most fault conditions. A contact with a low tension power line will, however, cause burn-out of the ballast resistor in most cases.



TRANSMISSION BRIDGE WITH BALLAST RESISTORS.

FIG. 38.

The use of the ballast resistor allows the minimum transmitter current (about 50 mA) to be obtained on longer lines than otherwise possible. Although the ballast resistor produces a general improvement in the volume efficiency of a subscriber's circuit, it does not necessarily result in a corresponding gain in transmission performance which takes into account all factors, such as distortion and sidetone reduction, as well as attenuation. With earlier C.B. telephone circuits, the high value of sidetone and bad frequency distortion prevent any material gain in transmission performance when using ballast resistors. However, with modern anti-sidetone telephone circuits, the introduction of ballast resistors enables the line resistance to be increased by some 12 per cent. for the same standard of transmission performance.

/ 9.

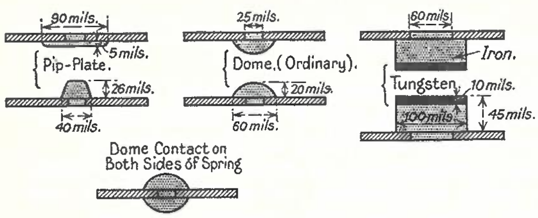
9. CONTACTS AND SPARK QUENCHES.

9.1 Contact Materials. As a reliable electrical connection could not be assured between nickel-silver springs themselves, domes of special material are fitted to form the actual points of contact. Various pure metals have been used from time to time for these contacts, the aim being to find a material of high electrical conductivity which, in addition to resisting atmospheric corrosion, is not burnt by the sparking which occurs when an electrical circuit is broken. Pure silver is normally used as contact material. If, however, the circuit to be made or broken has a current greater than 300 mA but not more than 1.25 amperes; if the voltage is greater than the normal exchange voltage, or where the contacts will be subjected to heavy service, platinum is used. Springs fitted with contacts of this metal are identified by having a V-notch cut in one end.

Some early types of relays used an alloy as contact material. The alloy commonly used was that known as "P.G.S." consisting of 7 per cent. platinum, 67 per cent. gold, and 26 per cent. silver.

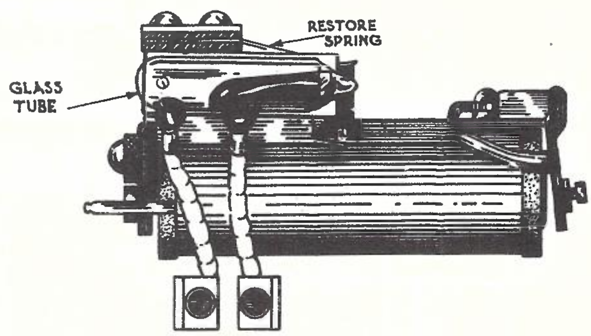
Tungsten contacts are used when the carrying capacity of platinum is exceeded, and currents up to 5 amperes may be broken without undue contact wear. Tungsten contacts are also used when the spring-set is subjected to very heavy service. The tungsten cannot be fixed directly to the contact springs, and it is usually welded to a disc of iron or mild steel and the disc is riveted or spot-welded to the spring.

The approximate ratio of costs of relay spring contact is silver 1, P.G.S. 4, platinum 24 and tungsten 16. The contacts are fixed to the spring either by spot welding or riveting a shank formed on the back of the contact. (See Fig. 39.)



CONTACT SHAPES.

FIG. 39.



MERCURY CONTACT RELAY.

FIG. 40.

9.2 Mercury Contact Relays. When it is desired to make and break high voltage circuits, relays with mercury contacts are used. The mercury is contained in a sealed glass tube containing a non-oxidising gas which prevents failure of the contacts. The glass tubes may be provided with porcelain liners to prolong their life. The external connections are generally provided by means of contacts sealed through the glass tube and extended to fixed terminals by means of bead-insulated flexible wires. A typical relay is shown in Fig. 40. When the relay armature is attracted, the glass tube is tilted and the mercury bridges the contacts, closing the circuit. Various forms of mercury contacts are made, that is, make, break, change-over and make-before-break.

9.3 "Wetting" of Contacts. The slightest oxidation of relay contacts will introduce a high resistance effect, which causes almost complete disconnection under low voltage conditions. It is, therefore, not desirable to allow contacts to carry tone or voice currents without superposing a D.C. potential of at least one volt. This is usually arranged by shunting any blocking condensers with a high value of resistance, about 40,000 ohms, to ensure breaking down of the film of oxide.

/ 9.4

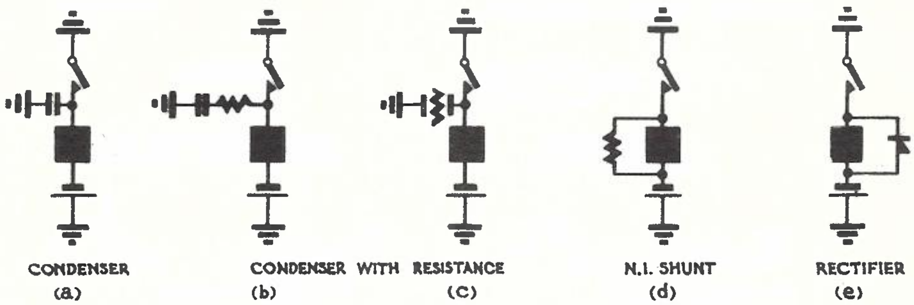
9.4 Contact Bounce. There is a tendency for all relay contacts to bounce at the moment of coming into contact. This bounce interrupts the flow of current at the contacts and causes circuit failures which are difficult to trace, also it shortens the life of the contacts.

In some relays, the effects of contact bounce are minimised by the adoption of thick fixed springs in conjunction with lighter lever springs, thereby damping any tendency for persistent vibration. In another relay design, the fixed springs are buffered, reducing their effective vibration length.

Another form of contact bounce due to vibration of the armature during operation can be reduced by introducing a very small slug at the armature end of the core. In the 3,000 type relay this takes the form of a copper front coil cheek.

9.5 Spark Quenches. When currents in an inductive circuit are broken, high induced voltages are produced which may cause a destructive spark at the contacts. The object of a spark quench circuit is to absorb this inductive energy, and this may be effected by a condenser shunted across the contacts as in Fig. 41a.

The condenser charges when the contacts break, thereby absorbing the energy, which otherwise would be dissipated in the form of a spark. However, when the contacts reclose, the condenser would discharge through them causing a momentary heavy current. This has been found to generate too much heat in platinum or other contacts and they melt slightly and weld together. This can be guarded against by inserting resistance in series with the spark quench condenser as in Fig. 41b. This resistance detracts from the efficiency of the condenser in absorbing the spark energy, thus, it is necessary to decide on the optimum value of capacity and resistance for every material and every circuit. Where a 46 ohm selector magnet is broken by platinum contacts at 50 volts, the spark quench is fixed at 1 μF and 200 ohms. In some cases a condenser having inherent resistance may be used making an additional resistor unnecessary (Fig. 41c).



SPARK QUENCH CIRCUITS.

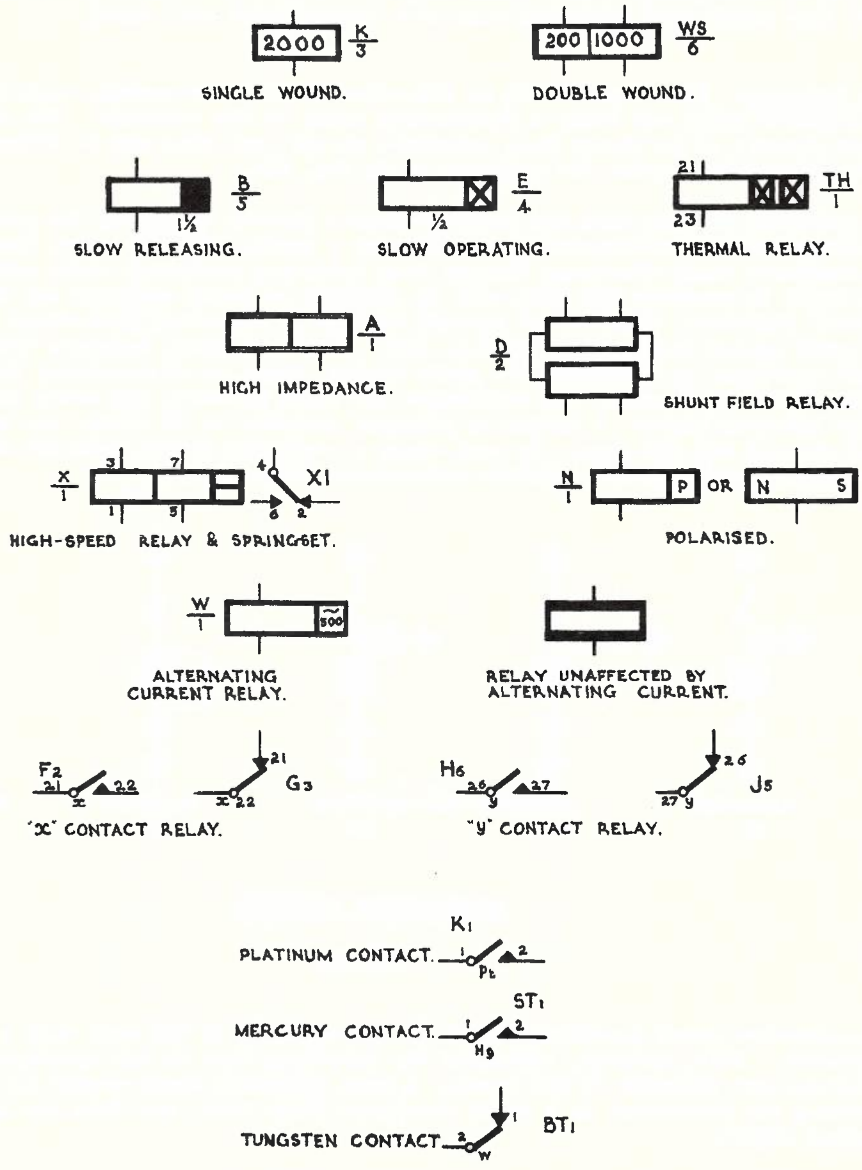
FIG. 41.

An alternative spark quenching device is the shunting of the coil with a non-inductive resistance. This, however, increases the releasing time of the armature and is, therefore, not suitable in all cases. A more effective spark quench is obtained by replacing the resistance by a metal rectifier (Fig. 41e), but this has a heavy slugging effect.

/10.

10. CIRCUIT DIAGRAMS.

10.1 The circuits in this Course are drawn on the detached contact principle, the coils and contacts are placed where it is convenient for the layout of the circuit. Fig. 42 shows the standard symbols for the various types of relays which have been described in this Paper. Each relay coil has indicated against it the number of contact units associated with it, for example, $\frac{K}{3}$ which means that the K relay has three contact units, and as these are numbered K1, K2 and K3, there is no possibility of a contact being overlooked.



GRAPHICAL SYMBOLS - TELEPHONE RELAYS.

FIG. 42.

11. TEST QUESTIONS.

1. State the reasons for fitting nickel-iron sleeves over the cores of certain telephone relays, and explain why the sleeves affect the desired results.

2. Describe briefly three delayed action devices for providing delay periods longer than those obtained by the use of slow releasing or slow operating relays.

3. Describe the construction of an impulsing relay of the 3,000 type.

4. Explain briefly the principle of a metal rectifier as used in telephone exchange circuits, and give two examples of its application.

5. Describe how contact bounce and contact failures are minimised in the design of a 3,000 type relay.

6. What do you understand by the terms -

   (i) Shunt Field Relay, and

   (ii) Shaded Core Relay.

   By means of suitable diagrams indicate conditions requiring the use of each of these types of relay.

7. (i) What is a ballast resistor?

   (ii) Where and why is it used?

   (iii) State any disadvantages of its use.

   (iv) Draw a characteristic curve of a ballast resistor.

8. List the requirements of a relay for telephone working.

9. What is meant by a "minor" relay? Give two examples of minor relays.

10. In the horizontal switch type relay, when is a 2:1 armature used, and what is the reason for its use?

11. How may the iron parts of a relay be protected against oxidation? Which method do you prefer?

12. Give the features of the Standard Relay and compare them with similar features of the horizontal type and Siemens type relays.

/ 12.

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END OF PAPER.

COMMONWEALTH OF AUSTRALIA.

Engineering Services,
Postmaster-General's Department,
Treasury Gardens,
Melbourne, C.2.

COURSE OF TECHNICAL INSTRUCTION.

CONTENTS:

1. INTRODUCTION.

1.1 An Automatic telephone system is one in which a calling party can, without the aid of a telephonist, effect connection with another party by operating switching mechanism located at a remote point. It is a recognised fact that a well-maintained machine is more efficient than a human operator, therefore a more efficient telephone service will be given by an automatic system than by a system operated manually.

1.2 Some of the advantages to be gained with an automatic system are -

(i) With an automatic system, a continuous service is afforded without the need for retaining staff during slack periods of the day and during night hours. It is well known that under Manual conditions the telephonist becomes less efficient during slack periods, wholly due to the fact that she is called upon to attend calls received on a number of different positions. During the night hours, the number of calls received is small but staff must be available to attend to them; under such conditions the cost of attending to calls is out of all proportion to the revenue received.

(ii) Operating irregularities are eliminated with the use of the machine. Irregularities arise under manual conditions from a variety of causes directly associated with the human element. The phonetic similarity of certain numbers, bad articulation, transmission difficulties, etc., result in wrong number troubles and render necessary repetitions which, to busy telephone users particularly, are likely to cause annoyance. The liability of errors, due to the phonetic similarity of some numbers, necessitates the use of distorted expressions, such as "fife" for "five" in order to prevent confusion with "nine," pauses are required between numbers, similar numbers occurring in succession must be carefully transmitted, etc. Such restrictions are unnecessary in an automatic system.

(iii) The use of different languages does not present difficulty nor does this call for special treatment with an automatic system. People speaking different languages will not be inconvenienced if connected to the same exchange. The caller, as will be explained, spells the required number by hand.

(iv) The apparatus used for setting up connections in an automatic system is built for "precision" operation; connections are therefore set up with speed and accuracy.

(v) Operating time is less with an automatic system. In addition to improving the service, the elimination of ineffective time results in more efficient use of the plant.

(vi) The elimination of an operating staff, generally speaking, results in considerable saving in favour of an automatic system. While the first costs are generally greater in the automatic case, these are counterbalanced by the saving of staff and the probable reduction in building charges.

1.3 The first automatic exchange to be installed in Australia was at Geelong, Victoria, in 1912, and the Department subsequently adopted the policy of automatisation of exchanges in capital cities and large country centres. In more recent years this policy has been extended to include small rural exchanges.

2. TWO-MOTION SELECTORS.

2.1 There are many different types of automatic systems in use in the world, but in Australia the Step-by-Step system is the only one in common use. This is developed about the basic 100 line unit, using the two-motion selector, which has been introduced in Telephony II.

Three types of two-motion selector have been used by the Department, namely -

(i) Strowger,
(ii) Siemens, and
(iii) 2,000 type,

and these will each be described in detail in later Papers of this Course.

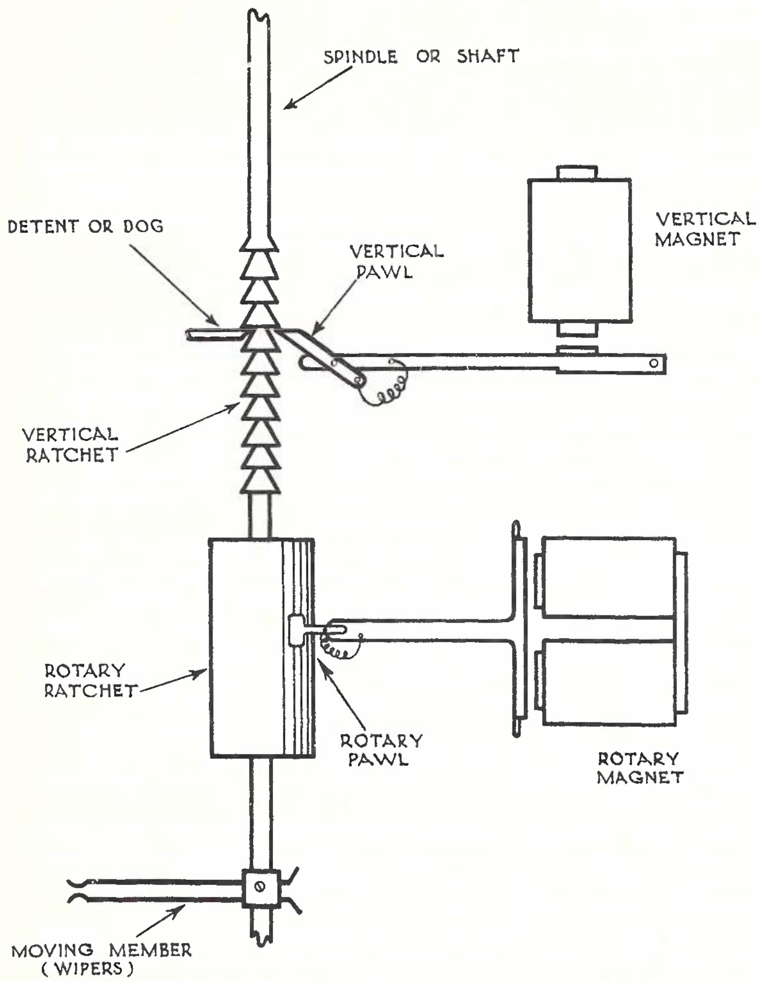

FIG. 1. ELEMENTS OF TWO-MOTION SELECTOR MECHANISM.

2.2 Fig. 1 shows the fundamental parts of the two-motion switch mechanism. It contains two electromagnets, one for lifting the shaft and wipers vertically and the other for turning the shaft and wipers rotarily. The vertical magnet, when energised, attracts its armature, and the vertical pawl engages with the vertical ratchet teeth cut into the shaft causing the shaft to be lifted one step. When the magnet is de-energised a powerful spring ensures prompt release of the armature, but the shaft is prevented from falling by a support called a detent or dog.

In a similar manner, when the rotary magnet is operated the shaft is rotated one step at a time, winding up a cup spring and being held by the rotary detent

2.3 The release of the selector is effected by a third magnet, the release magnet (not shown in Fig. 1). This is energised at the completion of a call and causes the vertical and rotary detents to be withdrawn from the ratchet teeth. The shaft is then free to return to its normal position under the influence of spring tension and the force of gravity.

/2.4

2.4 Attached to the bottom portion of the shaft are two sets of moving contact members called wipers, and these make the required connections to the contact bank (see Fig. 2). Note that there are two banks, the lower one being the line connections, requiring one hundred insulated pairs of contacts arranged in ten levels. The upper bank is similar in arrangement to the line bank, except that only single contacts are necessary. This contact, known as the "private" contact, is the equivalent of the "sleeve" wire in a multiple manual exchange, and is used for the engaged test, metering and other purposes.

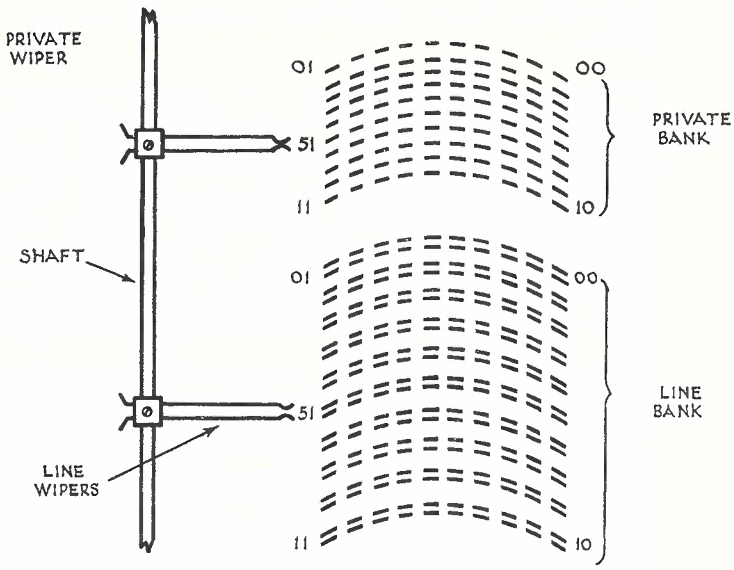

FIG. 2. TWO-MOTION SELECTOR BANK CONTACTS.

2.5 Associated with the selector mechanism are a number of relays which are arranged so that the selector will perform its required functions. It is not practicable to operate the selector magnets in series with the subscriber's line circuit and dial contacts because of the heavy current required (1 ampere approximately) to operate the magnets. An impulsing relay (relay A in Fig. 3), therefore, is connected to the line, and this relay also serves as a battery feed retard. Relay A will be operated in series with the subscriber's telephone loop when the receiver is lifted. Contact A1 completes the circuit of relay B, which also operates. When the subscriber dials the first digit, a number of interruptions in the line current (impulses) corresponding to the digit dialled, are transmitted. Relay A responds to the impulses, but relay B, being slow to release, will hold during the periods when A1 is normal. With A1 normal and B1 operated, a circuit is completed for the vertical magnet, which will operate with each impulse and cause the selector shaft and wipers to be lifted a number of steps according to the digit dialled. The wipers will now be standing alongside the bank level containing the required number.

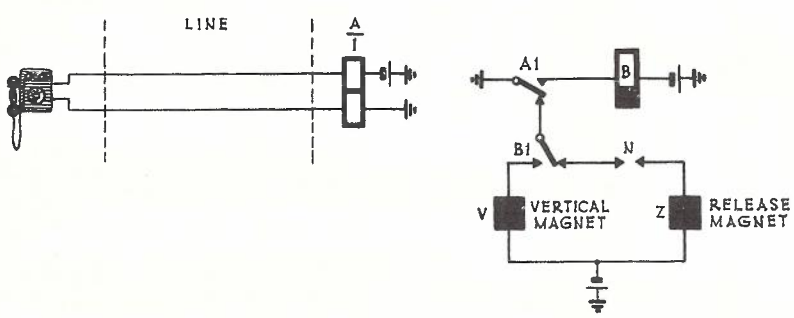

FIG. 3. IMPULSING CIRCUIT.

At the end of the first "train" of impulses, relay A remains operated and the release of a third relay, relay C (not shown in Fig. 3), causes a change in the circuit. Upon

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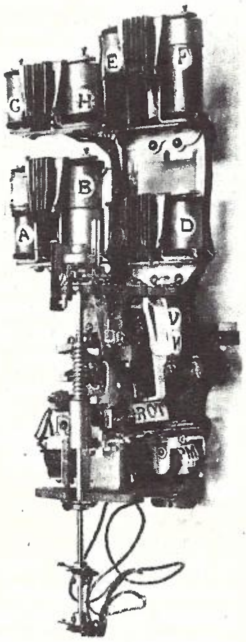
the second digit being dialled, the impulses repeated by the A relay are directed to the rotary magnet, which causes the wipers to be stepped on to the required bank contacts. Connection between the two subscribers is thus established as a result of dialling two digits, and the resultant transmission of two impulse trains.



AUTOMATIC SWITCH (CONNECTER) AS FIRST INSTALLED IN AUSTRALIA.
FIG. 4.

At the completion of the call, the caller replaces the receiver, opening the circuit of relay A which releases. Relay B releases after its slow release period (approximately 350 mS) and the circuit of the release magnet is completed via A1 and B1 normal and contact (N) operated. The off-normal spring-set (N) operates when the switch moves from its normal position. The operation of the release magnet causes the release of the selector mechanism. Contact N is opened when the shaft reaches the normal position, opening the circuit of the release magnet.

2.6 The Connecter. Fig. 4 shows an early type of two-motion switch known as a connecter. Besides the A, B and C relays previously referred to, this selector has a D, E, F, G and H relay, and these are necessary to perform the many functions required. This type of switch is now called a "Final Selector," as, in large exchanges, it performs the final stages of selection. If a comparison is made with manual practice regarding the method of selection during the progress of a call through an automatic system, it will be found that the stages of operation are very similar. The following is a summary of operations in both manual and automatic working -

C.B. MANUAL Subscriber Removes Receiver.	AUTOMATIC. Subscriber Removes Receiver.
Lamp glows on answering position	Automatic mechanism seized.
Operator inserts plug into answering jack.	Subscriber operates dial.
Operator ascertains the required number and tests same in the multiple.	Automatic mechanism extends the caller to the bank contacts of the required number and tests same.
If the called line is free, the operator inserts a calling plug into the jack and depresses the ringing key, thus sending a calling signal to the required number.	If the called line is free, the mechanism sets up conditions for calling the required number.
If the called number is already engaged, the operator informs the caller, either orally or by means of a signal, that the connection cannot be completed.	If the required number is "busy" the mechanism transmits a busy signal to the caller.
When the call matures, the operator meters it against the caller.	When the called party answers, the call is metered against the caller.
On completion of the call, supervisory signals are displayed to the operator, who takes down the connection.	On completion of the call, the mechanism is immediately released and becomes available for other calls.

During the progress of the call, and until the connection is released, both the calling and the called lines are made "busy," thus guarding them from intrusion. In the manual case, the circuits affected are marked "engaged," while the connecting plugs remain in the respective jacks.

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2.7 Supervising the Call. As indicated earlier, to enable the caller to know how a call is progressing, a system of "tones" is provided. The tones have different characteristics; the significance of the tones are known to the subscribers who are thus provided with a means of knowing whether the call is progressing satisfactorily or whether it should be abandoned. Certain tones have been set down as standard, but some of the older exchanges have tones which differ from these standards.

A more modern method of advising the calling subscriber of the progress of the call is by reproduction of a voice repeating such words as "Number engaged," "Dial now" or "Number unobtainable." The reproduction employs the principle of the talkies. So far, it has been used only for trial purposes in the Commonwealth.

The standard tones are as follows -

(i) Dial Tone. This tone is transmitted to the caller when the line has been extended to a free mechanism as a result of lifting the receiver - the tone indicates that the call may be commenced. The tone continues until the first digit in the called number is sent by the caller. It is a continuous purring low note.

(ii) Ring Tone. This tone indicates to the caller that the call has proceeded satisfactorily and that ringing conditions have been set up, and may be represented by -

Burr--Burr------Burr--Burr------Burr--Burr.

(iii) Busy Tone. This tone indicates to the caller that the call is not progressing satisfactorily, due either to the called party being already engaged or to the connecting circuits involved in setting up the connection being engaged. The tone implies that the "hold up" is temporary and the call may be attempted later. It is a high pitched tone interrupted at regular intervals, thus -

Buzz-------Buzz-------Buzz-------Buzz-------Buzz.

(iv) Number Unobtainable Tone. This tone indicates to the caller that the call should be abandoned. The tone may be given when non-existent numbers are called or numbers which are spare. It is a high pitched tone similar to the busy tone, but uninterrupted.

Schedule of Standard Tones used in Automatic Systems.

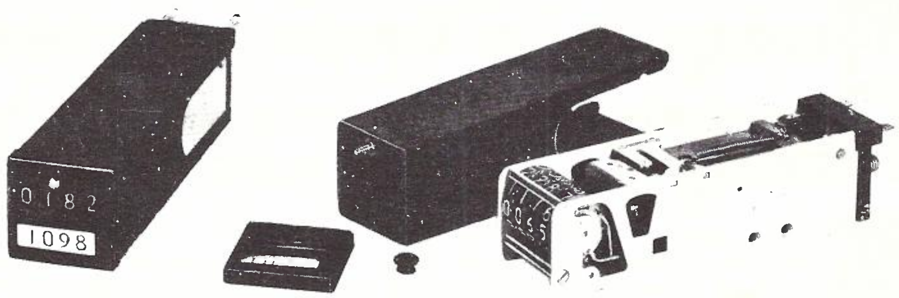
Name of Tone	Periodicity of Interruptions per Second, etc.	Note Given
Dial	33 periods per second continuous	Low (purr)
Ring	133 periods per second superimposed on the 33-c/s ringing current, interrupted as follows - 0.4 sec. (On) 0.2 sec. (Off) 0.4 sec. (On) 2.0 sec. (Off)	Medium
Busy	400 periods per second interrupted as follows - 0.75 sec. (On) 0.75 sec. (Off)	High
Number Unobtainable (N.U.)	400 periods per second continuous	High

It will be clear that the characteristics of the tones must differ sufficiently to enable them to be readily distinguished. The tones in most exchanges are derived from interrupters associated with the exchange ringing machines. The interruptions are transmitted

/to

to transformers and thence to distribution points from which they are connected to the apparatus concerned. The latest machines are of the inductor type in which the unwound soft-iron rotor has teeth which cause the current in a stator winding to vary at the desired periodicity. The circuit details will be dealt with later. In the older type of exchanges, and particularly in those exchanges supplied from America, harmonic converters were used to provide the tones as well as the ringing, but these are now being eliminated in favour of the machine generation of tones.

2.8 Metering the Call. In an automatic system it is necessary to provide some indication of the number of calls made by a subscriber. The metering of calls is made on a meter or register of the Veeder counting type associated with each subscriber's apparatus in the exchange. The stage at which the meter is operated differs with various systems, metering occurring either when the called party removes the receiver or upon the release of an effective call. In Australian and British practice, metering occurs when the cálled party removes the receiver. Automatic metering is catered for on all calls within a predetermined area, termed the "Unit Fee Area." Such calls involve one count of the meter only.



THE METER COMPLETE, AND ALSO WITH COVER AND LABEL CAP REMOVED.

Calls beyond the Unit Fee Area are routed to a Telephonist's position from which the call is operated manually, effective calls being recorded on a ticket.

Multiple metering schemes, which enable more than one count upon the meter, are in use to a limited extent in other countries. Difficulty arises in applying such schemes where trunk or long distance calls charged on a "time" basis are concerned. Involved circuit arrangements are necessary in such cases to meet the metering requirements and to provide the necessary warning and release conditions at the expiration of the "unit" time.

Because the metering is to be effected when the called party lifts the receiver, it is necessary to pass some signal from the equipment leading to the called subscriber back over the connection to the calling line circuit where the meter will be. To avoid the use of separate wires just for this purpose, various schemes have been adopted to pass the required signal over the line or the "private" wire without interfering with the normal working over these wires.

Generally, three methods of metering effective calls are available -

(i) Reverse Battery. The circuit arrangements provide for the operation of a relay controlling the meter when the direction of the current is reversed by the removal of the called party's receiver.

(ii) Booster Battery. The circuit arrangements provide for the application to the meter of an assisting voltage for a short period (200 to 300 mS) after the removal of the called party's receiver.

(iii) Positive Battery. This is used with 2,000 type circuits. Normally, the negative pole of battery is connected to the apparatus but, when metering is required, the positive pole of a metering battery is connected to the circuit leading to the meter and a rectifier in the circuit then allows current in this direction to operate the register.

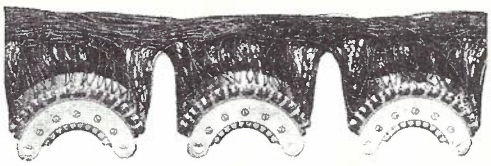
/A

A further scheme termed "Reverse Meter" is in limited use in some of the older exchanges but this is really a type of reverse battery metering, the modification being that the reversal of battery operates the meter without the interposition of the reverse battery metering relay.

In one system the Booster effect is obtained by reducing the resistance in the meter circuit when the called party removes the receiver, thus increasing the value of the current flowing to a figure sufficient to energise the meter which remains operated until the release of the connection. As will be readily seen, this arrangement avoids the necessity for adding cells to obtain the increased current.

3. SIMPLE 100 LINE SYSTEM.

3.1 A simple 100 line automatic exchange would require one final selector (or connecter) per line, that is, 100 final selectors. Each of the subscribers must be represented by contacts in the banks of every switch provided, and this is arranged by connecting similarly numbered contacts on all banks together by means of multiple wiring. (See Fig. 5.)



BANK MULTIPLE WIRING.

FIG. 5.

When a subscriber lifts the receiver to make a call, a final selector is taken into use and, by dialling two digits, the required connection is made. To prevent the final selector associated with the called line being seized, a pair of relays, designated L and K, are provided for each line. These function in a similar way to the line and cut-off relays in a C.B. manual exchange, the operation of the K relay on an incoming call disconnecting the L relay and final selector, giving a clear line to the called subscriber.

3.2 Fig. 6 shows a "trunking diagram" of a call through a 100 exchange. Subscriber No. 21 is calling No. 30 and, on lifting the receiver, final selector No. 21 is seized. This is stepped up 3 levels by the first digit dialled and on to contacts 30 by the second digit and, providing subscriber 30 is disengaged, ringing current would be applied to the line. The operation of relay K disconnects final selector No. 30, preventing false operation.

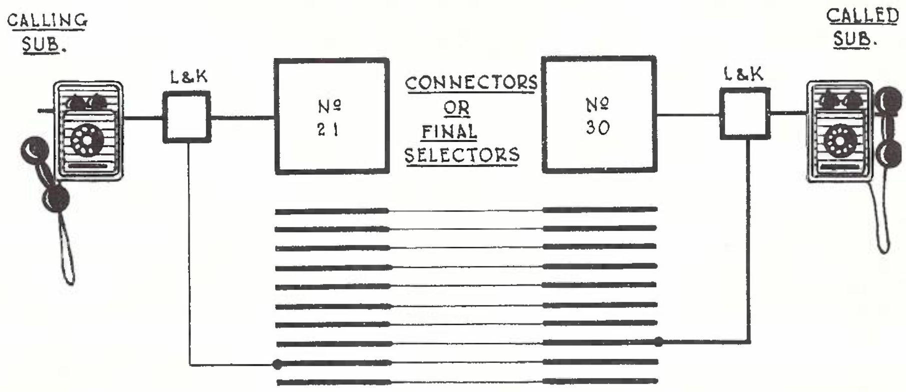


FIG. 6. SIMPLE 100 LINE EXCHANGE.

On outgoing calls from subscriber No. 30, the L relay would operate and final selector No. 30 would be used.

/3.3

3.3 The 100 line exchange described would require 100 final selectors and banks. Each subscriber's line would have a final selector which would be used when that subscriber originated a call, but would not be required on calls from other telephones. If the 100 telephones were all in use, only 50 of the final selectors would be required. In fact, only a small number of subscribers are likely to be using the telephone at any one time, depending on their calling rate. Under average conditions, about 10 final selectors would be required to handle the greatest number of simultaneous calls from 100 subscribers.

4. UNISELECTORS.

4.1 As the two-motion selector is an expensive item of equipment, it is economical to provide only sufficient to handle the normal traffic load and to give the 100 subscribers access to these as a common group. This is made possible by using a cheaper item of equipment, known as a uniselector, individual to each line.

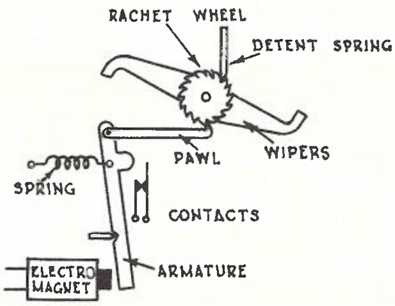
4.2 There are two types in general use in Australia -

(i) The Plunger Uniselector (or Line Switch).

(ii) The Rotary Uniselector.

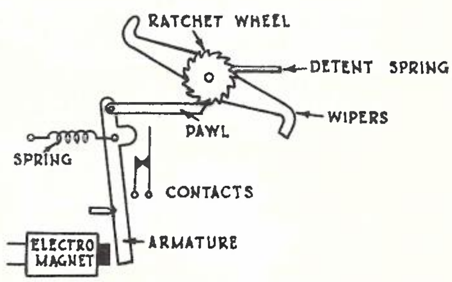
the latter type now being the standard type. It is provided with a ratchet mechanism controlled by magnet operation; the ratchet operates a spindle with which wipers are associated moving in one plane only. The wiper tips engage bank contacts arranged in an arc. Two principles of operation are used. In Fig. 7, the operation of the magnet results in the pawl being withdrawn from the tooth in which it is normally resting far enough to slip into the base of the next tooth. Upon the cessation of current through the magnet and the resultant restoration of the pawl under the influence of the armature restoring spring, the wipers are moved forward. This is known as "reverse action."

The principle of the other type of uniselector is shown in Fig. 8. The pawl is thrust into the tooth when the magnet armature is operated, moving the ratchet wheel and with it the wipers. This is referred to as "forward action."



REVERSE ACTION.

FIG. 7.



FORWARD ACTION.

FIG. 8.

Both types of action are in general use, the reverse action type now being the Australian standard.

In the reverse action type, as the advancement of the ratchet and wipers takes place during the period when the flow of current through the magnet is interrupted, the current through the magnet need only be enough to place the pawl into engagement with the next tooth on the ratchet. This operation is affected less by irregular impulses than the forward action type, in which the advancement of the wipers is dependent on the power given by the current impulse which requires that the current must flow long enough to fully operate the magnet armature and thrust the pawl, and with it the ratchet, one full step forward.

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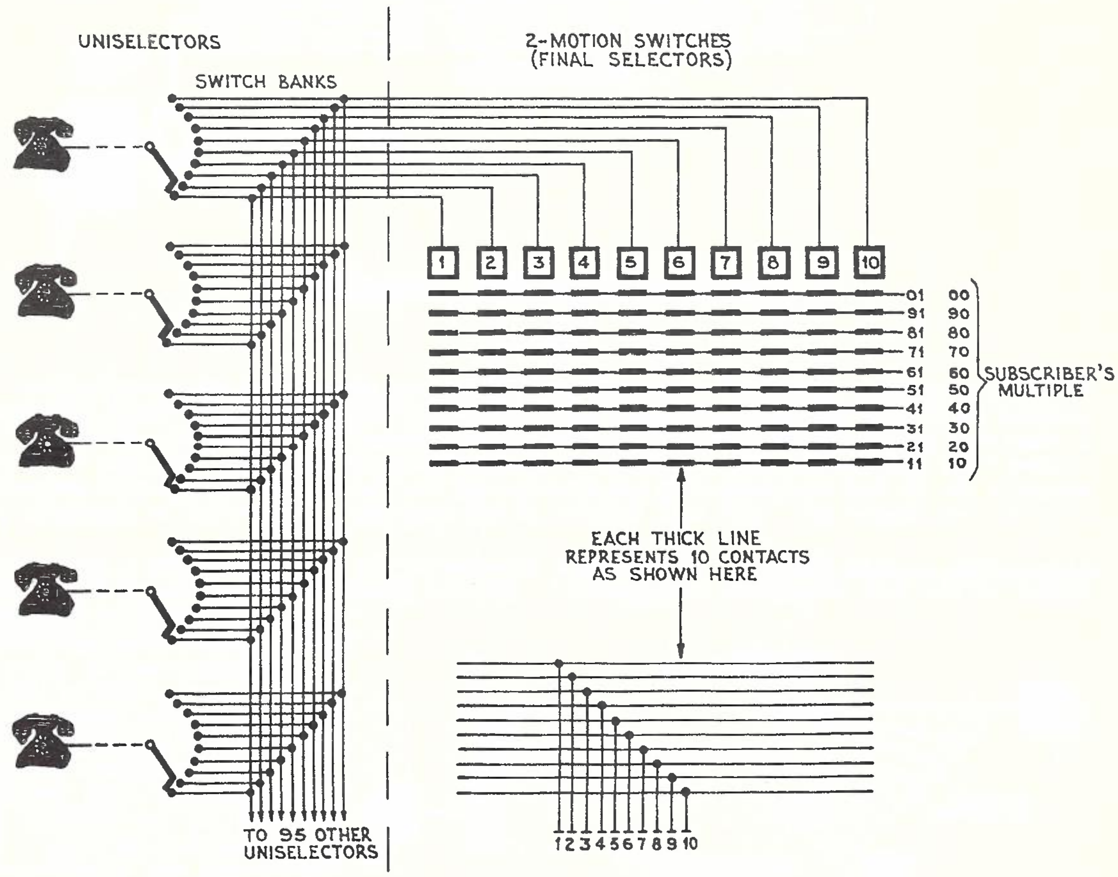
Another type of single-motion switch has a small electric motor which is geared to a wiper spindle. When the appropriate contact in the wiper bank is reached, current is cut off from the motor and the wipers rest on the selected contacts.

The types of uniselectors in common use in Australia, as well as the Plunger line switch, will be described in detail later in this book.

5. 100 LINE SYSTEM USING UNISELECTORS.

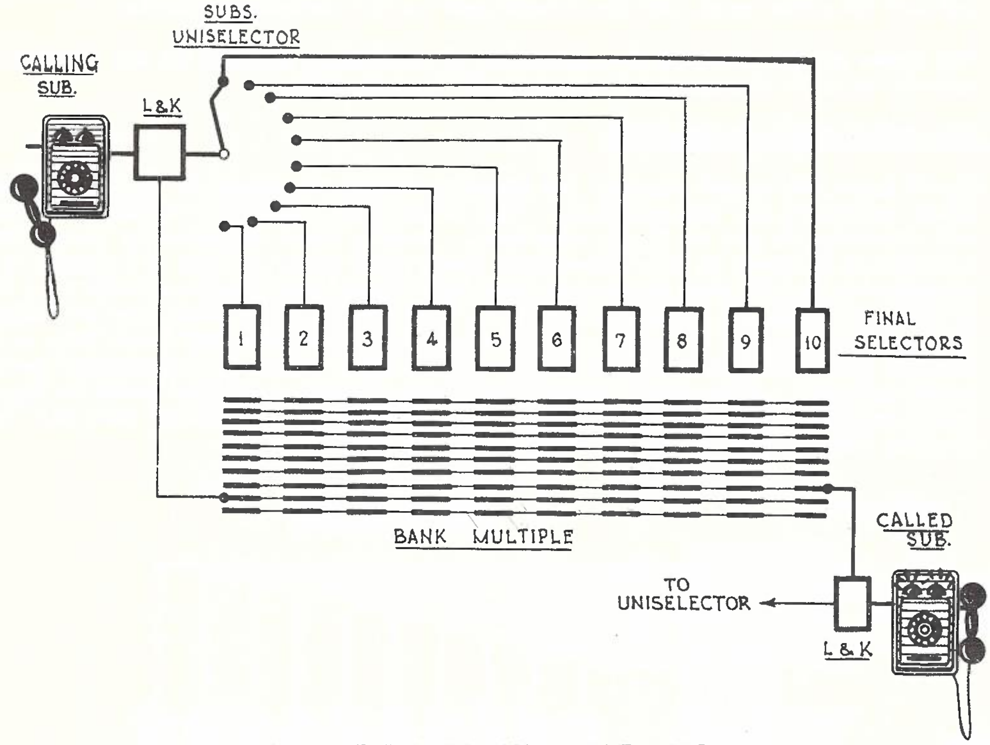
5.1 Fig. 9 shows the method whereby the subscribers may be connected to a common group of final selectors via uniselectors. The uniselector banks are "multipled" together and connected to the 10 final selectors. When a final selector is in use the associated contacts on the uniselector banks test busy, so that the wipers of another uniselector in the same group will step over these particular contacts when the uniselector is used for an outgoing call. When the 10 final selectors are engaged further calls cannot be made, and the absence of dial tone indicates this to the calling party or, alternatively, busy tone is given when the uniselector passes the tenth contact. Although 10 uniselector bank contacts only are shown in Fig. 9, the usual capacity of the bank is 24 or 25 contacts. The reason for this will be explained when larger groups of lines are being discussed.



PRACTICAL 100 LINE EXCHANGE.

FIG. 9.

5.2 A simplified trunking diagram is shown in Fig. 10, where subscriber No. 21 is calling No. 30 as before.

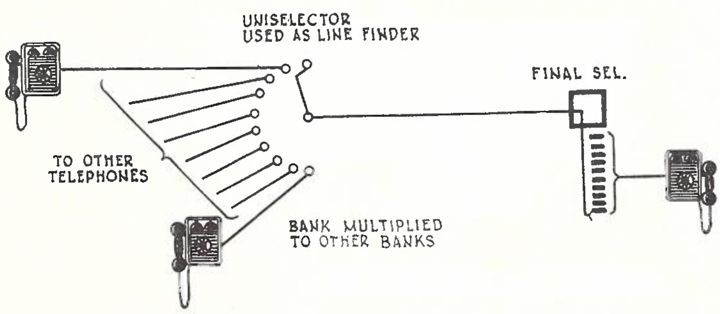


100 LINE EXCHANGE USING UNISELECTORS.

FIG. 10.

When the subscriber lifts the receiver, the uniselector wipers will be automatically stepped until they are standing on an outlet to a free final selector. This is known as a "hunting" action and requires no impulses for its operation. The free outlet is "seized" and guarded against intrusion by other calling subscribers. In Fig. 10 final selector No. 10 has been seized by uniselector No. 21, and the subscriber will proceed to dial the two digits 30. The call matures in the same way as described in paragraph 3.2.

5.3 Uniselectors as Line Finders. Providing a uniselector for each subscriber's line will not always be the most economical arrangement. It is a sound policy to arrange the switching equipment common to a group of subscribers rather than to make it individual to one line. Then it can be used by any one of a group, and, generally, it will be more economically used. In a small automatic exchange requiring only a few two-motion switches for the traffic, this will certainly be true. In these cases the uniselectors are coupled with a two-motion switch and the subscribers' lines are connected to the bank contacts of the uniselector as shown in Fig. 11.



PRINCIPLE OF LINE FINDER EXCHANGE.

FIG. 11.

/There

There is no alteration in the mechanical operation of the uniselector with this arrangement. The removal of the receiver causes the wipers of an idle uniselector to hunt for the contacts of the calling party which, when found, is switched through to a two-motion switch. Thus, the uniselectors in use are similar to those in the switch per line scheme, but the number of uniselectors is much less than before. Uniselectors used in this manner are known as Line Finders.

If the uniselectors have 25 outlets the subscribers in the exchange would be divided into groups of 25 lines, each group being provided with a number of line finders and a similar number of final selectors. Two-motion selectors may also be arranged as line finders and give groups of 100 lines or, in some cases, 200 lines. Each line would have, of course, its line relay and cut-off relay, and it would be necessary to have some common equipment which allots the line finder and starts at least one of the line finders hunting as soon as the call is made. It is a matter of economics to determine whether a line finder system is preferable to the switch per subscriber's line scheme and, as stated previously, when the traffic is light the line finder system is more economical.

5.4 Necessity for Dial Tone. With the introduction of the uniselector, and the consequent limitation in the number of connecting circuits, it may occasionally happen that a subscriber, on removing his receiver, is not immediately connected to a two-motion selector, and some little time elapses before the exchange apparatus is prepared to accept the dialled impulses. Should the subscriber dial before the apparatus is ready to accept the impulses, a wrong number or a mutilated call would result. To indicate to subscribers that the exchange apparatus is ready to receive the call, "dial" tone is connected to the calling line by the two-motion selector.

If the telephones are fitted with the standard dial, in which the lost motion period precedes the impulse train, some safeguard is given against premature impulsing when a subscriber fails to wait for dial tone before commencing to dial. However, when the connection is via line finder equipment, the time taken to switch through may be several seconds. Thus, it is essential for the caller to listen for dial tone before dialling.

6. 1,000 LINE EXCHANGE.

6.1 The principles of a 100 line exchange have been described. Such an exchange is often referred to as a 2-digit system because it is necessary to dial 2 digits to gain connection to any number.

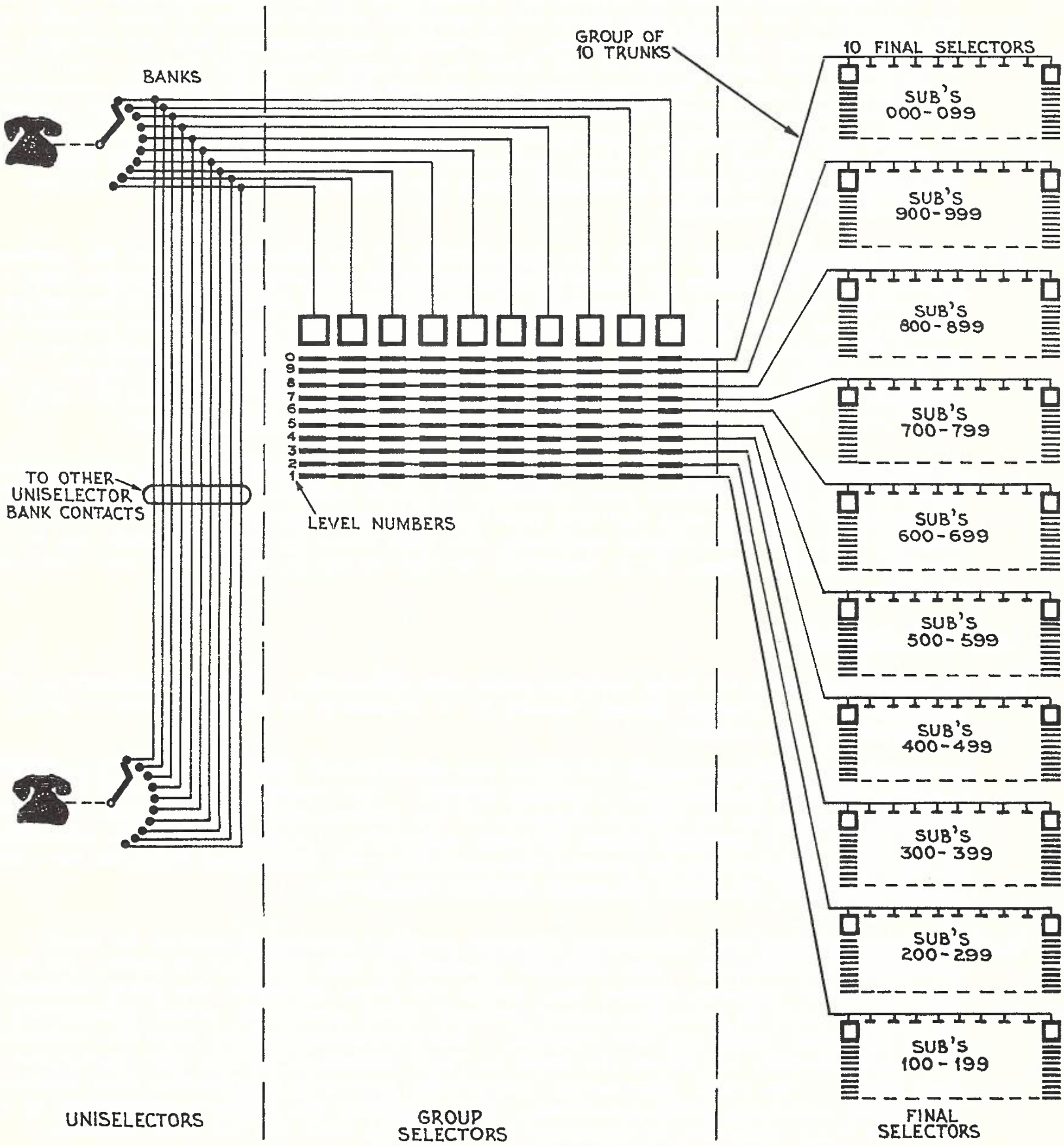
To extend the exchange beyond 100 lines the subscribers' numbers must have 3 digits, and the exchange thus becomes a 3-digit system. The numbering on a 1,000 line exchange is from 000 to 999 and consists of ten groups, each of 100 lines, each group being served by a suitable number of final selectors. A group selector, controlled by the first digit dialled, selects the particular 100 line group required and gives access to one of the final selectors serving that group.

6.2 The Group Selector is a two-motion selector having a mechanism similar to those described in Section 2. The vertical movement of this selector is controlled by the first train of impulses dialled but, unlike the final selector, the group selector is provided with an automatic rotary movement which comes into action immediately after the first digit has been dialled. The wipers are stepped over the contacts of the level reached, and these are wired to final selectors serving that particular 100 line group. The first free outlet encountered is seized and guarded from intrusion from other searching group selectors. The remaining two digits are accepted by the selected final selector, as explained in connection with the 100 line exchange.

This automatic rotary movement is not controlled by the dial and is known as a "hunting" action.

/6.3

6.3 Fig. 12 shows the trunking arrangements for a 1,000 exchange. Assuming that 10 final selectors are sufficient to carry the average number of simultaneous calls incoming to each of the 100 line groups, then the banks of all of the group selectors in the exchange will be multiplied together. Should more than 10 final selectors be necessary in any one group, then a scheme of "interconnecting" or "grading," to be explained later in the course, would be used.

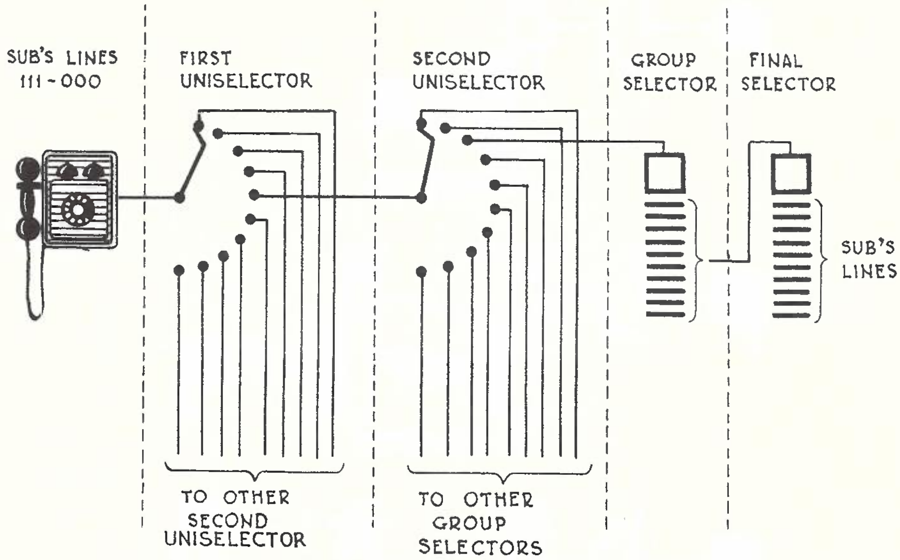


TRUNKING DIAGRAM OF 1,000 LINE EXCHANGE.

FIG. 12.

6.4 The exchange contains 1,000 uniselectors, and these are divided into 10 groups of 100. Each of these groups has access to 10 group selectors, requiring 100 group selectors in all. If all of the group selectors serving, say, the 200-299 group are taken into use, then any other subscriber in this group will be unable to make a call until one of the group selectors is released. It is quite likely that one of the 90 other group selectors serving the other groups would be free at the same time that congestion conditions are occurring in the 200 group. It will be seen then that it will be of considerable advantage to give each group of uniselectors access to a larger number of group selectors. In practice, this may be done in two ways -

(i) Uniselectors with 25 outlet banks.
(ii) Secondary Working. This is illustrated in Fig. 13. Using 10 point uniselectors, each outlet is wired in tandem to a secondary 10 point uniselector giving access to 10 group selectors. This principle is used in the Siemens No. 16 system, which is treated in Paper No. 8, and gives each subscriber access to 100 group selectors. Assuming that 10 group selectors would carry the traffic from each 100 lines, then, by using secondary working, it would be found that something less than 100 selectors would be required for the same grade of service. It is a basic principle of automatic telephony that greater efficiency in trunking is obtained by increasing the size of a group.



SECONDARY WORKING.

FIG. 13.

6.5 Some of the terms commonly used in automatic telephony are defined hereunder -

Trunking is the branch of automatic telephony which is concerned with the provision and arrangement of switching plant as needed to carry the traffic.

Telephone Traffic. The aggregate of telephone calls passing over a group of circuits or trunks having regard to their duration as well as their number.

Busy Hour. The hour during which the traffic of an exchange, or the traffic over a group of trunks, is greatest.

Grade of Service is a measure of the service given from the point of view of sufficiency of plant. In practice, it is expressed as the proportion of calls which are allowed to fail during the busy hour, owing to limitation for economic reasons of the amount of switching plant.

/Rank

Rank of Selectors. The selectors which provide for any one stage of call selection.

Trunk. A connecting circuit between selectors of different rank.

Availability. The number of trunks to which a selector has access on any route. Thus, in a 25 outlet uniselector the availability is 25.

Full Availability is the condition under which a selector has access to the whole of the trunks on a given route.

Limited Availability is the condition under which a selector has access to a limited number only of the trunks on a given route. The availability is usually limited by the number of outlets per level in the hunting selector.

6.6 To increase the ultimate capacity of an exchange 10 times, that is, from 100 to 1,000, etc., an additional switching stage is necessary, and the fact that the two-motion switches are set up in a definite sequence enables rank numbers to be used. For example, in the 100 line exchange one rank of switches only occurs, that is, final selectors; in the 1,000 line exchange two ranks occur, group and final selectors; whilst in the 10,000 line exchange (4-digit system) three ranks occur, first group selectors, second group selectors and final selectors. In general, as illustrated in Fig. 14, one rank of switches is added when the capacity of an exchange is increased 10 times.

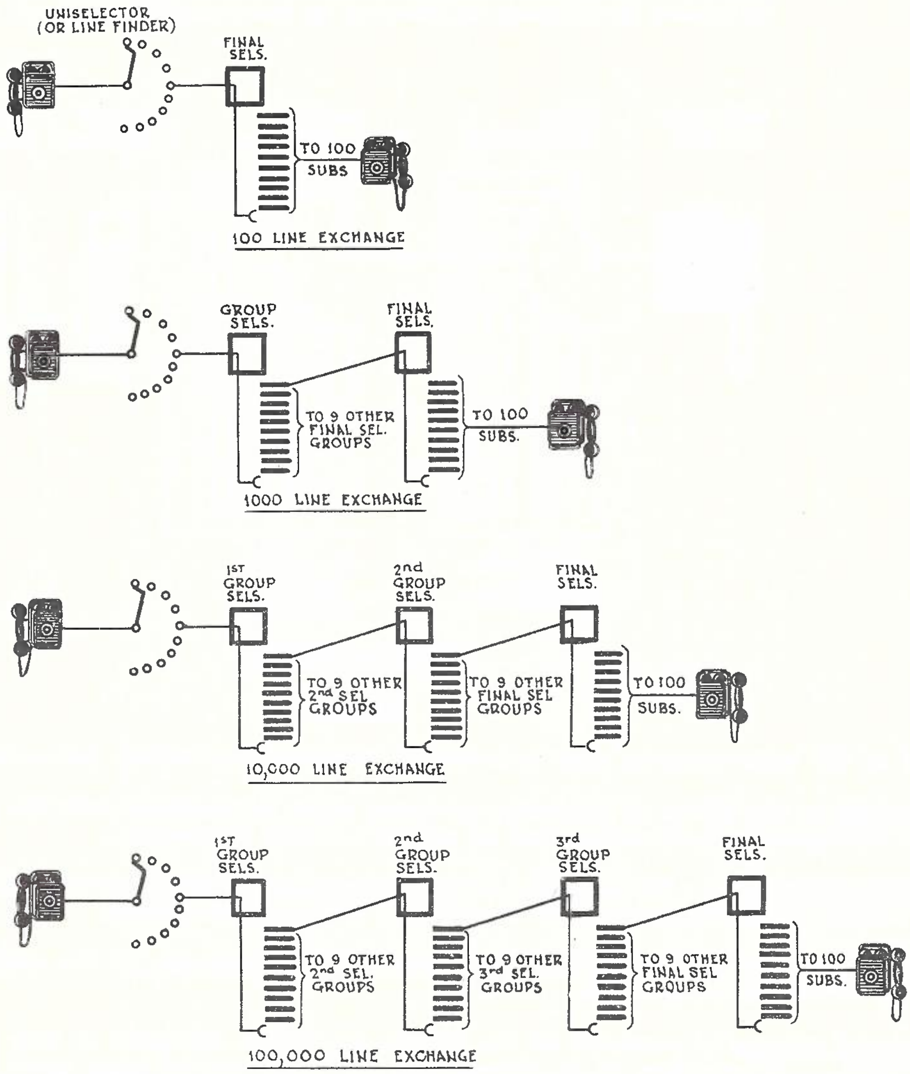
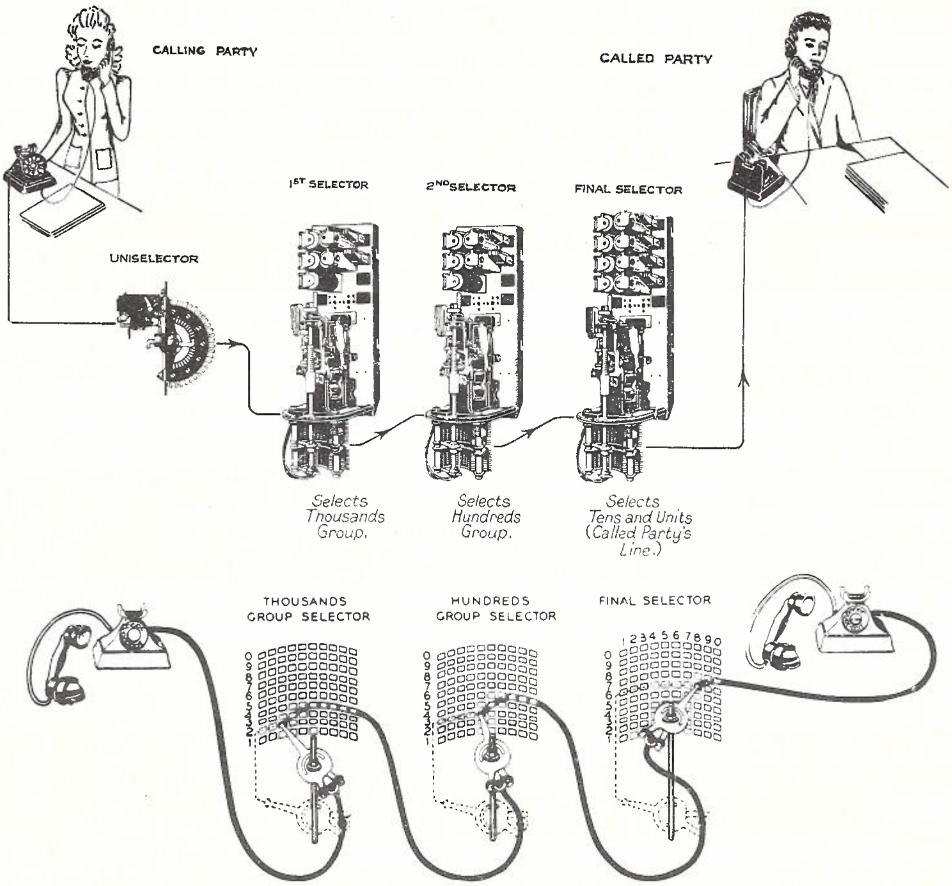


FIG. 14. AUTOMATIC EXCHANGE TRUNKING DIAGRAMS.

The top sketch of Fig. 15 shows pictorially the switches used in an exchange with a capacity of 10,000 lines where 4-digits are dialled in selecting one subscriber from the 10,000. This sketch also gives a general idea of the appearance of a two-motion switch. The mechanism is the same in group and final selectors of the same type, but the relays and contacts differ. The lower sketch in Fig. 15 shows the actual position of the wipers at each two-motion switch on a call to a particular subscriber. The uniselector has been omitted, but called subscriber's number may be ascertained from this sketch.



A CALL THROUGH AN AUTOMATIC EXCHANGE.
What is the called subscriber's number?

FIG. 15.

The number of contacts in a level was determined by the limits of the dial, which can give a maximum of 10 impulses for the final selector's last digit. As a similar bank is used for group selectors, the number of contacts searched was thus only 10, but there is no reason for limiting the contacts available, in fact, there are distinct advantages in most installations in increasing the number, and switches are now being used which search two sets of bank contacts at a time, that is, there are 20 outlets for each of the 10 levels. Final selectors are also used which have access to two groups of 100 subscribers' lines.

The terms Trunk and Link occur extensively in automatic practice, and refer to the internal connecting circuits which provide access to common switching equipment. The arrangement and distribution of switches is referred to as the trunking scheme and, as the trunking scheme is correlated to the traffic requirements, the trunking scheme will differ for most exchanges.

/6.7

6.7 Why Level 1 is not Allotted. In practice, numbers commencing with the digit 1 (or "A") are not usually allotted. This is due to the risk of wrong number troubles arising out of the transmission of a false impulse. A false impulse may result from the misoperation of the switch hook, breaking the loop circuit and thus sending one impulse which, in the case of a group selector, would erroneously step the switch to the first level. If the level were a working one the legitimate impulses would operate switches of the wrong rank, resulting in the connection to a wrong number. When the level is not allotted, the circuit may be arranged to suppress or neglect the single false impulse and allow the switch to receive the proper train of impulses or, alternatively, the outgoing trunks may lead to other switches also in the first rank, thus routing the proper train to the relative rank, or the outlets from level 1 may be connected to number unobtainable tone or to a manual telephonist. The method employed will be determined by the requirements of the area. It should be noted that this reduces the size of an exchange by 10 per cent., as there can be only nine working levels from first selectors. Thus, a 10,000 line exchange is reduced to 9,000 lines, a 1,000 exchange to 900 lines and a 100 line exchange to 90 lines.

7. TEST QUESTIONS.

1. Discuss the necessity for providing tones in an automatic system. Give a list of the standard tones and state the function of each.
2. What are the advantages of an automatic system over a manual system?
3. Show by means of a sketch the location in a bank of the following numbers - 38, 07 and 55.
4. Discuss the relative differences between reverse and forward action switches.
5. In Fig. 12 of this Paper, what is the availability of the group selectors?
6. In that case, is it Full or Limited Availability?
7. What are the advantages and disadvantages of secondary working?
8. What is meant by the term "Grade of Service?"
9. How many ranks of selectors would be provided in a 6-digit system?
10. What function would be performed by the second group selectors in a 6-digit system?
11. What methods are used to meter the subscribers' calls in an automatic exchange?
12. Why are uniselectors used?
13. Draw a trunking diagram for a 100 line exchange using uniselectors.
14. Why is level 1 of 1st Group Selectors not generally allotted?

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END OF PAPER.

COMMONWEALTH OF AUSTRALIA.

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COURSE OF TECHNICAL INSTRUCTION.

UNISELECTORS.

CONTENTS.

1. INTRODUCTION.

1.1 The uniselector which has been introduced in Paper No. 2 is defined as "a selector having unidirectional motion". This switch was previously known as a line switch or a preselector.

1.2 Our first automatic exchanges were equipped with plunger type uniselectors having 10 outlets. As these switches cannot be overloaded without serious risk of double seizure, it was necessary to provide a comparatively large number of first selectors. Subsequently, 10 point local secondary uniselectors of the plunger type were installed, with a resultant increase in trunking efficiency.

1.3 In 1919, 25 outlet rotary uniselectors were introduced as local secondaries, in conjunction with plunger primary uniselectors. This combination gave the subscribers a maximum availability of 10 x 25, or 250, first selectors.

1.4 Since 1924, most exchanges installed were fitted with rotary uniselectors as primary line switches, and, because of the greater traffic efficiency of the rotary switch, due to its greater availability, the use of local secondaries was rendered economically unsound.

2. UNISELECTORS - ROTARY TYPE.

2.1 Unlike the two-motion selector, the uniselector has no natural resting place, or "normal" position. In some cases, special conditions necessitate the return of the uniselector wipers to a particular position after use. This position is known as a "home" position, and uniselectors which return to such a position after use are known as "homing" type uniselectors.

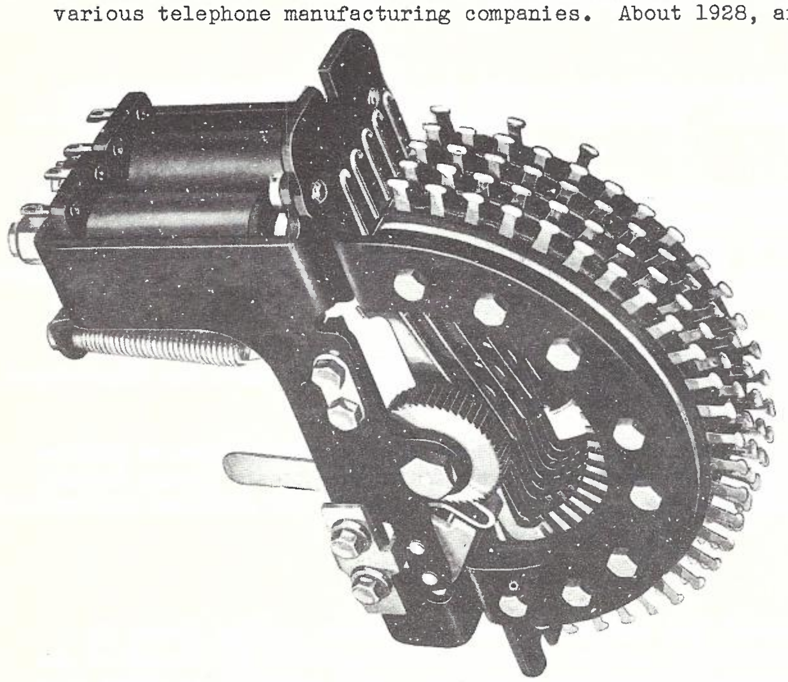
Both homing and non-homing types are in use. In the non-homing type, the wipers may be standing on any set of bank contacts and the circuit arrangements provide for the disconnection of the subscriber's line from the circuit upon which the wipers are standing when the switch is idle. If the circuit upon which they are resting is busy when a call is originated by this particular subscriber, the wipers automatically move on until a free outlet is found.

Mechanically, the uniselector is similar for both types but there is a difference in the trunking to first selectors. The non-homing uniselector has 25 outlets and the traffic is distributed evenly over them. The homing uniselector has 24 effective outlets, the 25th being used as a home position. In this switch the earlier choices carry the bulk of the traffic, the second outlet only being used when the first is busy, and so on. Thus, the later choices are used only for traffic peaks. Because the homing switch commences its search at the same point for each call, it is possible to "grade" the outlets. The purpose of grading is to common the later choices of several groups, leaving the early choices, which carry the heavy traffic, connected to individual trunks. The traffic peaks are taken by the common groups, and the result of this grading is the reduction in the number of first selectors required over several groups to an extent of approximately 20 per cent.

For each call made, the homing switch takes 25 steps, or half a revolution, which includes the search and return to home position. The non-homing switch only steps until a free outlet is found.

2.2 The specification for subscribers' uniselectors requires that a switch should complete one hundred thousand half-revolutions without any readjustment and one million half-revolutions without any appreciable wear. A subscriber's uniselector is only used intermittently, so that a long service life is ensured. However, in many applications of the uniselector, a more continuous operation is required and a stronger switch is necessary. Thus, there is the need, in the interests of economy and efficiency, for a light duty and a heavy duty uniselector. Heavy duty uniselectors have been life tested to one hundred million steps or four million half-revolutions.

2.3 There are many different types of uniselectors in use in Australia, manufactured by the various telephone manufacturing companies. About 1928, after a close examination of the various types in use, the British Post Office developed a standard uniselector (Fig. 1). Most of the equipment supplied by British manufacturers after 1928 used the B.P.O. No. 1 uniselector, resulting in a considerable saving in manufacturing and maintenance costs.



B.P.O. NO. 1 UNISELECTOR.

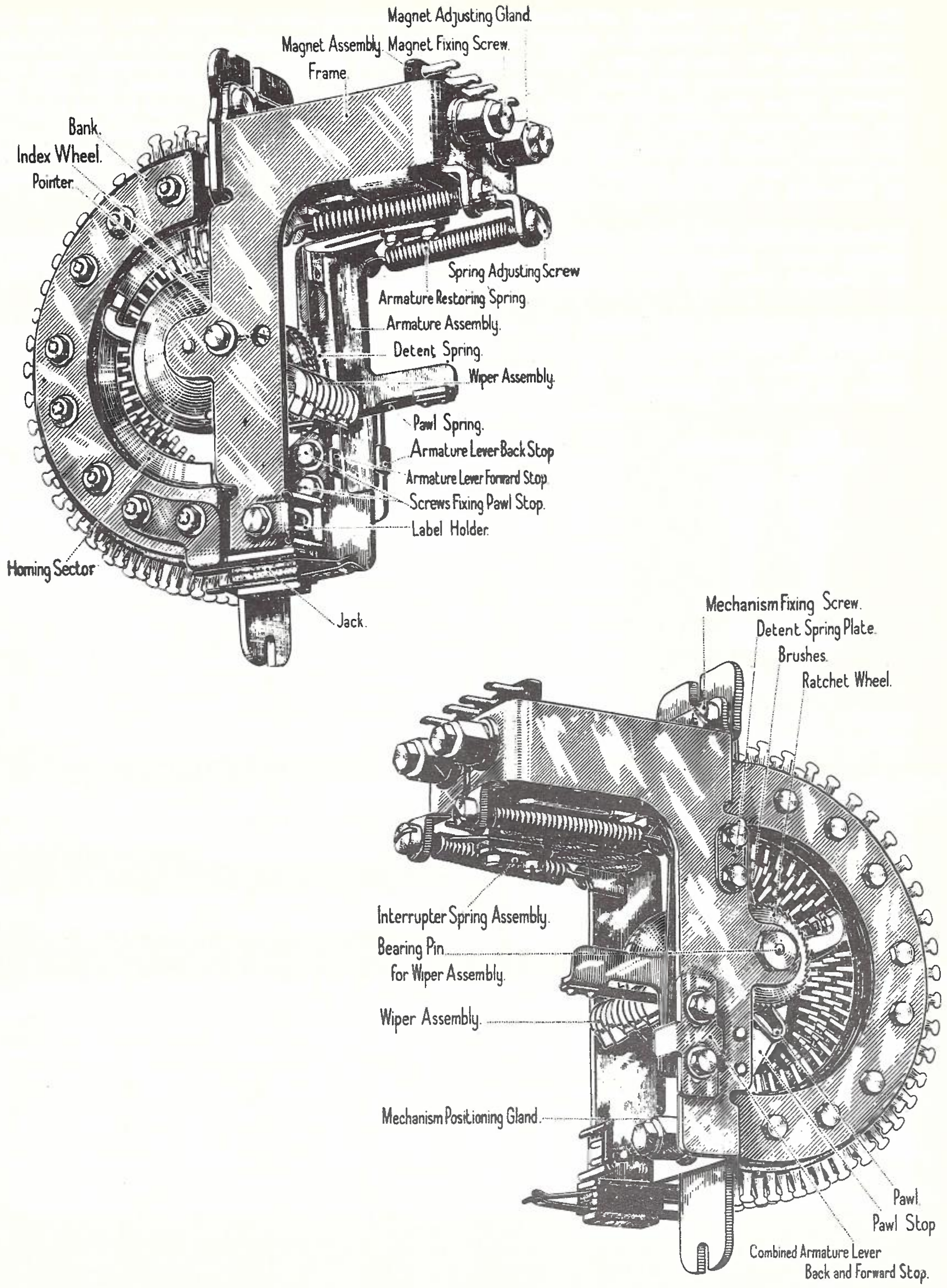
FIG. 1.

The City West (Melbourne) Exchange, installed in 1938, was supplied with homing type subscribers' uniselectors of the B.G.E. C.3100 type. This uniselector has several improvements on the B.P.O. No. 1 type, and was subsequently adopted as the A.P.O. standard. It has since been supplied by various manufacturers, both local and overseas.

2.4 <u>B.P.O. No. 1 Uniselector</u> is generally similar to the original B.G.E. uniselector. Two views of the uniselector are given in Fig. 2. The uniselector consists of four main portions -

(i) <u>The Bank</u>. This is made up of a number of rows each having 25 contacts. The number of rows or "levels" depends on the circuit requirements. The contacts are spaced radially and are stampings of hard rolled brass, the direction of grain being along the length. The bank contacts are insulated by two thicknesses of oiled silk on both sides of each row. The levels are separated by aluminium spacers placed between them, and these also act as electrostatic screens to guard against crosstalk between adjacent contacts.

/ Fig. 2.



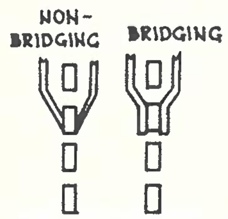
B.P.O. NO. 1 UNISELECTOR.

FIG. 2.

The bank used with homing switches has one continuous level, broken only for the home contact. This is usually a single metallic arc, but for special circuit facilities a twin homing arc can be used. This consists of two metallic arcs insulated from one another but forming one level. The bank of contacts is bolted between two mild steel frames, which are zinc-plated and given a coat of clear lacquer. One end of each of the outer steel plates is bent at right-angles to form a straight strip at each end of the bank. These are slotted to provide a means of mounting the bank on the rack, and drilled to enable the magnet assembly to be secured to the bank. A test jack assembly is attached to the bank in a convenient position.

Associated with the bank assembly are the wiper feed brushes of hard-drawn phosphor-bronze wire. These can be seen in Fig. 1, and are mounted in such a way that they can be detached from the bank without necessitating the removal of the bank wiring.

(ii) The Wiper Assembly. The wipers are made of hard rolled phosphor-bronze and are arranged in pairs. When the wipers pass over the contacts they wipe on opposite sides of the same contact. When one end of a wiper is in the bank the other end is outside, as shown in Fig. 2. Normally, a wiper passes from one contact to the next without causing connection between them, but circuit requirements frequently call for a wiper which is capable of connecting adjacent bank contacts together for a short period whilst moving from one contact to the next. Such a wiper is called a "bridging" wiper in contradistinction to the ordinary or "non-bridging" wiper. Fig. 3 shows the arrangement of the two types and an example of a bridging wiper may be seen in the top diagram in Fig. 2. The wipers are assembled on, and insulated from, a brass rotor. Connection to the wipers is made by phosphor-bronze wire brushes running in collector rings which are associated with each pair of wipers. An index wheel is fixed to the wiper assembly and, in conjunction with a fixed pointer, shows the number of the bank contact on which the wipers are standing. The rotor is driven by a 50 tooth ratchet wheel of aluminium-bronze, a very hard alloy, and revolves on a stationary shaft of stainless steel which is provided with a lubricant retaining cavity.



WIPER TIPS.

FIG. 3.

(iii) The Frame of the uniselector carries the wiper assembly and magnet assembly, and is attached to the bank at the top end by two screws. At the other end, the position of the frame is adjusted in respect to the bank by a mechanism positioning gland, thus enabling the wipers to be adjusted centrally on the bank contacts.

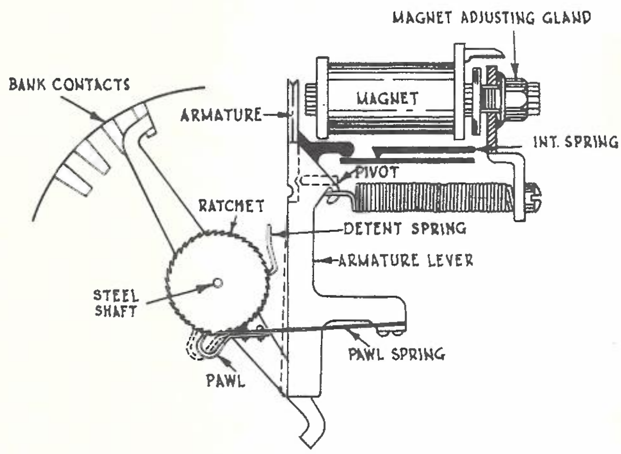
An adjustable detent spring, attached to the frame, prevents the wiper assembly from being rotated in the wrong direction and holds the wipers rigid. The frame also carries the fixed pointer and a label holder.

(iv) The Driving Magnet is a double coil type mounted on the upper portion of the frame. Two coils, each of 37.5 ohms, are connected in series and are adjustable by means of magnet adjusting glands. The armature is hinged on a knife-edge and is restored by two adjustable spiral wire restoring springs which have felt inserts to damp out vibration. An ebonite buffer, carried on an extension of the armature, is arranged to open a pair of interrupter contacts when the armature if fully operated. The spark quench is an 0.5 μF condenser with inherent resistance. An extension of the armature carries a pawl, engaging with the ratchet wheel via a pawl spring. The forward and return movements of the armature assembly, and hence the pawl, are limited by a combined armature lever back and forward stop, which is adjustable by reason of the slanting stops through which its fixing screws pass. The downward movement of the pawl is limited by an adjustable stop.

/ Operation

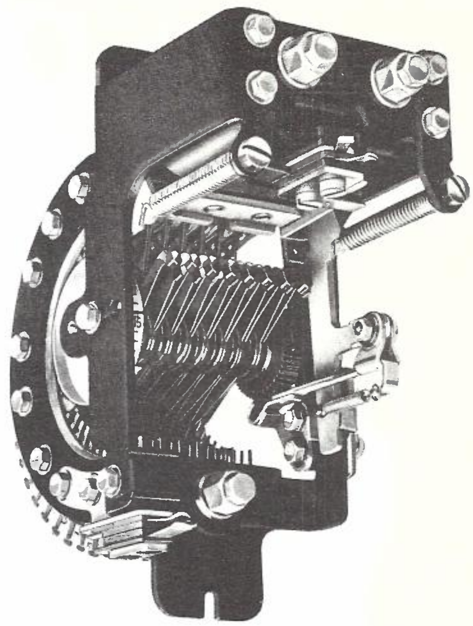
Operation of the Uniselector. The basic mechanical arrangement for stepping the wipers is given in Fig. 4. When the driving magnet is energised, the armature is attracted to the core and the armature lever moves forward, pushing the pawl spring until the pawl slips over the next tooth. The ratchet wheel is prevented from moving by the detent spring. Upon de-energisation of the magnet the controlling springs push the armature back, causing the pawl to pull the wipers forward until it comes against the pawl stop (not shown). The detent spring slips over one tooth and the wipers move forward one step.

If the driving magnet is connected through the interrupter springs, the current flows through the magnet until the armature is attracted. When the circuit is broken by the interrupter springs, the armature releases and steps the wipers. This operation is repeated and the wipers rotate automatically at a speed of approximately 60 r.p.m. or 50 steps per second. This is known as a "self-drive" operation.



MECHANICS OF THE UNISELECTOR.

FIG. 4.

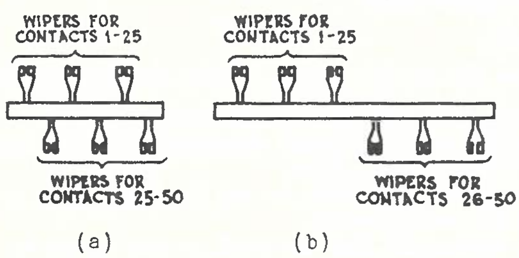


B.P.O. NO. 1 UNISELECTOR - 6-8 WIPER TYPE.

FIG. 5.

Light and Heavy Duty Switches. The frame for the B.P.O. No. 1 uniselector is made in two sizes, the smaller takes 2-5 pairs of wipers and the larger takes 6-8 pairs. The larger frame will accommodate 10 pairs of wipers if modifications are made to the wiper assembly and bank. The 6-8 level switch is designed as a heavy duty switch (see Fig. 5). Heavy duty switches use nickel-silver bank contacts and wipers, and the pawl is much stronger.

Double Search. The uniselector can be arranged to give access to 50 sets of contacts in lieu of the normal 25. The wipers and their associated bank contacts may be arranged in either of the ways shown in Fig. 6.



ARRANGEMENT OF WIPERS FOR 50 CONTACT BANK.

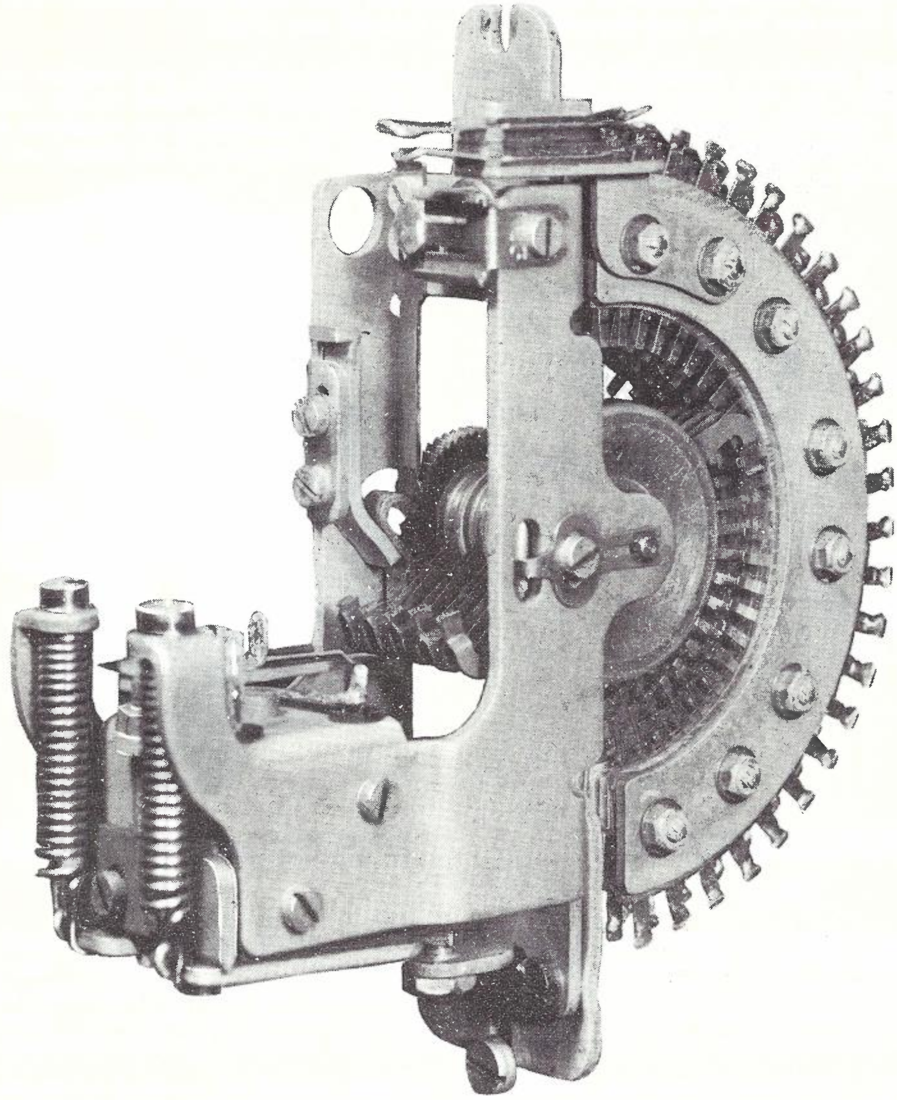
FIG. 6.

In each case single-ended wipers are used, and by arranging the wipers alternately at an angle of 180° to each other, as shown in Fig. 6a, only alternate wipers are in engagement with the bank at any given time. Thus, by commoning pairs of wipers, it is possible to give access to 50 sets of contacts. In the second method shown in Fig. 6b, the right-hand side of the wipers engages with one bank of 25 contacts and the other half engages with the second bank fitted adjacent to the first one. In either case, the effect is the

/ same

same and uniselectors of this type are termed "double search" uniselectors.

2.5 A.P.O. Standard Uniselector. This type, as originally installed in City West Exchange, is shown in Fig. 7. In general appearance, it is somewhat similar to the B.P.O. No. 1 uniselector. It has the same contact bank and brush feed assembly, and is interchangeable with the B.P.O. No. 1 uniselector. In this case it is mounted with the magnet uppermost.



A.P.O. STANDARD UNISELECTOR.

FIG. 7.

The A.P.O. Standard Uniselector differs from the B.P.O. No. 1 type in the following respects -

(i) A single coil magnet is used. Its resistance is 75 ohms for 50 volt working.
(ii) The armature stroke is adjusted by adjusting the knife-edge armature bearing, instead of adjusting the magnet coils as in the B.P.O. No. 1 type.
(iii) The magnet coil and armature assembly are normally fitted in the lower portion of the mechanism, thus facilitating inspection and maintenance.
(iv) The armature and pawl assembly have been redesigned and the pawl is now close to the detent spring. There is only one free tooth between the pawl and the detent spring, so that even if the pawl does overstep, it cannot move the wiper assembly more than one step. A further advantage is that manufacturing errors in the cutting

/ of

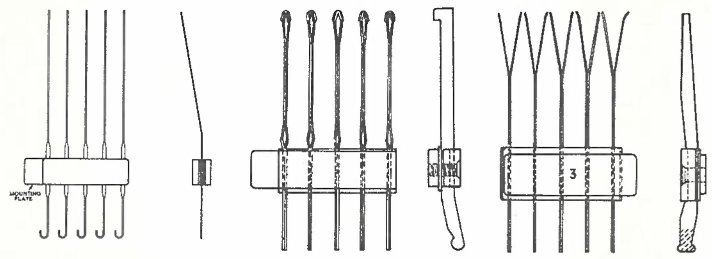
of the ratchet teeth do not appreciably affect the positioning of the wipers on the bank contacts. The maximum error is that due to one tooth and not to the cumulative error of 12 teeth as in the B.P.O. No. 1 switch.

(v) The wiper tips are flared to prevent the wipers locking behind bank contacts in the event of "backlash" developing during service.

(vi) The pawl backstop is of more substantial construction, thus reducing the liability of breakage.

(vii) The mechanism frame has been redesigned so as to secure a more compact switch. The new type mounts on 1-3/4" centres as against 2-1/8" centres for the B.P.O. No. 1 type.

A.P.O. Uniselectors Types 1, 2 and 3. Since the introduction of the A.P.O. type uniselector, several modifications have been made to the switch, mainly in connection with the wiper feed brushes (see Fig. 8). The original uniselector, now known as the A.P.O. No. 1 type, had wire brush springs, and these were found to be prone to the effects of dust trouble and undue wear. In the A.P.O. No. 2 uniselector, these were replaced by pairs of flat phosphor-bronze springs, tensioned together and making contact on each side of a circular disc. These springs overcame the disadvantages of the first type, but were difficult to retension in service. The present standard uniselector, A.P.O. No. 3 type, uses pairs of nickel-silver brush springs tensioned outwards and making contact on the sides of U-shaped collector rings. This method minimises the possibility of faulty connections due to dust, and makes retensioning of the blades relatively easy. However, a special comb tool must be used to hold the pairs of brush springs together when assembling the mechanism to the bank.



No. 1. No. 2. No. 3.

WIPER FEED BRUSH SPRINGS.

FIG. 8.

The A.P.O. type switches now being manufactured in Australia are using nickel-silver for both bank contacts and wipers. The frames are made in two sizes, the first 2-5 (B.G.E. type C.3500) and the second 6-8 levels (B.G.E. type C.3600), the latter being adaptable to 10 levels, as explained in paragraph 2.4.

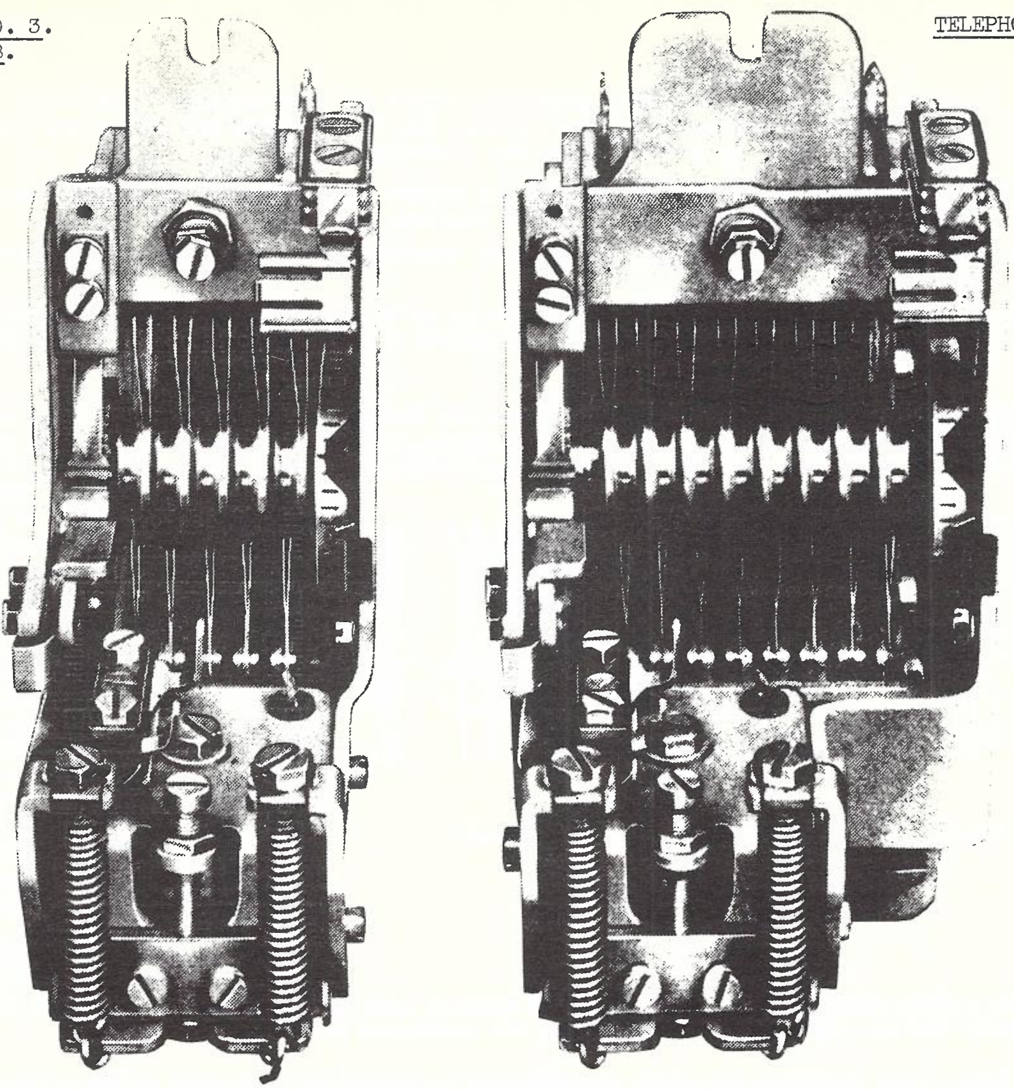
B.P.O. Uniselector, No. 2 Type. Fig. 9 shows the two sizes of a new B.P.O. standard switch known as the No. 2 type. These are heavy duty switches and will be equipped in some apparatus supplied by British manufacturers. In many respects they are similar to the A.P.O. No. 3 uniselector but with the following differences -

(i) A wiper assembly locking device allows the wiper tips to be aligned with the bank contacts without disturbing the setting of the driving mechanism. The locking device lies inside the index wheel and is fully accessible for maintenance purposes (Fig. 10).

(ii) The interrupter striker is a compressed fabric plate, securely riveted to the striker arm, and cannot become loose due to vibration and other causes. Adjustment of the interrupter gap is made both positive and easy by providing the base-plate of the spring-set with a slight camber on its underside (Fig. 11).

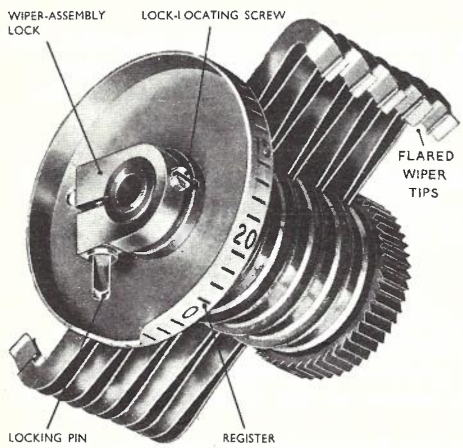
Relative adjustment of the two screws securing the spring-set to the yoke brings the lever spring nearer to, or further away from, the striker without recourse to

/ Fig. 9.



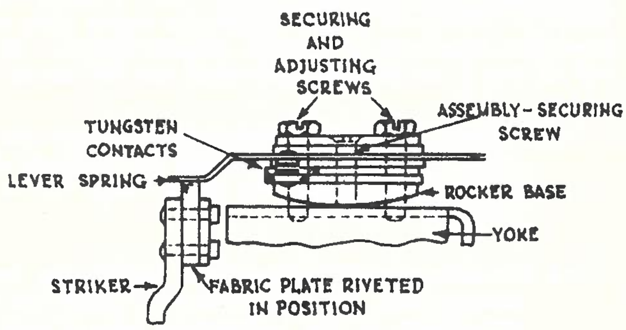
B.P.O. NO. 2 UNISELECTORS, 2-5 AND 6-8 WIPERS.

FIG. 9.



WIPER ASSEMBLY.

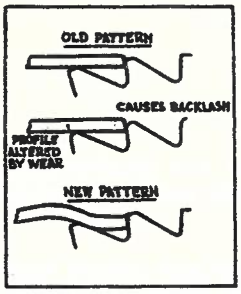
FIG. 10.



INTERRUPTER ASSEMBLY.

FIG. 11.

bending adjustments. The contact pressure, once set, is not altered during this adjustment. The interrupter contacts are of tungsten.



DETENT SPRING.

FIG. 12.

(iii) A redesigned detent spring has been fitted, with the object of minimising the development of backlash due to wear of the ratchet teeth. The old and new patterns are shown in Fig. 12.

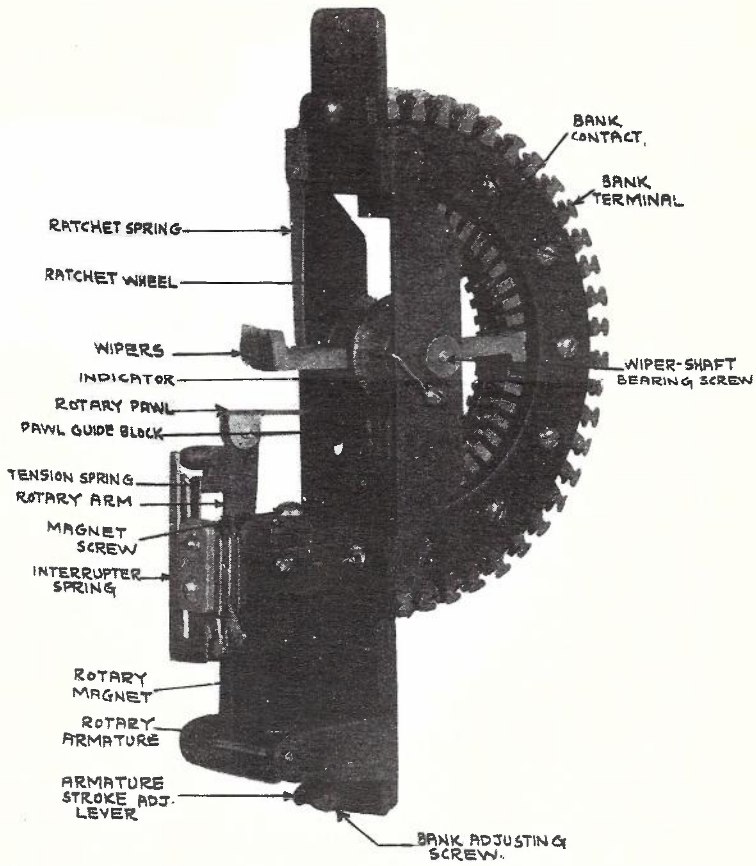
2.6 Many early types of rotary uniselectors are still in service and are briefly described below -

A.E.C. (Chicago) Uniselector (Fig. 13) can be identified by the following -

(i) The driving magnet is mounted vertically below the wiper assembly.

(ii) Extended insulation pieces are fitted between pairs of wipers in later deliveries.

(iii) Round-head screws with American thread are used.



A.E.C. (CHICAGO) UNISELECTOR.

FIG. 13.

A.T. and E. (Liverpool) Uniselector (Fig. 14) has the following characteristics -

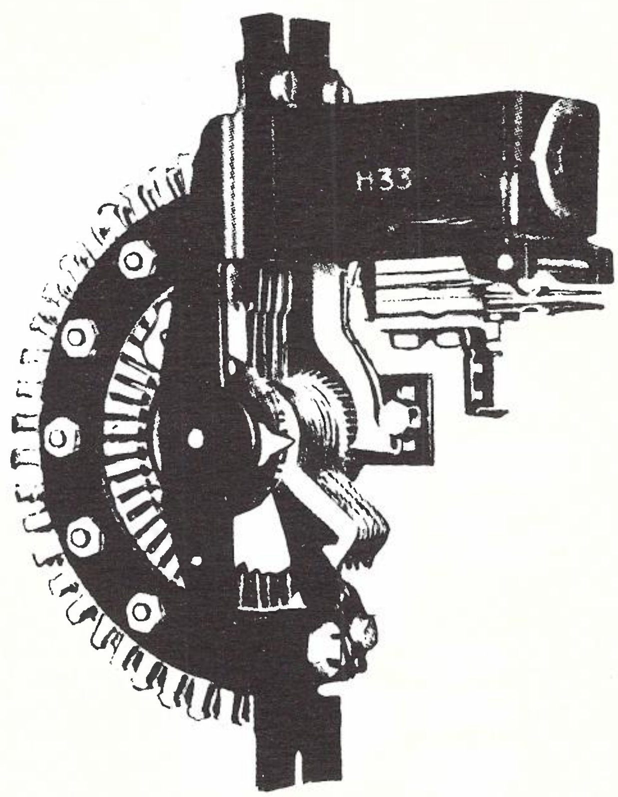
(i) A single coil driving magnet is mounted horizontally, sometimes at the top and sometimes at the bottom of the mechanism.

(ii) The wipers are much wider at the tips.

(iii) The ratchet wheel is rather small in diameter.

(iv) A flat armature restoring spring is used. Originally the tension adjustment was made by bending this spring. A rocker adjustment was subsequently developed and adopted as standard.

(v) A wide ratchet wheel was originally used and both pawl and detent engaged in the same tooth. The detent engages two teeth behind the pawl in later switches. In this switch and in several other types, the wiper feed forms an extra contact which is passed over by one end of a pair of wipers while the other end is on the 25th contact. This increases the load for the armature restoring spring at this contact. Ordinarily, the action of the switch is not affected but sticking and chattering may result, and it is partly to avoid this trouble that the B.P.O. No. 1 uniselector was equipped with the wiper brush feed in a separate alignment from the wipers.

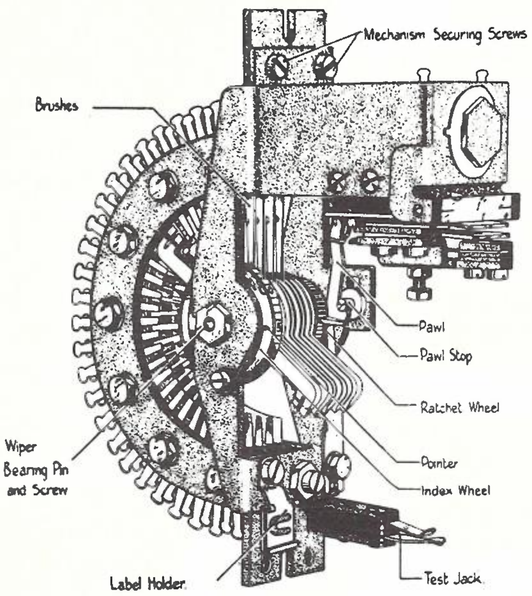


A.T. AND E. (LIVERPOOL) UNISELECTOR.

FIG. 14.

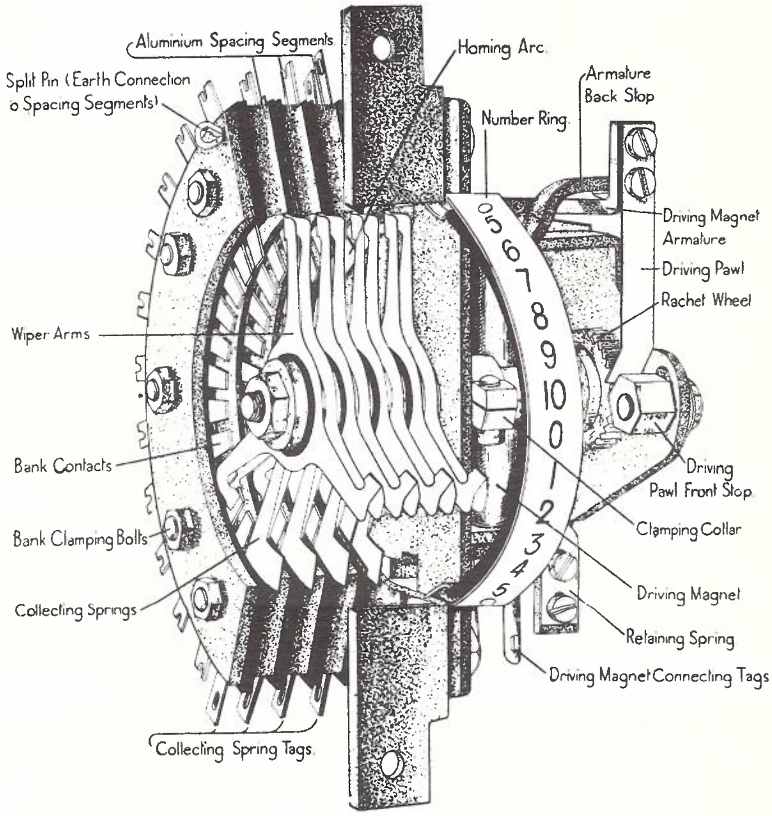
S.T. and C. Uniselector is very similar to the original A.T. and E switch, but may be distinguished by its split wiper tips. It is sometimes provided with a leather mounting to absorb vibration. The uniselector is shown in Fig. 15.

Siemens No. 16 Uniselector (Fig. 16) is a 10 point switch used as primary and secondary uniselectors in Siemens No. 16 exchanges. The primary uniselector is a homing switch and the secondary uniselector a non-homing switch. The driving magnet is not self-interrupted; it is driven by pulses supplied from machine driven interrupters, which give the uniselectors a speed of 32 steps per second. Triple-ended wipers spaced at 120° are used, giving 30 steps per revolution. These switches differ from the types previously described in that the "forward" drive principle is used, the wipers being driven by the pawl as the armature operates.



S.T. AND C. UNISELECTOR.

FIG. 15.



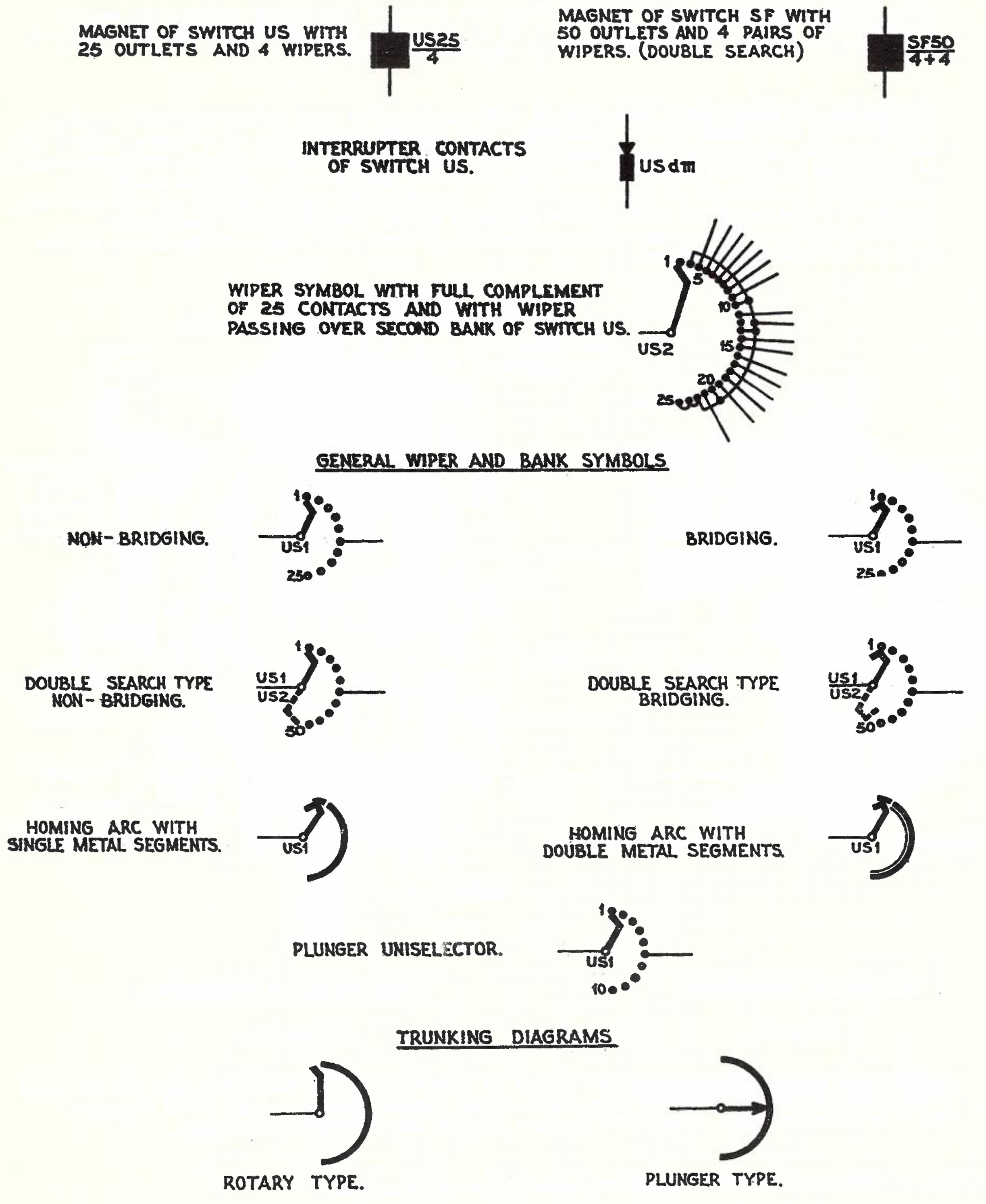
SIEMENS NO. 16 UNISELECTOR.

FIG. 16.

Siemens and Halske Uniselectors are in use in some P.A.B.X's. The types used are 18 point homing and non-homing switches with single-ended wipers, giving access to 36 circuits; and a 10 point switch. These switches are also of the forward action type.

2.7 Fig. 17 shows the standard graphical symbols for uniselectors.

/ Fig. 17.

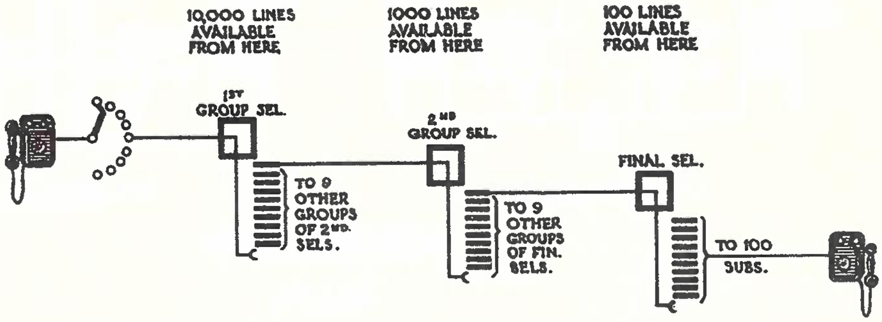


UNISELECTOR SYMBOLS.

FIG. 17.

3. SUBSCRIBERS' LINE CIRCUITS (ROTARY UNISELECTORS).

3.1 Circuit Principles. In Paper No. 2, the principles of automatic switching have been explained, uniselectors being used for reasons of economy of switching plant and the addition of a rank of group selectors being necessary for every digit added to the exchange numbering. A trunking diagram of a 4-digit exchange is shown in Fig. 18.



TRUNKING FOR A 10,000 LINE (4-DIGIT) EXCHANGE.

FIG. 18.

In calling tenders for automatic exchange equipment, circuits which are standard at the time of issue of the tender are published and these indicate the principles to be employed and the circuits which are favoured. The circuits given in this Course are standard circuits, but the details of the circuits may vary in different exchanges. A study of the standard circuits will form a sound basis from which the operation of any similar circuit can quickly be appreciated.

When studying circuits, method is important and as far as possible the scheme to be adopted here will be to give, firstly, the purpose of the circuit; secondly, the functions the circuit is required to perform; and, thirdly, details of how the circuit provides these functions.

A complex circuit can be divided into a number of small component circuits which in themselves are simple and easily recognisable. With an understanding of these circuit elements, the complete circuit, although complicated, is simplified.

Before proceeding to the description of subscribers' line circuits, some of the terms used in describing circuit operation will be defined -

(i) Line Wires. These are the two wires which form the speaking channel between two subscribers. Inside the exchange they are called the negative and positive wires and, in many circuits, they are shown in heavy lines for clearness.

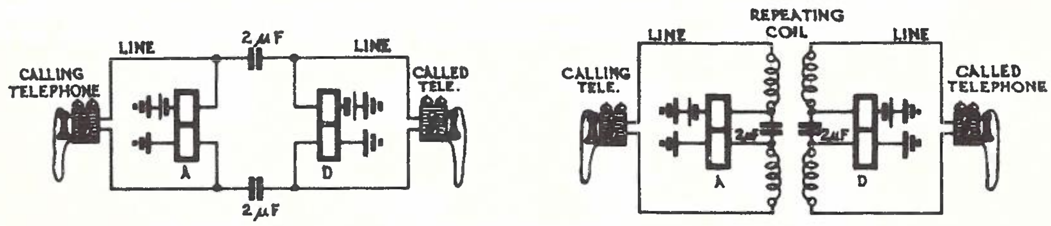
(ii) Private Wire (P Wire). Inside the exchange, the line wires have associated with them a third wire called the private wire, which serves two purposes -

(a) It acts as a guard wire to indicate whether a switch is busy or free. In this respect, it is similar to the sleeve wire in a multiple manual exchange.

(b) It acts as a holding wire. This means that certain relays which must remain operated throughout a call are connected to the private wire and are energised as long as an earth is connected to it. Removal of this earth causes the relays to release and the selectors restore to their normal positions. The private wire is sometimes called the release trunk on this account.

/ (iii)

(iii) Transmission Bridge is the point from which the subscribers are supplied with current for their transmitters. It is usually of the "Stone" type, consisting of relays and condensers as in Fig. 19a. The "Hayes" bridge (Fig. 19b) is rarely used in automatic circuits.



(a) Stone Bridge.   (b) Hayes Bridge.

TRANSMISSION BRIDGE.

FIG. 19.

(iv) Busy Condition. This is the condition put on the private wire of an outlet when that outlet is in use. In most cases, an earth potential is connected to the P wire to indicate the busy condition.

(v) Free Condition. The disengaged condition of a circuit.

(vi) Hunting Action. This is the act of searching for a free outlet and consists of an automatic rotary action which steps the wipers past busy contacts, and which ceases only when a free outlet is found or when the whole of the outlets have been tested.

(vii) Testing. While a selector is hunting, the private wires of the outlets passed over are "tested" for the busy condition and the circuit conditions are such that the wipers will stop when a free contact is reached but will not stop on busy contacts.

Automatic telephone exchange apparatus consists essentially of two parts, individual apparatus and common apparatus. The subscriber's uniselector, for example, is individual apparatus when one is associated with each line. The primary duty of a uniselector is to connect the subscriber's line to a group selector. All group selectors and final selectors are common apparatus because (with certain exceptions) they may be used by any of the subscribers connected to the exchange.

3.2 Functions of Subscriber's Line Circuit. A subscriber's line circuit is the circuit of all apparatus which is individual to that line, and in a uniselector exchange includes the L and K relays and subscriber's meter as well as the uniselector switch. The functions of a subscriber's line circuit using rotary uniselectors are -

(i) Hunts for and seizes the first free outlet upon the lifting of the subscriber's receiver.

(ii) Guards the selected outlet from intrusion.

(iii) Guards the calling party's line from intrusion.

(iv) Keeps the wipers disconnected during hunting, thus preventing interference with contacts over which they are passing.

(v) Extends the calling party's line to the switch ahead for the next stage of operation, and removes all "bridges" from the line wires.

/ (vi)

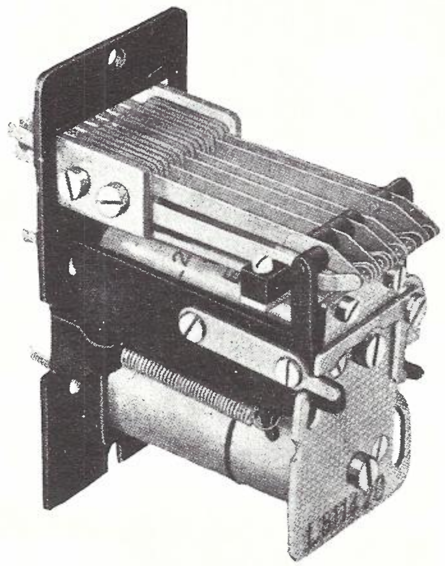
(vi) Prepares the circuit of the calling subscriber's meter for ultimate operation when the called party answers.

(vii) When release conditions are applied -

(a) Releases itself and disconnects the wipers from the contacts on which they are standing (non-homing type).

(b) Releases itself and returns the wipers to the home position (homing type).

3.3 Non-Homing Type Uniselectors. The switch mechanism is similar for both homing and non-homing types, but a continuous contact level is not required for the non-homing type. Also, on a call incoming to the subscriber associated with the uniselector, it is necessary in a non-homing switch for the circuit to the wipers to be disconnected, and this is usually done by half operating the contacts of the cut-off relay in the line circuit. This requires a special interlocking arrangement of the armatures of the line (L) and cut-off (K) relays. Fig. 20 shows the special type of relays used in some exchanges. The relays are mounted below the uniselector on the same mounting plate.



MECHANICAL LATCH AND
FACE PLATE ON L AND K RELAYS.

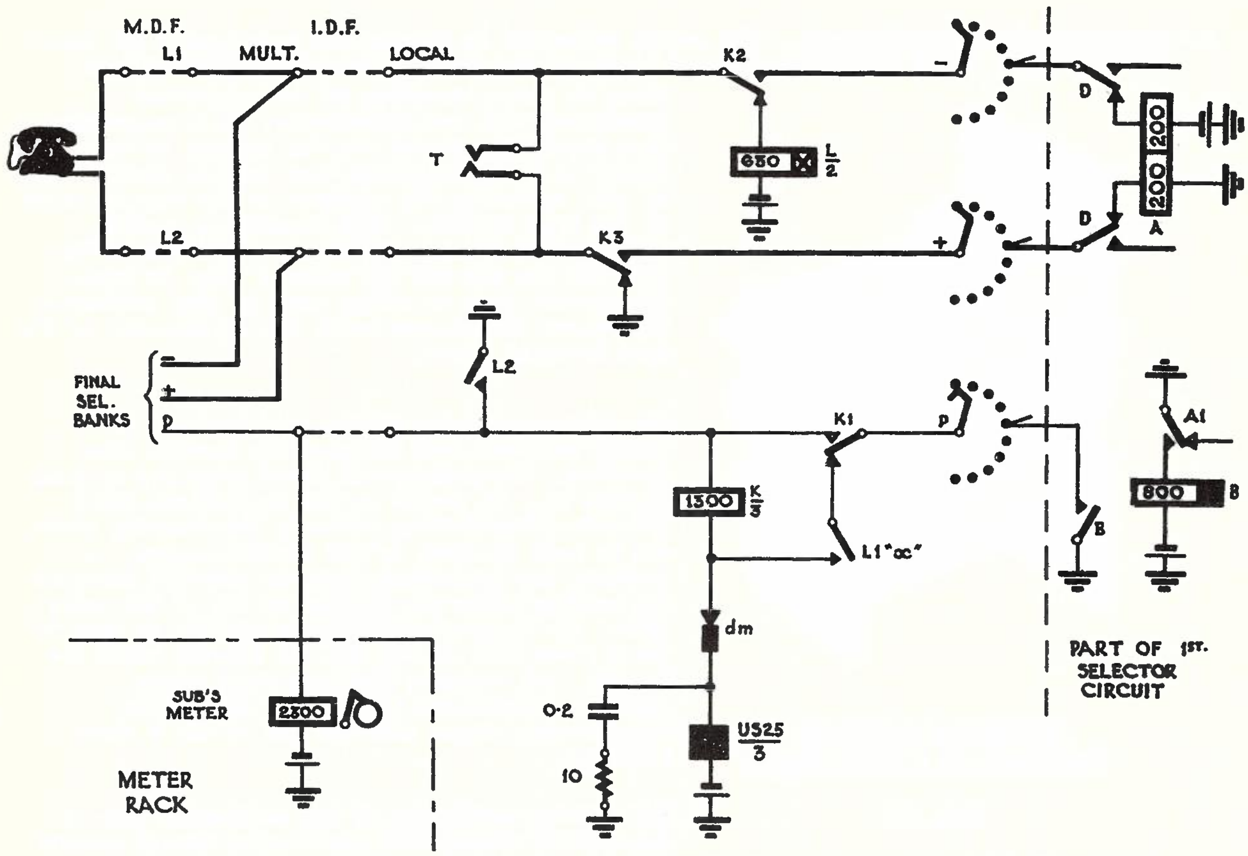
FIG. 20.

The armatures of the relays are fixed one on either side and move horizontally inwards when operated. The armature of the K relay may be seen in Fig. 20. It pivots on two projections which fit into corresponding slots in the mounting plate and is held in place by the control spring. A vertical bar projecting from the armature controls the springs which are mounted on top of the relay unit. The L relay mechanism is similar to that of the K relay but, as the coil is mounted below the K relay, the vertical arm from the L relay armature controlling the L relay springs is considerably longer than the arm of the K relay armature.

The circuit conditions of the non-homing type of uniselector demand that the K relay should operate fully only if the L relay is already operated, otherwise on an incoming call the subscriber's line would be connected to the wipers of the uniselector which are always standing on contacts leading to the next rank of switches. If the L relay is not operated then the K relay must break its normally made contacts but must be prevented from making its normal break contacts. To meet these requirements, the mechanical latch has been designed. With this latch in the position shown in Fig. 20, that is, with the L relay de-energised, the projection on the armature of the K relay is level with the end of the mechanical latch which prevents the armature making a full stroke when the K relay is energised. If, however, the L relay is energised first, its armature pressing against the shorter side of the latch raises the longer end and permits the K relay to operate fully if energised.

/ Circuit

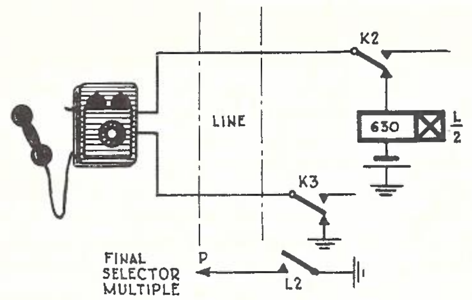
Circuit Operation - Subscriber's Line Circuit (Non-Homing Uniselectors). Fig. 21 shows a typical subscriber's line circuit using a 3-level non-homing type uniselector and arranged for booster battery metering. Part of a group selector circuit is included for explanatory purposes.



SUBSCRIBER'S LINE CIRCUIT - NON-HOMING TYPE UNISELECTOR.

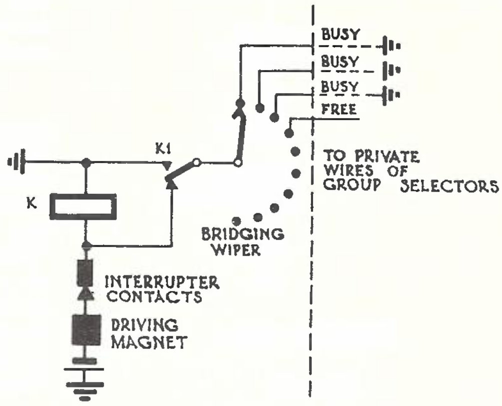
FIG. 21.

Outgoing Call. When the subscriber lifts the receiver to originate a call, current flows via contacts K2 and K3 to operate relay L. (See Figs. 21 and 22.) L2 earths the final selector multiple P wire, marking the subscriber's line busy. Contact L1 makes before L2 and places a short circuit around relay K to prevent it operating prematurely. Assuming that the outlet on which the wipers are standing is marked with the busy condition, that is, earth on the P wire, then the drive magnet is energised via its interrupter contacts, L1 operated and K1 normal to the busying earth encountered by the P wiper (Figs. 21 and 23). This circuit is broken when the interrupter contacts open, and the wipers are stepped on to the next outlet. Should it be busy, the drive magnet is again energised and the wipers stepped until a free outlet is reached. This will be free of earth on the P wire and relay K, being no longer shunted, operates in series with the drive magnet. (The magnet does not operate in series with relay K.)



SUBSCRIBER LIFTS RECEIVER.

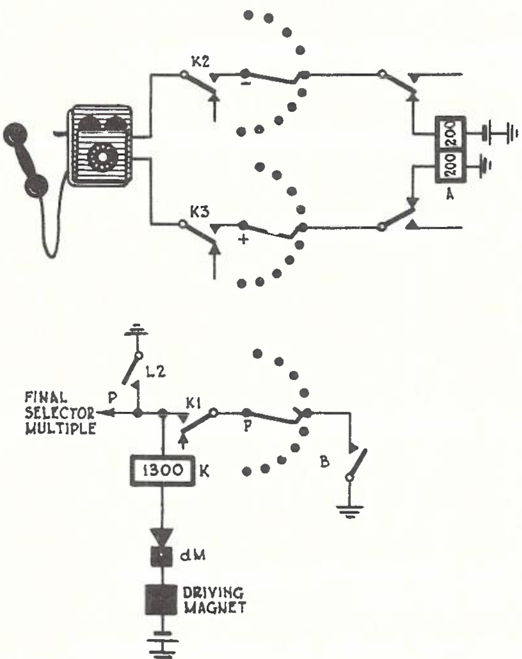
FIG. 22.



HUNTING AND TESTING.

FIG. 23.

To prevent the possibility of relay K operating when the P wiper is passing from one contact to the next, a bridging private wiper is used. Note that the line wipers are non-bridging, and are disconnected during hunting to prevent interference to conversations proceeding on the contacts passed over.



SWITCHING THROUGH.

FIG. 24.

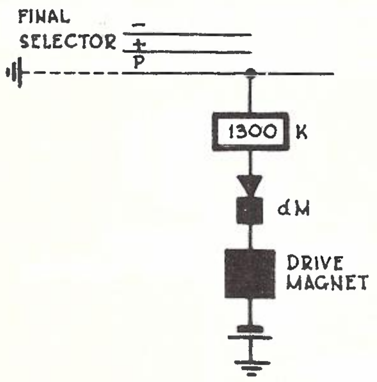
The operation of relay K switches the negative, positive and P wires through to the first group selector (Figs. 21 and 24.) The subscriber's loop operates the group selector A relay, and contact A1 completes a circuit for the operation of relay B, the contact of which returns an earth on the P wire to hold relay K operated after contact L2 opens. The circuit of relay L is opened at K2, but it will release slowly to allow time for the operation of relays A and B in the group selector. The combined operate lags of relays A and B are approximately 30 mS, and the copper slug on relay L gives it a release lag of approximately 100 mS. Placing the slug on the armature end of the core makes it slow to operate, and this ensures uniform release lags even if the wipers are standing on a free outlet when the receiver is lifted.

Dial tone is supplied to the caller from the first selector and the required number may then be dialled. An earth is maintained on the P wire for the duration of the call and when the subscriber replaces the receiver, this earth is

/ removed.

removed. Relay K releases, disconnecting the wipers at K2 and K3 and reconnecting relay L.

Incoming Call (Fig. 25). When the subscriber's number is called from a final selector, assuming the line to be free, an earth is connected on the P wire, and relay K is operated in series with the drive magnet. The stroke of relay K is limited on these calls by the mechanical latch, so that all contacts break but no contacts make. Thus, relay L is disconnected from the line but no connection is made to negative, positive or P wipers.



INCOMING CALL.

FIG. 25.

Fault Conditions. On an outgoing call, should the selected outlet be faulty, no holding earth is returned on the P wire and relay K releases when L2 opens. Relay L reoperates, reoperating relay K and the cycle is repeated, relays L and K "chattering". This can result in much inconvenience to a subscriber, particularly when the exchange is unattended. In homing type circuits, next to be considered, these faults do not deprive a subscriber of service, as the switch will step-on over "open-circuit trunks".

3.4 Homing Type Uniselectors. Non-homing type uniselectors have several points in their favour -

(i) Traffic is distributed evenly over the outlets.

(ii) Wear on the uniselector is reduced to a minimum. (In the homing type, the wipers step over 25 contacts for every call.)

(iii) All 25 contacts may be wired to first selectors. (Only 24 outlets are available from homing type switches.)

(iv) The additional homing level is not required, as in the homing type.

(v) Less battery consumption.

The advantages of the homing type are -

(i) The outlets may be graded. This results in a saving of up to 20 per cent. in the total number of first selectors required.

(ii) Will step-on over open-circuit trunks.

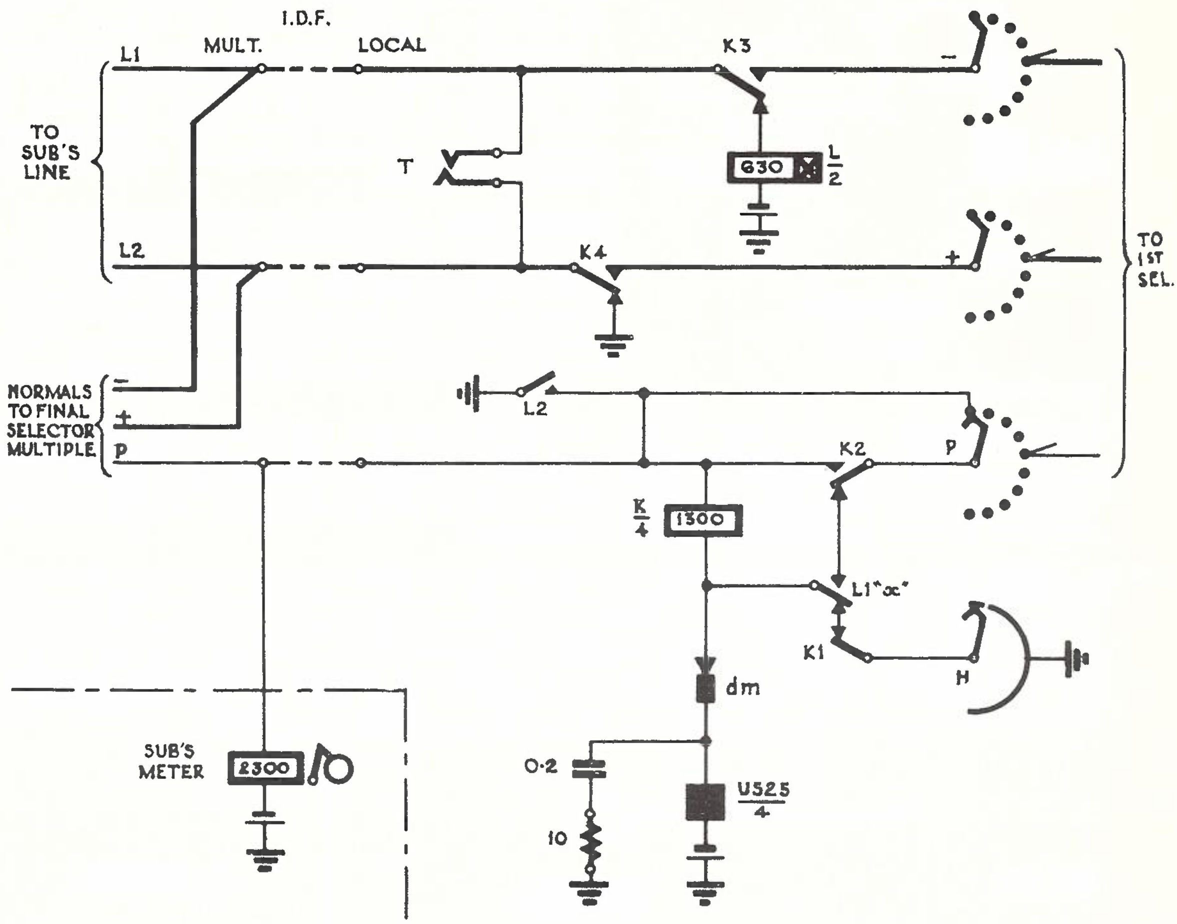
(iii) The mechanical latch and face plate on the line and cut-off relays are not required, and conventional types of relays may be used.

(iv) It has been found that a homing type switch is less liable to contact troubles than a non-homing type. This is due to the cleaning action of the wipers on the bank contacts.

/ For

For the above reasons, homing type uniselectors are preferred, and are now the standard type for subscribers' line circuits.

Fig. 26 shows a typical subscriber's line circuit using a homing type uniselector.



SUBSCRIBER'S LINE CIRCUIT - HOMING TYPE UNISELECTOR.

FIG. 26.

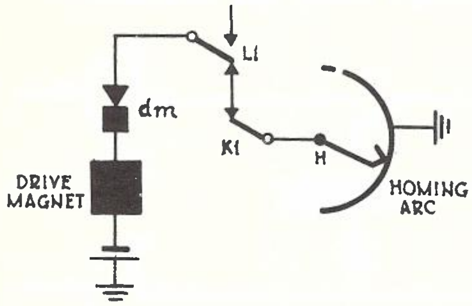
Circuit Operation on Outgoing Call. This is similar to the operation of the non-homing circuit, except that the wipers are normally resting on the home contact, and must be stepped on to the first outlet before beginning to test. Also, at the completion of the call, the wipers must be driven to the home contact and an additional wiper and bank level are provided for this purpose.

When the subscriber lifts the receiver, current flows through relay L which operates. The driving magnet is connected to the private wiper via contacts L1 and K2. The home or No. 1 contact of the private bank is connected to the private wire, and earth from L2 (which is applied after L1 has operated to short-circuit K) completes the circuit of the driving magnet which in operating causes the switch to step from its home position to the first outlet and to search for a non-earthed contact. The earth at L2 also causes the calling line to test busy at the final selector bank. When a free contact is located, the short-circuiting earth on relay K no longer exists, and K operates to switch the negative,

/ positive

positive and P wires to the selected first selector.

When the subscriber's loop is switched to the first selector, the relays in the first selector operate to return an earth on the P wire, and when, after a short interval, relay L releases, this earth holds relay K operated. These conditions prevail until the call is completed when the earth is removed from the P wire and relay K releases. A homing drive circuit is completed for the magnet through its interrupter contact, L1 and K1, to earth on the homing arc, and the switch self-drives until the homing wiper moves from the earthed homing arc and the switch comes to rest in the home position (Fig. 27).



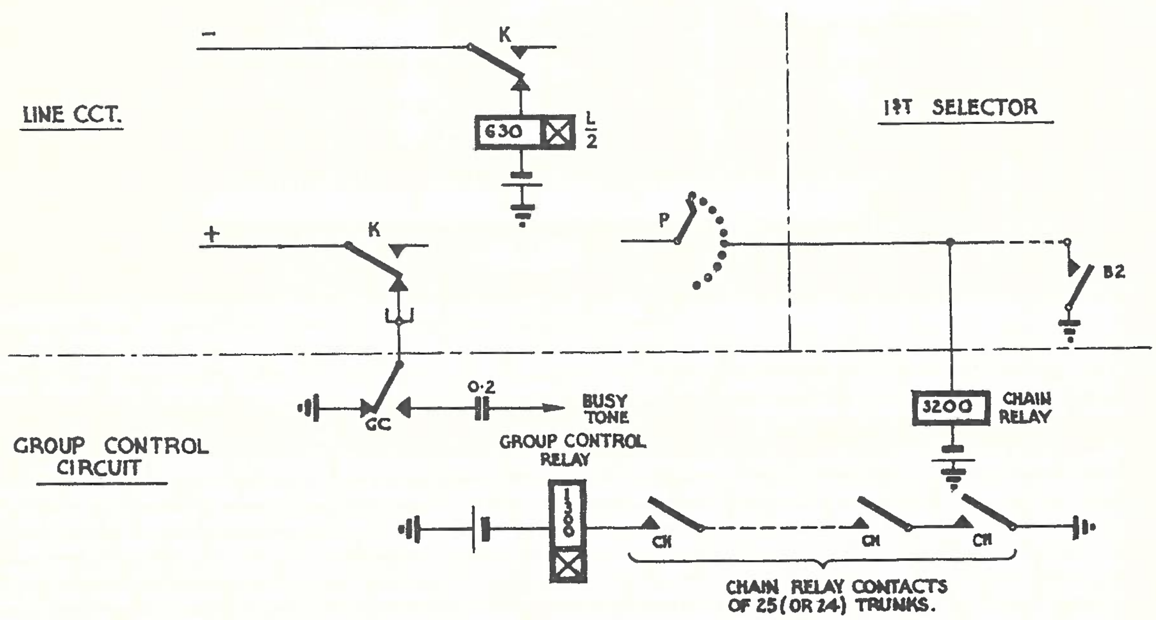
HOMING DRIVE.

FIG. 27.

Incoming Call. An earth is extended over the P wire from the final selector to operate relay K, as before. In the homing circuit, a mechanical latch is not necessary; relay K operates fully and extends the lines through to the wipers. These, however, are standing on the home contacts, which are not multipled, so there is no interference to the incoming call.

Fault Conditions. On an outgoing call, should the selected outlet be faulty, relay K releases when L2 opens. Because relay L is slow to operate, the switch commences to home drive until relay L reoperates. The reoperation of relay L, after a few steps have been taken, interrupts the drive and the next free outlet is seized. Thus, the call may be completed without inconvenience to the subscriber.

3.5 All Trunks Busy. In both non-homing and homing type circuits, if all outlets are busy when a subscriber lifts the receiver, the wipers rotate continuously until such time as an outlet becomes free, or until the subscriber replaces the receiver. To prevent undue wear on uniselectors, the circuit may be arranged to prevent this condition when all trunks are busy. In earlier circuits each outlet is provided with a "chain" relay which operates when the trunk is busy. When the last free trunk is taken into use, the contacts of the chain relays complete the circuit of a "Group Control" relay (Fig. 28).



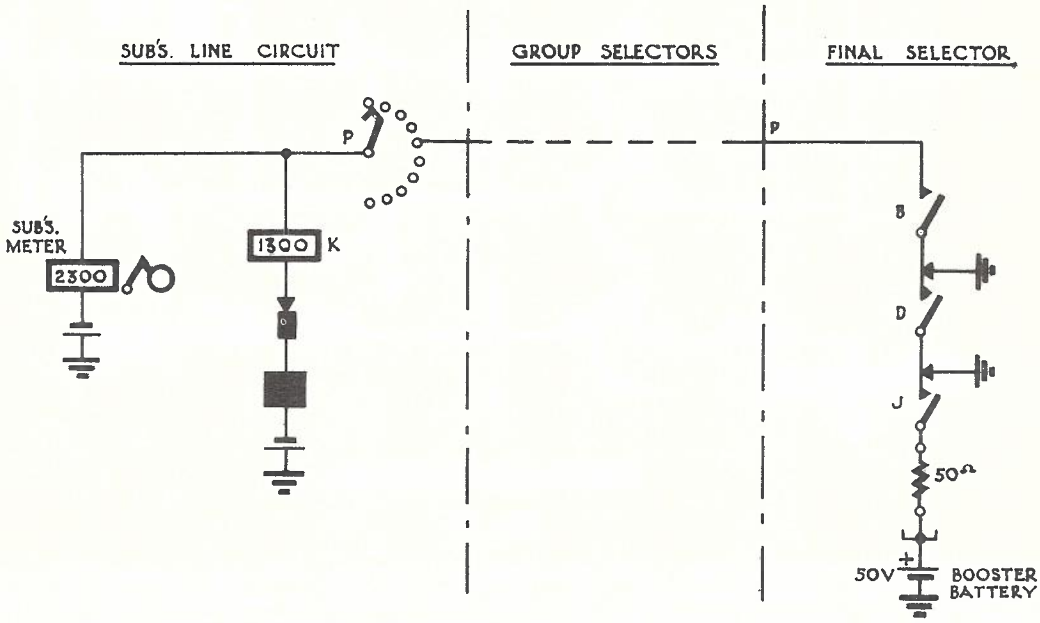
GROUP CONTROL CIRCUIT.

FIG. 28.

The operation of the group control relay removes earth from the K relay contacts of all lines connected to that group and replaces it with busy tone through a condenser. Thus, operation of relay L is prevented when the subscriber lifts the receiver and busy tone is heard in lieu of dial tone.

This arrangement is rather unsatisfactory, due mainly to faults in the chain contacts. Also, rearrangement of trunking entails changes in the chain wiring. In the latest circuits, a more satisfactory scheme is used and the circuit is designed to stop the wipers at the 25th contact if all outlets are busy, and busy tone is given to the caller. The 25th contact is not wired and the 1st contact is the home position, so that only 23 outlets to first selectors are available.

3.6 Metering of Calls. The circuits described have been arranged for "Booster Battery" metering. When the called party lifts the receiver, relay operation in the final selector causes the earth potential on the P wire to be replaced with 50 V positive battery for a short period (approximately 300 mS). Referring to Fig. 29, which shows the relative circuit elements, relays B and J in the final selector operate when the switch is seized. Relay D operates when the called subscriber answers and applies the booster battery to the P wire.



BOOSTER BATTERY METERING.

FIG. 29.

The operation of relay D opens the holding circuit of relay J, which releases slowly and replaces the booster battery with earth. Thus, the booster potential is applied to the P wire during the release time of relay J. The contacts of relays D and J are make-before-break units to avoid disconnecting the P wire during operation, which would allow holding relays to release. A 50 ohm resistor is included in the booster battery lead to prevent sparking at these contacts, and short-circuiting the booster battery while they are changing-over.

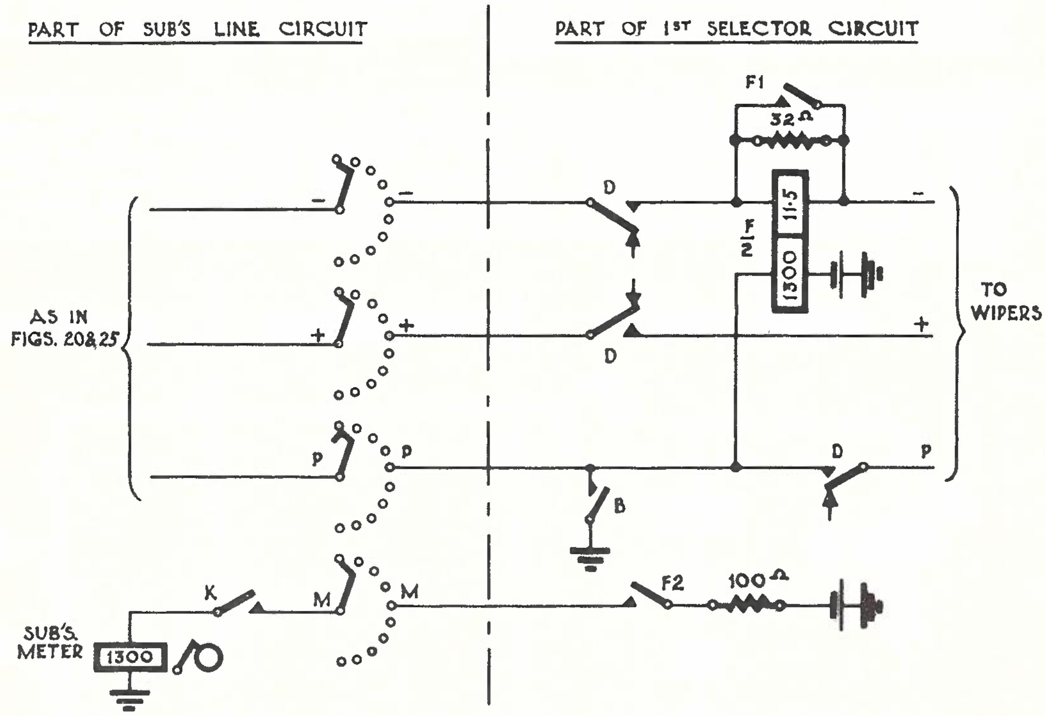
Subscribers' meters are adjusted to not operate on 25 mA and to operate on 35 mA, therefore, the meter will not operate when the P wire is earthed, but when the booster battery is applied to the P wire the potential across the meter is raised to 100 V and it operates. It will hold operated for the duration of the call, and there is no

/ possibility

possibility of more than one operation of the meter for each call.

Reverse Battery Metering. This is an earlier method and utilises the reversal of current which is given to the calling line when the called party answers, primarily used for supervisory purposes.

By including a polarised relay in the first group selector circuit as in Fig. 30, the reversal of line current is used to operate the subscriber's meter.



REVERSE BATTERY METERING.

FIG. 30.

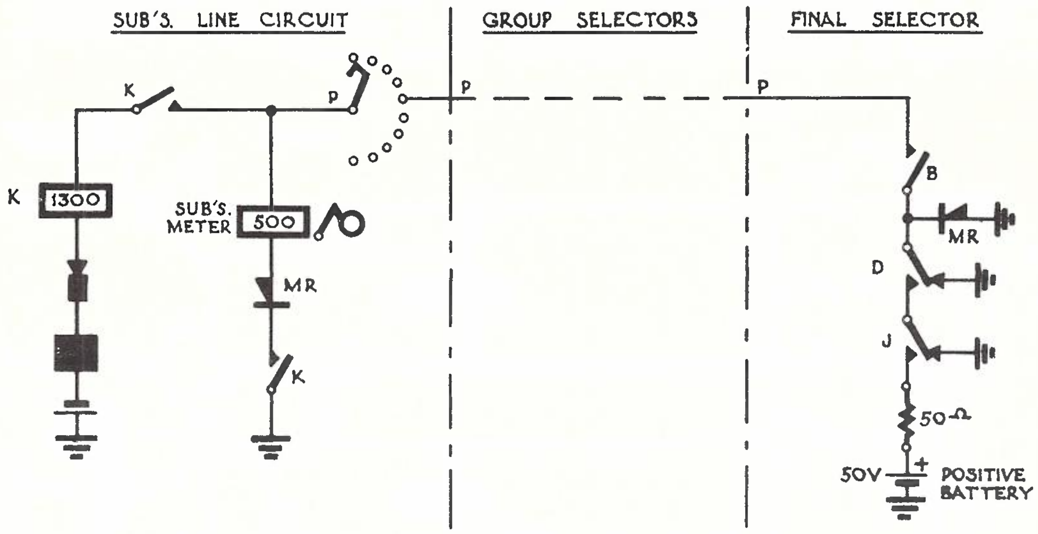
Relay F will not operate on the 1,300 ohm winding alone nor with the current in the 11.5 ohm winding in the normal direction. When the line current is reversed (from the final selector) the two windings assist and relay F operates. Contact F1 shunts the 11.5 ohm winding and relay F will hold on the 1,300 ohm winding for the duration of the call. The 32 ohm shunt on the line winding is to provide a low impedance path for impulsing and for speaking on calls where no reversal is given (Service Enquiries, etc.).

Contact F2 connects negative battery through a protective resistance to the M wire of the trunk; the subscriber's meter is operated via an additional M bank and wiper on the uniselector and a contact of relay K. In this system also, the meter will remain operated for the duration of the call.

In some exchanges, the polarised relay is not included in the first selectors but in the trunk, that is, "Trunk Metering Relays". The operation is similar to that shown in Fig. 30. In the first exchanges installed in Australia, a polarised meter was used in lieu of the polarised relay. However, it was found to be unsatisfactory owing to the difficulty in obtaining the necessary marginal adjustment of the meter.

/ Positive

Positive Battery Metering. Fig. 31 shows the circuit arrangements for positive battery metering which is now the standard method.



POSITIVE BATTERY METERING.

FIG. 31.

A metal rectifier in series with the meter prevents it operating to a negative potential on the P wire. When the called subscriber answers, a positive battery pulse is applied to the P wire from the final selector and the rectifier conducts, allowing the meter to operate. The meter releases at the end of the pulse, therefore "Multi-metering" is possible, although not in use in Australia to date.

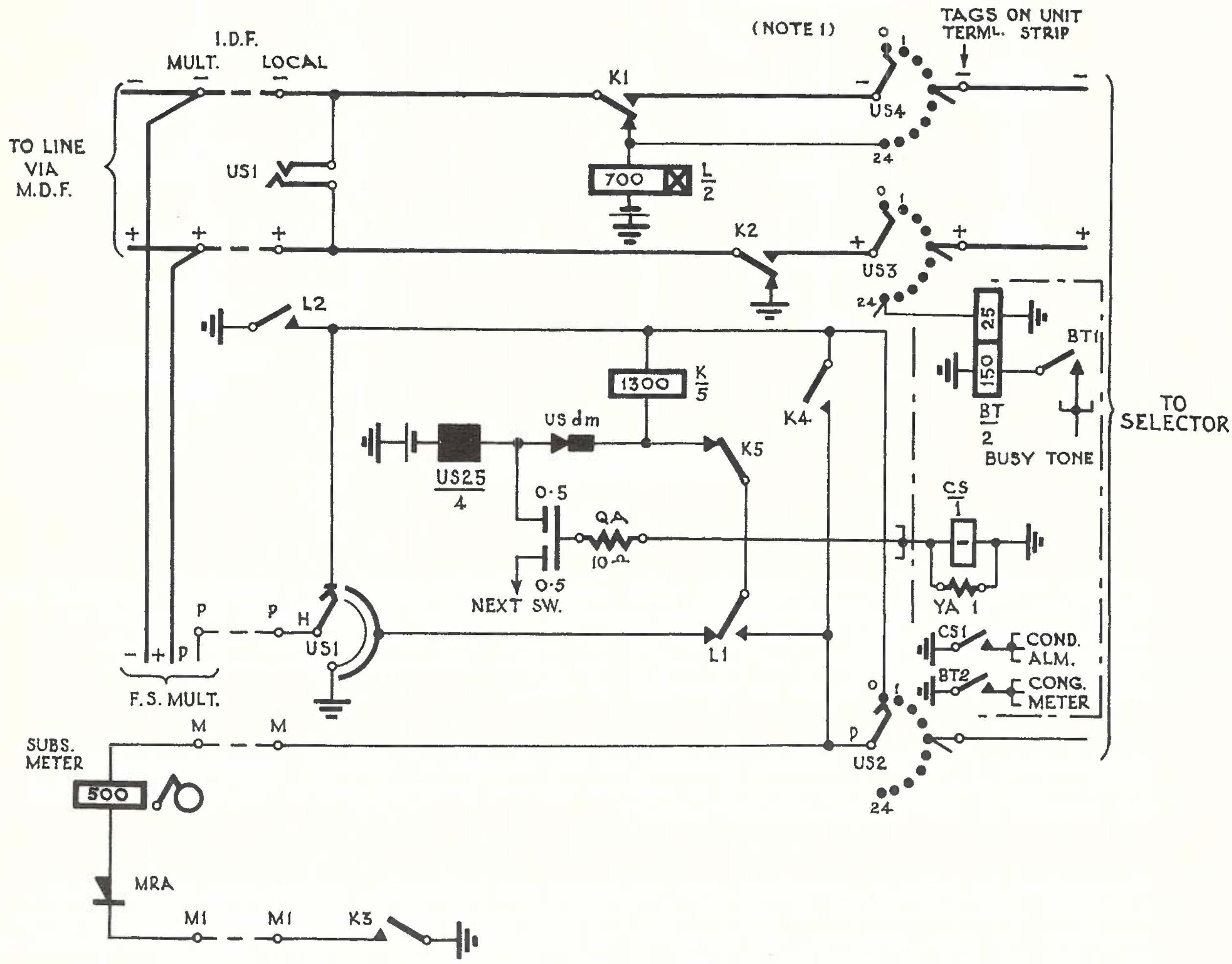
An advantage of positive battery metering is the absence of critical marginal adjustments, which were necessary on the meters in booster battery metering and on the polarised relays (or meters) in the reverse battery method.

The contact of relay K, in series with the meter and rectifier, removes the earth from the rectifier when the circuit is not in use, preventing a possible break down of the rectifier elements. In some circuits, the rectifier is included in the trunk, so that fewer rectifiers are required, and an additional M bank and wiper are necessary on the uniselector. The present standard circuit has the arrangement as shown in Fig. 31, using more rectifiers, but simplifying the uniselector. Also, there is no possibility of false operation of the meter under fault conditions.

The final selector circuit in Fig. 31 is similar to that shown for booster battery metering but the make-before-break contacts are superseded by change-over units. The rectifier maintains a holding earth on the P wire during change-over of the contacts, and does not shunt the positive battery. A 50 ohm resistor in the positive battery lead protects the relay contacts against accidentally applied earths, and also prevents heavy sparking at uniselector P wipers, which may occur when the wiper bridges a contact carrying positive battery to an adjacent earthed contact.

/ 3.7

3.7 Subscriber's Line Circuit, Positive Battery Metering. In the earlier homing type circuit, the final selector bank multiple of the line is not completely guarded during the release period after an outgoing call, earth being disconnected from the private trunk for a brief period to allow relay K to release. The present standard circuit (Fig. 32) guards the subscriber's line during the whole of the release period. The homing arc is "split", that is, it is made up of two insulated metal segments, which are bridged by the wiper while the switch is "off normal".



SUBSCRIBER'S LINE CIRCUIT - POSITIVE BATTERY METERING (CE-292-A, SHEET 2).

Note. 1. The 0 and 24th Contacts of the Uniselector are not wired to Selectors.

FIG. 32.

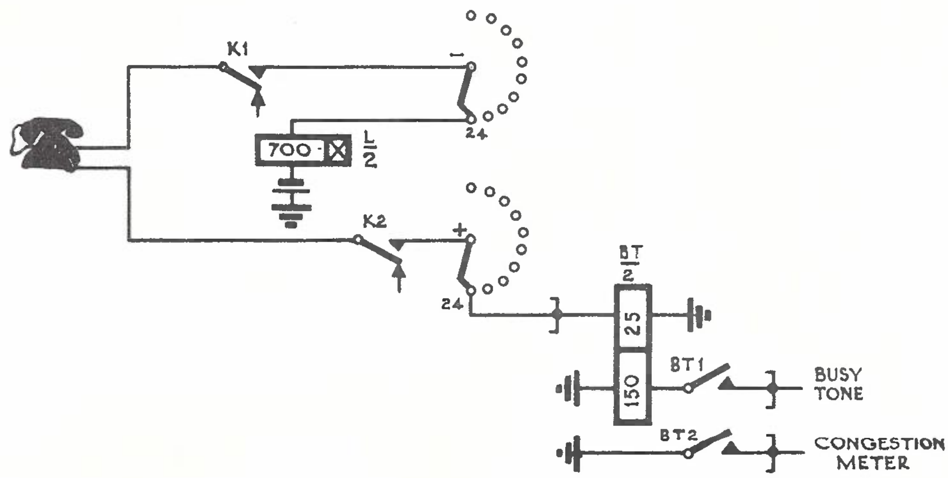
Outgoing Call. The subscriber's loop allows relay L to operate. L1 makes before L2, short-circuits relay K, and prepares the drive magnet circuit. L2 earths the final selector P wire, and completes the circuit for the drive magnet to make its first step, when hunting and testing begin. At the first step, earth from the homing arc busies the final selector multiple contacts.

/The

The switch hunts and at the first free outlet relay K operates, being no longer short-circuited by earth on the P wiper. The operation of relay K switches the line and P wires through to the first selector, L2 maintaining the earth on the P wire until earth is returned from the first selector. K5 opens the homing circuit and K3 prepares the circuit of the subscriber's meter. The switch will step-on over open-circuit trunks, as described in paragraph 3.4, and the circuit is not unguarded during this operation.

At the completion of the call relay K releases, and a homing drive circuit is completed via K5 and L1 normal to earth on the bridged homing arc. The switch self-drives until the wipers are resting on the home contacts. During this time the line circuit is guarded from intrusion by earth from the homing wiper and bank.

All Trunks Busy. The 24th outlet is not wired to a first selector, but is arranged so that if all 23 outlets are busy the wipers are stopped on the 24th contacts and busy tone is given to the caller. The 24th P contact is not wired so that relay K operates and switches through the lines (see Fig. 33).



ALL TRUNKS BUSY.

FIG. 33.

Relay L is held operated over the negative bank and wiper in series with the subscriber's loop to earth via the positive wiper and bank and the 25 ohm winding of a common BT relay (one BT relay per 50 lines). L2 (Fig. 32) maintains the holding circuit of relay K. The operation of relay BT connects busy tone to its 150 ohm winding, being induced into the 25 ohm winding and so heard by the caller. BT2 extends an earth for the operation of a congestion meter, used for measuring the overflow traffic in each group of lines.

Condenser Alarm. Break down of a spark-quench condenser causes overheating of the associated uniselector magnet and consequent fire risk. A condenser supervisory relay CS (one per 50 lines) operates and gives an indication on the exchange alarm system in this case.

Incoming Calls. Earth from the final selector is extended via homing wiper and home contact to operate relay K in series with the drive magnet.

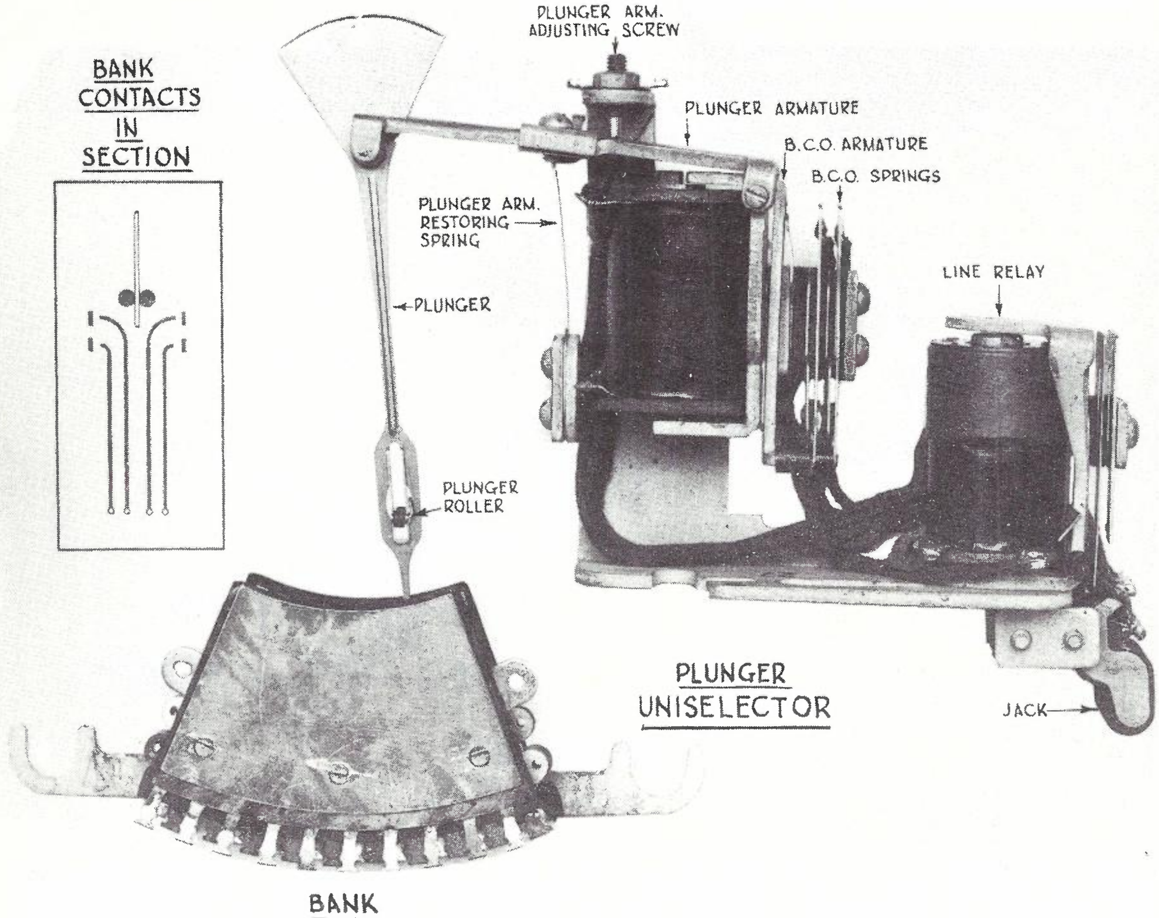
/ 4.

-7

4. PLUNGER UNISELECTOR (KEITH LINE SWITCH).

4.1 As mentioned earlier, our first Automatic exchanges were equipped with Plunger type uniselectors of the Keith type. These were used both as primary and secondary uniselectors in subscribers' line circuits and in later installations served as primary uniselectors in conjunction with rotary type secondary switches. This latter scheme is in use in many busy A.E.C. (Chicago) exchanges, including City North (Sydney), Carlton (Melbourne) and Central (Perth). There are several types of Plunger uniselectors but the "two-coil" type will be described as it is used in Australia more than other types.

4.2 Fig. 34 shows a plunger uniselector and bank.



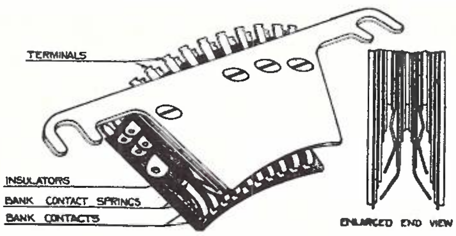
PLUNGER UNISELECTOR AND BANK.

FIG. 34.

The complete uniselector consists of a line relay and a cut-off relay, the latter having two armatures, one of which (the outer) is known as the plunger armature, and the other (the inner) as the bridge cut-off (B.C.O.) armature. The line relay is slugged at the armature end, hence is slow acting. The cut-off relay has two windings, one referred to as the "pull-down" winding having a resistance of 45 ohms, the other of 1,200 ohms is the B.C.O. winding. The pull-down winding, when energised, will operate both armatures, but the B.C.O. winding can only operate the B.C.O. armature, although it will hold both armatures if previously operated by the pull-down winding.

/ When

When the subscriber lifts the receiver to make a call, the line relay A operates and closes the circuit of the pull-down winding of the cut-off relay B. Both armatures of relay B, therefore, are operated and the plunger is forced into the bank operating the contacts shown (see Fig. 35). The B.C.O. armature disconnects relay A, and relay A being slow to release, holds the circuit of the pull-down winding of relay B closed until the B.C.O. winding is energised from the switch ahead. Ten sets of bank contacts are arranged in a horizontal plane in the arc of a circle. These contacts connect the subscriber through to a two-motion selector when the plunger enters the bank.

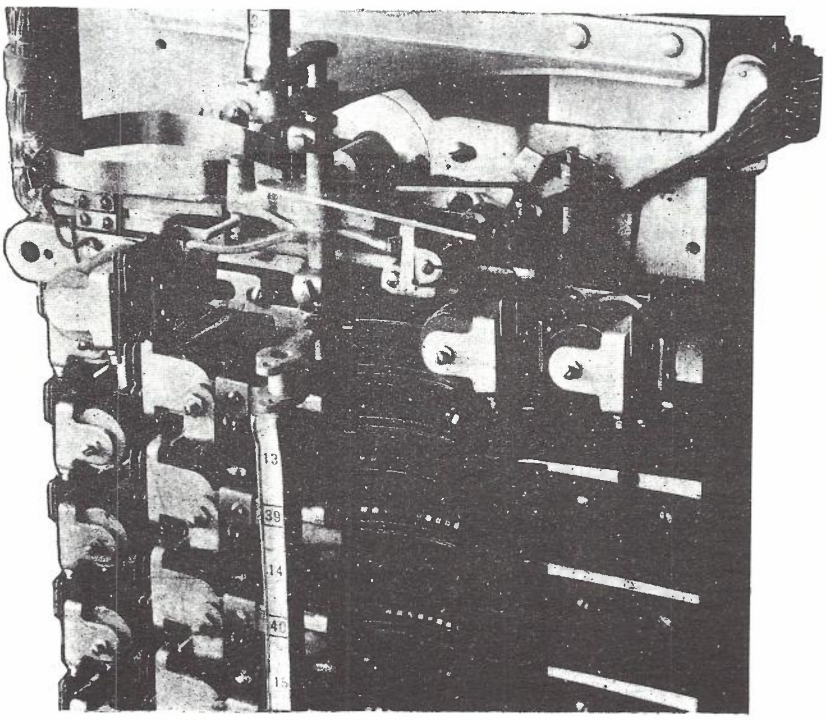


PLUNGER UNISELECTOR BANK.

FIG. 35.

When a call comes in to the subscriber, the B.C.O. winding of relay B is energised, operating the B.C.O. armature but not the plunger armature, thus cutting the line relay out of circuit and clearing the line. The uniselectors are mounted one above the other, in groups of 25 switches and a rod running the length of the group engages the plungers by fitting in the small niche in the fan-shaped end. Each plunger is pivoted on the plunger armature, so that as the rod moves around the arc of a circle it will carry all the plungers associated with it. When a plunger enters the bank, it is disengaged from the rod, or guide shaft, and when any uniselector in a group plunges, the shaft moves one step, carrying the remaining plungers to a position opposite the next free outlet.

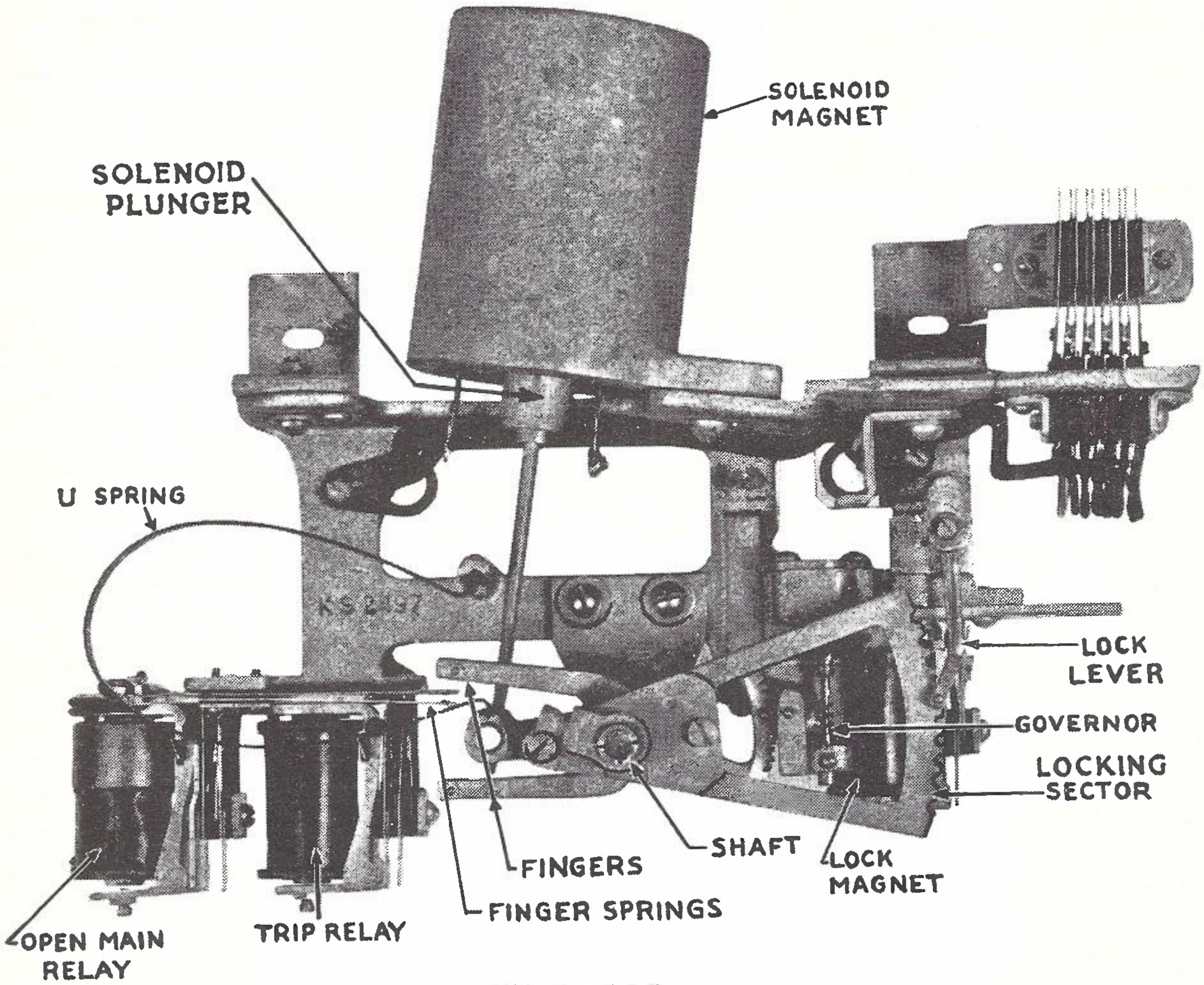
4.3 Master Switch. The movement of the guide shaft is controlled by a "Master Switch", as shown in Fig. 36. The master switch steps the guide shaft on every time a plunger operates, until the plungers associated with it are opposite a free trunk. After reaching the last outlet, the master switch then sweeps the shaft back to the normal position, thus picking up on the way all the plungers which have released since its last such action. This is called a "Pick-up" movement.



MASTER SWITCH AND PLUNGER GUIDE SHAFT.

FIG. 36.

Fig. 37 shows a master switch demounted from the uniselector unit. The power for moving the master switch from trunks one to ten is supplied by the solenoid. The movement from trunks ten to one is the period during which it selects trunks. A "U" spring furnishes the motive power during this period.



MASTER SWITCH.

FIG. 37.

That part of the mechanism which holds the plungers in position and transmits to them an oscillatory motion is called the shaft (plunger guide shaft). Rigidly fixed to this shaft are the locking sector and the governor driving sector with No. 1 trunk finger and No. 10 trunk finger. The solenoid plunger through its arm is attached to the governor driving sector. The U spring is held between two U spring posts, one of which is a part of the frame and is stationary, while the other is part of the governor driving sector and is movable. These parts, namely, solenoid plunger, U spring, plunger guide shaft, locking sector, governor driving sector with No. 1 trunk finger and No. 10 trunk finger are definitely fixed mechanically and their motions are correlated.

The armature of the locking magnet carries a locking arm (lock lever), which is normally engaged with one of the notches of the locking sector, but when the magnet is energised the locking arm is lifted and the sector is free to move in either direction. The notches of the locking sector correspond in number with the bank contacts or the trunks to the next succeeding switches, so that the locking arm in a given notch means that the trunk

/ corresponding

corresponding to that notch is unoccupied and all the plungers of the idle uniselectors are in front of it ready to plunge in should a subscriber make a call. When this trunk, say, No. 5, is seized, a plunger enters the bank, the locking arm is lifted and the locking sector moves counter-clockwise, moving the shaft and all free uniselectors with it, until the next idle trunk is found and the locking arm re-engages the locking sector. When the last notch is reached, No. 1 trunk finger closes two springs called the finger springs preparing the circuit to the trip relay. The trip relay energises on the next call and closes the circuit to the solenoid. The solenoid plunger is now pulled in and the locking sector, as well as the plunger guide shaft, moves in a clockwise direction. The spring contacts of the trip relay are held closed by its own locking spring until the solenoid plunger has been pulled in far enough, so that the 10th notch of the locking sector has just passed the locking arm when the No. 10 trunk finger comes against the locking spring and allows the trip relay springs to return to normal and re-energise the solenoid. The motion of the locking sector is again placed under the force of the U spring, the speed being controlled by the governor between the limits of 105 and 110 cycles per minute.

The idle trunk is preselected, and, without any testing or hunting, the plunger of a calling switch enters its bank when the receiver of the calling telephone is lifted.

The master switch bank (not shown in Fig. 37) is an auxiliary bank composed of two rows of stationary contacts (10 in each) corresponding to the 10 trunks in the switch banks. These banks are located at the top or bottom of each group of switch banks.

The master switch wiper, which is attached to the guide shaft and is always engaged with a set of contacts on the master switch bank, has the same relative position on this bank that the switch plungers (which are engaged with the guide shaft) have with respect to the switch bank. One master switch wiper and one master switch bank are used with each master switch.

It is common practice to mount 100 uniselectors on one side of a frame, and these may be controlled by one master switch, or by two or four master switches, according to the density of the traffic.

4.4 Circuit Operation - Plunger Primary Uniselector. A schematic circuit of a plunger uniselector and associated master switch is given in Fig. 38. The functions performed are -

Plunger Uniselector.

(i) Operates the plunger, causing it to enter the bank and extend the caller's loop to the switch ahead.

(ii) Disconnects the subscriber's line equipment when receiving incoming calls.

(iii) Causes the master switch to drive away other plungers, so that privacy on the seized trunk is assured.

(iv) While in use, extends earth from switch ahead to final selector multiple to mark the caller's line busy.

Master Switch.

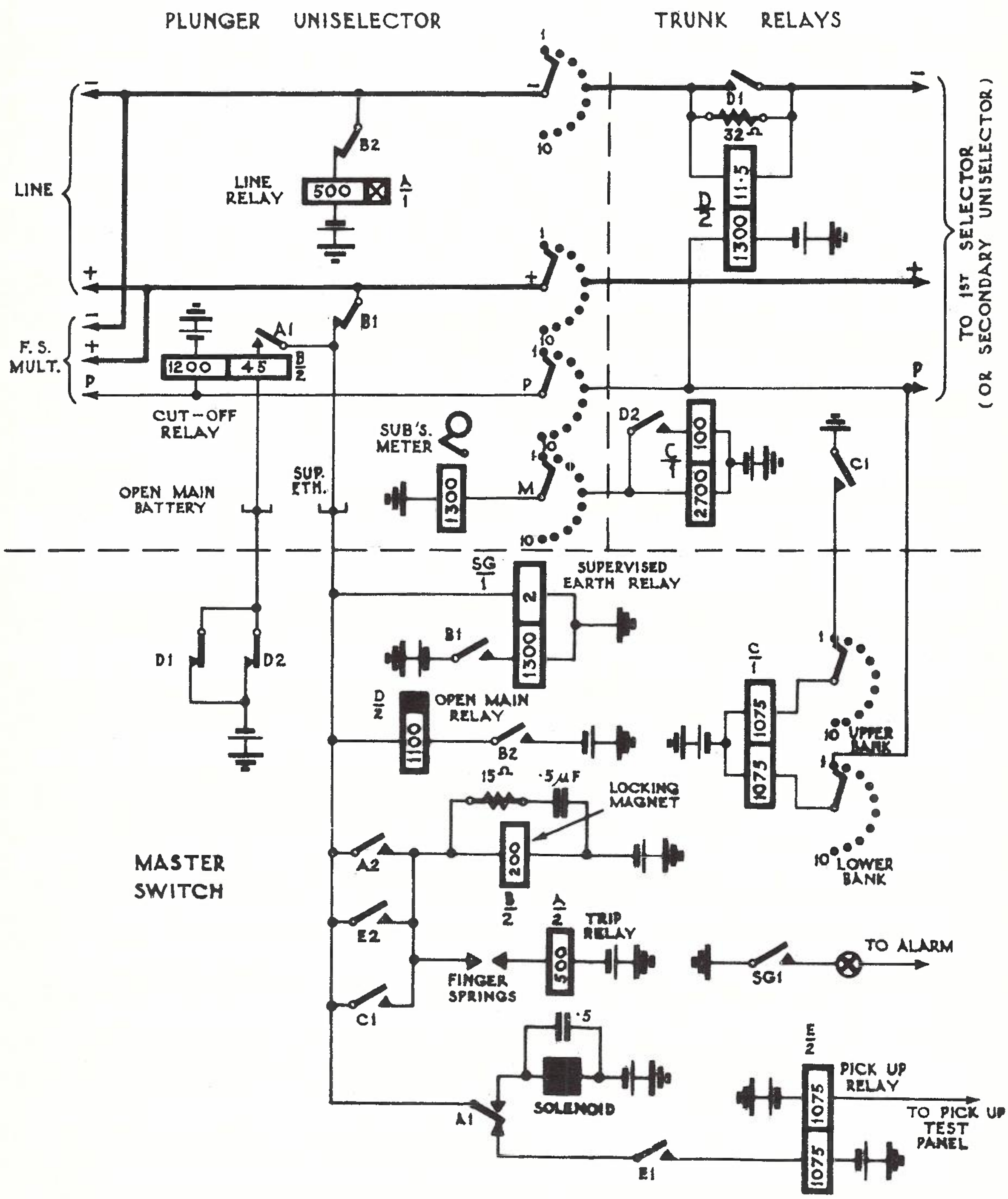
(i) Keeps shaft with plungers engaged in such a position that all idle plungers will be held opposite an idle trunk.

(ii) Prevents any uniselector from operating while the master switch is moving.

The circuit operation is described below -

Uniselector. The calling loop completes the circuit of the line relay A via normal contacts B2 and B1 to supervised earth.

/ Fig. 38.



PLUNGER UNISELECTOR CIRCUIT.

FIG. 38.

Contact A1 closes the circuit of the pull-down coil of the cut-off relay from supervised earth to open main battery via contacts of relay D (master switch circuit). The plunger operates, extending the calling line to the first selector (or secondary uniselector) via the plunger uniselector bank contacts. The B.C.O. armature also operates and B1 and B2 open the circuit of the line relay, which releases slowly. An earth returned on the P wire from the switch ahead holds the B.C.O. and plunger armatures operated when A1 opens. This earth is extended to the final selector multiple to mark the caller's line busy.

Metering of Calls. Reverse battery metering is used, trunk relays C and D being provided for this purpose. When the uniselector plunges, relay C is operated on its 2,700 ohm winding in series with the subscriber's meter and uniselector bank M. The meter will not operate in series with the 2,700 ohm coil of C.

Polarised relay D has its 11.5 ohm winding connected in the negative wire of the trunk and its 1,300 ohm winding is energised from the earth on the P wire. When the call has been set up and the called party answers, the line current is reversed by the final selector and relay D operates. D2 connects the 100 ohm winding of relay C in parallel with its 2,700 ohm coil, allowing the subscriber's meter to operate. Relays C and D, and the meter remain operated for the duration of the call.

Release of Uniselector. When the caller's loop circuit is disconnected, earth is removed from the P wire and allows the cut-off relay to release both B.C.O. and plunger armatures. The plunger is removed from the bank, and the line relay is reconnected at B1 and B2.

Incoming Calls. Earth extended from the final selector multiple energises the cut-off relay on its 1,200 ohm winding, operating the B.C.O. armature. The plunger armature does not operate and the plunger remains under the control of the master switch guide shaft.

Master Switch. When a uniselector plunges, the operation of the trunk relay C causes an earth to be placed on the upper master switch bank contact and master switch relay C operates.

C1 (master switch circuit) operates the locking magnet B which disengages the locking lever from the locking sector, allowing the plunger guide shaft to be rotated so that the plungers are standing opposite the next idle trunk.

B2 operates the open main relay D to disconnect open main battery from the group, preventing uniselectors plunging while the master switch is operating.

B1 operates the supervised earth relay SG which extends earth to a delayed alarm circuit.

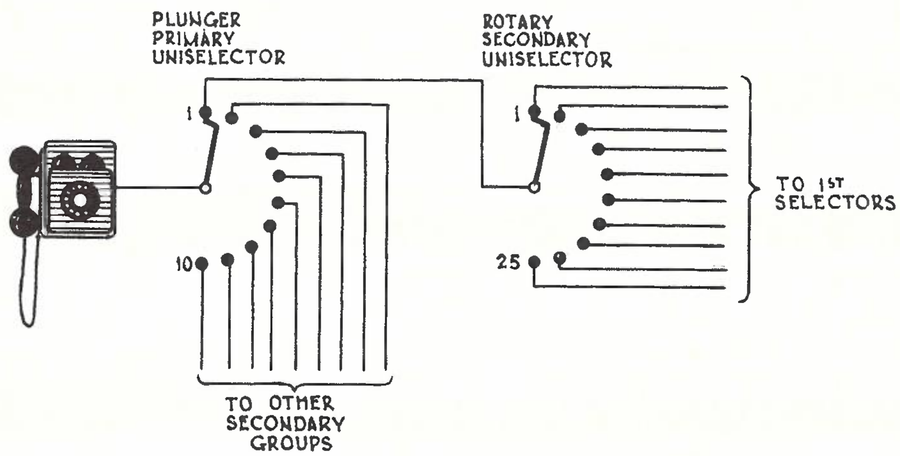
When a free trunk is reached, relay C restores, releasing the locking magnet, which causes the movement of the locking sector and guide shaft to be arrested by the locking lever.

When the plungers are standing opposite No. 1 trunk, the trunk finger closes the finger springs and when this trunk is taken into use, the trip relay A is operated together with the locking magnet from supervised earth via C1 operated.

The armature of the trip relay is held operated mechanically until the plungers are brought back to No. 10 trunk. A2 completes a holding circuit for the locking magnet and A1 completes the solenoid circuit. When the master switch reaches No. 10 trunk, the trip relay is restored opening the solenoid circuit and the master switch will search for the first free trunk, and the locking magnet releases.

/ 4.5

4.5 Rotary Secondary Working. Fig. 39 shows a trunking diagram of rotary uniselectors arranged as secondary line switches, interworking with plunger primary uniselectors. A group control circuit operates when all outlets from a secondary group are busy.



PLUNGER PRIMARY AND ROTARY SECONDARY WORKING.

FIG. 39.

The functions of the circuits are -

Secondary Uniselector.

(i) When switch is seized, returns earth to hold plunger engaged, guards calling subscriber's line from intrusion, and busies master switch bank.

(ii) Hunts for and seizes the first free outlet, and while searching prevents interference with trunks over which the wipers are passing.

(iii) Extends the calling line to the switch ahead and removes all bridges from the line wires.

(iv) When release conditions are applied, releases itself and disconnects the wipers from the contacts on which they are standing (non-homing).

Group Control Circuit.

When all outlets are busy -

(i) Artificially busies all free secondary uniselectors serving the busy group.

(ii) Extends busy tone to any subscriber held in busy group.

(iii) Prevents continuous rotation of wipers.

(iv) Extends an earth pulse to the master switch "pick-up" relay, causing the master switch to operate and pick-up idle plungers.

(v) Meters all trunks busy condition and overflow calls.

/ Circuit

Circuit Operation - Secondary Uniselector (see Fig. 40). When the primary uniselector plunges, relay A of the secondary switch operates via B1 normal, negative line wire, subscriber's loop, positive line wire, B2 normal, to earth from the group control circuit S5 normal.

A2 returns an earth on the P wire to hold the plunger engaged and busy the final selector and master switch bank contacts.

A1, operating before A3, completes the drive magnet stepping and testing circuit via the interrupter contacts, A1 operated, B3 normal to the P wiper. The switch hunts until a free outlet is reached.

Absence of earth on the P wiper allows relay B to operate from earth via A2 and A3 to battery through the drive magnet. B1 and B2 switch the line wires through to the first selector. B3 holds the B relay operated from earth returned on the P wire when relay A releases after its slow release period. B4 extends the P wire from the first selector back to the plunger uniselector for holding and guarding purposes.

At the release of the connection, earth is removed from the P wire and relay B releases, restoring the circuit to normal.

Group Control. Each outlet from a rotary secondary switch is provided with a chain relay wired to the P wire. The contacts of these relays are connected in series to form a chain.

When all 25 outlets are busy, the operated chain contacts complete the circuit of relay S and the group busy lamp. S1 operates the all trunks busy meter. S2 completes the circuit of relay O, which operates extending an earth to the P wire of all free rotary secondary uniselectors serving that particular group of 25 outlets via normal A2 and B4. S5 disconnects earth from the positive leg and connects busy tone, removes the shunt from relay F, 7,850 ohms, which operates in series with the caller's loop and completes the overflow meter circuit if a call has been switched in while the group control is functioning. Relay A does not operate in series with 7,850 ohms and the switch does not hunt.

S2 also opens the normally operated circuit of relay M, 2,500 ohms. Relay M is slow to release and, during its slow release period, earth is extended via operated M1, S3, and pick-up test panel press buttons to the E relays of all master switches serving that group of rotary secondaries (see Fig. 38). The E relay of the master switch operates and locks up on its second winding to supervised earth via operated E1 and normal A1. Relay E is released when trip relay A operates. E2 operates locking magnet B and holds it energised until the wipers reach No. 1 trunk, when trip relay A operates completing its own locking circuit and restoring the wipers back to Trunk No. 10 under control of the solenoid.

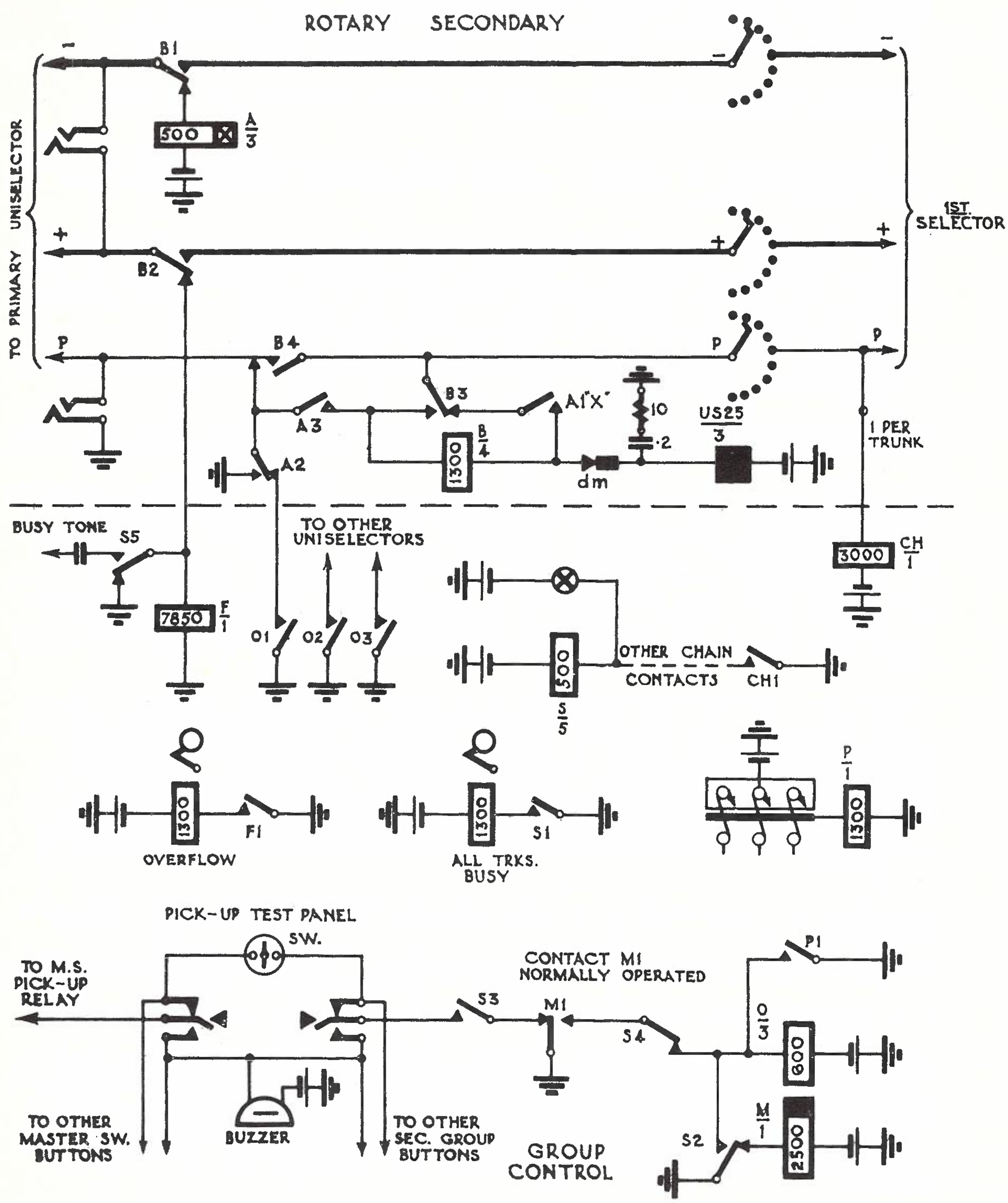
This allows all free plungers to be picked up by the shaft, preventing their plunging on busy groups.

The operation of a fuse serving a rotary secondary group completes the circuit of relay P.

P1 on operating closes the circuit of relay O busying all rotary secondary uniselectors.

4.6 Improvements in Plunger Uniselectors. With the plunger uniselectors previously described, the plunger is released from the bank at the conclusion of a call, but is not re-engaged with the master switch guide shaft until the next pick-up movement. This can result in much inconvenience to subscribers who may become connected to a faulty trunk, especially in periods of light traffic. Also, there is a possibility that two uniselectors may simultaneously plunge and seize the same trunk, that is, "double plunging".

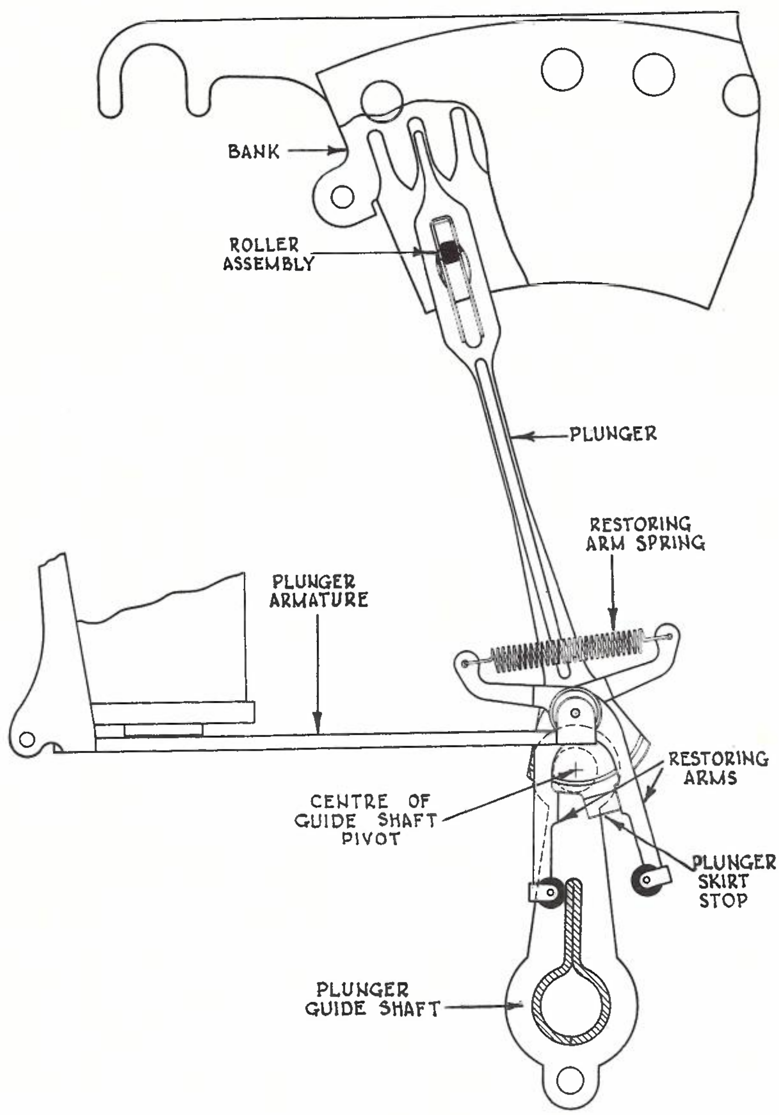
/ Fig. 40.



ROTARY SECONDARY CIRCUIT.

FIG. 40.

Self-Aligning Plunger. In later units these disadvantages have been overcome. The "self-aligning" type of plunger uniselector (Fig. 41) is arranged to re-engage the plunger guide shaft immediately it becomes released from the bank.



SELF-ALIGNING PLUNGER.

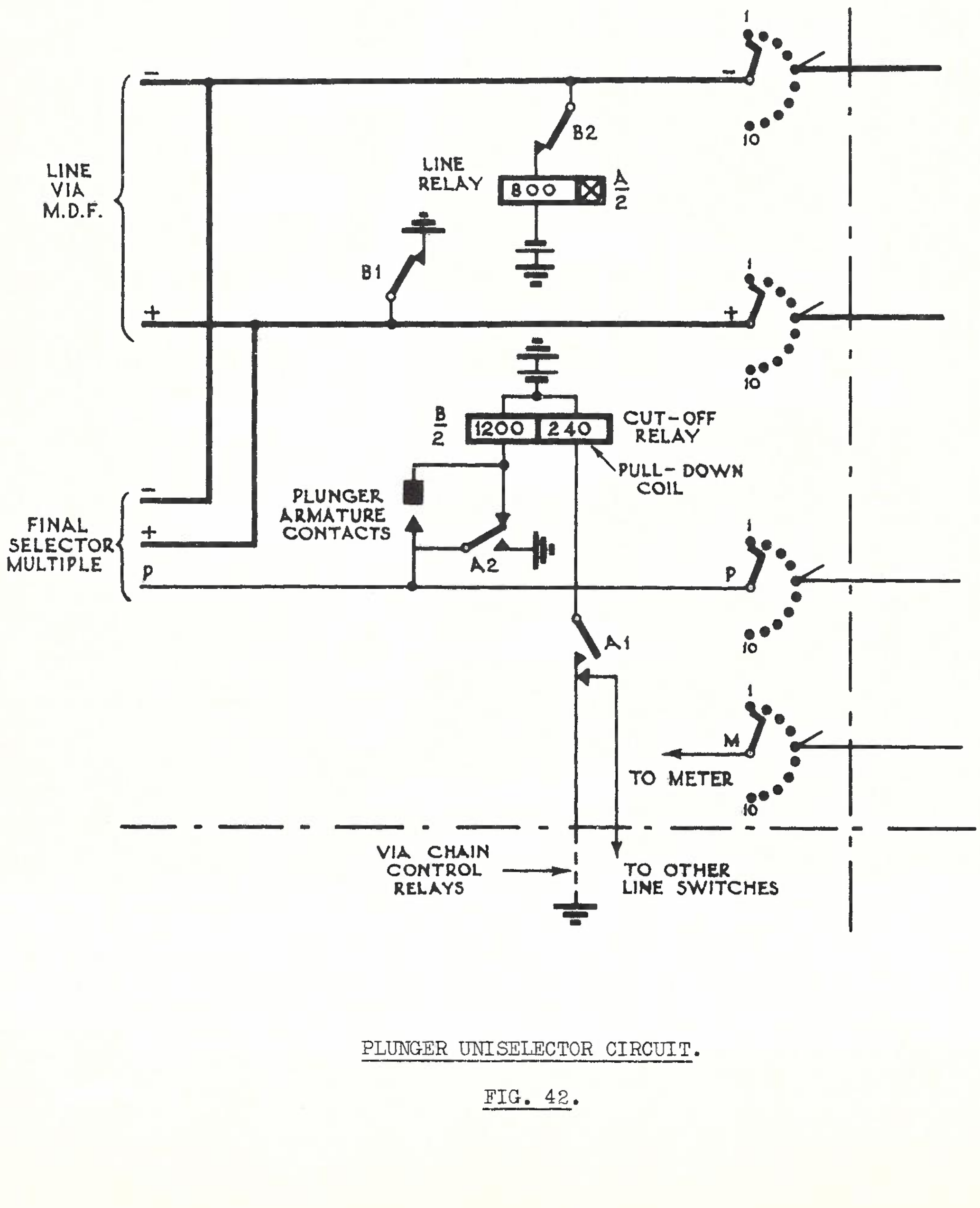
FIG. 41.

The self-aligning action of the plunger is accomplished by means of two arms, independently pivoted to the bearing hub of the plunger and normally held in close parallel relationship with each other by means of a spiral spring. The tips of the two restoring arms are fitted with insulated rollers, which normally engage opposite sides of the tongue or spline of the plunger guide shaft, this being wide enough to include the line of travel of the plunger when it enters and releases from the bank. Consequently, the plunger will normally be lined up with free trunks as the plunger guide shaft is moved by the master switch.

/ When

When the plunger is engaged in the bank, as shown in Fig. 41, one arm is in contact with one side of the plunger skirt stop and the other arm is in contact with the opposite side of the guide shaft spline as the guide shaft is stepped around. The spiral spring allows the two arms to spread and when the plunger releases from the bank, the two arms are drawn together. As the arm in contact with the plunger skirt stop is the one which is free to move, it carries the plunger with it until it comes in contact with the guide shaft. Thus, the plunger is lined up with all other free plungers of the group.

Circuit Improvements. As shown in Fig. 42, the operating earth for pull-down coils is connected in a chain circuit. With this arrangement, if more than one line relay of the same group operates at one time, the operated relay nearest the earth end of the chain extends an earth to the pull-down coil, at the same time opening the chain circuit to other switches. Therefore, double plunging can not occur.



PLUNGER UNISELECTOR CIRCUIT.

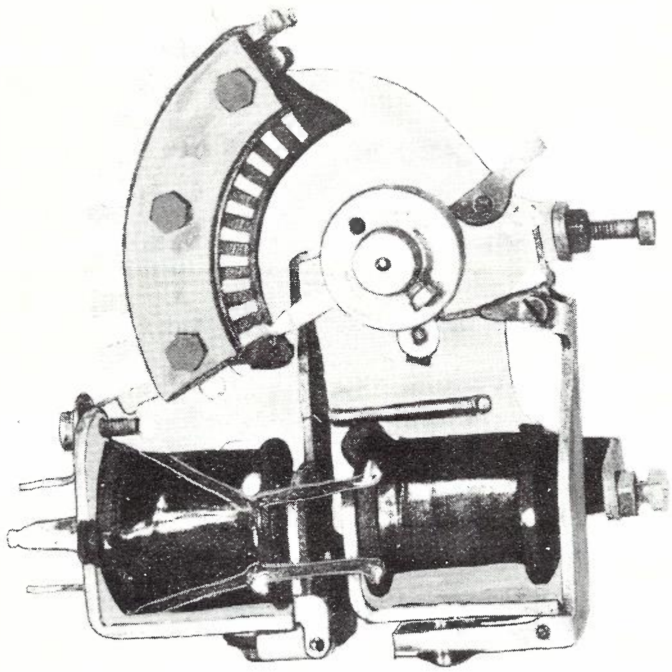
FIG. 42.

In the earlier circuit (Fig. 38) the calling subscriber is not guarded at the final selector multiple contacts until the uniselector plunges and earth is returned from the switch ahead. The new circuit earths the P wire immediately relay L operates from contact L2. The B.C.O. winding is energised when the plunger operates via contacts actuated by the plunger armature.

The pull-down magnet on the new switches is self-protecting, in case the circuit of the magnet is accidentally closed for an abnormal length of time.

5. MINOR SWITCH.

5.1 Another mechanism of the same type as the uniselector is shown in Fig. 43. This is known as a minor switch and is usually associated with a bank of 10 contacts and has a release magnet as well as an operating magnet, the release taking place by the wipers moving backwards to normal, which incidentally necessitates that the shape of the wipers and tips should be the same as in a two-motion switch and not as in a uniselector. The operation is on the forward action principle and is not self-driven. This type of switch is used for a number of auxiliary purposes such as impulse registers, distributors, etc.



A.T.M. COY. MINOR SWITCH.

FIG. 43.

6. TEST QUESTIONS.

1. State the functions of a uniselector.
2. Why are uniselectors used?
3. Describe briefly the main points of difference between the Rotary Uniselector and the Plunger Uniselector.
4. What is a bridging wiper and why is it used?
5. Give a brief description of the operating principle of uniselectors.
6. What are the differences between homing and non-homing uniselectors?
7. Why is a divided level used in the homing arc of some uniselector circuits.
8. Describe a uniselector contact bank.
9. Why is it desirable that Plunger Uniselectors be self-aligning?
10. Explain the principle of Booster battery metering, giving a circuit of the operating conditions.
11. Write brief descriptions of four types of uniselectors.
12. How may a uniselector be converted to provide 50 outlets?
13. What are the main differences between heavy and light duty uniselectors?
14. Describe the special features of the line and cut-off relays used with non-homing uniselectors.
15. What are the functions of a Master Switch?
16. By what means is the Plunger Uniselector Guide Shaft moved over the contacts?

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END OF PAPER.

COMMONWEALTH OF AUSTRALIA.

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Postmaster-General's Department,
Treasury Gardens,
Melbourne, C.2.

COURSE OF TECHNICAL INSTRUCTION.

TWO-MOTION SELECTORS.

CONTENTS.

1. INTRODUCTION.

1.1 The two-motion selector is the fundamental unit in automatic switching systems used by the Department. Its development since first being patented by Strowger in 1891 forms practically the history of automatic telephony. The first switches installed in Australia were similar to that shown in Fig. 4 of Paper No. 2 of this Book. By that time (1912), the form of the switch was well established and subsequent changes were more in the nature of refinements. Some of the main changes that have taken place since are -

(i) Elimination of the side-switch.

(ii) Use of cast-iron instead of Britannia-metal for the selector frame.

(iii) Horizontal mounting of the relays.

(iv) Use of a dust cover for each switch.

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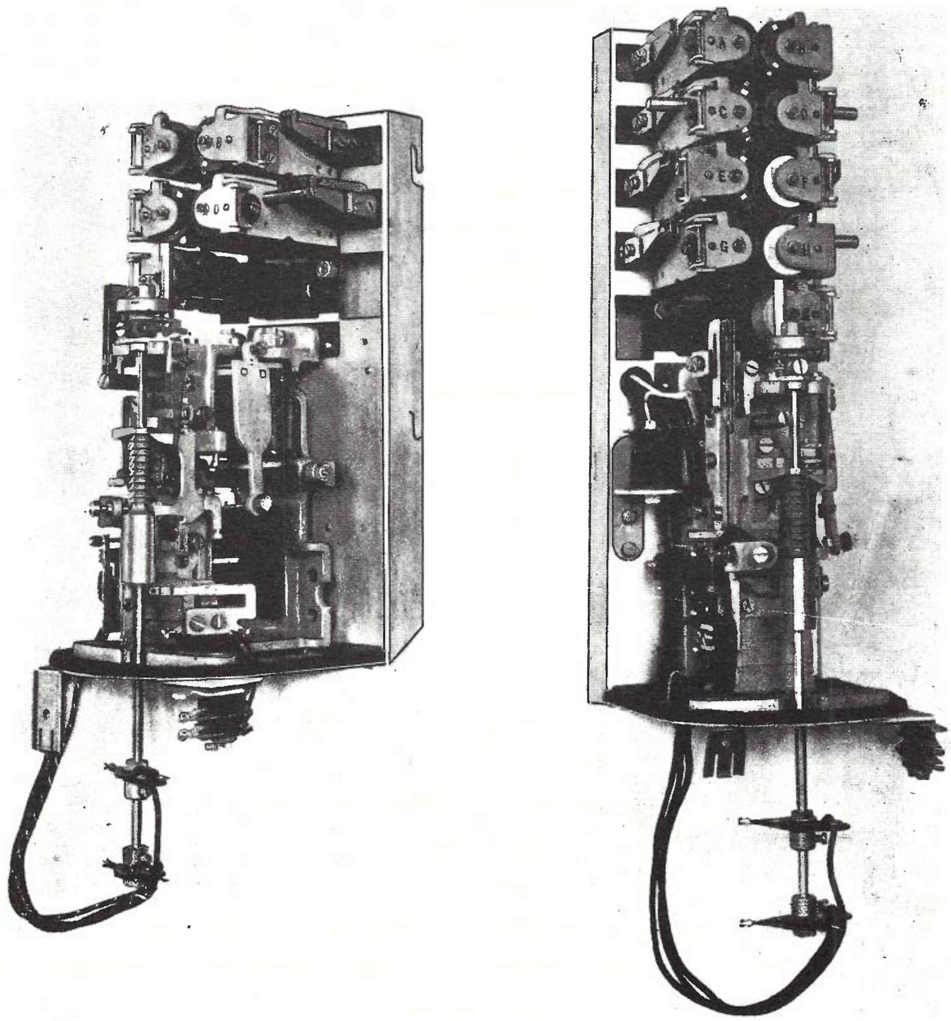
2. STROWGER TWO-MOTION SELECTOR.

2.1 This Paper will provide a description of a typical mechanism of the switch which is in general use throughout Australia. The switches described are those manufactured by the Automatic Telephone and Electric Co. (Liverpool). Switches manufactured by other firms differ only in detail, the principles remaining the same.

Fig. 1 shows two views of switches (at about one-third actual size) with horizontal type relays. In later types the switch mechanism is similar to that shown, but 3,000 type relays are used. The switch mechanism (comprising the frame, shaft, vertical, rotary and release magnets and incidental details) is secured to a mounting plate at the top of which are fixed the controlling relays. It will be noticed in Fig. 1 that the number of relays differs in the two switches. This is because the switches perform different electrical functions, although the common main mechanical functions are that each switch must lift the wipers to a particular level, rotate them around the bank and finally allow them to return to their normal position. The bank contact assembly is fastened to the base of the switch.



(a) Group Selector.   (b) Final Selector.

STROWGER TWO-MOTION SELECTORS.

FIG. 1.

Figs. 2 and 3 are two views of the switch mechanism with the various details marked. The bank rods on which the bank is fitted may be seen in Figs. 2 and 3 and it is suggested that each detail be located before proceeding with the description of the switch function. Fig. 4 gives a simplified view of the various switch mechanism details.

2.2 Mechanics of Vertical and Rotary Actions. The wiper or switch shaft is provided with two ratchets which may be seen in Figs. 2, 3 and 4 -

(i) The upper or vertical ratchet provided with conical teeth cut at right-angles to the axis of the shaft. The pawl of the vertical magnet armature acting on this ratchet lifts the wipers to the vertical level required.

(ii) The lower or rotary ratchet (hub) consists of a cylinder on the outside of which are cut teeth parallel to the axis of the wiper shaft. These may be seen on the shaft in Figs. 1, 2 and 3, but as they do not extend around to that part of the cylinder normally seen from the front, they cannot be seen as clearly as the teeth on the vertical ratchet.

The rotary magnet armature pawl (see Fig. 4), which acts in the teeth of the rotary ratchet, rotates the wipers to the particular set of contacts required in the selected level.

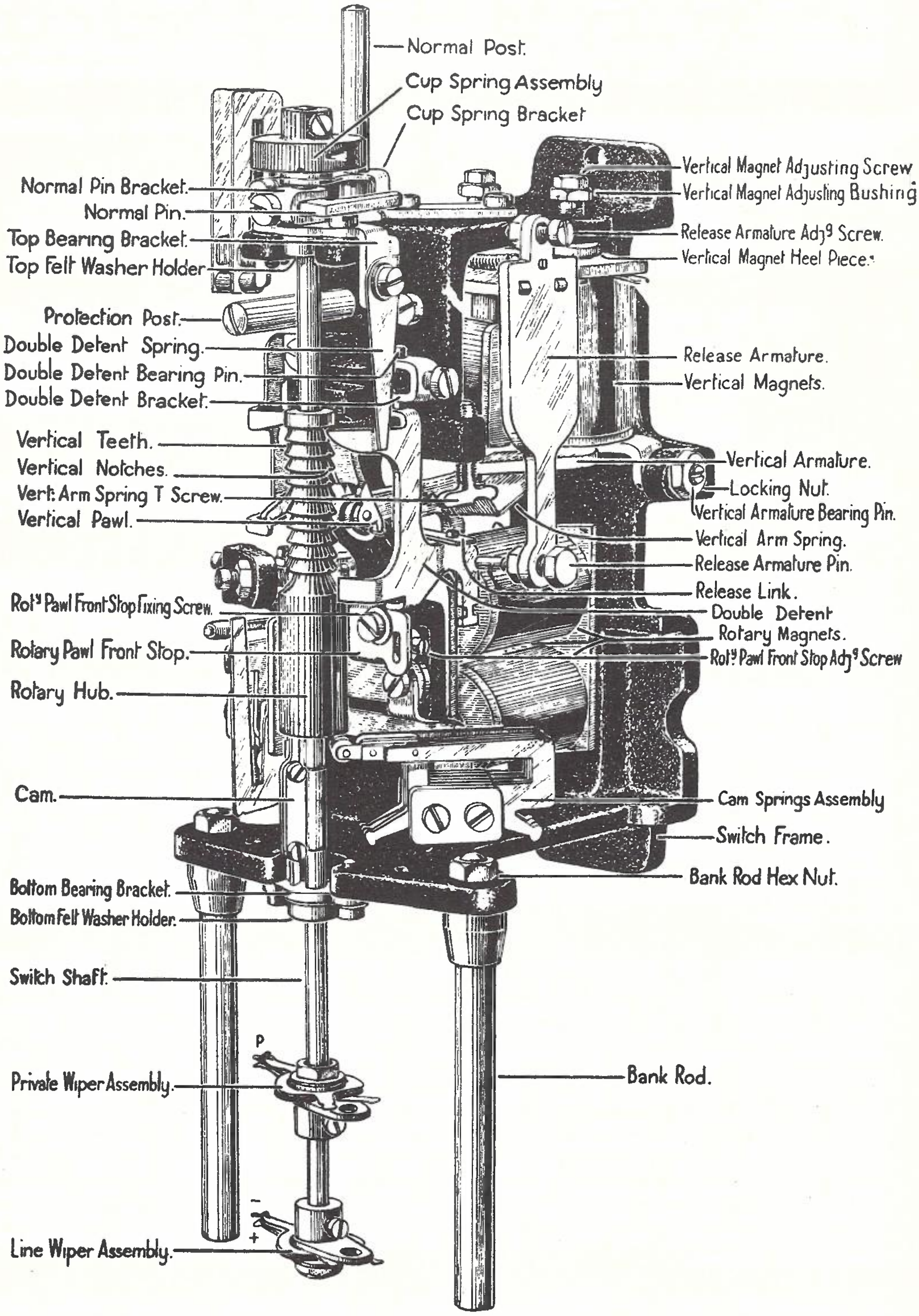
The direction of rotation of the wiper shaft, under the action of the rotary magnet, is such that the wipers move from left to right. When the wiper shaft returns to normal after operation it rotates in the opposite direction under the influence of a shaft restoring spring.

The Stationary Detent. This detent may be seen in Figs. 3 and 4 and consists of a steel stamping securely fastened to the switch frame and provided with two projections. The lower projection serves as a rest for the extension of the vertical magnet armature pawl. The upper projection enters a slot cut in the vertical ratchet parallel to the axis. During the vertical action the projection does not affect the movement of the shaft, but immediately the wipers cut into a level the projection comes into contact with the underside of one of the vertical teeth and supports the weight of the shaft but does not impede the rotary motion. On release, the shaft rotates, still supported by the stationary detent, until the slot reaches the projection when the shaft falls back to its normal position under the action of gravity. Fig. 4 indicates the relationship of these parts.

Double Detent. The double detent or dog is shown in Figs. 2 and 4. It also has two projections and is pivoted on a vertical axis. Normally, it is held away from the shaft by the release link, a hole in the end of which engages a small vertical projection on the double detent. On the first vertical step the release link is raised by the armature of the vertical magnet, and the double detent, under the action of the double detent spring (shown in Fig. 2), engages the teeth on the shaft. After each vertical step, the upper projection of the double detent slips into the root of the tooth, supporting the shaft until the next step occurs. When rotation commences, the duty of preventing the shaft from falling is transferred to the stationary detent. The lower projection of the double detent, by engaging with and riding over the teeth of the rotary ratchet, prevents the shaft from rotating backwards after each step. When the shaft has been stepped up and around by the actions described and the wipers thereby brought on to the particular set of contacts desired, the shaft is held in this position by the double detent and the stationary detent.

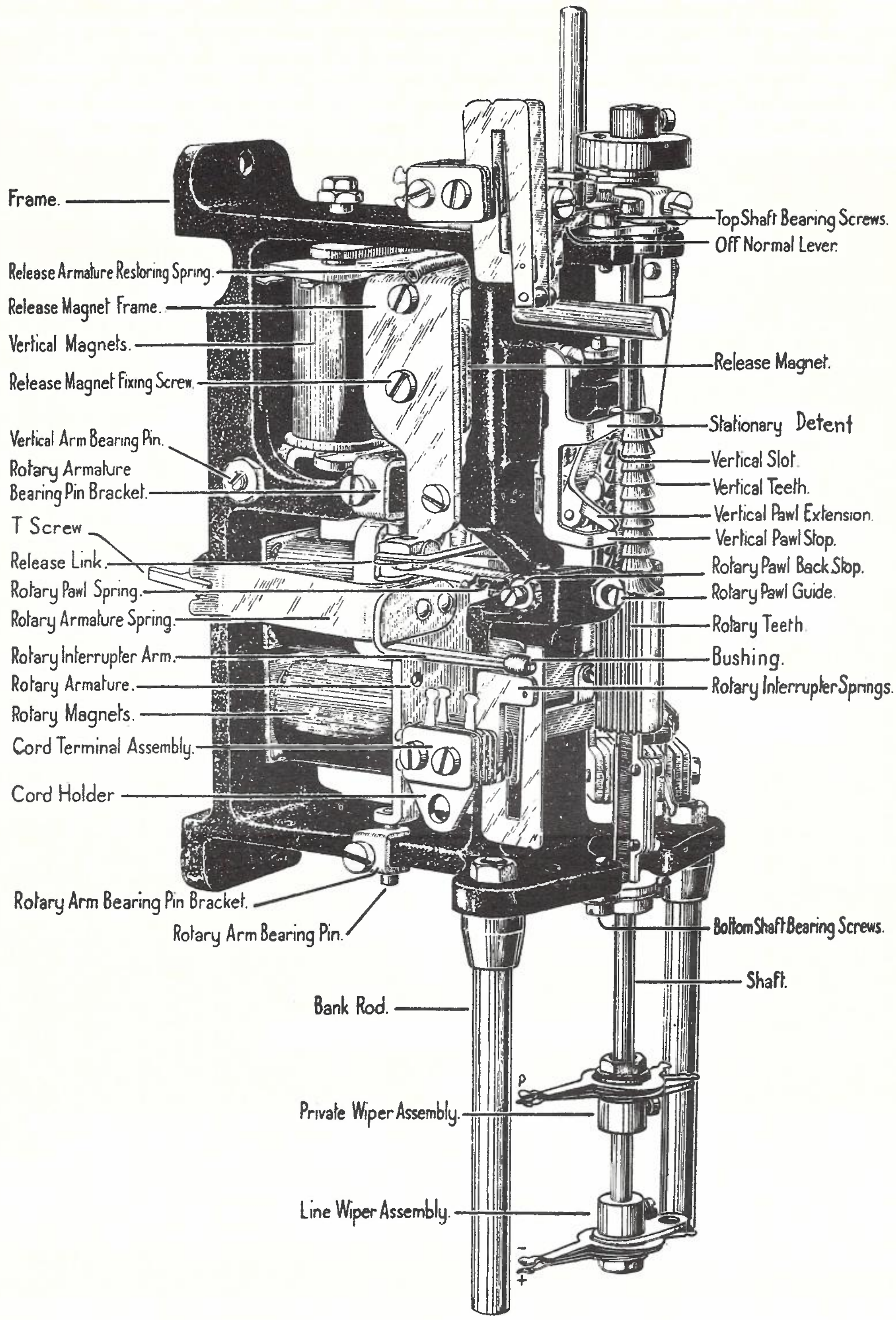
An arrangement which has certain advantages is the division of this double detent into two separate detents with individual restoring springs, one controlling the vertical holding and the other the rotary holding. The positions of the separate detents correspond with that of the double detent shown in the diagrams. This arrangement facilitates adjustment of the detent and reduces wear.

/ Fig. 2.



SWITCH MECHANISM (STROWGER TYPE).

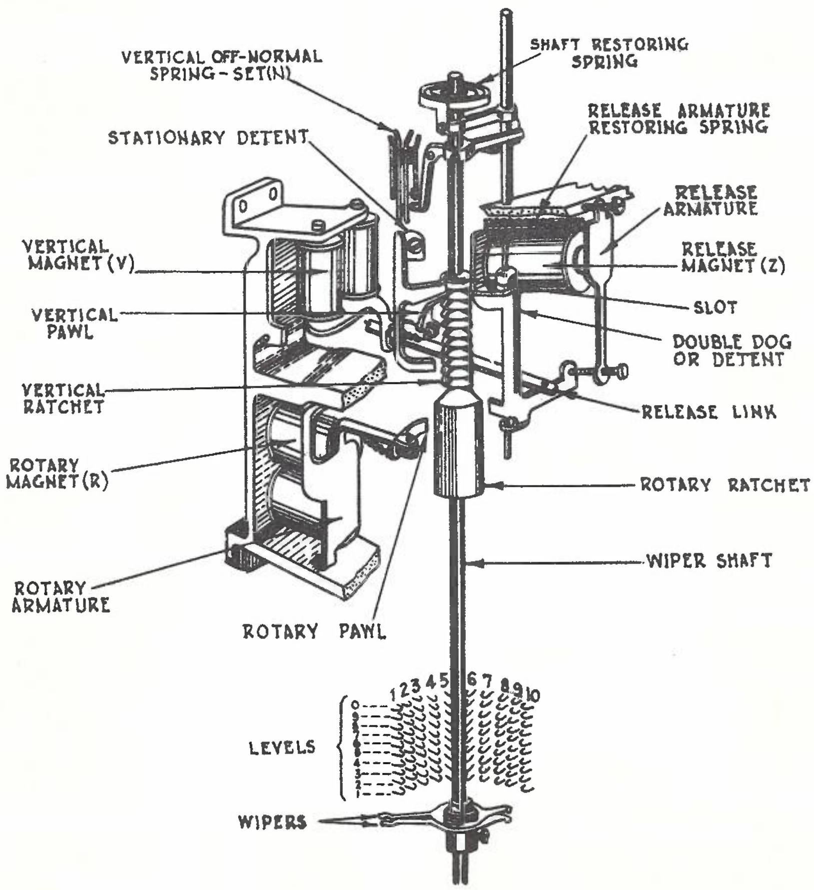
FIG. 2.



SWITCH MECHANISM (STROWGER TYPE).

FIG. 3.

2.3 Release Magnet. The release magnet is shown in Figs. 2, 3 and 4. The magnetic circuit of the release magnet is completed by the soft-iron yoke (the release magnet frame shown in Fig. 3) which is brought around the magnet coil and is terminated in two lugs in order to support the armature. These lugs fit loosely into two holes in the armature (see Fig. 2) which is held in place by means of the release armature restoring spring; this spring also serves to pull the armature away from the core of the release magnet when it is de-energised. A brass residual plate is usually fitted to the release armature.



MECHANICS OF THE TWO-MOTION SELECTOR.

FIG. 4.

The normal position of the armature may be adjusted by means of the release armature adjusting screw at its upper end (see Fig. 2). A longer screw, called the release armature pin, fitted at the lower end of the armature strikes the double detent when the release magnet operates. This causes the small vertical projection on the double detent to be engaged by the release link, thus disengaging the ratchet and allowing the shaft to return to normal and locking the double detent in its normal position, that is, free from engagement with either ratchet.

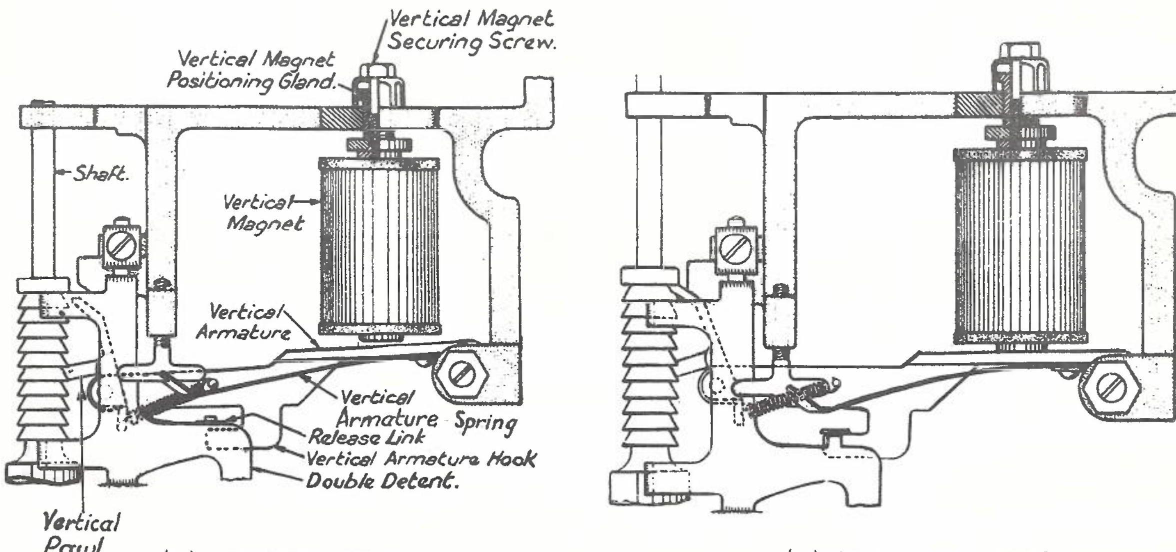
The reason for providing this latch is that after one call is terminated the switch may be seized for another before the shaft has reached its normal position. This would cause the release magnet to de-energise and, if the double detent were not locked away from the shaft, it might engage the teeth of the ratchet before the shaft had fully

/ released.

released. This, in turn, would mean that the switch would not start its vertical motion from normal and a wrong number would be obtained. In most switches, however, circuit arrangements prevent the switch from being seized until it has fully restored to normal.

2.4 The Cup Spring Assembly. In the description of the wiper or switch shaft, it was stated that a spring is supplied to rotate the wipers clear of the bank when the shaft is released after a call. This spring must have the same restoring tension on all levels but no impeding effect upon the vertical motion of the shaft, and the cup spring assembly designed to meet these requirements is shown in Figs. 2 and 3, whilst the restoring spring itself may be seen in Fig. 4. This spring is of the type used for the main spring in watches and is placed inside a circular cup. One end of the spring is fixed in a saw cut in the cup, whilst the other is secured in a similar manner to the cup spring bracket. This bracket fits loosely on the shaft but is held in position by the cup and by the normal pin bracket (Fig. 2) immediately below it. It is, however, capable of rotation relative to the shaft. Actually, the cup spring bracket is prevented from rotation by the normal post fastened to the switch frame which passes through an elongated slot. During the vertical motion the cup spring bracket will rise as if fixed to the shaft, but it will not move during the rotary motion and therefore acts as if it were fixed to the frame. As the cup is secured to the shaft by means of a screw, the spring is wound up during rotation. On release, it will unwind and restore the shaft to the normal position. Immediately below the cup spring bracket, and held in place by the normal pin bracket, is the normal pin which lies in a groove cut in the shaft. The initial tension given to the cup spring causes the shaft to rotate in a counter-clockwise direction until the end of the longer side of the normal pin presses against a turned up lip on the cup spring bracket (see Fig. 2). The actual position of the shaft when this occurs, that is, the normal position, can be adjusted by loosening the screw of the normal pin bracket and sliding the shorter end of the normal pin in or out.

2.5 Vertical Motion. Fig. 5 indicates how the vertical motion of the switch takes place.



(a) Armature Normal. (b) Armature Operated.

HOW THE SHAFT AND WIPERS ARE LIFTED.

FIG. 5.

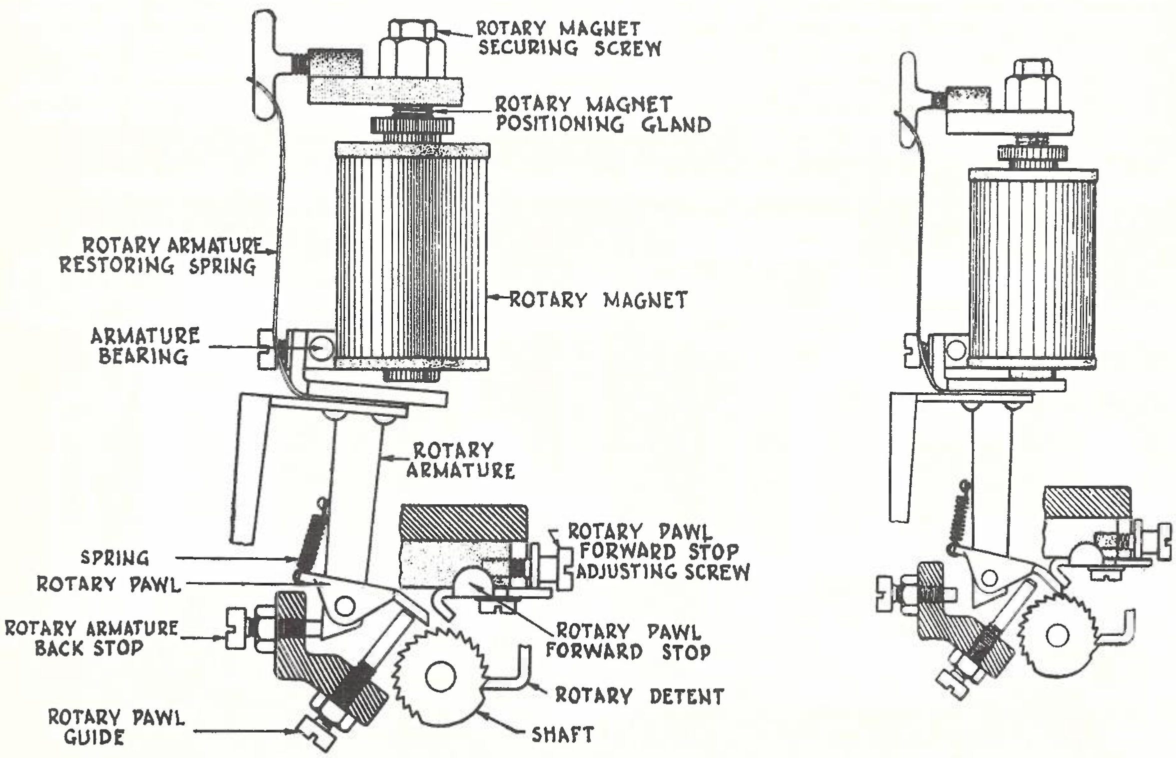
The vertical magnet consists of two coils, only one of which is visible from the side (see Fig. 5). These coils are secured to the switch frame in such a manner that they may be raised or lowered by means of the adjusting screws and glands. This provides an easy method of adjusting the amount of travel of the vertical armature. The vertical armature is hinged to the switch frame at the rear end, and at the outer end carries a pawl by means of a horizontal spindle. A small spiral spring is fastened to the armature and to

/ the

the pawl tending to force the point of the pawl into engagement with the vertical ratchet. When the vertical magnet is energised, the armature moves upwards and the spiral spring causes the tip of the pawl to move outwards until it strikes a vertical tooth and starts to lift the shaft. At the end of the stroke the armature strikes the magnet cores and the upper surface of the end of the pawl comes into light contact with a projection on the front of the switch frame. If the switch is properly adjusted, the motion of the vertical armature is checked by the vertical magnet cores and almost simultaneously the vertical pawl meets the projection. When the magnet coils are de-energised the armature is returned to its normal position by a steel restoring spring riveted to it. The tension of this restoring spring may be adjusted by means of a "T" shaped screw, the head of which fits into a groove cut in the spring.

It has been explained that the double detent is normally held away from the shaft by means of a release link which is lifted when the first vertical step takes place. This is accomplished, as shown in Fig. 5, by means of a lug on the armature of the vertical magnet.

2.6 Rotary Motion. The method adopted for converting operations of the rotary magnet into rotary steps of the wiper shaft is shown in Fig. 6.



(a) Normal Position of Rotary Magnet Armature.

(b) Rotary Armature Full Operated.

HOW THE WIPERS ARE ROTATED.

FIG. 6.

The system employed is similar to that used for the vertical movement. With this method, two adjustable stops are provided, one serving as a back stop to the armature and governs the distance between the tip of the pawl and the tip of the teeth when the rotary magnet is de-energised. The other stop serves as a guide to the rotary pawl and, when the magnet operates, it affects the point of contact between the pawl tip and the rotary teeth. The

/ front

front stop, as shown in Fig. 6, is screwed to the frame and is adjusted to prevent overstepping. The forward stroke of the pawl should be sufficient to ensure that the double detent drops over one tooth at each rotary step. The rotary magnet coils and the adjustable rotary back stop and rotary pawl guide may also be seen in Figs. 2 and 3.

2.7 Mechanically Operated Spring-sets. It is usually desired that certain electrical contacts should be mechanically operated at various stages of the switch operation. These mechanical spring-sets include off-normal springs, eleventh step or cam springs, rotary interrupter springs, rotary off-normal springs and normal post springs. Any or all of these types of springs may be fitted on the same switch. For example, in Fig. 1, off-normal springs, cam springs and rotary interrupter springs may be seen on the group selector.

Off-Normal Springs. This actual spring assembly will depend on the particular circuit requirements. In the case shown in Figs. 2 and 3, there are two long moving springs tensioned to make contact normally with smaller and fixed springs. A bell-crank shaped piece, termed the off-normal lever, pivots on a screw, the head of which may be seen. The horizontal arm of this lever rests under the longer arm of the normal pin and the weight of the shaft normally presses down on it thus separating the off-normal contact springs. During the first vertical step, however, this weight is removed and the spring tension allows the contacts to make.

Eleventh Step or Cam Springs. Immediately below the rotary ratchet of the shaft in Fig. 2 may be seen a small sleeve secured by means of two screws which also serve to attach a small cam plate to the shaft. If the duty of the switch is to search over the contacts to find a free outlet, and if all contacts in the level are busy, the shaft will make an eleventh rotary step. The cam is adjusted so that it causes the cam spring assembly contacts to operate whenever this eleventh step is made.

Rotary Interrupter Springs. On the left-hand side of the switch in Fig. 2 and the centre of Fig. 3 just below the back stop of the rotary magnet will be seen a projecting arm with an insulated bushing at the end. This is attached to the armature of the rotary magnet and projects to the front of the switch until it is level with the top of the moving member of the rotary interrupter springs. When the rotary magnet operates, the rotary interrupter arm moves with the armature and opens the rotary interrupter spring contacts. The arm must be adjusted (for circuit reasons) so that the rotary interrupter spring contacts are opened near the end of the stroke of the rotary magnet armature.

Rotary Off-Normal Springs. These springs are operated on the first rotary step of the switch shaft. Their position and method of operation will be given when circuits in which they are used are being discussed.

Normal Post Springs. These springs are fastened to the normal post parallel to its axis, and are operated by the cup spring bracket when the wipers reach a certain level.

Release Magnet Springs. This spring-set is operated during the time that the release magnet armature is operated.

2.8 Wipers. In Figs. 2 and 3 the two wiper assemblies are shown in their correct normal position. Each wiper assembly consists of a hub which is fastened to the shaft by means of a screw. Each hub carries two flexible springy brass wipers which, whilst giving sufficient spring tension to secure good contact with the bank, must not be so hard at the contact points to unduly wear the bank contacts. A projection from each wiper is brought out at the back to serve as a wiring tag. The wipers are insulated from each other and from the hub by means of insulating collars and washers. A fibre plate completes the assembly which is rigidly fastened together by a nut. The fibre plate has a second hole through which the wiper cords are passed in order to take the strain off the soldered connections.

2.9 Test Jack. On the right-hand side of the bank position of the switches in Fig. 1 is an assembly of six springs and insulation pieces fastened to the switch base. The four springs to the front serve as the test jack of the switch, the top spring being connected to the negative line, the second to the positive line, the third to the private wire and the fourth to earth. The two springs to the side are provided in order that a lamp may

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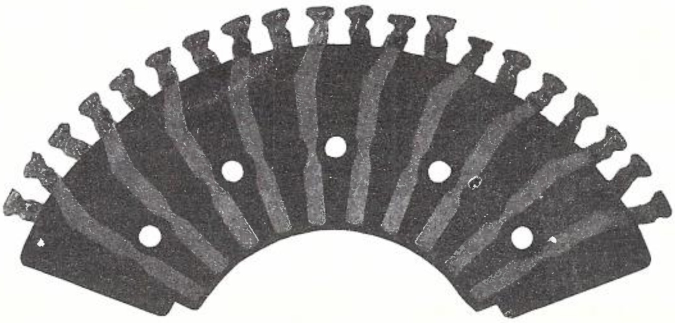
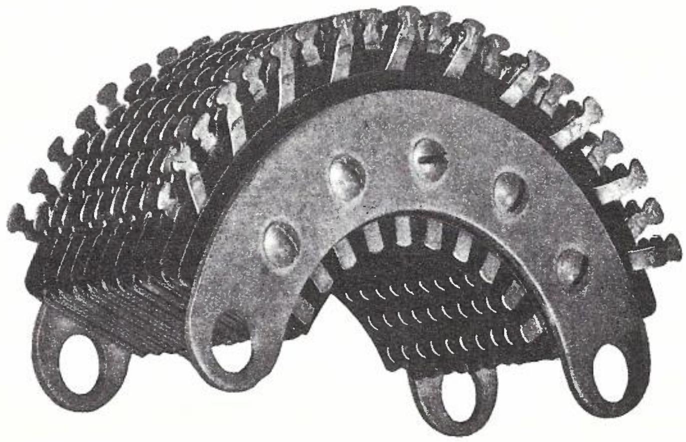
be fitted when required to give a visual indication of the occurrence of certain specified circuit conditions.

2.10 Contact Banks. Fig. 7 shows the details of a line contact bank. In Fig. 7a will be seen a single row of contacts, which are stamped from hard rolled brass. The black section is the insulation which is made of empire cloth and phenolic plate to give a high value of insulation resistance. The complete bank is shown in Fig. 7b, ten contact levels being clamped between two steel plates. Each plate has two holes through which pass the bank rods when the bank is assembled on the switch.



(a) One Level of Bank Contacts.



(b) Complete Bank Assembly.

CONTACT BANK.

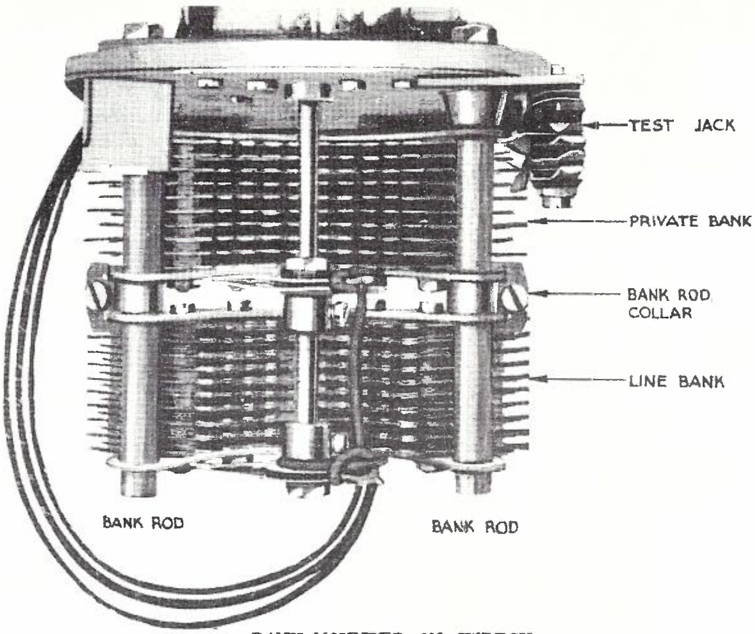
FIG. 7.

The private bank is similar in construction to the line bank but single contacts are employed. In group selectors, an eleventh contact is necessary on each level of the private bank for operation of a congestion meter when all outlets in the level are busy. Banks having eleven contacts per level are now standard for all switches, the eleventh position being used for testing purposes in many cases. In later banks, an aluminium spacing plate is placed between levels, the plates being bonded to act as screens against electrostatic induction between adjacent levels.

The rear end of the bank contacts are notched and tinned to facilitate wiring, and are staggered to left or right (see Fig. 7a) to minimise the possibility of faults occurring. A bank is generally known by the number of contacts it contains. Thus a private bank is a 110 point bank and a line bank a 220 (or 200) point bank.

/ Fig. 8.

Fig. 8 shows the line and private banks in position on a switch. The banks are threaded on the two bank rods on which they are held in place by bank rod collars. The ends of the bank rods pass through holes in the switch base to which they are fastened by nuts. To remove a switch from the bank, it is necessary for the bank rod nuts to be removed. Spare banks are supported by brackets to which the bank rods are fastened.



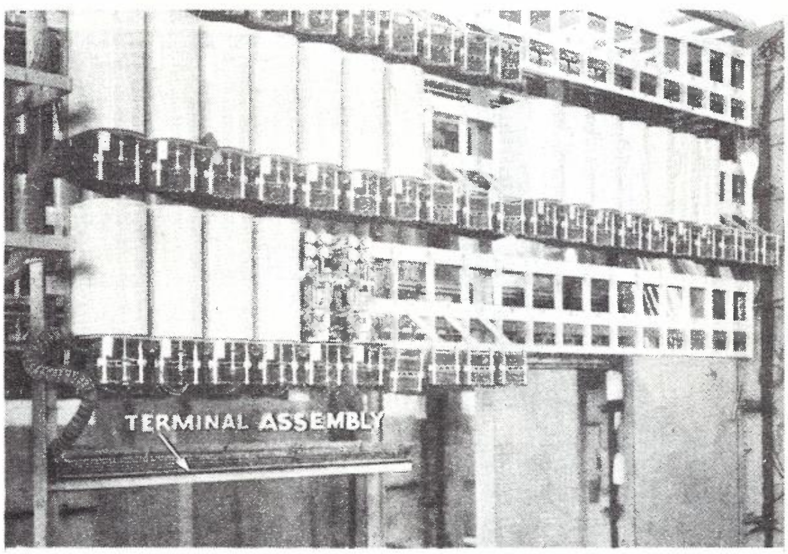
BANK MOUNTED ON SWITCH.

FIG. 8.

Connections to the wipers are made by flexible wiper cords, as shown in Fig. 8.

The banks of group selectors are permanently wired in sets of ten and are wired to a terminal assembly. Loop multiple wiring is used, the line wires being suitably twisted.

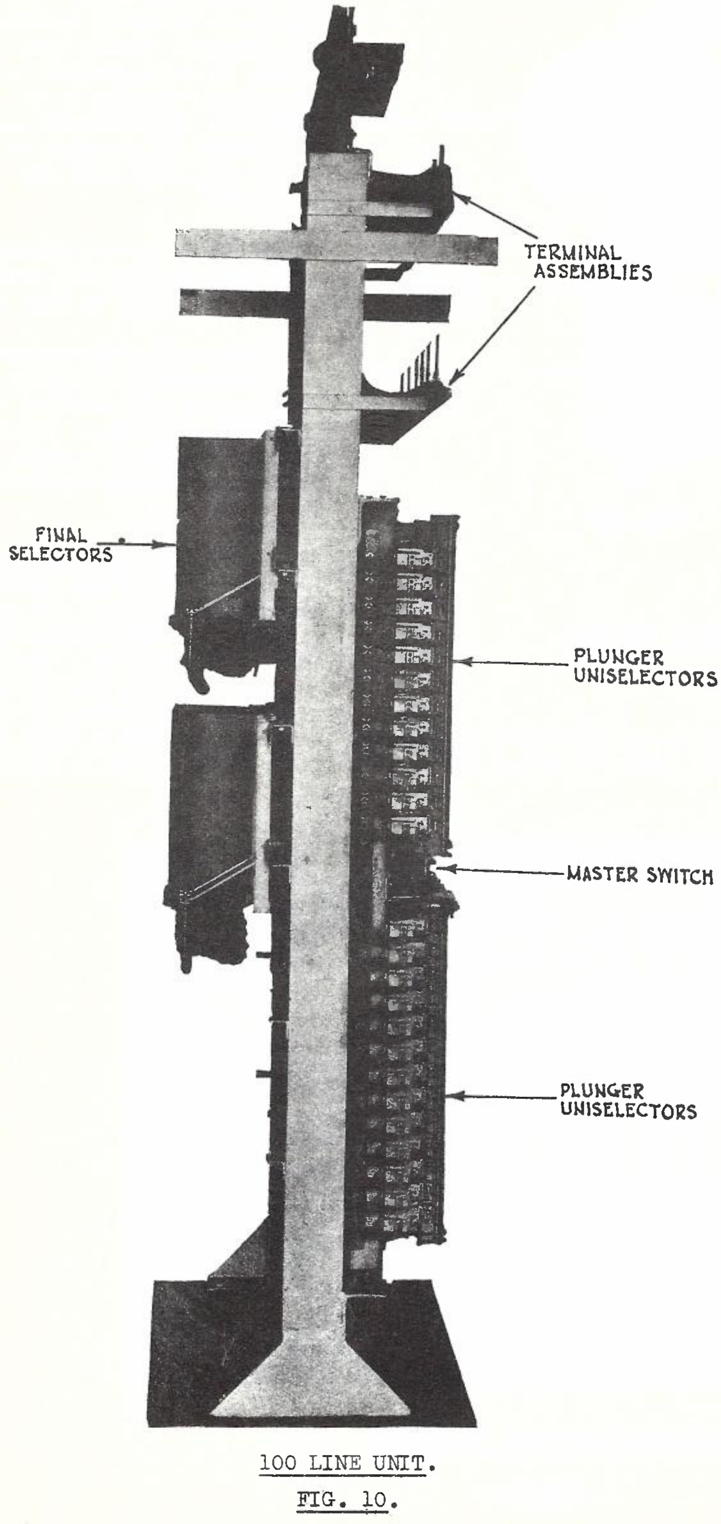
2.11 Mounting of Switches. Group selectors are usually mounted on shelves, as shown in Fig. 9. Twenty switches may be mounted on a shelf and six shelves are fastened one above the other to form a rack or bay. With this type of switch two bays are mounted back to back with a space in between to permit technicians to work. A set of two bays completely assembled is called a selector trunk board.



MOUNTING OF GROUP SELECTORS.

FIG. 9.

Final selectors are usually mounted on shelves fitted at the rear of uniselector boards. Fig. 10 shows a side view of a 100 line unit equipped with plunger uniselectors and the associated final selectors.



100 LINE UNIT.

FIG. 10.

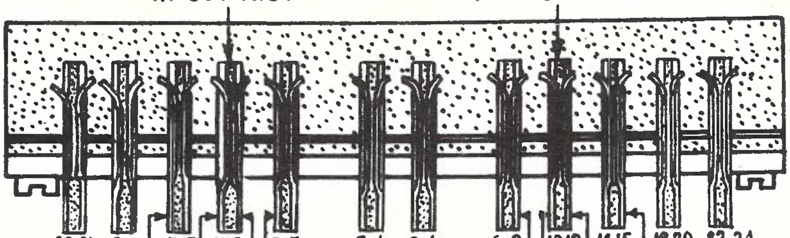
Owing to the possibility of faulty switch operation being caused by dust settling on the contacts, each switch is protected by a metal cover, as shown in Figs. 9 and 10. The two sides of the top of this cover fit closely to the mounting plate of the switch. The bottom is open and rests on the base of the switch to the rim of which a narrow piece of felt is fastened to make a dust-proof joint. A metal plate is placed at the back of the mounting plate to prevent dust passing through the relay mounting holes. In addition, every effort is made to keep exchanges free from dust and the floor is kept well polished; in many exchanges some means of dust extraction is used to ensure that the ventilating air is free from dust.

2.12 Switch Jack. Referring to Fig. 9, it may be seen that between each two switches is a small upright member fastened to the horizontal shelf angle irons. Small projections are fixed to these uprights and the switches are hooked on to these projections by means of slots in the sides of the mounting plate (bayonet mounting).

Electrical connections to the switches are made by a special type of jack fixed to the middle horizontal of the shelf frame. These jacks may be seen in the spaces from which the switches have been removed in Fig. 9. A suitable form of male jack is fastened to the back of the switch. To remove a switch it is necessary only to unfasten the two nuts which secure the bank and to lift the switch upwards and outwards clear of the projections and of the jack.

/ Fig. 11.

Fig. 11 shows a switch jack.



SWITCH JACK SHOWING NUMBERING OF CONTACTS AND TYPICAL CONNECTIONS.

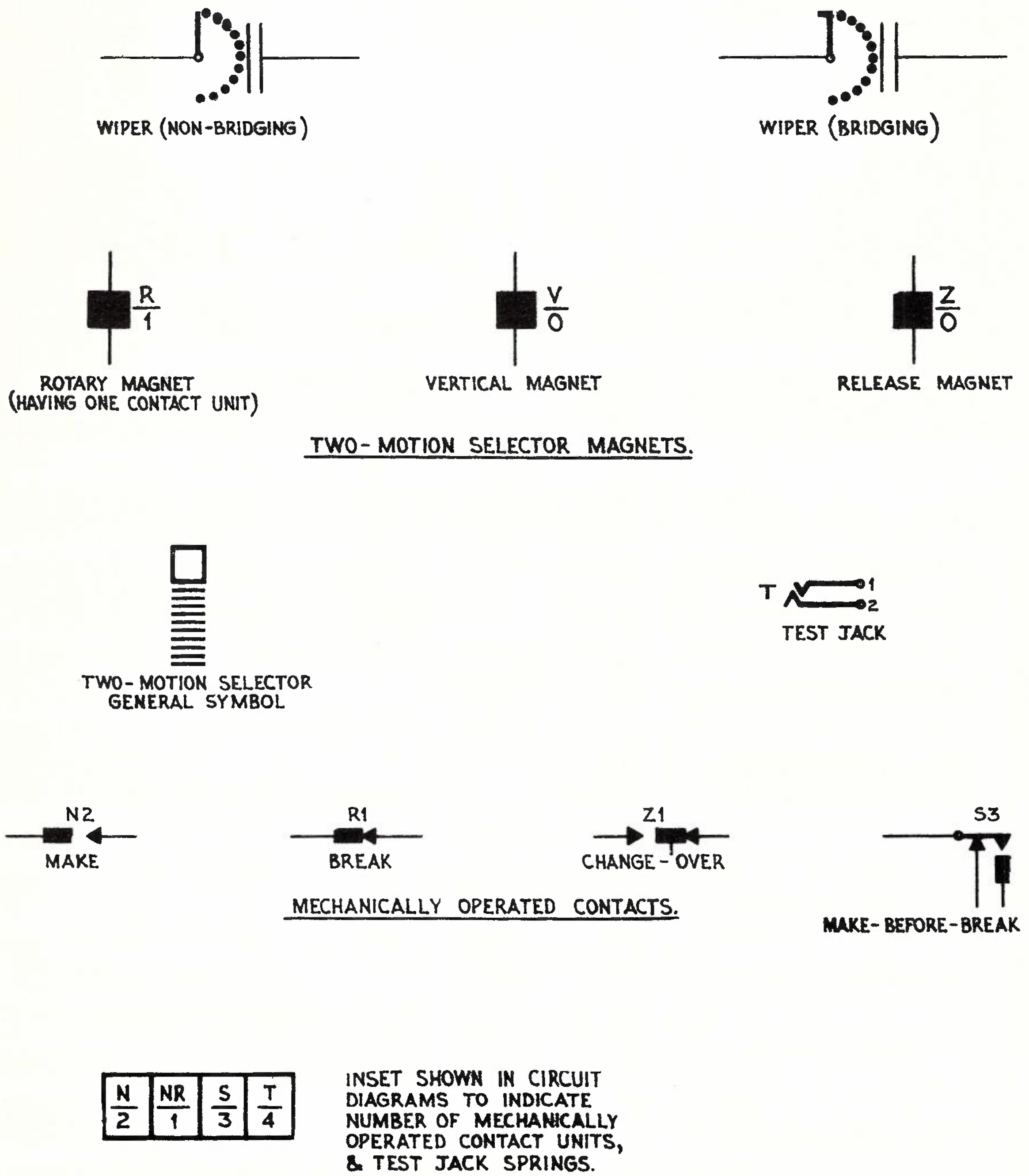
FIG. 11.

2.13 The conventional circuit symbols associated with the two-motion selector are given in Fig. 12. Mechanically operated contacts are designated by a code letter as indicated in the following table -

Function of Assembly	Coding	Maximum No. of Springs	Remarks
Vertical Off-normal Springs	N	8	Subject to combined "N" and "NP" springs not exceeding 11.
Rotary Off-normal Springs	NR	3 Contact Units	Subject to combined "NR" and "S" springs not exceeding nine.
Eleventh Step Springs	S	9	Less "NR" springs when required.
Release Magnet Springs	Z	4	Subject to combined number of "NR" and "S" springs not exceeding nine.
Vertical Detent Springs	DD	3	Cannot be used simultaneously with Z springs.
Vertical Magnet Springs	V	2	
Rotary Magnet Springs	R	4	
Normal Post Springs	NP	4	Subject to combined "N" and "NP" springs not exceeding 11.
Rotary Release Magnet Springs	RZ	2	

The operation of Vertical Detent Springs, Vertical Magnet Springs and Rotary Release Magnet Springs has not been described as they are not in common use in this country.

/ Fig. 12.



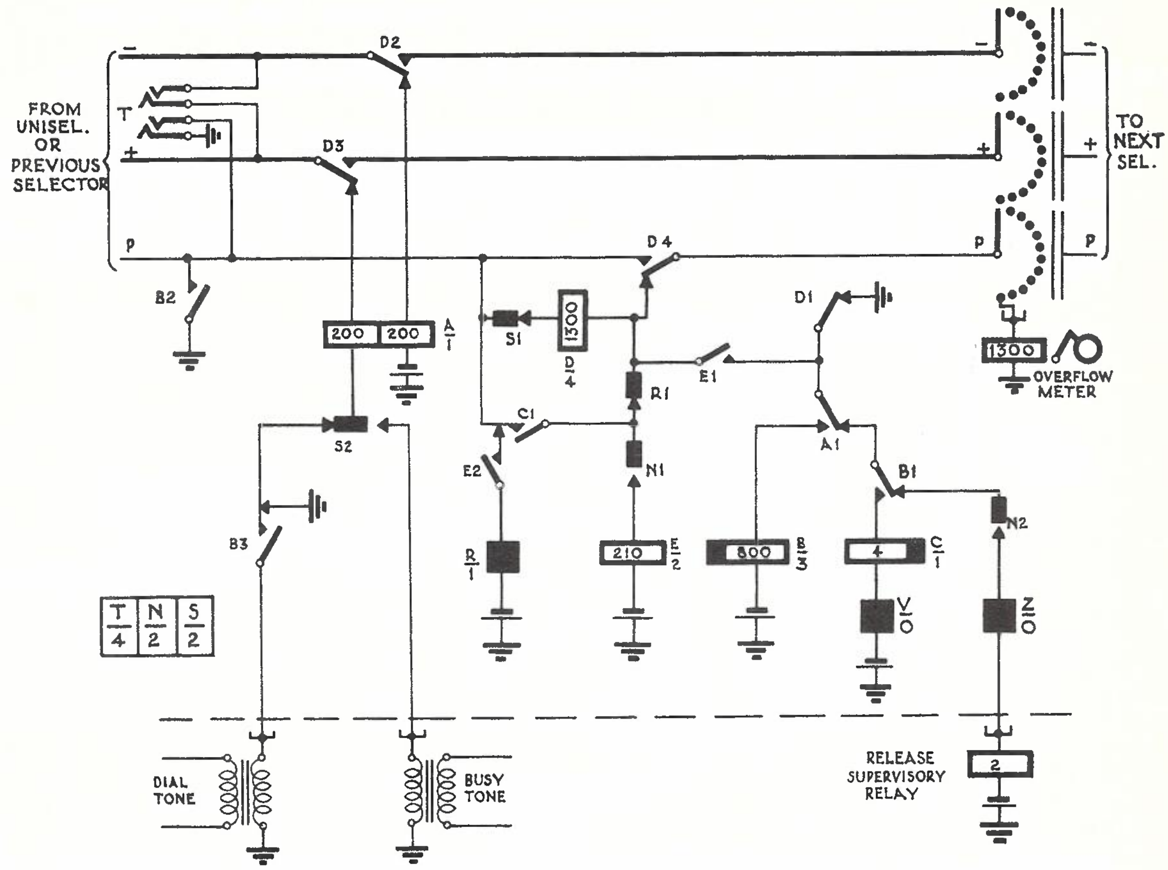
TWO-MOTION SELECTOR SYMBOLS.

FIG. 12.

3. GROUP SELECTOR CIRCUITS.

3.1 The group selector has been introduced in Paper No. 2 of this Book. In the Strowger system the same circuit is used for 1st, 2nd, 3rd, etc., group selectors, with the exception that dial tone is fed from 1st selectors only. Also a supervisory lamp may be fitted to some selectors, when required.

Fig. 13 shows the circuit of a group selector using Strowger relays.



GROUP SELECTOR CIRCUIT (C.711, SHEET 1).

FIG. 13.

3.2 Functions. The functions performed by this switch are -

(i) Returns dial tone to the calling party when it is seized from the previous switch (1st selectors only).

(ii) Returns guarding and holding earth on P wire.

(iii) Steps the shaft and wipers vertically under the control of the calling party's dial.

(iv) At the end of the impulse train, steps the wipers into the level reached and hunts for and seizes the first free outlet in that level.

(v) Prevents interference with circuits over which the wipers are passing during hunting.

(vi) Guards the seized circuit from intrusion.

(vii) Extends the calling party's line to a switch in the next rank.

/ (viii)

(viii) Should all outlets in the level be busy, connects busy tone to the caller, and operates an overflow meter.

(ix) When release conditions are applied, releases itself without interference to other circuits.

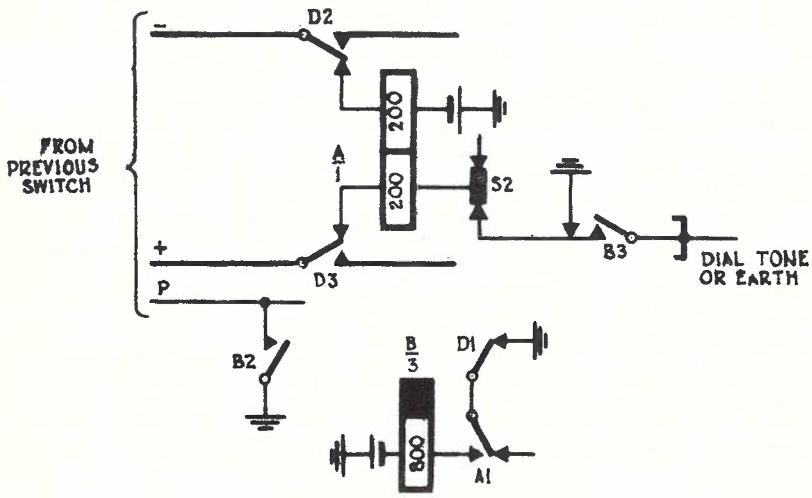
(x) Provides a supervisory alarm -

(a) If it is seized and dialling does not take place (permanent loop conditions). Only provided on 1st and incoming selectors.

(b) If the switch fails to release due to a mechanical fault when release conditions are applied.

3.3 Circuit Operation. (The simplified circuits in this paragraph should be studied in conjunction with Fig. 13.)

Switch Seized. (Fig. 14.) When the circuit is seized, relay A is operated over the calling subscriber's loop via D2 and D3 to earth via S2 and B3. A1 completes the circuit from earth at D1 for relay B, which operates and at B2 earths the P wire to hold the connection. B3 connects dial tone to the calling line in the case of 1st selectors; in other group selectors the dial tone common is wired to earth. B1 prepares the impulsing circuit of the switch.



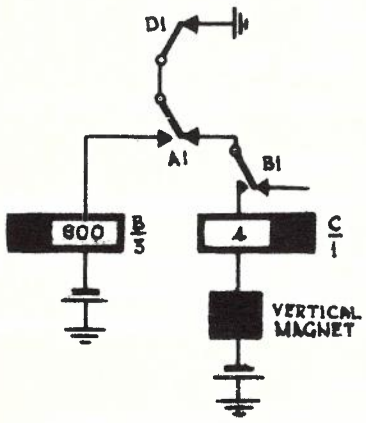
Switch Seized -

A operates.
B operates.
Private wire earthed.

SWITCH SEIZED.

FIG. 14.

Impulsing. (Fig. 15.) Upon the receipt of dial tone, the subscriber will proceed to dial the required number and relay A responds to the train of impulses received.



Caller Dials

A impulses.
C operates.
Vertical magnet operates.
N springs operate.
E operates and locks.

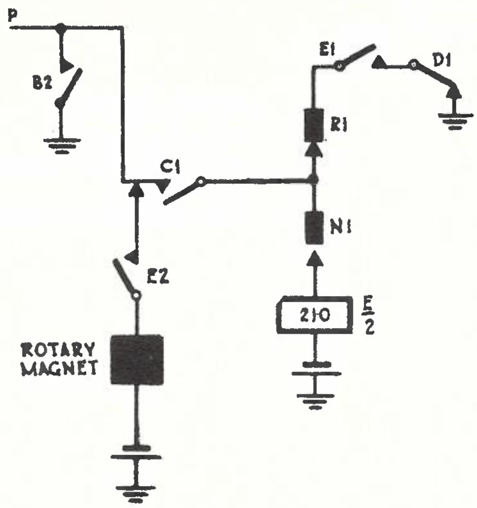
IMPULSING.

FIG. 15.

Relay B receives current during the make periods of the impulses, and holds during the break periods because of its copper slug.

During the break periods of the impulses, a circuit is completed for the vertical magnet and relay C in series via B1 and A1 normal to earth at D1. Relay C operates first and, being slow to release, holds during the dial make periods when it receives no current. The vertical magnet restores after each impulse, stepping the shaft and wipers to the dialled level.

The vertical off-normal contacts operate during the first vertical step and N1 completes the circuit of relay E to earth via B2 and C1 operated. E operates and locks up via R1 normal and E1 operated to earth at D1 (Fig. 16).



At End of Impulse Train -

C releases.
Rotary magnet operates.
E releases.
Rotary magnet releases.

CUT-IN.

FIG. 16.

Cut-In. (Fig. 16.) After the last impulse of the train relay C releases slowly, completing the circuit of the rotary magnet via E2 operated, C1 normal to earth at B2. The rotary magnet operates, stepping the wipers on to the first contact of the level dialled.

Towards the end of the rotary armature stroke its interrupter contact (R1) opens, releasing relay E. E2 opens the rotary magnet circuit and the magnet restores.

This is known as a "Cut-in" action and is entirely automatic. It is followed by a hunting action to find and seize the first free outlet in the level.

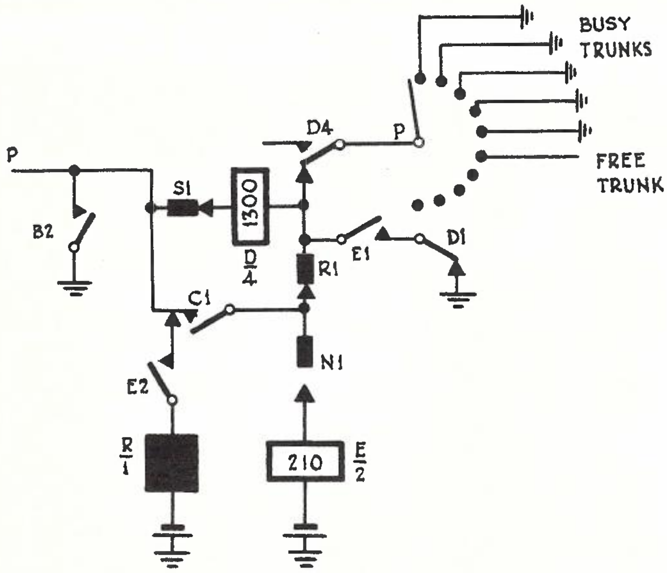
Hunting and Testing. (Fig. 17.) Assuming that the first outlet is busy, relay E re-operates to the earth on the P wiper via D4, R1 and N1. Relay E locks via E1 as before and E2 completes the circuit of the rotary magnet. The wipers are stepped to the second outlet and relay E releases, its circuit being opened at the interrupter contacts. The rotary magnet restores and the second outlet is tested.

This cycle of operations continues until a free outlet (one with no earth on the P wire) is reached. The hunting speed when the switch is in correct adjustment is not less than 33 steps per second.

During hunting, relay D is shunted by the earth on the P wiper, and because that wiper is non-bridging, the shunt is maintained while the magnet is operating by contact E1. The

/ test

test on the P wiper is made when the rotary interrupter contacts remake, and, if no earth is encountered, relay D operates in series with relay E via N1, R1 and S1 to earth at B2. Relay E does not operate under this condition (see Fig. 17).



On Busy Outlets -

E reoperates.
Rotary magnet operates.
E releases.
Rotary magnet releases.

HUNTING AND TESTING.

FIG. 17.

Switching Through. The operation of relay D switches the caller through to the selected trunk, the through conditions being shown in Fig. 18.

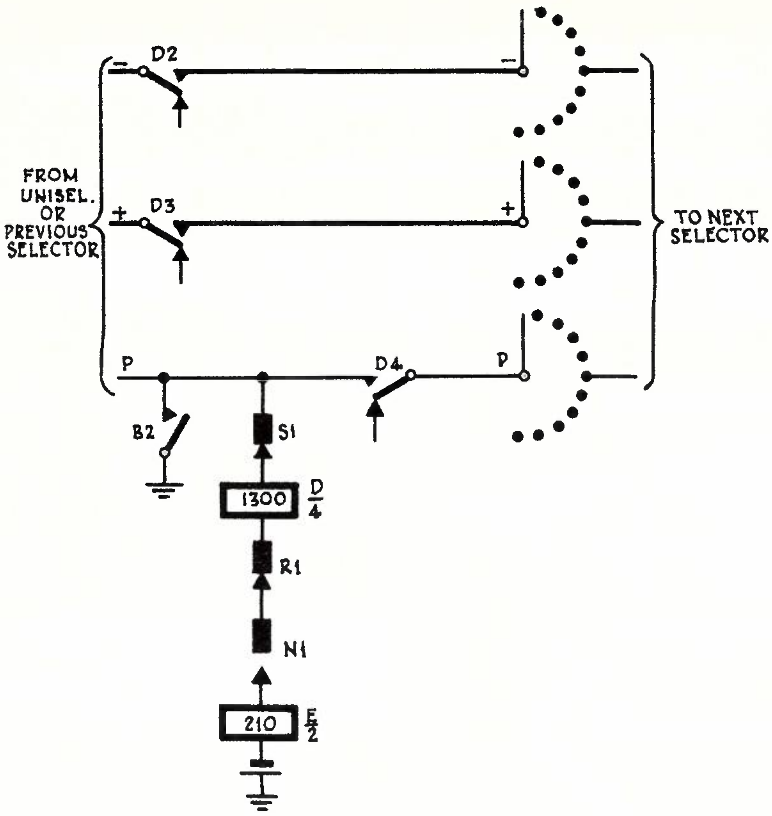
Relay A releases, and the circuit of relay B is opened at D1. Relay B releases slowly, and at B2 maintains a holding and guarding earth on the P wire until it is returned from the switch ahead. Relay D remains operated for the duration of the call.

Release. At the end of the call earth is removed from the P wire and relay D releases. D1 completes the release magnet circuit (Fig. 19) via D1, A1 and B1 normal, N2 operated to release alarm battery. The release magnet operates and the switch restores.

When the switch reaches the normal position the N springs restore, opening the circuit of the release magnet.

The alarm circuit is necessary to give an indication when the release of the switch is mechanically prevented, otherwise a burn out of the release magnet would be likely and a fire possibly started. Its operation will be described later in this Book.

/ Fig. 18.

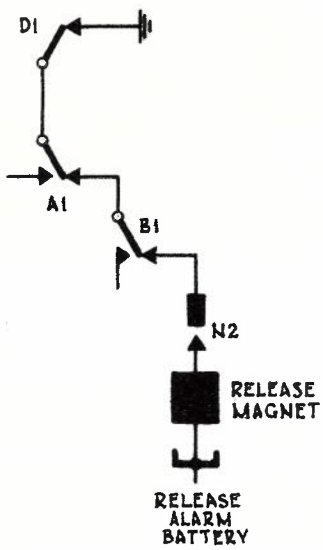


When Free Trunk is Found -

D operates.
A releases.
B releases slowly.

SWITCHING THROUGH.

FIG. 18.



When Earth is Removed from P Wire -

D releases.
Release magnet operates.

When Switch Reaches Normal Position -

N springs restore.
Release magnet releases.

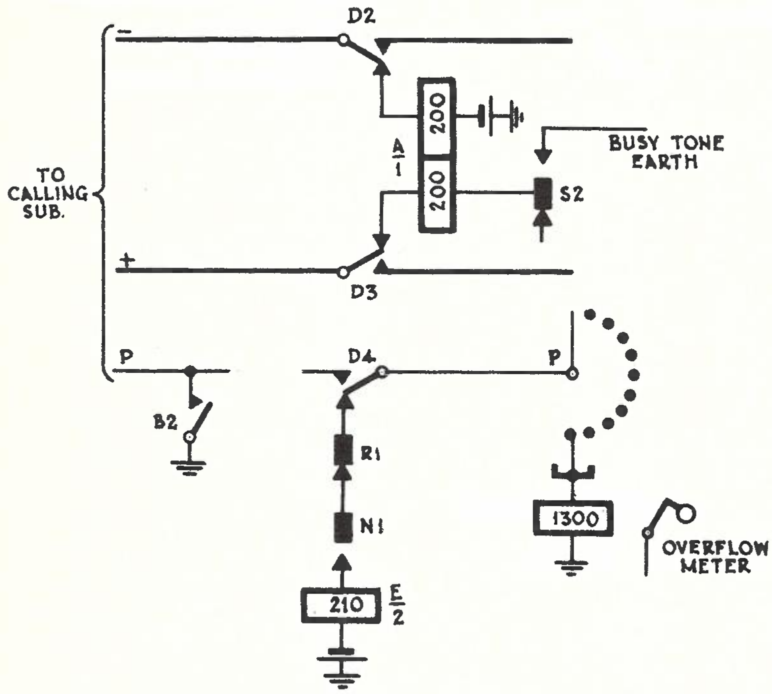
RELEASE.

FIG. 19.

All Outlets Busy. (See Fig. 20.) In this case, the hunting continues until the wipers reach the eleventh bank contact, when the eleventh step contacts (S) operate. S2 connects busy tone earth to the caller. S1 prevents the operation of relay D.

Relays A and B remain operated until the caller replaces the receiver and the release circuit is completed as before.

An overflow meter may be wired to the eleventh contact of each bank level to indicate traffic congestion. This is operated from battery through the E relay, N1, R1 and D4 to the P wiper. Relay E does not operate in series with the 1,300 ohm meter.



At the Eleventh Rotary Step -

S springs operate.
Busy tone connected to caller.
Overflow meter operated.

ALL OUTLETS BUSY.

FIG. 20.

Spark Quenches. For clearness, all spark quenching devices have been omitted from Figs. 13 to 20. The vertical and rotary magnet circuits, which each have a resistance of 46 ohms, are quenched with a 1 μF condenser and 200 ohm resistor to earth. The release magnet, of 100 ohms, is shunted with a non-inductive winding of 500 ohms.
To prevent sparking at the rotary interrupter contacts, relay E is shunted with a non-inductive winding of 1,300 ohms.

Several contact springs in the circuit are fitted with platinum contacts. These will be shown in a later circuit using 3,000 type relays.

Relays. The following table lists typical information regarding relays in the group selector circuit -

/ Code

Code	Title	Type of Relay	Operate Current (mA)	Operate Lag (mS)	Release Lag (mS)
A	Impulsing	Impulsing Fast	20	8	8
B	Guard	Heel Slug, 1-1/2"	15	12	350
C	Impulse Control	Heel Slug, 11/16"	116	15	150
D	Wiper Control	Ordinary Fast	27	50	3
E	Test	Fast	100	8	4

In some switches the Wiper Control relay is coded "H" and the Test relay "G".

3.4 Seizure Before and During Release. On the release of a connection, earth is removed from the P wire and the selector releases. The release action consists of three operations -

(i) Release lag of relay D (approximately 3 mS).

(ii) Operate time of the release magnet (approximately 15 mS).

(iii) The time required by the switch to restore out of the bank and drop vertically to the normal position. This time varies from a minimum of about 44 mS when the switch is standing up one and in one to a maximum of approximately 142 mS when the switch is up ten and in ten.

During all of this time, the circuit is unguarded and may be seized by a searching selector of the previous rank, the possibility rising with increase in traffic density. If seized during the first 18 mS, relay A operates and release is prevented. An outlet in the level on which the wipers are standing is seized and this results in the caller obtaining a wrong number.

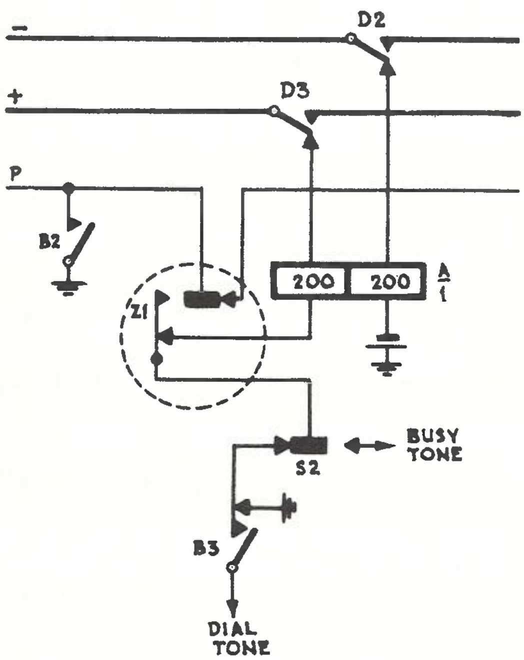
Should the circuit be seized after the release movement has commenced, operation of relay A prepares the vertical and rotary magnet circuits and allows the possibility of their operation. This has lead to the discovery of switches with the shaft off-normal and the wipers caught between bank levels.

This inherent weakness in the circuit rests on two factors -

(i) The P wire is not earthed though the switch is off-normal.

(ii) Reoperation of Relay A, which opens the release magnet circuit.

In later circuits, these conditions are prevented by the addition of a spring-set associated with the release magnet, and operated by the release magnet armature. The spring-set may be fitted to existing circuits, as shown in Fig. 21. It will be seen that the P wire is earthed via Z1 when the release magnet operates; at the same time reoperation of relay D is prevented. The circuit of relay A is opened so that its operation is prevented until the switch reaches the normal position.



PART OF GROUP SELECTOR CIRCUIT WITH RELEASE GUARD.

FIG. 21.

/ With

With such a spring-set fitted to a group selector, the circuit is still unguarded for approximately 18 mS, but from this may be subtracted the operate time of relay A (approximately 8 mS) so that the circuit has to be seized within 10 mS of being unguarded in order to reoperate relay A and prevent the release of the switch.

Thus, the effective unguarded interval is reduced from 62-160 mS to approximately 10 mS, and the liability of seizure before release trouble is much reduced. If seized in this brief interval the wipers will remain on the bank contact, giving wrong numbers.

3.5 Group Selector Circuit with 3,000 Type Relays. Standard 3,000 type relays are used on later type selectors. Many refinements are also incorporated in the circuit design, resulting in improved switch performance and lowered fault liability.

Fig. 22 shows the standard circuit for a group selector using 3,000 type relays. The circuit operation is similar to that previously described (Fig. 13), but there are many differences in details and these are listed below -

(i) C1 is now a change-over unit. Change-over contacts are used in preference to make-before-break units wherever possible, for ease of maintenance. With the earlier circuit using Strowger relays make-before-break contacts were used, because it was found that if a change-over unit was fitted, contact bounce caused increased contact wear.

(ii) The impulsing relay is fitted with a make-before-break contact unit and this gives a slight improvement in the impulsing characteristics. (See Paper No. 1, Page 17.)

(iii) Relay B is shunted with a 2,000 ohm non-inductive winding to reduce sparking at the make contact of A1.

(iv) The circuit is guarded during release by Z1, and N3 opens the circuit of relay A until the switch reaches the normal position.

(v) Contact B2 prevents a possible operation of relay E when the wipers are returning over busy contacts during release of the switch.

(vi) S3 is make-before-break to prevent breaking the circuit of relay A during operation of the eleventh step springs.

(vii) Contact S2 in series with the vertical magnet prevents further operation of the magnet when the caller continues to dial after the switch reaches the eleventh step and busy tone is connected.

(viii) S1 has been shifted to prevent a possible interaction between E relays when a number of selectors rotate to the eleventh bank contact on busy levels.

Switch jack connections are shown thus $\overline{\wedge}$ on the circuit of Fig. 22. These may be checked with the diagram shown in Fig. 12.

/ Fig. 22.

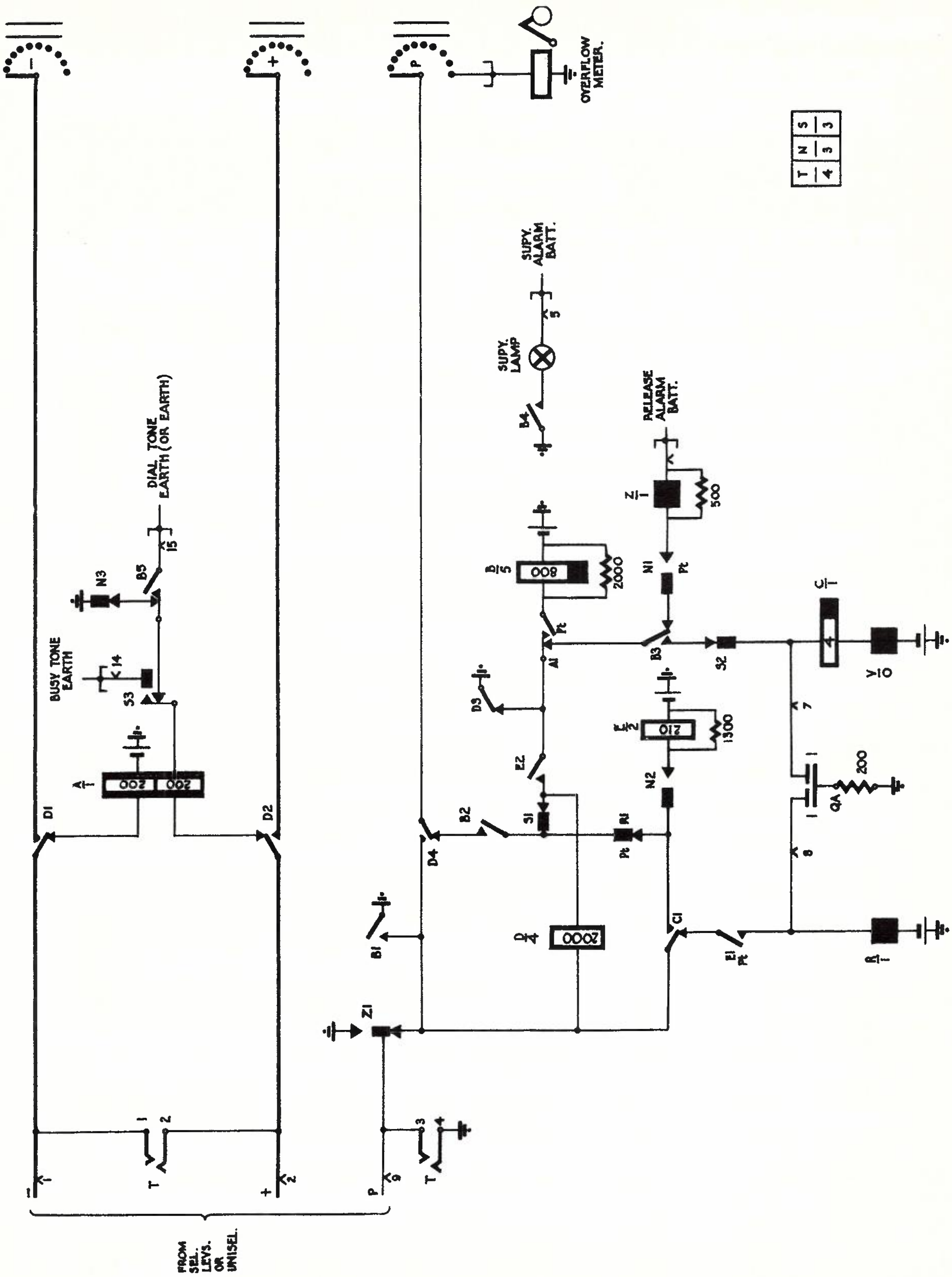


FIG. 22. GROUP SELECTOR CIRCUIT WITH 3,000 TYPE RELAYS (C.711, SHEET 2).

4. FINAL SELECTOR CIRCUITS.

4.1 As its name implies the final selector is the last selector used in setting up a call through an automatic exchange. It accepts the last two digits to be dialled and selects the required number by a vertical and a rotary movement. Final selectors may be classified under two main headings -

(i) Ordinary or Straight Line.
(ii) P.B.X. type.

The ordinary type is designed to operate into groups having only single lines connected, and the P.B.X. type caters for groups of two or more lines. If the first line of a group is busy, then a P.B.X. final selector will test all lines in that group before giving busy tone to the caller. Paper No. 5 deals with P.B.X. final selectors used in the Strowger system.

4.2 Fig. 23 is the circuit of an ordinary final selector using Strowger relays, and the functions performed by this circuit are -

(i) When seized, returns guarding and holding earth on the P wire.

(ii) Executes vertical and rotary movements under the control of the dial.

(iii) Prevents interference with the lines passed over by the wipers during rotary motion.

(iv) Tests the selected line, and prevents the calling line being extended to the called line while testing.

(v) If the called line is busy -

(a) Guards against connection to the called line.
(b) Transmits busy tone to the caller.

(vi) If the called line is free -

(a) Guards both lines from intrusion.
(b) Allows the call to proceed.

(vii) Cuts off the calling equipment of the called line.

(viii) Sends out ringing current to the called line.

(ix) Transmits ringing tone to the calling line to indicate that ringing conditions have been set up.

(x) When the called party answers -

(a) Cuts off ringing current and ring tone.
(b) Provides a transmission bridge to supply transmitter current to calling and called parties.
(c) Operates the calling party's meter.
(d) Reverses the line current to the calling party for supervisory purposes.

(xi) When the calling party clears, releases itself and restores connections to normal without interfering with other lines.

(xii) Provides a supervisory alarm -

(a) If the shaft fails to restore to normal when release conditions are applied. (Release alarm.)
(b) If the called party's line is held by failure of the calling party to clear. (C.S.H. alarm.)

/ Fig. 23.

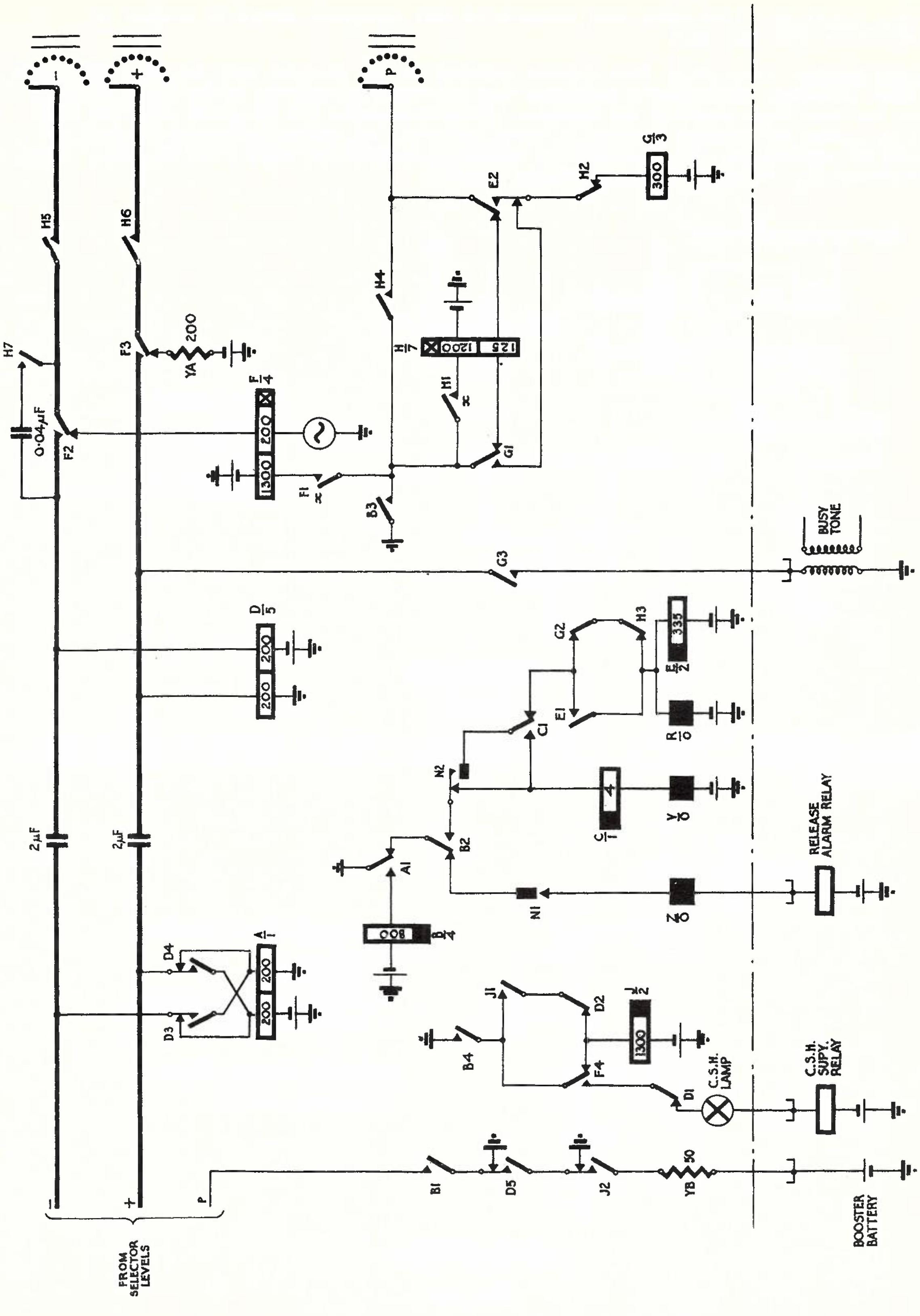
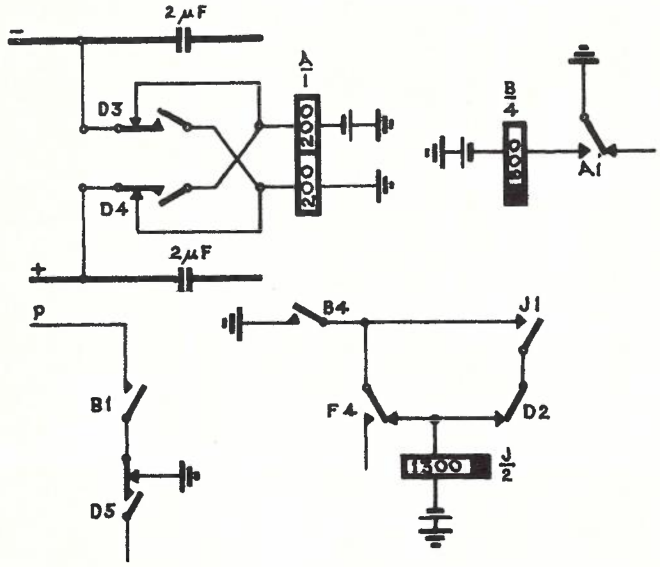


FIG. 23. FINAL SELECTOR CIRCUIT, (C.712, SHEET 1).

4.3 Circuit Operation. (The simplified circuits in this paragraph should be studied in conjunction with Fig. 23.)

Switch Seized. (Fig. 24.) When a group selector in the previous rank switches through to a final selector, the caller's telephone loop is connected through to the final selector over the line wires clear of all bridges. Relay A operates via D3 and D4 over the loop, and A1 closes the circuit of relay B, which operates. B1 earths the P wire to hold and guard the connection. B4 completes the operating circuit for relay J via F4, and J locks via D2 and J1. B2 prepares the impulsing circuit.



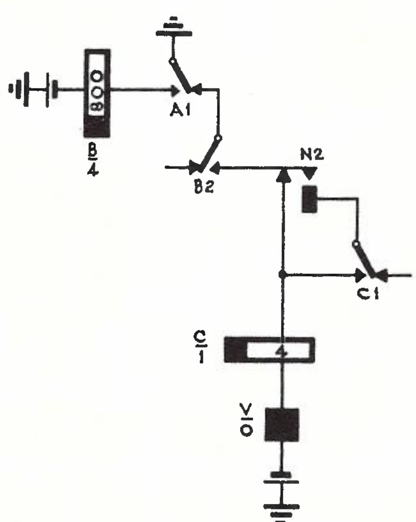
Switch Looped -

A operates.
B operates.
P wire earthed.
J operates and locks.

SWITCH SEIZED.

FIG. 24.

Vertical Stepping. (Fig. 25.) At the first break of the dial impulse springs, relay A releases and A1 normal completes the circuit of the vertical magnet and relay C in series via N2 and B2.



Penultimate Digit Dialled -

A impulses.
C operates.
Vertical magnet operates.
N springs operate.

At End of Impulse Train -

C releases slowly.

VERTICAL STEPPING.

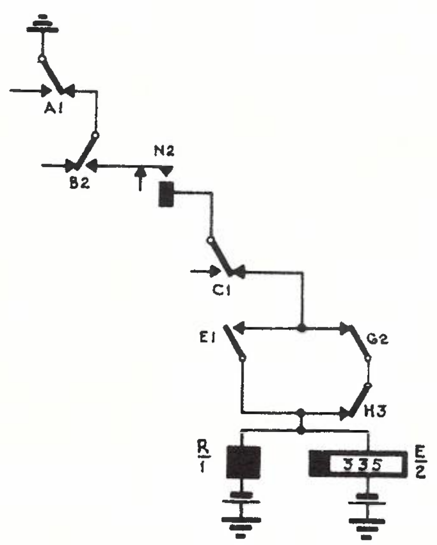
FIG. 25.

Relay C operates before the vertical magnet and C1 prepares an alternative vertical stepping circuit when N2 operates during the first vertical step.

Impulses after the first are repeated from A1 via B2, N2 and C1 operated to the vertical magnet and C relay. Relays B and C being slow releasing hold during impulsing, and at the end of the impulse train relay C releases. C1 normal prepares the rotary magnet circuit.

The wipers are now standing outside the dialled level, with relays A, B and J operated.

Rotary Stepping. (Fig. 26.) The final train of impulses is repeated by relay A to operate the rotary magnet and relay E in parallel from earth at A1 via B2 and N2 operated, C1, G2 and H3.



Last Digit Dialled.

A impulses.
E operates.
Rotary magnet operates.

At End of Impulse Train -

E releases slowly.

ROTARY STEPPING.

FIG. 26.

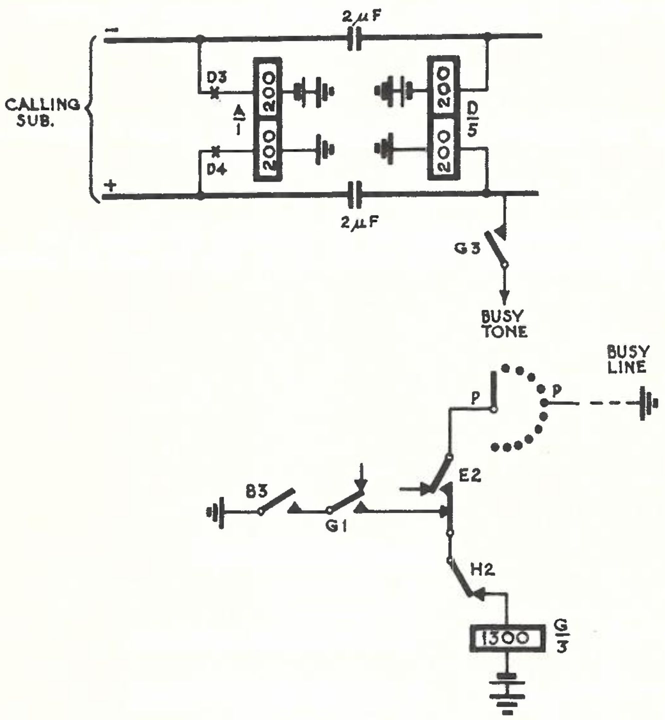
Relay E operates first and E1 gives an alternative impulsing circuit independent of G2 and H3. E2 prepares the testing circuit of relay G, which may operate during rotary stepping if busy contacts are passed over.

Relay E is slow releasing, and holds during the train of impulses, but releases after the last impulse. During its release time a test is made on the selected line for the busy condition.

/ Testing

Testing - Called Line Busy. (Fig. 27.) The P wire of a busy line is earthed while the P wire of a free line is connected to battery through the 1,300 ohm relay K. Assuming that the selected line is busy, relay G operates to the busying earth via the P wiper and when E releases locks up via E2 and G1 to earth at B3.

G3 connects the positive wire to busy tone, which will be heard by the caller, indicating that no connection will be given and that the call should be attempted later. G2 opens the rotary magnet circuit, preventing further stepping should the caller continue to dial.



If Called Line is Busy -

G operates and locks.
Busy tone given to caller.

TESTING - CALLED LINE BUSY.

FIG. 27.

Called Line Free. (Fig. 28.) In this case, relay G does not operate and when E releases relay K associated with the called line is operated in series with relay H (125 ohm winding) over the P wiper and contacts E2 and G1 to earth at B3.

Relay H is slow operating and allows the line circuit relay K to operate first to clear the called line of bridges before the application of ringing current.

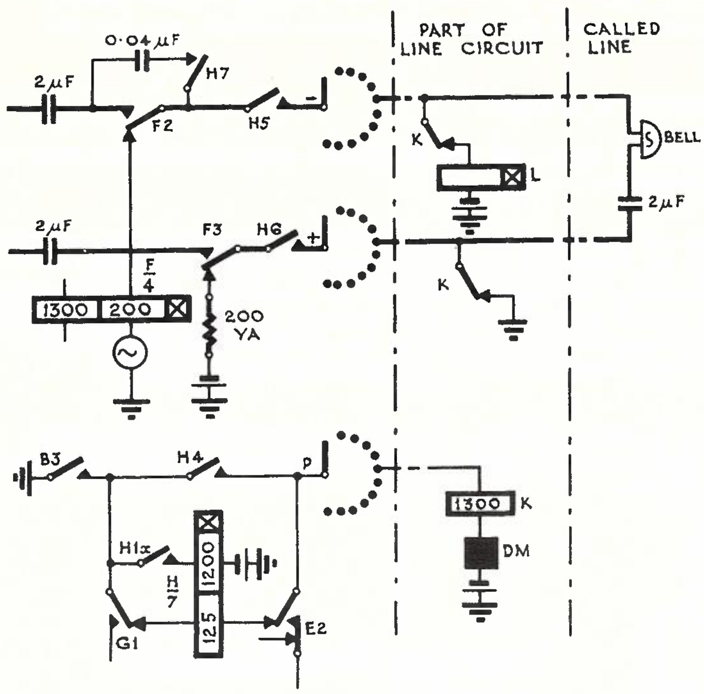
Ring Cut-On. The current through the 125 ohm winding of H is only strong enough to cause the operation of contact H1 "x", which completes the circuit of the 1,200 ohm locking winding to earth at B3. H operates fully and H4 connects a full earth on the P wire of the called line to effectively guard that line. H3 opens the rotary magnet circuit to prevent further stepping.

Ringing current is sent out to the called line through the 200 ohm winding of relay F, via F2, H5 and the negative wiper and the ring return is to battery through 200 ohm resistor YA, F3, H6 and the positive wiper. Only A.C. will flow, the D.C. being blocked by the condenser in the telephone bell circuit. A leak circuit is provided through H7 and a small capacity condenser, and allows portion of the ringing current to be fed to the caller to provide a ring tone signal.

Relay F has a copper slug on the armature end, and in addition is fitted with a copper sleeve over its core, consequently it will not respond to the ringing current in its

/ 200

200 ohm coil (see Fig. 28).



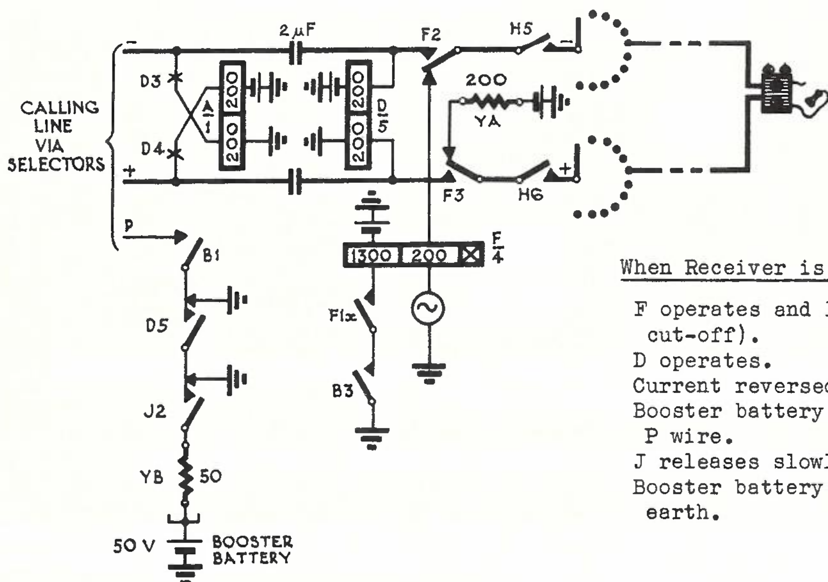
When E Releases -

K (line circuit) operates.
H operates and locks.
Ring current connected to called line.
Ring tone given to caller.

CALLED LINE FREE - RING CUT-ON.

FIG. 28.

Called Party Answers. (Fig. 29.) When the called party lifts the receiver, a circuit is given for a D.C. in lieu of the circuit through bell and condenser. Relay F operates its F1 "x" contact and locks up on the 1,300 ohm winding to earth at B3.



When Receiver is Lifted -

F operates and locks (ring cut-off).
D operates.
Current reversed to caller.
Booster battery connected to P wire.
J releases slowly.
Booster battery replaced by earth.

CALLED PARTY ANSWERS.

FIG. 29.

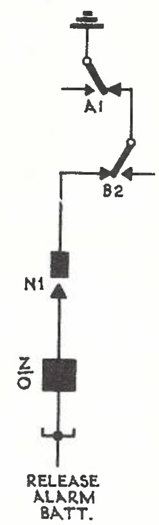
F2 cuts off the ring current and ring tone and F3 cuts off the ringing return battery. These contacts extend the called party's loop to the transmission bridge, and the two parties are connected together.

F4 opens the original operating circuit of relay J.

Relay D operates over the called party's loop. D3 and D4 change over the battery feed to the calling line for supervisory purposes.

Metering. D5 changes the potential of the P wire from earth to 50 V positive for booster battery metering. At the same time D2 opens the holding circuit of relay J, which releases slowly. Contact J2 disconnects the booster battery and replaces it with earth, so that booster battery is applied to the P wire for the slow release period of relay J (about 300 mS). The 50 ohm resistor YB prevents short-circuiting the booster battery during operation of D and J contacts. D1 prepares the C.S.H. supervisory alarm circuit.

Release of Connection. (Fig. 30.) In this circuit, the release is controlled by the calling party. When the caller replaces the receiver, relay A releases and A1 opens the circuit of relay B which releases slowly.



Calling Party Replaces Receiver -

A releases.
B releases.
Release magnet operates.
D, F and H (or G and J) release.

When Switch Reaches Normal Position -

N springs restore.
Release magnet releases.

RELEASE.

FIG. 30.

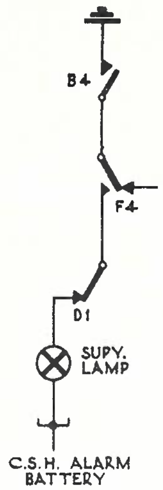
B1 removes the earth from the P wire, releasing all group selector and uniselector holding relays, and these switches restore to normal.

B3 removes the earth from the P wiper, releasing the called party's K relay.

B2 completes the release magnet circuit via A1 and N1, and the final selector is restored to normal, when N1 opens and the release magnet is de-energised. An alarm is given if the release is prevented by a mechanical fault.

/ C.S.H.

C.S.H. Condition. (Fig. 31.) As the calling party controls the connection, it is possible for a subscriber to be called and held busy indefinitely. To avoid this condition, a supervisory alarm is included in the circuit.



Called Subscriber Replaces Receiver -

D releases.
C.S.H. lamp glows.

CALLED SUBSCRIBER HELD.

FIG. 31.

If the called party replaces the receiver before the calling party clears, relay D releases and D1 completes the C.S.H. supervisory alarm lamp circuit via F4 to earth at B4. The lamp on the switch glows and the operation of a common alarm relay gives an indication on the exchange alarm system.

Relays. Typical figures for final selector relays are given below -

Code	Title	Type of Relay	Operate Current (mA)	Operate Lag (mS)	Release Lag (mS)
A	Impulsing	Impulsing, fast	14.5	7	9
B	Guard	Heel slug, 1-1/2"	15	12	350
C	Impulse control	Heel slug, 11/16"	116	15	150
D	Forward supervisory	Fast	20	15	8
E	Rotary control	Heel slug, 11/16"	18	10	250
F	Ring trip	Armature slug, 1"	{ 26x 20	100	80*
G	Test	Standard fast	10	40	6
H	Wiper cut-in	Armature slug, 11/16"	{ 27x 32	100	30
J	Meter pulse timing	Heel slug, 11/16"	16	10	300

"x" indicates operate currents measured on low resistance winding for "x" operation only, the figure below being that on the other winding for full operation.

* releasing lag measured at the "x" contact.

It might be noted that the characteristics of the impulsing relay are slightly different from those of the group selector A relay. This is to compensate for the impulse distortion due to the bridging condensers and relay D in the final selector impulsing circuit.

4.4 Ordinary Final Selector With 3,000 Type Relays. (Fig. 32.) While this switch performs the same functions as that previously described (Fig. 23), its circuit operation differs in many respects -

/ Fig. 32.

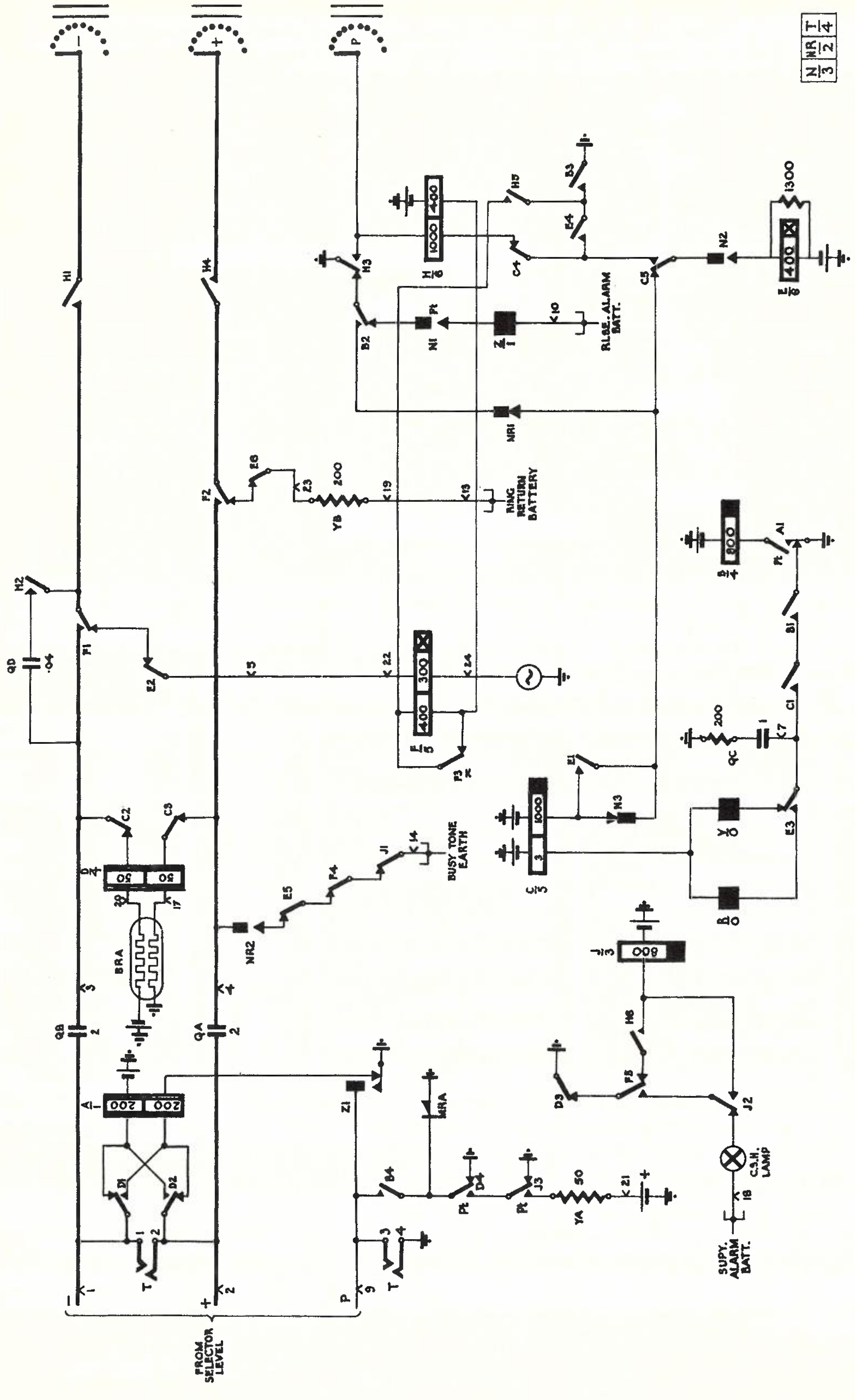


FIG. 32. ORDINARY FINAL SELECTOR, WITH 3,000 TYPE RELAYS (C.712, SHEET 2).

(i) Relay C is preoperated. This allows it to carry a greater spring load, and two of its contacts disconnect relay D during impulsing to reduce distortion.

(ii) A ballast resistor is provided in the transmission bridge, and the resistance of relay D is correspondingly reduced, giving improved transmission performance over longer lines. Relay A only feeds the caller with transmitter current on local calls, and the ballast resistor is not necessary in that side of the circuit. On calls over junction circuits, as shown in Paper No. 6, a relay set known as a repeater supplies the transmission bridge for the calling party.

(iii) There is no busy test G relay. If relay H does not operate while E is releasing, then busy tone is given to the caller. In the earlier circuit, it is possible under fault conditions for neither G nor H to operate, the caller receiving no indication of the call's progress.

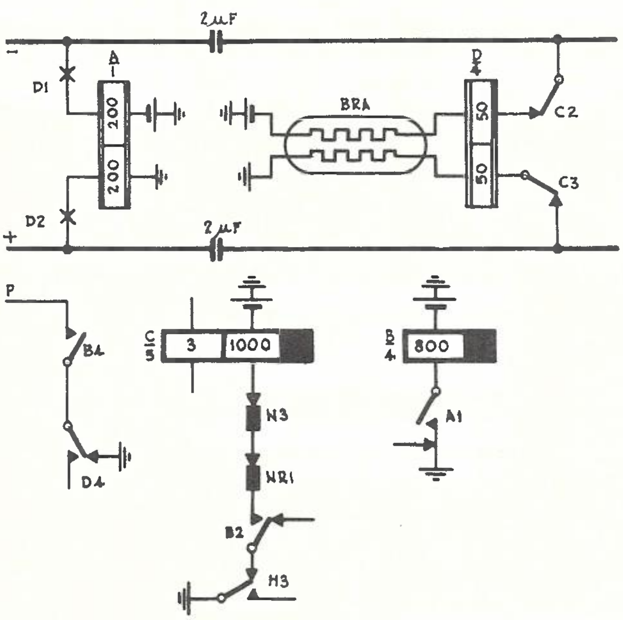
(iv) Relay H is fast operating and the "x" contact is eliminated. The application of ringing current is delayed by the slow operation of relay E. This is to prevent premature operation of relay F, which is fitted with an armature end slug, and its 400 ohm locking winding normally is short-circuited by F3 "x" to give additional slugging effect.

(v) Contacts D4 and J3 in the metering circuit are now change-over units. Rectifier MRA maintains the earth on the P wire during the change-over time of these contacts, but does not shunt the metering pulse. (See also Paper No. 3, Page 24.)

(vi) The switch is guarded during release by the operation of the release magnet contacts.

Circuit Operation. (The simplified circuits in this paragraph should be studied in conjunction with Fig. 32.)

Switch Seized. (Fig. 33.) Relay A operates over the caller's loop and A1 completes the circuit of relay B which operates. B4 guards the P wire from earth at D4. B2 completes an operating circuit for relay C on its 1,000 ohm winding from earth at H3 via NR1 and N3. C2 and C3 remove relay D from the circuit to reduce impulse distortion. B1 and C1 prepare the circuit for vertical stepping.



Switch Looped -

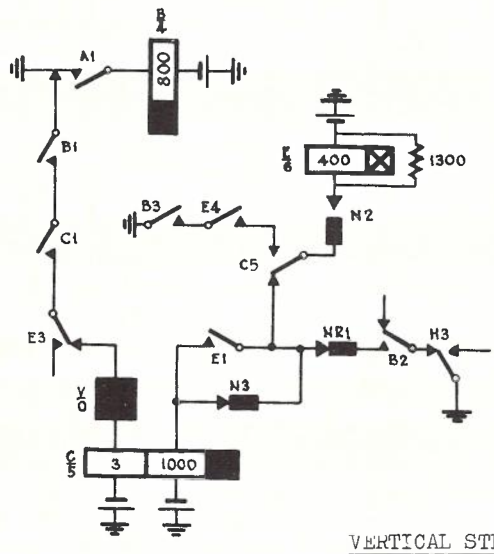
A operates.
B operates.
C operates.

SWITCH SEIZED.

FIG. 33.

Vertical Impulsing. (Fig. 34.) Relays A, B and C are operated and the switch is at normal. When relay A falls back it completes the vertical magnet circuit from earth at A1 via B1, C1 and E3. The 3 ohm winding of relay C is in series with the vertical magnet.

During the first vertical step the N springs operate, opening the 1,000 ohm winding of C, but due to the slug relay C holds during the impulse train, releasing slowly at the completion of vertical stepping. When C falls back E operates from ground at H3, via B2, NR1, C5 and N2. E1 completes the circuit of the 1,000 ohm winding of relay C, which re-operates. Relay E holds via E4 to earth at B3 when C operates and E3 prepares the circuit for the rotary magnet.



Subscriber Dials -

A impulses.
Vertical magnet operates.
N springs operate.

At End of Impulse Train -

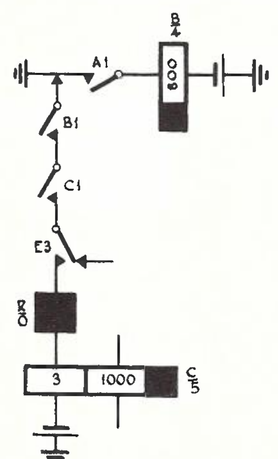
C releases slowly.
E operates slowly.
C reoperates.

VERTICAL STEPPING.

FIG. 34.

Rotary Stepping. (Fig. 35.) Relays A, B, C and E are operated and the wipers are standing opposite the selected bank level. When the caller dials the final digit, the rotary magnet is operated in series with the 3 ohm winding of relay C to earth at A1 via B1, C1 and E3 operated.

At the first rotary step, the rotary off-normal (NR) springs operate and NR1 opens the circuit of the 1,000 ohm winding of relay C. C holds on its 3 ohm winding during impulsing and releases at the end of the train.



Final Digit Dialled -

A impulses.
Rotary magnet operates.
NR springs operate.

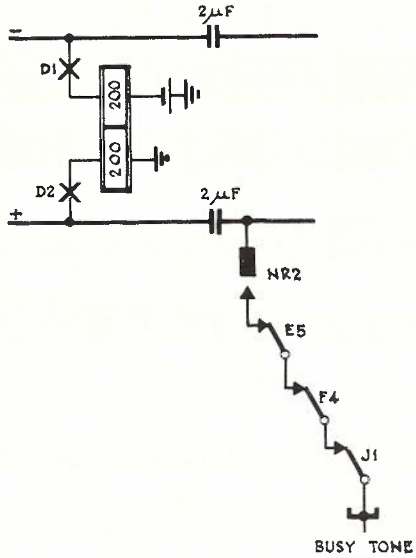
At End of Impulse Train -

C releases slowly.

ROTARY STEPPING.

FIG. 35.

Testing - Called Line Busy. (Fig. 36.) When C releases, C4 completes a testing circuit for relay H (1,000 ohm winding) to the P wiper from earth via B3 and E4. C5 opens the circuit of relay E which releases slowly. H operates in series with relay K if the called line is free but, if the line is busy, H does not operate and when E releases E5 connects busy tone to the positive line wire via J1, F4 and NR2.



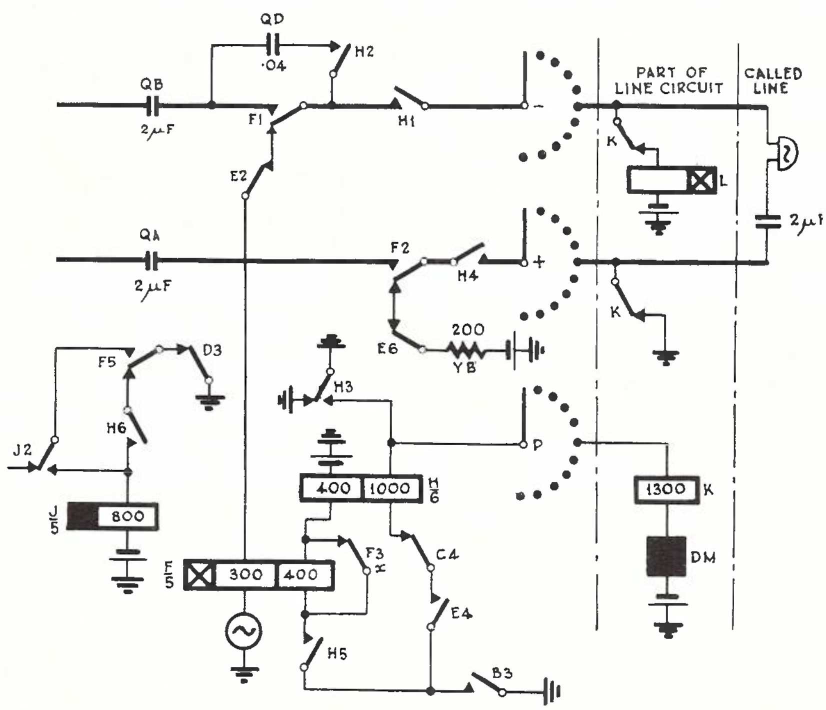
If Called Line is Busy -

E releases slowly.
Busy tone connected.

TESTING - CALLED LINE BUSY.

FIG. 36.

Called Line Free. (Fig. 37.) Relays H and K operate in series, and the called line is cleared of bridges.



If Called Line is Free -

H operates and locks.
J operates and locks.
K (line circuit) operates.
E releases.
Ring cut-on.

CALLED LINE FREE - RING CUT-ON.

FIG. 37.

H5 completes the circuit of the 400 ohm locking winding of H via F3 to earth at B3. H3 connects a full earth to the P wiper to guard the called line against intrusion. H6 completes an operating circuit for relay J via F5 to earth at D3. J2 prepares a holding circuit for J when relay F operates. J1 opens the busy tone lead. H1, H2 and H4 prepare the ringing, ring tone and ring return circuits respectively and when E restores these circuits are completed by E2 and E6.

Relay F in series with the ring feed, does not operate on ringing current because of its copper slug and shunted winding.

While the called subscriber's bell is being rung, a leak circuit is provided through a small condenser QD. Thus, a small portion of the ring is fed back to the caller giving an audible ring tone.

Called Party Answers. (Fig. 38.) When the called party answers, a loop is placed on the line and D.C. superimposed on ringing current operates relay F.

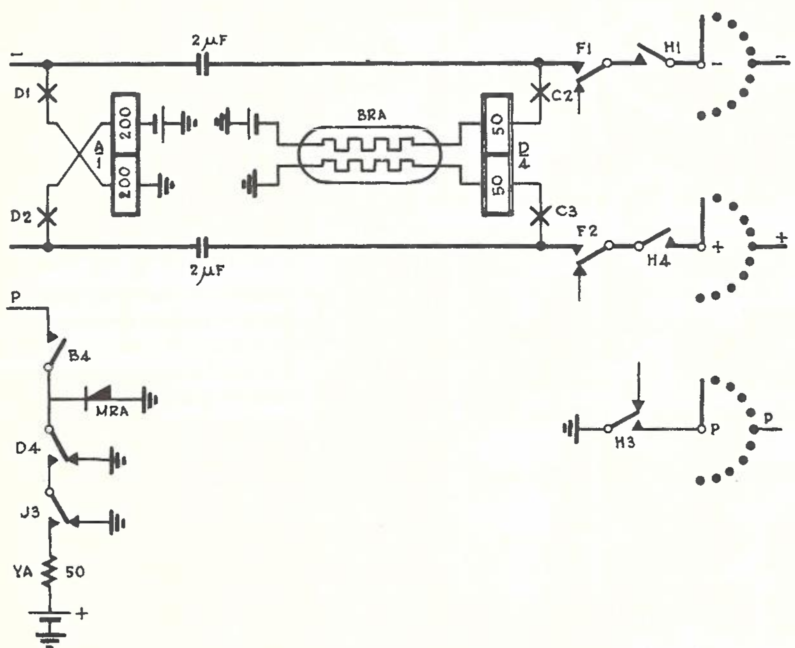
F3 "x" removes the short circuit from its 400 ohm winding and it locks in series with relay H. F5 prepares the C.S.H. alarm circuit. F4 opens the busy tone lead (already opened at J1). F1 and F2 cut off the ringing and ring return leads respectively and extend the called party's loop through to the transmission bridge and relay D operates.

D1 and D2 reverse the battery supply to the calling party for supervision on junction calls and calls from automatic public telephones.

Metering. D4 connects positive battery to the P wire via J3 and 50 ohm resistance YA. D3 opens the holding circuit of relay J, which releases slowly.

When J restores J3 replaces the positive battery with earth, thus positive battery is applied to the P wire for the release time of relay J (approximately 300 mS).

Rectifier MRA maintains an earth on the P wire while D4 and J3 are changing over.



When Receiver is Lifted -

F operates and locks (ring cut-off).
D operates.
Current reversed to caller.
Positive battery connected.
J releases slowly.
Positive battery disconnected.

CALLED PARTY ANSWERS.

FIG. 38.

Release. (Fig. 39.) In this circuit, the connection is controlled by the calling party. When the caller replaces the receiver, relay A releases, followed by the slow release of relay B.

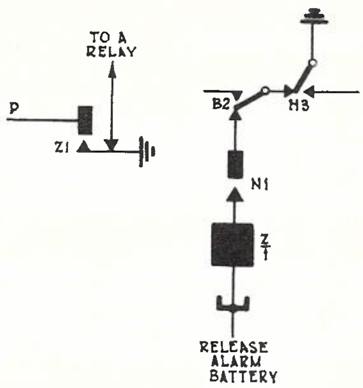
B4 removes earth from the P wire allowing all group selectors and uniselectors to release.

B3 opens the holding circuit of relays H and F. H3 removes the earth from the P wiper allowing the called party's line circuit to restore to normal.

H3 and B2 normal complete the release magnet circuit via N1 to supervised battery, and the switch releases.

Z1 earths the P wire and opens the A relay circuit, guarding the circuit against seizure during release.

When the switch reaches the normal position the N springs restore, opening the release magnet circuit, and the switch is free to accept the next call.



Caller Replaces Receiver -

A releases.
B releases.
H, D and F release.
Release magnet operates.

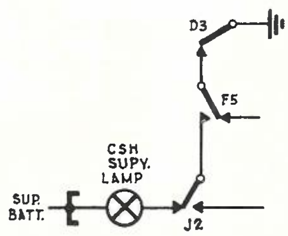
When Switch Reaches Normal Position -

N springs restore.
Release magnet releases.

RELEASE.

FIG. 39.

C.S.H. Alarm. (Fig. 40.) When the called party clears before the caller, the release of relay D completes the C.S.H. lamp circuit, from earth at D3 via F5 and J2 to supervised battery. The lamp on the switch glows and an indication is given on the exchange alarm system.



If Called Party Clears -

D releases.
C.S.H. lamp glows.

CALLED SUBSCRIBER HELD.

FIG. 40.

4.5 Ringing Circuit. Ringing current is produced by a motor-driven generator which also carries tone generating apparatus and gear-driven interrupter cams. The standard ringing frequency is 16-2/3 c/s although some earlier machines produce a ringing current of 33 c/s. Ring tone is superimposed on the ringing current by transformer action.

Before distribution to final selectors the continuous ringing current is interrupted by a cam as follows -

0.4 second ring.

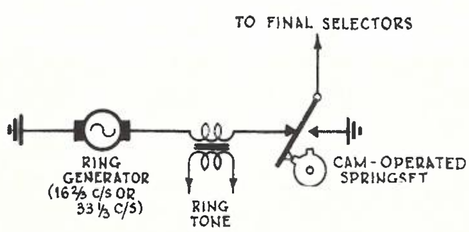
0.2 second silent (short silent period).

0.4 second ring.

2.0 seconds silent (long silent period).

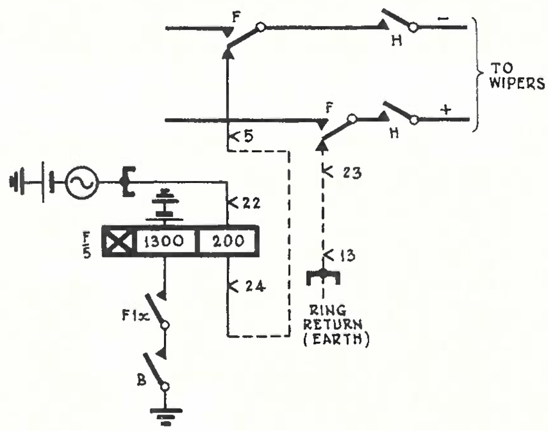
As shown in Fig. 41, one side of the ring supply is earthed, and to allow the final selector ring trip relay to operate should a called party answer during the silent periods, the ringing lead is earthed at the interrupter springs. In the standard circuits, as described previously, the ringing return is to negative battery via 200 ohm resistance.

Some earlier exchanges use an earth ring return, the ring supply being connected to negative battery in these cases. The final selector switch jack wiring must be altered to ensure correct operation of the ring trip relays. Referring to Fig. 42, ringing current is connected to U22, and straps are wired between U24 - U5 and U23 - U13.



RINGING CIRCUIT.

FIG. 41.



BATTERY CONNECTED RINGER CIRCUIT.

FIG. 42.

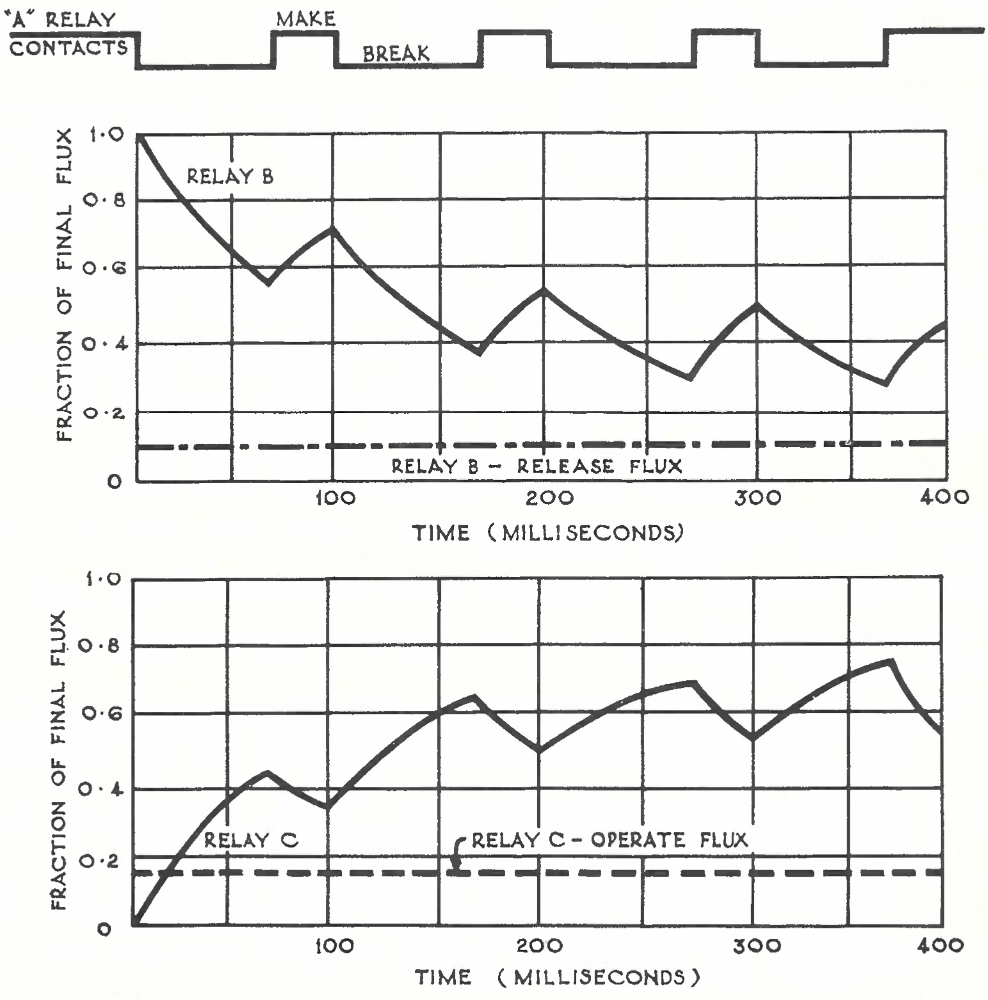
5. IMPULSING.

5.1 From the foregoing circuit descriptions it is seen that the impulses repeated by the A relay contacts perform three functions -

(i) Relay B is re-energised during the make periods of the impulses and must remain operated during the break periods. The maximum release lag (from the saturated condition) of relay B is approximately 350 mS, and this relay will hold operated on impulses with a make ratio of not less than 20 per cent. (20 mS at an impulse frequency of 10 impulses per second). If these limits are exceeded, relay B releases prematurely, completing the release magnet circuit, and the selector "drops out".

(ii) Relay C is energised by the break contacts of the impulsing relay and, therefore, is energised during the break periods and must hold during the make periods of the impulses. The maximum release lag of relay C is approximately 150 mS, and this relay will hold on impulses with a break ratio of not less than approximately 35 per cent. (35 mS at an impulse frequency of 10 impulses per second). Failure of the C relay results in a premature change-over to rotary stepping, resulting in a "wrong number".

Fig. 43 shows in graph form the magnetic conditions of relays B and C during impulsing.



FLUX-TIME GRAPHS OF RELAYS B AND C.

FIG. 43.

(iii) The vertical magnet (or the rotary magnet), which is also energised by the break contacts of the impulsing relay, differs from relay C in that it must release during each disconnection period (make period of the dial) and, as it has a certain release lag, approximately 15 mS, the make period of the dial must not fall below this value. Again, since the magnet must operate during each break period of the dial, there is a pulse-operating lag of approximately 36 mS, below which the break period of the dial must not fall.

This "pulse-operating lag" refers not only to the movement of the shaft, but to the full operation of the magnet armature, in which position a pawl on the armature engages with a front stop and prevents the shaft from taking more than one step at a time. If there is insufficient break period for this locking to take place, the shaft may overstep, often reaching the tenth position with 3 or 4 impulses.

Impulse Limits. From the above, it can be seen that the impulse ratios and periods must remain within the following limits -

Make Ratio	-	20-65 per cent.
Break Ratio	-	35-80 per cent.
Make Period	-	15-150 mS.
Break Period	-	36-350 mS.

Dial Impulse Ratio. Standard dials are designed for an impulse ratio of 2 to 1 break to make, that is, a break ratio of 66-2/3 per cent. and a make ratio of 33-1/3 per cent. Before dials are fitted to standard telephones they are adjusted between the limits of 33 per cent. and 34 per cent. make ratio.

Dial Impulse Frequency. The normal frequency of impulsing is 10 impulses per second, but selectors will operate over a range from 7 to 14 impulses per second from dials. To give a margin of safety, the frequency limit for dial testing is 9 to 11 impulses per second.

5.2 Impulse Distortion. The standard impulse ratio and frequency, as laid down, provide a margin of safety for the operation of selectors. This is necessary as various electrical and mechanical conditions affect the impulse ratio.

Impulse Distortion may be defined as the variation between the impulses produced by the dial contacts, and the impulses received by the selector magnets and relays.

From Fig. 44, it will be seen that to obtain distortionless repetition of impulses, the impulsing relay should have equal values of operate and release lag under all conditions. When the time lags are caused to increase or decrease from the normal, distortion of the impulse takes place. It may be useful to remember the following rule -

Increase in operating lag increases the break ratio.
Increase in releasing lag decreases the break ratio.

Conditions of "long line" distortion produce an increase in the break ratio, producing "heavy" impulses to the selector magnets.

"Short line" conditions reduce the length of the break period, giving "light" impulses.

A summary of the variations which will be encountered by impulsing circuits, and their effects, is given below -

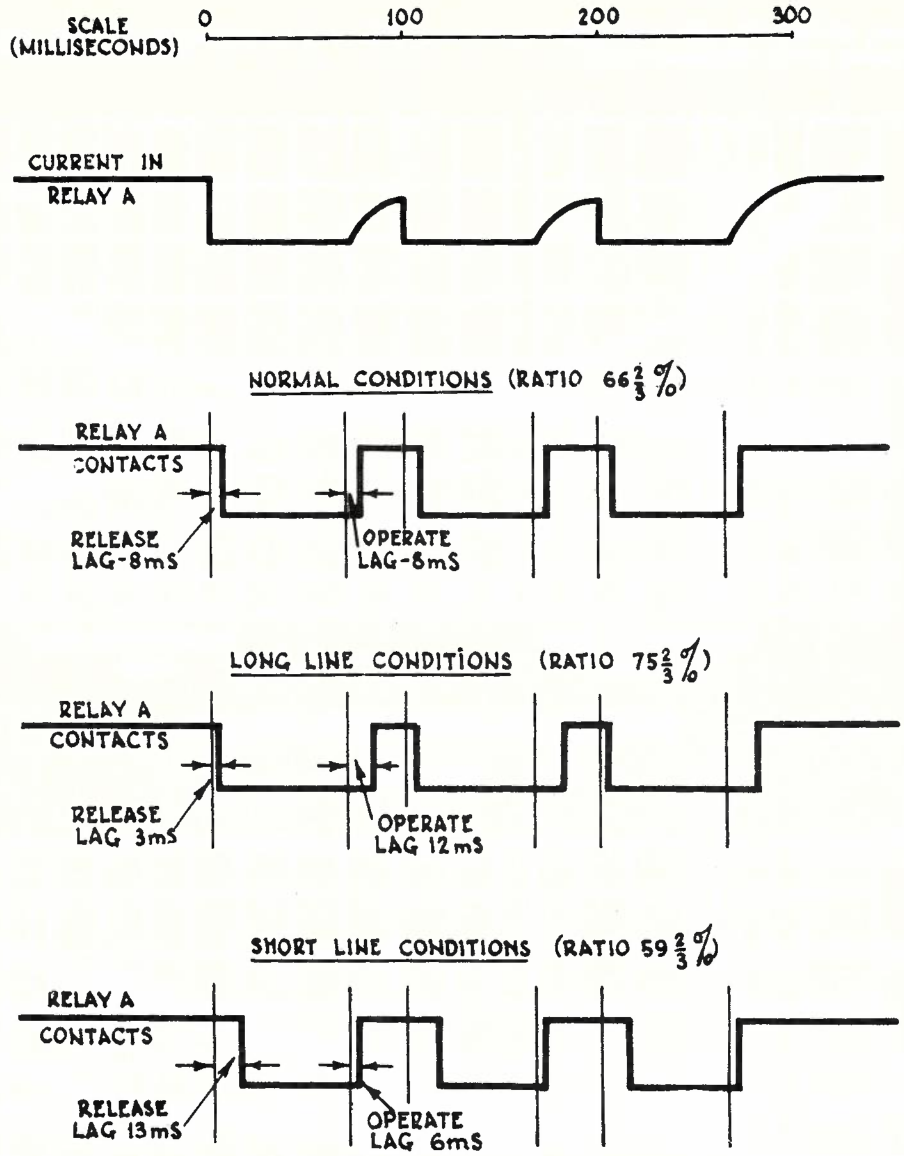
(i) Voltage Limits. In a 50 V exchange the voltage may vary from 46 to 52 V. A decrease in voltage causes an increase in operating time and a decrease in releasing time. At 10 impulses per second there is 1/4 to 1/2 per cent. increase in break ratio per volt drop.

(ii) Loop Limits. The maximum permissible loop resistance of subscribers' telephone lines has been fixed at 750 ohms for the impulsing condition.

The effect of adding resistance in series with the impulsing relay is to reduce the releasing lag, and increase the operate lag, thus increasing the break ratio.

(iii) Leak Limits. For impulsing, the limit of permissible leak resistance is 10,000 ohms for subscribers' lines.

/ Fig. 44.

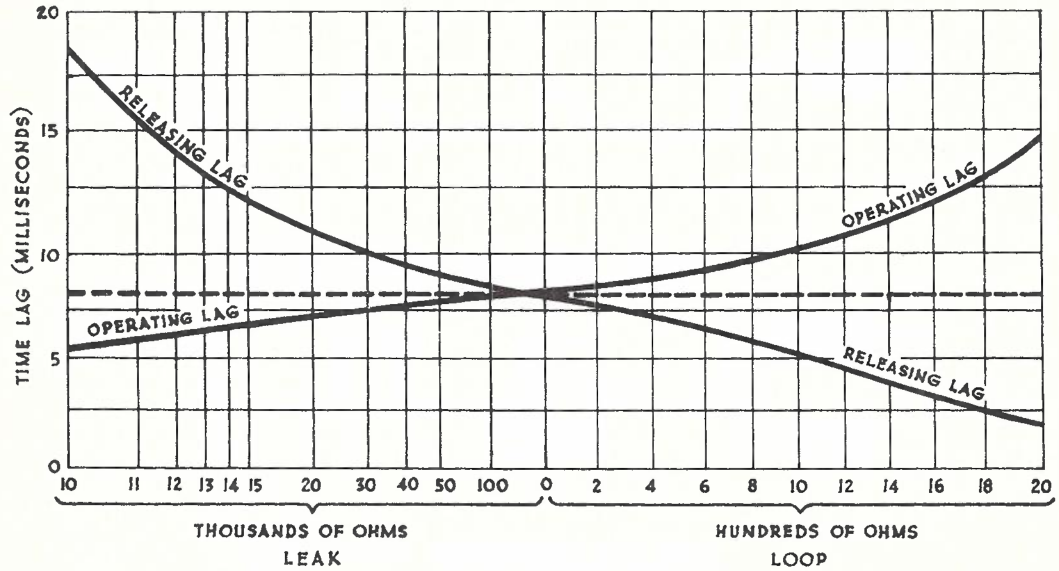


EFFECTS OF TIME LAGS ON IMPULSE RATIO.

FIG. 44.

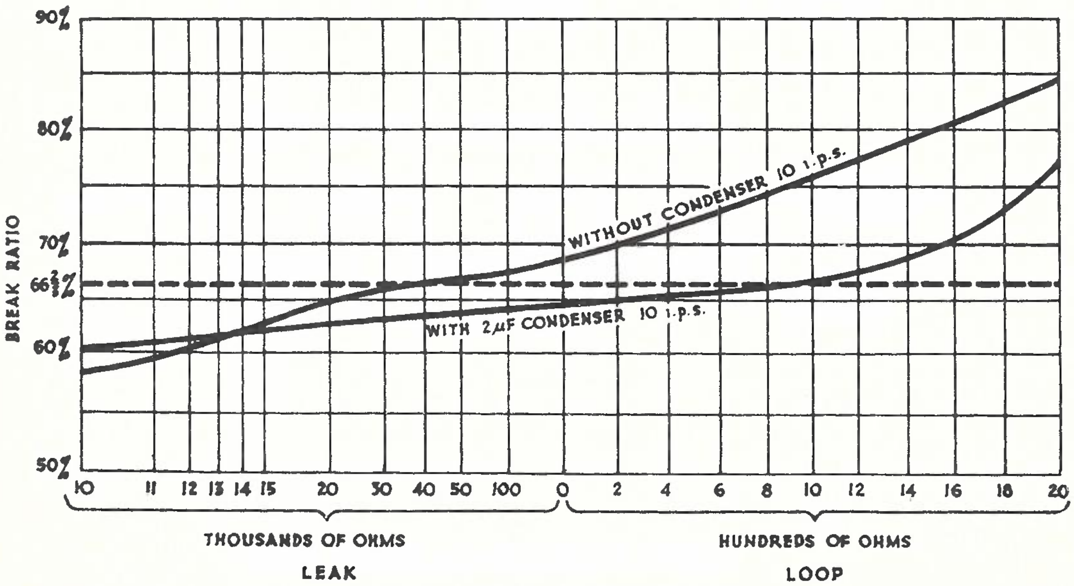
The general effect of leaks from one wire to the other is opposite to those of loop resistance. For this reason, when making leak impulsing tests, the loop resistance is reduced to zero.

Figs. 45 and 46 show the effects of loop and leak resistances on time lags and impulse ratio respectively.



EFFECT OF LINE RESISTANCE ON TIME LAGS.

FIG. 45.



EFFECT OF LINE RESISTANCE ON BREAK RATIO.

FIG. 46.

(iv) Adjustment Limits. The spring tension, armature travel, residual air-gap and contact clearance adjustments all have an effect on the operating and releasing lags of the impulsing relay, and thus produce impulse distortion.

Distortion due to adjustments is usually catered for by providing a good margin of safety after allowing for the other working limits.

(v) Dial Condenser. The spark quench condenser in the dialling circuit is charged through the impulsing relay when the impulse springs break, thus causing an increase in the releasing lag. The dial condenser has no appreciable effect on operating lag.

The effect of the condenser is to stabilise the releasing lag, and thus considerably reduces the distorting effects of leak and loop resistance. This is shown in Fig. 46. Note that under extreme loop conditions the condenser surge is damped out, and there is no such stabilisation; hence the rapid increase in ratio for loop resistances over 800 ohms.

The condenser raises the make ratio of the impulses by approximately 3 per cent., making the ratio for a standard telephone, as measured on the test desk at 36-37 per cent., ± 2 per cent., that is, 34 per cent. to 39 per cent.

(vi) Cable Capacity. The conditions previously mentioned apply to non-inductive resistance, and this is reasonably accurate for overhead lines. When underground cables are used, however, the capacity between the wires is important, although it usually gives an improved performance on impulsing. As the capacity is increased in proportion to the loop resistance, the two effects will tend to cancel out.

Beyond a certain limit, that is, with very long lines, junctions, etc., the beneficial effect of cable capacity is nullified somewhat by the excessive capacity on the line.

(vii) Extension Telephone. In some circumstances, an extension telephone is connected in parallel with the normal instrument, and the additional bell and condenser remain shunted across the line. This gives the effect of an increase in the capacity of the dial condenser.

An additional 1,000 ohm bell with a 2 μF condenser causes an average increase in make ratio of 3 per cent., and to avoid distortion of impulses, this type of connection should not be used.

(viii) Transmission Bridge. Where the impulsing relay forms part of a Stone Transmission Bridge, the transmission condensers have an effect on the wave form of the impulses, and there is an increase in the make ratio of the order of 3 per cent. under most conditions.

A Repeating Coil Bridge has an effect even greater than a Stone Bridge, and this circuit is, therefore, rarely used for impulsing.

/ 6.

6. TEST QUESTIONS.

1. State the various types of mechanically operated contacts fitted to a two-motion selector and when they operate and restore.

2. What is the purpose of the release link, and is it necessary in modern switches?

3. State the functions of a group selector.

4. With the aid of a circuit diagram describe the rotary action of a group selector and explain what happens when all contacts of a level are engaged.

5. A group selector is found whose wipers are resting on an outlet, but whose relays A, B and D are interacting. What do you consider the most likely cause of this fault?

6. What functions are performed by an ordinary Final Selector?

7. Explain with the aid of a simple circuit the method of ringing telephone bells from a final selector.

8. What function is performed by contact H3 in Fig. 23?

9. It is noticed that a certain final selector instead of stepping up under the control of the tens digit when there are two or more impulses in the train, steps up one and then rotates into the level. What is the probable cause of this?

10. It is usual to specify that automatic switches should be capable of working under the following conditions -

    (i) Impulse speeds varying from 7 to 14 impulses per second.
    (ii) Line resistances up to 1,200 ohms.
    (iii) Insulation resistances as low as 10,000 ohms.

    What combination of these conditions would give the most severe test for -

    (i) Relay B.
    (ii) The vertical magnet of the switch.

    Give reasons for your answer.

7. REFERENCES.

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Vol. 3, No. 2. "Final Selectors, Pre-2,000 Type Equipped with Ballast Resistors and 3,000 Type Relays" by M. A. Mackey.

Vol. 6, No. 4. "The Development of the Automatic Selector" by J. A. Kline.

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END OF PAPER.

COMMONWEALTH OF AUSTRALIA.

Engineering Services,
Postmaster-General's Department,
Treasury Gardens,
Melbourne, C.2.

COURSE OF TECHNICAL INSTRUCTION.

P.B.X. FINAL SELECTORS.

CONTENTS.

1. INTRODUCTION.

1.1 P.B.X. Lines. A subscriber with more than one exchange line will naturally expect that a call made to him will not receive the busy signal unless all his lines are in use.

In manual exchanges, this facility is obtained by grouping his lines together on the switchboard and by marking them in a distinctive manner (that is, by painting a white line immediately underneath the jacks), so that the telephonist will know that if the first line is busy she must test the other lines of the group in turn until a free line is found. The reply, "Sorry, number engaged", is not given unless all lines in the group are tested and found busy.

In automatic exchanges a similar arrangement is adopted, the lines being grouped together and marked, but in this case the marking is electrical instead of visual.

A subscriber having several exchange lines is usually provided with a switchboard. Although several lines may connect the switchboard with the exchange, only one number is included in the Telephone Directory, this being denoted by an asterisk (Fig. 1).

Gibbs A F L SpringvaleRdNunwdng WU 1729
Gibbs A J 36WilsonMBtn .... XB 4074
Gibbs A K 27HighfieldRdCant .. WF 3665
Gibbs A L CarlyleCrMontA ... WX 2598
Gibbs Angus 19MonaroRdKoo .. . U 1653
GIBBS BRIGHT & Co 34Queen ★MB 2241
After 5 pm—
Genl Office MB 2243
Mrchndse MB 2249
Shippg MB 2244, MB 2245 or MB 2246
Timber Yard MB 2242
Lysaght Dept MB 2247
Timber&Plywood Dept MB 2248
Timber Yard BoundaryStSM .. MX 1784
Gibbs Bros (Agencies) Pty Ltd 317FlindersLa MU 3985
Gibbs Bros (Preston) Pty Ltd Produce Merchts 797HighPres JU 1159
GIBBS BROS & Sons Pty Ltd Textile Dyers ThompsonStAbfd JA 4445
GIBBS BURGE & Co Textile Dyers 9KentRich ★JA 5384
Gibbs C H 28YStAsh .... WM 2468

TELEPHONE DIRECTORY ENTRIES.

FIG. 1.

1.2 Night Service. When the P.B.X. switchboard is not staffed, say at night, one or more of the exchange lines may be connected at the switchboard to selected extensions for the receipt of calls during the unattended period. This arrangement is referred to as "Night Service".

The numbers of exchange lines selected for night service are often included in the Directory, as well as the number of the first line of the P.B.X. group.

It is sometimes the practice to night switch the first exchange line to a continuously attended extension, such as the night watchman's. The object of this is to provide a service on the Directory number in the event of a call from a subscriber who is unaware of the night service numbers.

The effect of night switching is to convert the P.B.X. group of exchange lines into a number of single direct exchange lines which terminate on the selected extensions. It is usually desired that, if the night service line is in use, another call made to it shall not be connected to any other free line in the group but shall receive busy tone.

The functions that must be provided by the automatic equipment are, therefore -

(i) Calls made to the first line of a P.B.X. group of lines shall be connected to the first free line in the group.

(ii) Busy conditions shall be transmitted only when all lines in the group are busy.

(iii) Calls made to lines other than the first line of a P.B.X. group shall be completed if the particular line is free, and shall receive busy tone if it is busy (night service facility).

1.3 P.B.X. Final Selectors. These functions must be added to those of the ordinary final selector, such a switch being called a P.B.X. Final Selector. The night service facility is not provided in some cases.

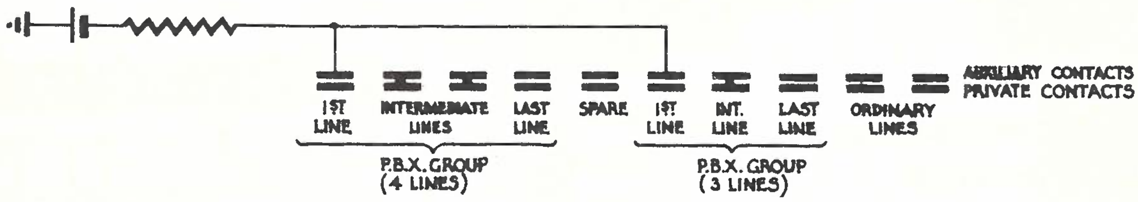
Most P.B.X. groups have less than ten lines, and such groups may be accommodated on adjacent contacts of a level in the final selector bank multiple. The final selectors in this case are called 2-10 P.B.X. types. When a subscriber dials the first line of a group, the call is completed on that line if it is free, but if the line is busy the switch automatically hunts until either a free line is reached or until the last line of the group is reached. If the last line is also busy, the wipers do not step further and busy tone is given to the caller.

In the case of a call to any line other than the first line of a group, automatic hunting does not take place and the switch functions as an ordinary final selector.

For this procedure to be possible, it is necessary that the final selectors shall be able to distinguish between the first line, the intermediate lines and the last line of each group, and also ordinary lines.

In some cases a "P.B.X. arc" is fitted to provide the necessary marking, and this scheme is described for the Siemens No. 16 System in Paper No. 9.

The Strowger system uses an additional wiper and bank contact for this purpose. The private bank differs from that used with the ordinary final selector, as each line has two contacts (a normal private and an auxiliary private). In construction, therefore, it is similar to the line bank. The private and auxiliary wipers are combined like the line wipers, having an upper and a lower member separated electrically and each controlling a separate circuit. The principal wiper completes the normal private circuit. The auxiliary wiper completes a local circuit to modify the action of the switch and thus provide the required discrimination. Fig. 2 shows typical connections to the private and auxiliary bank contacts of ordinary and P.B.X. (first and subsequent) lines.



TYPICAL CONNECTIONS ON PRIVATE AND AUXILIARY CONTACTS OF P.B.X. FINAL SELECTOR BANK.

FIG. 2.

It may be seen that the auxiliary private bank contact of the first line in each P.B.X. group accommodated in the level is connected to battery via a resistance, and it is this condition, combined with a busying earth on the private bank contact, which causes hunting conditions to be set up. The switch then tests through the auxiliary bank contacts in a similar manner to a group selector. The private and auxiliary bank contacts of intermediate lines are strapped and, therefore the condition prevailing on the normal private bank contacts of intermediate lines is also encountered on the auxiliary private

/ bank

bank contacts of these lines. When the last line is reached, hunting ceases whether the line is free or busy, as there is no connection to the auxiliary private contact. This latter arrangement allows single direct lines to be accommodated in the levels of the final selector. If the switch is directed by dialled impulses to a line having no connection on its auxiliary private contact, it acts as an ordinary final selector.

1.4 Allocation of P.B.X. Numbers. A P.B.X. final selector is more expensive than an ordinary switch, and it is usual to group the P.B.X. lines in an exchange into a limited number of 100 line units. An opposing consideration, however, is that the grouping of these particularly busy lines may lead to congestion of certain channels, and to avoid this possibility it is usually desirable that in any one unit the less busy straight lines should be interspersed with the P.B.X. groups. In a residential area 60 P.B.X. numbers and 40 ordinary numbers may be allocated to each P.B.X. unit. In practically every exchange, therefore, at least one 100 line unit is fitted with P.B.X. final selectors; the exchange numbers for the P.B.X. services connected to that exchange must be allotted from that group, and such lines must be consecutive in the final selector multiple bank. When allotting numbers, special care must be taken in estimating the growth and the required provision for spares in order to avoid a change in the Directory number at a later date.

In an ordinary 100 line group, it is not possible to have 100 working lines connected, owing to disconnections, removals, etc. In practice, when about 97 lines are connected, the group is considered to be fully allocated.

Because lines must be left spare to allow for growth of P.B.X. groups, only 82 lines can be worked for every 100 P.B.X. numbers. As an example, assume that the ultimate development of an exchange is anticipated to be 4,284 ordinary lines and 240 P.B.X. lines. The actual numbers allocated are obtained thus -

Ordinary lines	...	4,284 ÷ 0.97 =	4,417 numbers.
P.B.X. lines	...	240 ÷ 0.82 =	293 numbers.
	Total	4,524 lines =	4,710 numbers.

A Line Unit has provision for connecting 100 lines. The number of P.B.X. units required will be given by $\frac{293}{60}$, that is, 5 units.

The number of working lines in each P.B.X. unit will be -

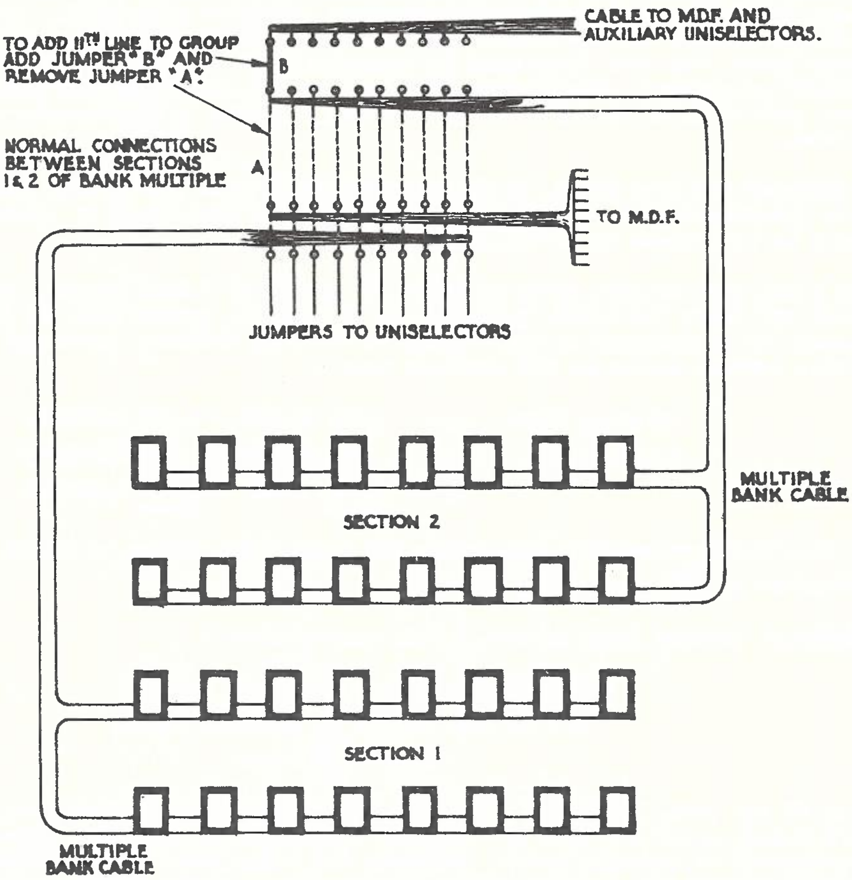
60 x 82 per cent. = 49 P.B.X. lines.
40 x 97 per cent. = 39 Ordinary lines.
Total = 88 lines.

That is, 88 per cent. of the full capacity of the unit can be assumed to be working lines. In the 5 P.B.X. units 5 x 39 = 195 ordinary lines will be connected, leaving 4,089 lines to be connected to straight units. Allowing for 3 per cent. of the lines on straight units being unavailable for allocation to subscribers, 4,089 working lines would require $\frac{4089}{97}$ = 43 units.

1.5 Double Appearance. A P.B.X. group will only be connected to a 2-10 P.B.X. final selector unit if it is estimated that the ultimate number of lines in the group will not exceed ten. It is possible, however, that through unexpected development the time may come when more than ten lines will be needed. In order to avoid the necessity of an immediate change of number when the increase is limited to one or two lines, facilities may be provided which enable extra lines to be added without transferring the P.B.X. to a large group unit. The P.B.X. final selectors are mounted on the unit on four shelves each taking eight selectors. The arrangement is shown in Fig. 3, from which it may be seen that the final selector multiple of the P.B.X. unit with its 32 banks is coupled to the terminal blocks in two sections, each section being the multiple from two shelves of eight switches.

/ Under

Under normal conditions, the two sections are strapped together at the terminal blocks, so that the 10 lines of each level in each section are available to all switches in the unit. When, however, an additional line is required in a P.B.X. group having the 10 lines in a level, the connection (A) of the first line of the group is cut away and an auxiliary line joined in by connection (B). With this arrangement, lines 1 to 10 are available to Section 1 of the multiple, and the lines 11 and 2 to 10 are available to Section 2. Full availability is, therefore, not given to callers as, for one level, only 10 lines are available from one section of the multiple. In extreme cases, this division could take place until there are no common lines between the two sections, but it is inadvisable to extend the arrangement to this limit because of the reduced availability. Night service may only be given on those lines which are not divided (see Fig. 3).



2-10 P.B.X. FINAL SELECTOR "DOUBLE APPEARANCE" BANK MULTIPLE.

FIG. 3.

1.6 Large Groups of P.B.X. Lines. Several schemes have been devised for dealing with groups of P.B.X. lines greater than 10 lines -

(i) One scheme uses one type of switch for groups of 11 to 20 lines, and another type for groups greater than 20. The switch used for the 11 to 20 group is fitted with a 600 point line bank, and the switch searches over two levels during one rotation. Services with more than 20 lines may be dealt with by means of either 25 or 50 point uniselectors arranged to search in tandem, so that, if a free line is not found in the first 25 lines, the circuit is connected to the second switch, which, after searching its contacts, connects the line through to the next switch, and so on. It should be noted that the time of search is not of particular importance in such circumstances.

/ (ii)

(ii) Another scheme used in some Siemens Bros. installations is one in which search takes place over the lowest level in the group, and, if all lines therein are busy, release takes place rotarily, following which a step up to the next level is made. The search then continues over that level and, if all lines are busy, releases rotarily again to repeat this cycle until the complete group has been tested.

(iii) A further scheme used in some exchanges for P.B.X. services exceeding 10 lines is to provide a group busying arrangement for each level in the group, and to mark a contact in a special vertical bank when all lines of a particular level are engaged. If the switch searches up this vertical bank until it finds a free contact, it will be opposite a level in which there is at least one free line. Search now takes place automatically over the level until the particular free line is reached. An ingenious method has been developed to enable switches of this type to act as a straight line ordinary final selector or as a P.B.X. selector, according to the first digit accepted by the switch. The number for a P.B.X. service may be B 3606, whereas for night service the third number in this group would be dialled as B 3663. The fourth digit in the calling number is the first one received by the switch. If this digit is 0, then the shaft steps to the 10th level where it closes normal post springs to -

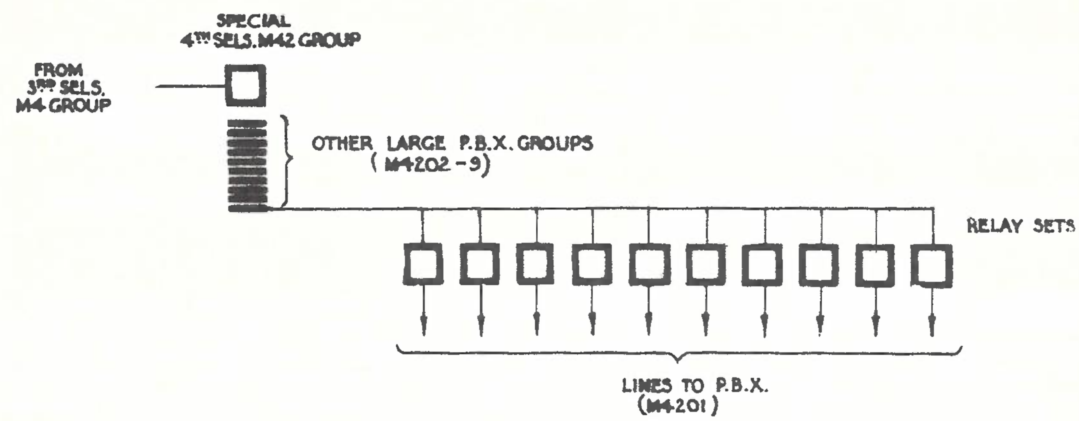
(a) Make the necessary changes, in order that it will function as a P.B.X. final selector.
(b) Release the switch to normal, but not free it.

The next digit steps the switch vertically a second time till it is opposite the level dialled, the first contact of which is the first line of the P.B.X. group. Search now takes place automatically, first vertically, as explained above, and then rotarily till the first free line is seized. If a special line in the group is required, that is, night service or a straight line, then the 4th digit (which cannot be 0) will operate the switch vertically and since, in this instance, the normal post springs are not operated, the switch acts as an ordinary final selector. The following restrictions will apply -

(a) All P.B.X. groups must commence at the beginning of a level.
(b) Night switching facilities are not available to numbers connected to the 0 level.
(c) Ordinary numbers cannot be allotted in 0 level.

It might be called a universal final selector, for it can act as an ordinary or a P.B.X. final selector dealing with groups ranging from 1 to 90 lines, and night service can obviously be given on all lines in any P.B.X. group.

(iv) A later method uses a Relay Set on each line to perform the ringing, metering and battery feeding functions normally provided by a final selector. The outlets from the last rank of group selectors are "graded" and this gives partial access to the group of lines. Fig. 4 shows the method of trunking used with this scheme.



TRUNKING TO LARGE P.B.X. GROUPS.

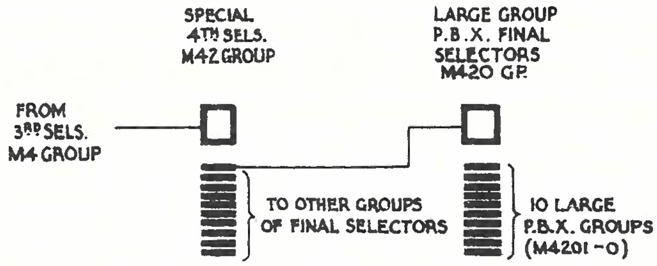
FIG. 4.

An additional rank of group selectors is used and these may be arranged to absorb the penultimate digit 0 to maintain the five digit numbering scheme.

Nine large P.B.X. groups may be served by this scheme, but a block of 100 numbers is taken from the five digit numbering scheme.

The scheme may be enlarged to make full use of the 100 directory numbers by providing a rank of special 5th selectors.

(v) The latest practice incorporates the relay set and the last group selector in one unit, which results in a saving in equipment. This switch is known as a Large Group P.B.X. Final Selector. The trunking arrangement is shown in Fig. 5.



TRUNKING TO LARGE GROUPS OF P.B.X. LINES.

FIG. 5.

Each service is restricted to one level and the outlets graded to provide the number of lines required. Full availability is not given.

The release of a large group P.B.X. final selector does not take place until both parties have cleared (last party release). This is necessary to guard the P.B.X. lines against intrusion from "follow-on" calls.

The lines on the P.B.X. are usually divided into separate groups of "Incoming" and "Outgoing" lines. Night service may be arranged by allotting and listing in the Directory lines normally used for outgoing calls during the day. The incoming lines cannot be night switched as it is a matter of chance which line will be reached.

On incoming lines, the uniselector is dispensed with, and replaced by a 1,300 ohm resistance in place of the K relay.

1.7 Busying of P.B.X. Lines. When a straight line service is out of order, N.U. tone is connected to the final selector multiple of that line. When a line in a P.B.X. group is out of order, the tone is not necessary while other lines in the group can be used, but it is necessary to prevent a caller from seizing the out of order line. To enable this to be done, the private wires of all P.B.X. lines may be cabled to the M.D.F. and there terminated on P.B.X. busying jacks, so that by inserting a plug any line may be busied.

/ 2.

2. 2-10 P.B.X. FINAL SELECTORS.

2.1 Fig. 6 shows the circuit of a Strowger 2-10 P.B.X. Final Selector. The functions provided by this circuit are -

(i) Returns a busy and hold condition to the preceding selectors.

(ii) Steps vertically under the control of the tens train of impulses.

(iii) Steps round under the control of the units impulse train.

(iv) Tests the called subscriber's line.

(v) Functions as an ordinary final selector when connecting to a subscriber with a single line.

(vi) Searches for and seizes the first free line in a particular group of P.B.X. lines when the first line is called.

(vii) Transmits busy tone to the calling subscriber if all the lines in the group are engaged.

(viii) When a free line has been seized, applies ringing conditions to the called subscriber's line and ringing tone to the calling subscriber.

(ix) When the called subscriber answers, removes ringing conditions and ringing tone.

(x) Provides a transmission bridge.

(xi) Meters the call when the called subscriber answers.

(xii) Releases itself and all selectors when the calling subscriber clears.

(xiii) Provides a supervisory alarm should the called subscriber's line be held.

(xiv) Provides night service facilities to any number in a P.B.X. group with the exception of the first.

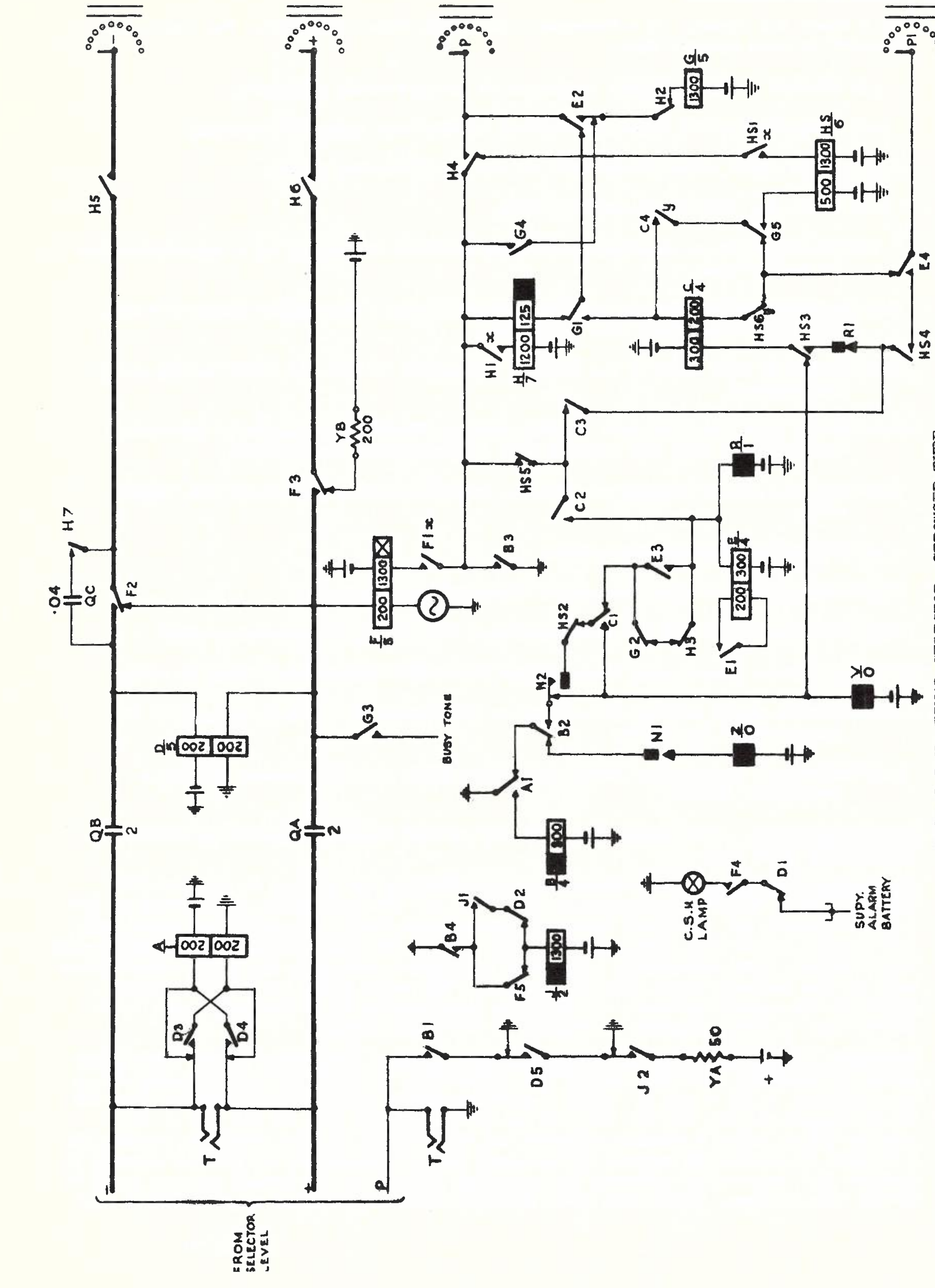
(xv) Provides a supervisory alarm should the shaft fail to restore through a mechanical defect.

2.2 Circuit Operation. (The simplified circuits in this paragraph should be studied in conjunction with Fig. 6.)

Preliminary Operation. The operation during dialling is similar to that of the ordinary final selector described in Paper No. 4. The tens digit is directed to the vertical magnet and the shaft raised to the desired level. It will be noticed that the C relay is, in this case, double wound and the 300-ohm winding is in parallel with the V magnet, this arrangement being more convenient here than the 4-ohm series relay used in the ordinary final selector circuit. The units digit rotates the switch round to the correct contact. If the line thus reached is an ordinary line, it is tested and, if free, ringing is applied in the usual manner.

Operation if the First Line of a P.B.X. Group is Free. Referring to the description given in Paper No. 4, at the end of the units train of impulses the following relays are operated, A, B, J and E. Relay E operates during impulsing in parallel with the rotary magnet via H3, G2, C1, HS2, N2 and B2 to earth at A1. At the end of the impulse train, relay A remains operated and the circuit of E is opened at contact A1. E is slow to release on account of the short circuit placed on the 200-ohm winding by contact E1. Contact E2 operated has connected relay G to the normal private wiper P. If the line is free, there will be no earth on the P contact and consequently G will

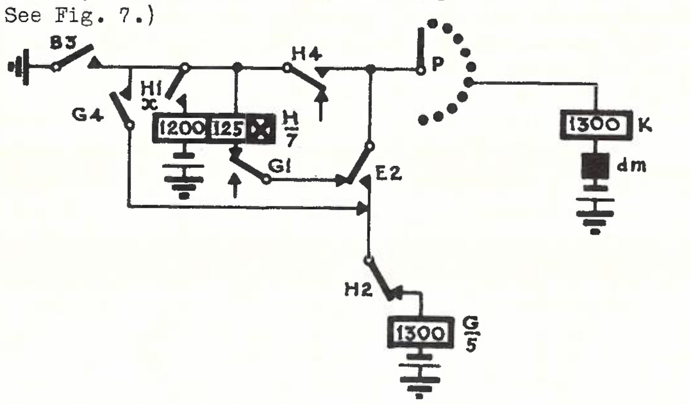
/ Fig. 6.



2-10 P.B.X. FINAL SELECTOR, STROWGER TYPE.

FIG. 6.

not operate. Relay E releases after a short interval to close the circuit of relay H, and the subsequent events for calling the wanted subscriber are the same as those for an ordinary final selector. The P1 wiper and bank have no effect in these circumstances. (See Fig. 7.)



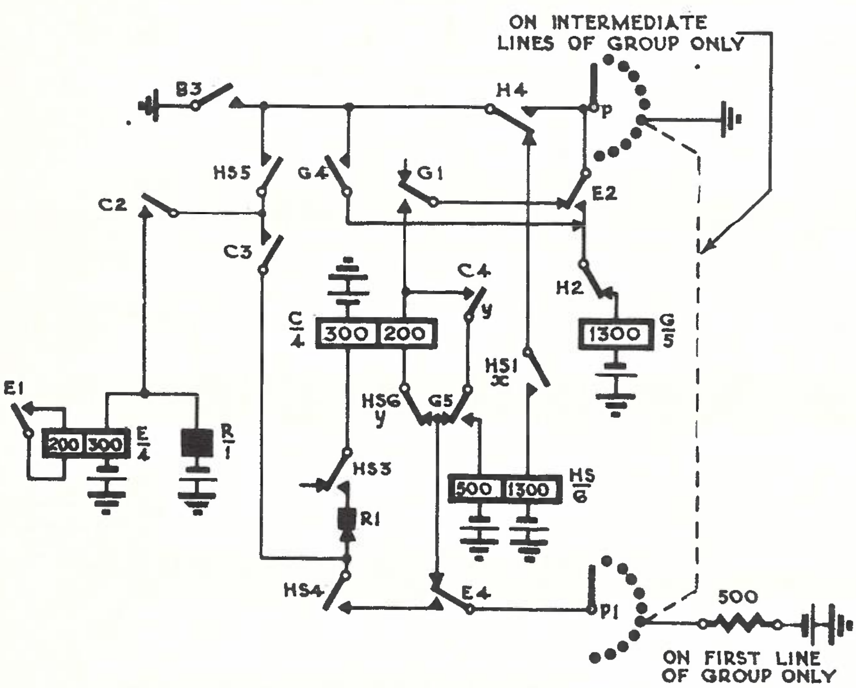
At End of Impulse Train -

E releases slowly.
K (line circuit) operates.
H operates and locks.
Ring cut-on.

OPERATION ON FREE FIRST LINE OR ORDINARY LINE.

FIG. 7.

Operation if First Line of a Group is Busy (Fig. 8). If the first line of the group is busy, there will be an earth on the private bank contact and this completes the circuit of relay G which operates.



If First Line is Busy -

G operates and locks.
E releases slowly.
C operates.
HS operates and locks.
E reoperates.
Rotary magnet operates.
G releases.

When Wipers Reach Second Line -

C releases.
Rotary magnet releases.
E releases slowly.

If Second Line is Busy -

C and G reoperate.
Rotary magnet reoperates.
E holds operated.
G releases.

When Wipers Reach Third Line -

C releases.
Rotary magnet releases.
E releases slowly.

When Free Line is Found -

K (line circuit) operates.
H operates and locks.
HS releases.
Ring cut-on.

HUNTING OVER A P.B.X. GROUP.

FIG. 8.

It is necessary that the hunting feature of the selector shall now be brought into use and, as indicated in paragraph 1.3, this is accomplished by the condition found on the auxiliary or P1 bank contact of the first line of the group. From Fig. 1, it will be seen that battery through a resistance is connected to the P1 bank. When relay G operates to the busy earth on the private wire, G1 prepares a circuit for relay C. When relay E releases at the end of its slow release period, relay G holds via H2, E2, G4 to earth at B3, while relay C operates on its 200 ohm winding from the busy earth on the private wire of the first line in the group, over the P wiper via E2, G1, HS6, E4 to negative marking battery via P1 bank and wiper.

C2 prepares a circuit for relay E and the rotary magnet. C3 prepares a circuit for the 300 ohm winding of relay C. C4, which operates last, closes a circuit via G5 for the operation of relay HS.

HS1 "x" closes a locking circuit for HS on its 1,300 ohm winding. HS2 opens the impulsing circuit to prevent interference should further impulses be transmitted. HS4 prepares a testing circuit for the 300 ohm winding of relay C. HS3 and HS5 complete a holding circuit for the 300 ohm winding of relay C via R1 and C3 to earth at B3. HS5 completes the circuit for the operation of relay E and the rotary magnet via C2. HS6 operates last and opens the circuit of the 200 ohm winding of relay C.

E2 extends relay G to the P wiper. E4 prepares a circuit for relay C to test the second line in the group via the auxiliary wiper, P1.

When the rotary magnet is fully energised, the wipers have stepped to the bank contacts of the second line in the group and the rotary interrupter springs open. Relay C releases and C2 opens the circuit of the rotary magnet and relay E. The rotary magnet releases and relay E commences to release slowly.

Operation if Second Line of a Group is Busy. If the line on whose bank contacts the wipers are now standing is an intermediate line and is busy, then, when the rotary interrupter springs make contact on the release of the rotary magnet, relay C energises via HS3, R1, HS4, E4, auxiliary private wiper and bank contact to the busy earth strapped across from the private bank contact. The switch wipers consequently step to the bank contacts of the next line in the group, the circuit operations following the principles already described. The hunting continues until the wipers step on to the bank contacts of a free line or the last line in the group.

Operation When Free Line Found. If the wipers reach the bank contacts of a free line, relay C cannot operate, as, in the case of an intermediate line, the negative battery from relay K in the uniselector is strapped across to the auxiliary private bank contact, while, if the line is the last in the group, the auxiliary private bank contact is disconnected. Relay G cannot operate and, when relay E falls back, a circuit is closed for the "x" operation of relay H, and the subsequent switching operations follow ordinary final selector principles.

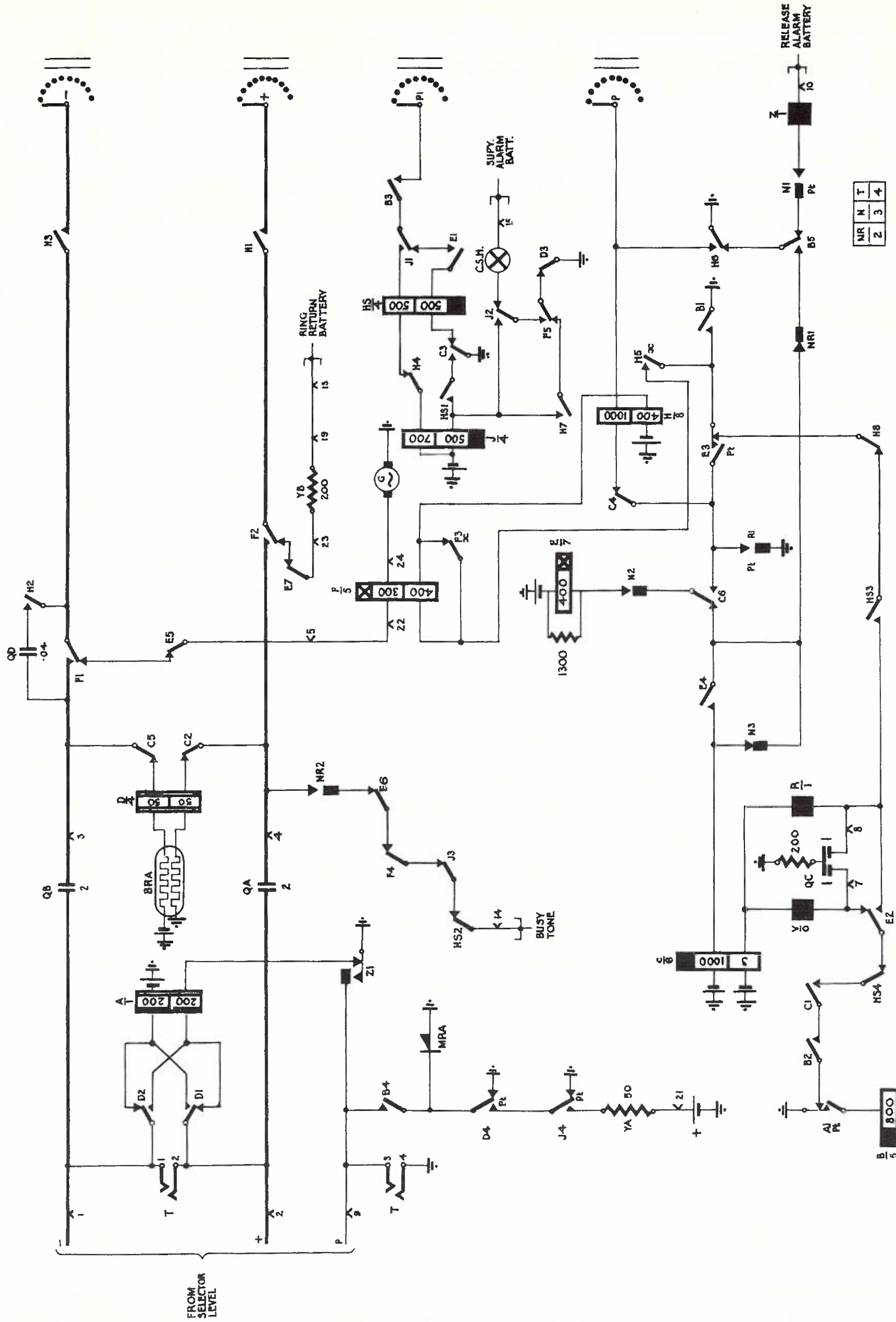
Operation if All Lines of a Group are Busy. If the wipers step on the bank contacts of the last line in the group and the line is busy, that is, all lines in the group are busy, it is necessary to return busy conditions to the calling subscriber. Relay G operates to the busy earth on the P wire; relay C cannot operate as the auxiliary private bank contact P1 is disconnected. When relay E releases, G remains operated through G4; G3 closes the busy tone circuit.

2.3 2-10 P.B.X. Final Selector with 3,000 Type Relays. Fig. 9 shows a later circuit for a 2-10 P.B.X. final selector with ballast resistance and using 3,000 type relays. This circuit incorporates the improvements listed in Paper No. 4 for the latest ordinary final selector. The circuit operation is described below -

Switch Seized. Relay A operates over the loop and A1 completes the operating circuit of relay B.

B4 guards the P wire with earth from D4. B5 completes an operating circuit for relay C on its 1,000 ohm winding via N3 and NR1 to earth at H6. B2 and C1 prepare the impulsing circuit.

/ Fig. 9.



2-10 P.B.X. FINAL SELECTOR WITH 3,000 TYPE RELAYS (C.1472).

FIG. 9.

C2 and C5 remove relay D from the lines to reduce impulse distortion. C6 opens the circuit of relay E until the completion of the vertical train.

Vertical Stepping. When the penultimate digit is dialled, the vertical magnet is energised in series with the 3 ohm winding of relay C via E2, HS4, C1 and B2 to earth at A1. N springs operate during the first vertical step. Relay C holds during impulsing due to the slug and releases slowly at the end of the train. When C releases C6 completes the operating circuit of relay E via N2, NR1 and B5 to earth at H6. E4 completes the circuit of relay C which reoperates.

Rotary Stepping. When the final digit is dialled, the rotary magnet is energised in series with the 3 ohm winding of relay C from earth at A1 via B2, C1, HS4 and E2. During the first rotary step NR springs operate, NR1 opens the circuit of the 1,000 ohm coil of relay C, which holds during the impulse train and then releases slowly.

Call to First Line of a P.B.X. Group. If the first line of a group is free when called, the operation is similar to that of an ordinary final selector. The P1 wiper and bank have no function in these circumstances.

When C releases, the testing circuit of relay H is completed in series with the line circuit relay K over the P wiper via C4 and E3 to earth at B1 (during slow release period of relay E). H operates and locks on its 400 ohm winding to earth at B1 via H5 "x" and F3.

H6 connects earth to the P wiper to guard the called line. H7 completes an operating circuit for relay J via F5 to earth at D3. J operates and holds via J2 when relay F operates. J3 holds the busy tone lead open when E6 restores.

Ring Cut-on. When E restores, the ringing circuit is completed via the 300 ohm winding of relay F, E5, F1 and H3 to the negative wiper. The ring return is to negative battery via 200 ohm resistance YB, E7, F2 and H1 to the positive wiper. A leak from the ringing circuit is fed to the caller via H2 and condenser QD to provide a ring tone signal.

Called Subscriber Answers. When the subscriber answers, relay F operates and F3 "x" breaks the short circuit on the 400 ohm winding of relay F, which locks in series with relay H.

F4 opens the busy tone lead. F5 prepares the C.S.H. alarm circuit. F1 and F2 cut off the ring and ring return and extend the called subscriber through to the transmission bridge, and relay D operates.

D1 and D2 change over and reverse the battery supply to the caller for supervisory and metering purposes.

Metering. D4 connects positive battery to the P wire and D3 opens the holding circuit of relay J, which releases slowly. A 50 ohm protective resistance YA is included in the positive battery circuit.

J4 replaces the positive battery with earth, so that the meter pulse is connected for the release time of relay J (about 300 mS).

Rectifier MRA maintains the earth on the P wire while D4 and J4 are changing over, but does not shunt the meter pulse.

Release. In this circuit, the release of the connection is controlled by the caller (calling party release). When the caller replaces the receiver, relay A releases followed by the slow release of relay B.

B4 removes earth from the P wire, allowing all preceding switches to release. B1 opens the circuit of relays F and H, which release. B5 completes a circuit from earth at H6 via N1 to operate the release magnet.

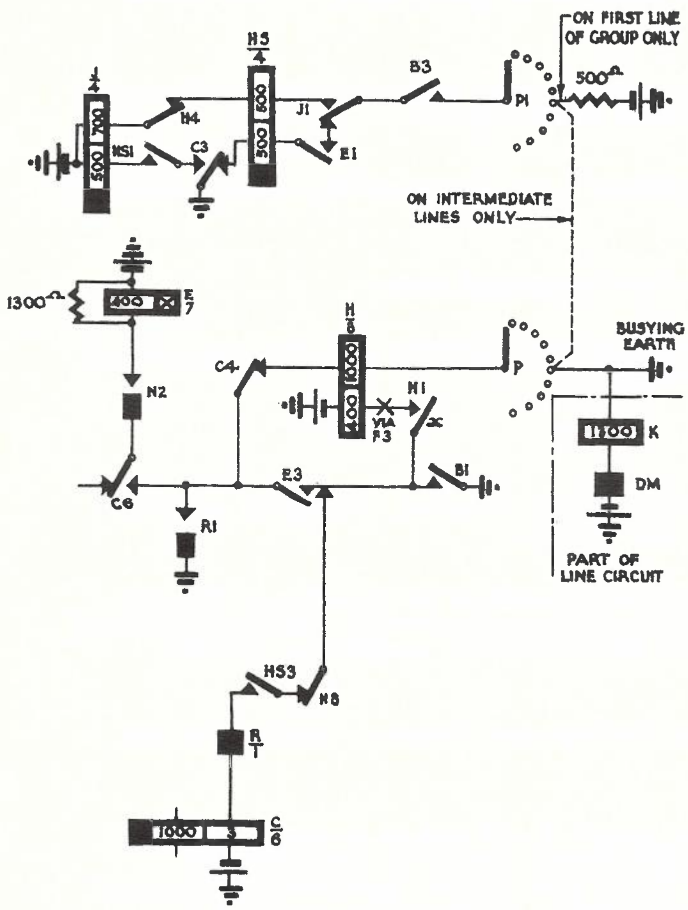
Z1 maintains an earth on the P wire until the switch restores to normal, when N1 opens the release magnet circuit.

/ C.S.H.

C.S.H. Alarm. In this circuit, since the complete train of switches may be held by the caller, it would be possible to call a subscriber and hold his line up indefinitely. In order to avoid this condition, a Called Subscriber Held (C.S.H.) alarm is provided should the called subscriber hang up prior to the caller.

When the called subscriber replaces the receiver, relay D releases and the lamp on the switch is energised from supervised battery to earth at D3, via F5 and J2. An indication is given on the exchange alarm system and on the particular final selector.

First Line in P.B.X. Group Busy. (Fig. 10.) Under this condition, when the final digit has been dialled and relay C releases, the P wiper encounters earth and relay H does not operate.



If First Line is Busy -

HS operates.
E releases.
C reoperates.
Rotary magnet operates.
J operates.

Wipers Reach Second Line (Busy) -

E reoperates.
Rotary magnet releases.
C releases.
E releases.
C reoperates.
Rotary magnet operates.

} Repeated until free line or last line of group is reached.

Wipers Reach Free Line -

E reoperates.
Rotary magnet releases.
C releases slowly.
K (line circuit) operates.
H operates and locks.
HS releases slowly.
E releases slowly.
Ring cut-on.

Wipers Reach Last Line of Group (All Lines Busy) -

E reoperates.
Rotary magnet releases.
C releases slowly.
HS releases slowly.
E releases slowly.
Busy tone given.
(H does not operate.)

HUNTING OVER A P.B.X. GROUP.

FIG. 10.

Relay HS operates from earth at C3 to marking battery on the P1 wiper (on first line of group only) via B3, J1 and E1.

HS2 opens the busy tone circuit.

HS4 opens the vertical magnet circuit to prevent further impulsing.

When E releases, the rotary magnet circuit is completed in series with the 3 ohm winding of relay C to earth at B1 via E3, H8 and HS3. C operates and the wipers are stepped to the next line. Contact R1 completes the circuit for relay E via N2 and C6, and E reoperates.

Second and Subsequent Lines in Group Busy. HS holds while the wipers are stepping due to its slug and when C reoperates a circuit is completed to operate relay J on its 500 ohm winding via HS1 to earth at C3.

The reoperation of relay E causes the release of the rotary magnet and relay C, and when C4 releases, a test is again made by the H relay on the P wiper.

Should the second line be busy, the same operation takes place depending upon the release of relays C and E.

Relays HS and J hold during stepping due to their respective slugs.

Free Line Reached. When the wipers are stepped on to the contacts of a free line, relay H operates in series with the line circuit relay K.

H7 holds relay J operated to earth at D3.

Relay HS releases and the ring is cut-on, as previously described. Subsequent operation is the same as in the case where the first line was free.

All Lines in the Group Busy. When the wipers have rotated to the last line of the group, relay HS releases due to the fact that the P1 contact is open-circuit. The testing circuit for relay H is completed when C releases, but the P contact is earthed, and H cannot operate.

Relay J releases and, when relay E releases, the busy tone circuit is completed via HS2, J3, F4, E6 and NR2.

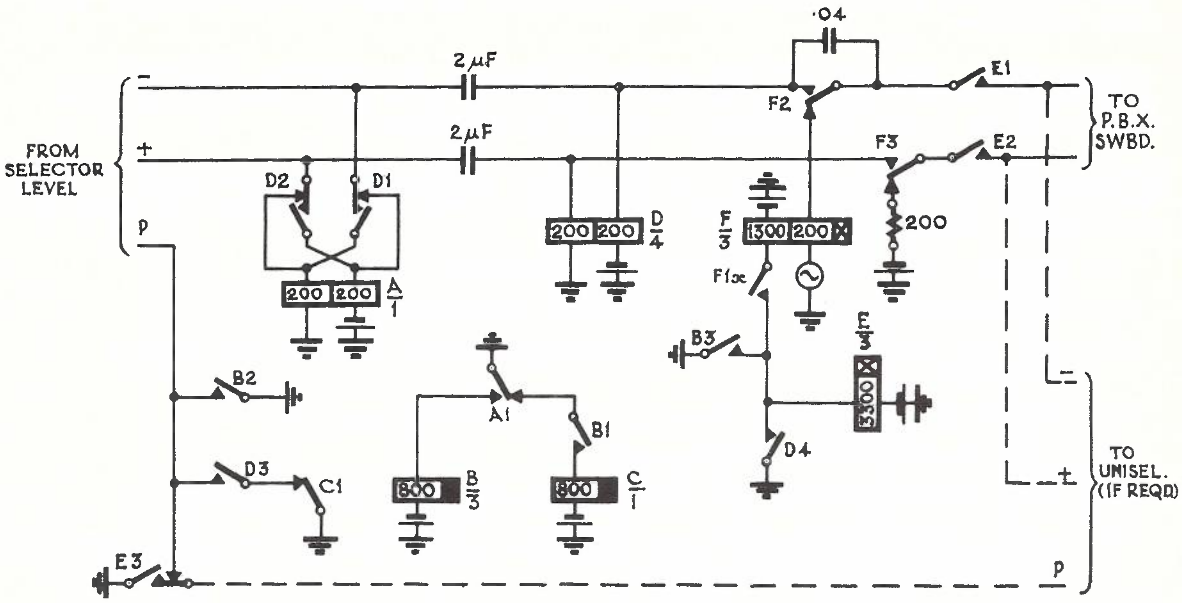
Call to Line Other than First Line of P.B.X. Group. A call made to an ordinary line or to a line other than the first of a P.B.X. group (night service) is completed, as previously described, if the line is free. If the line is busy, there will be no marking battery on the P1 contact and relay HS cannot operate. Consequently, when relay E releases after the final impulse train, busy tone is given to the caller.

/ 3.

3. LARGE GROUP P.B.X. FINAL SELECTORS.

3.1 As explained in paragraph 1.6 (iv) of this Paper, one method of trunking to large groups of P.B.X. lines uses a relay set per line. The outlets of the last rank of group selectors are graded and give partial access to the P.B.X. group (see Fig. 4).

Fig. 11 shows the circuit of a relay set which provides the ringing and transmission bridge facilities normally given by a final selector. The circuit is arranged for reverse battery metering.



RELAY SET WITH RINGING FACILITIES.

FIG. 11.

3.2 Circuit Operation. When the relay set is seized from the group selector, relay A operates over the caller's loop.

A1 completes the circuit of relay B which operates.

B2 earths the private wire, and operates the K relay if the line is used for "out" service. B3 completes the circuit of relay E which operates, and at E1 and E2 connects ringing current to the P.B.X. line.

A ring tone circuit is provided via a small condenser.

E3 maintains the earth to relay K.

When the call is answered, relay F operates and F1 "x" completes its locking circuit to earth at B3.

F2 and F3 extend the P.B.X. loop to the transmission bridge and relay D operates.

D1 and D2 reverse the current to the caller for supervisory and metering purposes.

Release. If the P.B.X. loop is cleared first, relay A releases when the caller replaces the receiver followed by relays B, E and F and the circuit is free to accept another call.

/ A

A last party release feature is provided to ensure that the P.B.X. line is ready to accept another call before the relay set is freed. If the P.B.X. line is not cleared when the caller hangs up, relay D remains operated and at D3 maintains an earth on the P wire. D4 holds relays E and F operated.

Relay A releases, followed by the slow release of relay B. During this time, relay C is energised via A1 and B1, and at C1 removes the earth from the P wire, allowing all preceding selectors to release.

After the release of relay B, relay C releases slowly and reguards the P wire at C1 until relay D releases.

Outgoing Calls. When "In" and "Out" service is required, the relay set is wired to a uniselector circuit, as shown by the dotted lines. The relay set is busied by an earth returned on the P wire via E3 while an out call is in progress.

3.3 P.B.X. Final Selector, Large Group. Latest practice combines the last group selector and the relay set into one unit, known as a Large Group P.B.X. Final Selector. The functions performed by this switch are -

(i) Returns a busy and hold condition to the preceding selectors.

(ii) Steps vertically under the control of the final train of impulses.

(iii) "Cuts in" on the selected level, hunts for and seizes the first free line in that level.

(iv) Prevents interference with circuits passed over while hunting.

(v) Guards the seized line from intrusion.

(vi) If all lines in the level are busy, transmits busy tone to the caller.

(vii) Applies ringing conditions to the called line when a free line has been seized and transmits ring tone to the caller.

(viii) Cuts-off ring and ring tone when called party answers.

(ix) Provides a transmission bridge.

(x) Operates the calling subscriber's meter.

(xi) When the calling subscriber clears, releases all preceding switches. (Last party release.)

(xii) Releases itself when both calling and called parties clear.

(xiii) Provides a supervisory alarm should the shaft fail to restore after release conditions are applied. (Release alarm.)

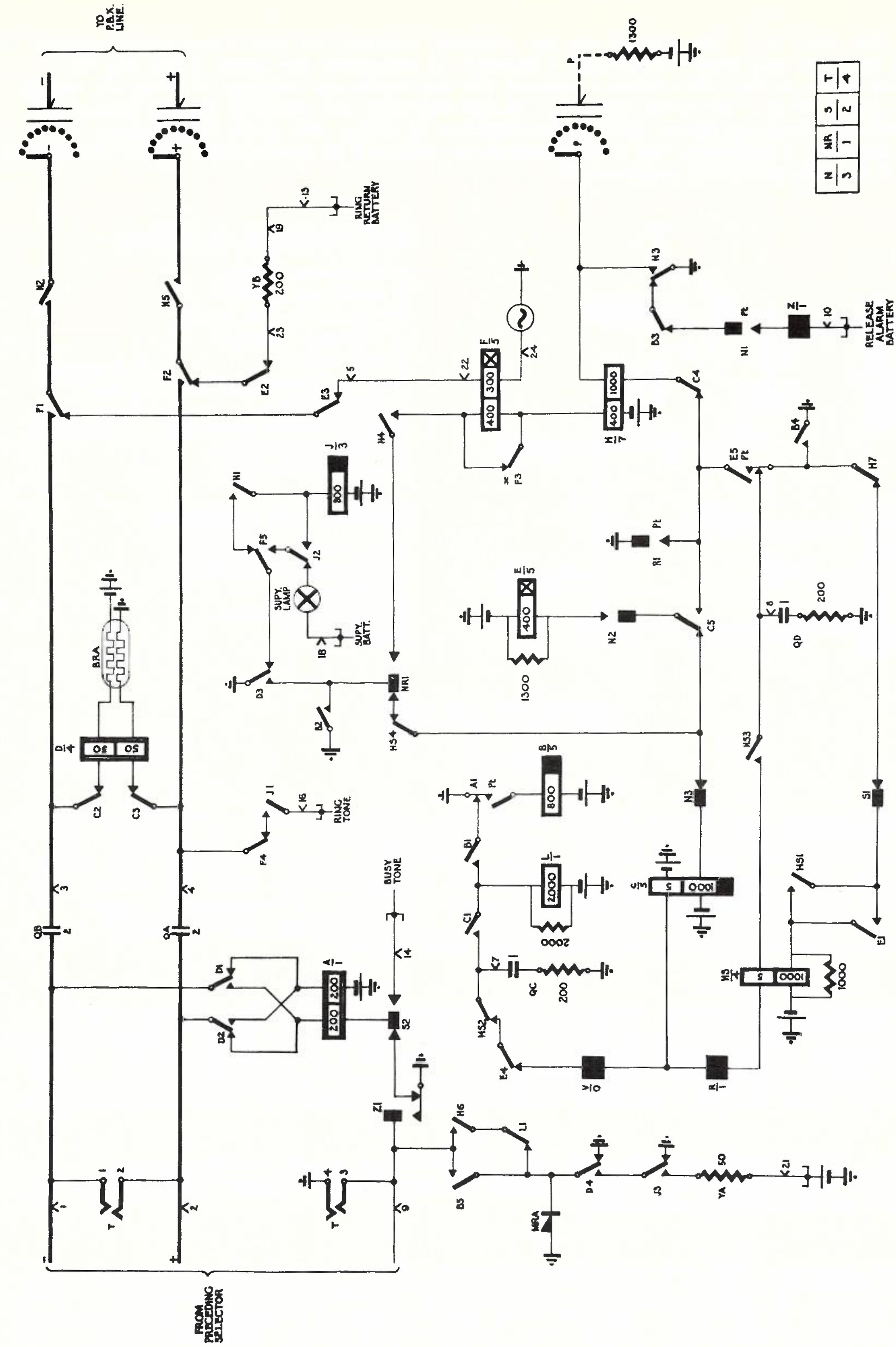
(xiv) Provides a supervisory alarm if the called subscriber's line is held. (C.S.H. alarm.)

3.4 Fig. 12 shows the circuit of a Large Group P.B.X. Final Selector circuit using 3,000 type relays. The circuit operation is described below -

Switch Seized. Relay A operates over the caller's loop and A1 closes the circuit of relay B. B5 earths the P wire, and B2 completes the circuit of the 1,000 ohm winding of relay C via NR1, HS4 and N3. C2 and C3 remove relay D from the line wires to reduce impulse distortion. B1 and C1 prepare the vertical magnet circuit for impulsing.

Vertical Stepping. Relays A, B and C are operated, and when the caller dials, A impulses. The vertical magnet is operated in series with the 5 ohm winding of relay C via E4, HS2, C1 and B1 to earth at A1. Relay L also operates but performs no function at this stage. During the first vertical step, N3 opens the circuit of the 1,000 ohm winding of relay C, which holds on the impulses in its 5 ohm winding and releases slowly at the end of the impulse train.

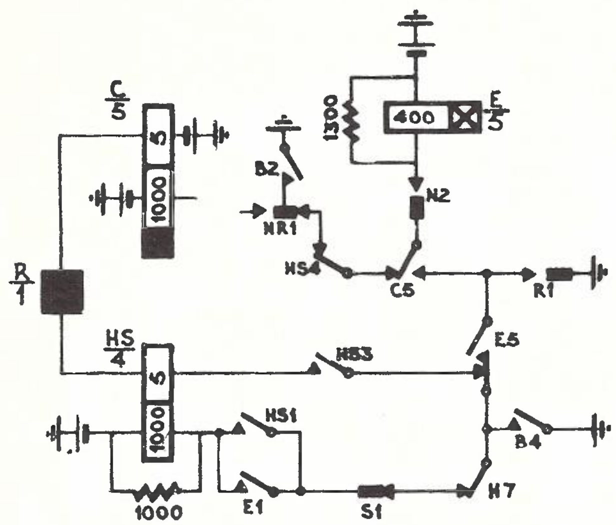
/ Fig. 12.



LARGE GROUP P.B.X. FINAL SELECTOR.

FIG. 12.

Cut-in. (See Fig. 13.) The wipers are now standing outside the bank level corresponding to the digit dialled, and when C releases, a circuit is completed for relay E via N2, C5, HS4, NR1 to earth at B2. E1 closes a circuit for the 1,000 ohm winding of relay HS via S1 and H7 to earth at B4. HS locks via HS1. E4 and HS2 open the vertical magnet circuit to prevent further stepping should the caller continue to dial. HS4 opens the circuit of relay E, and when E releases, the rotary magnet is operated in series with the 5 ohm winding of relay C via HS3 and E5 to earth at B4.



After Completion of Dialling -

C releases slowly.
E operates slowly.
HS operates and locks.
E releases slowly.
C operates.
Rotary magnet operates.
E reoperates.
Rotary magnet releases.
C releases slowly.
E releases slowly.
} Repeated until free line is found.

When Free Line is Reached -

H operates and locks.
J operates and locks.
HS releases.
E releases slowly.
Ring cut-on.

HUNTING FOR FREE LINE.

FIG. 13.

Hunting and Testing. The wipers are now standing on the first outlet in the dialled level and when the rotary magnet completes its stroke, R1 closes the circuit of relay E. When E operates, the rotary magnet circuit is broken at E5, and C releases slowly. The outlet is tested with the 1,000 ohm winding of relay H via C4, E5 to earth at B4 and if the free condition is encountered (negative battery through 1,300 ohms), H operates. On busy outlets, the P wire is earthed and H cannot operate. In this case, when E releases, the rotary magnet operates to step the wipers to the next outlet.

Free Line Reached. Interaction of relays C and E and the rotary magnet continues until a free line is found, or the 11th contacts are reached by the wipers. Relay H operates on its 1,000 ohm winding to the marking battery on a free line and H locks on its 400 ohm winding via F3, H4, NR1 to earth at B2. H3 earths the P wire to guard the seized line. H7 opens the circuit of relay HS which releases, and H1 closes the circuit of relay J via F5 and D3.

Ring Cut-on. J1 completes the ring tone feed to the caller via F4 and transmission condenser QA. When E releases, ringing current and ring return battery are applied to the seized line via E3 and E2 respectively.

Called Party Answers. When the called party answers, relay F operates and trips the ring. F3 operates first and removes the short circuit on the 400 ohm winding, allowing F to lock in series with H. F4 opens the ring tone lead, and F5 closes a holding circuit for relay J via J2. Relay D operates to the P.B.X. loop, and D1 and D2 reverse the current feed to the calling line. D4 applies positive battery to the P wire for metering purposes, and D3

/ opens

opens the circuit of relay J, which releases slowly. J3 replaces earth on the P wire after the meter pulse.

Last Party Release. The circuit is arranged for last party release, and when the calling party clears, relays A and B release, reoperating relay L during the release time of B. B5 removes the holding earth from the P wire, allowing preceding switches to release. After a brief unguarded interval, L releases and L1 reconnects earth to the P wire via H6.

When the P.B.X. line is cleared, relay D releases, followed by relays F and H. H3 completes the release magnet circuit and the switch restores to normal. During release, the switch is guarded by earth from Z1.

All Outlets Busy. Should all outlets in the dialled level be busy, the wipers are stepped to the 11th contacts, and S springs operate. S1 opens the circuit of HS and the opening of HS3 prevents further rotary stepping. At S2, busy tone is connected to the calling line.

4. TEST QUESTIONS.

1. List the functions performed by a P.B.X. Final Selector of the 2-10 type.

2. A P.B.X. group in a Strowger exchange extends from JA 3623 to JA 3628. What are the circuit operations immediately following the units train of impulses if a subscriber dials the number JA 3625 and that line is busy?

3. List and briefly describe five schemes for dealing with large P.B.X. groups.

4. A subscriber having eight exchange lines connected to a 2-10 P.B.X. group, applies for four additional lines. What arrangements could be made in the exchange to cater for this development?

END OF PAPER.

COMMONWEALTH OF AUSTRALIA.

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COURSE OF TECHNICAL INSTRUCTION.

TELEPHONY III.

MULTI-EXCHANGE SYSTEMS.

CONTENTS.

1. INTRODUCTION.

1.1 In previous Papers, it has been considered, for the sake of simplicity, that all telephone subscribers in an area are connected to the one exchange. This is rarely the case in actual practice, as in a large area it is more economical to break up the whole area into smaller "exchange areas".

Each subscriber can call every other subscriber in the area, and the unit fee (one operation of the meter) is charged for such calls. The area is, therefore, called a "Unit Fee" area. Calls to subscribers outside the unit fee area are obtained through a trunk line switchboard serving the area. In overseas practice, calls involving two or more counts on the meter may be made directly by the subscriber in some cases (multi-metering).

1.2 Metropolitan unit fee areas extend over hundreds of square miles and, if all subscribers were to be connected to a central exchange, many lines would be from 15 to 20 miles in length. To give the required standard of transmission performance (see Paper No. 1, page 20), it would be necessary for line wires of much larger diameter than normal to be used on long lines. This would mean an enormous increase in the costs of cable and aerial line construction.

Normally, subscribers' distribution is made with cable having wires of 6-1/2 lb. or 10 lb. per mile, the latter having a resistance of 176 ohms per loop mile. Thus, the length of subscribers' lines must be no more than about three miles in length in order to comply with transmission requirements.

1.3 By reducing the size of the exchange areas, the average length of subscribers' lines is correspondingly reduced and cable having lighter conductors may be used. This results in a considerable saving in line plant costs, but against this must be balanced the cost of the buildings and additional power and common equipment. Also, junction circuits must be provided to handle calls between exchanges in the network.

1.4 A typical metropolis may comprise a business and industrial centre or centres surrounded by residential and small business communities. The number of telephones per unit area (the "Telephone Density") is generally highest in the business and factory districts, while in the residential belt the telephone density is usually comparatively low.

If the area to be served is geographically small and the telephone density diminishes fairly regularly from the centre of the area, it is usual to provide a single exchange. If, however, the area is large and the telephone density is high in different parts of the area, two or more exchanges must be provided.

Geographical features, such as rivers, cliffs, etc., may also make it economical to establish an exchange in an isolated location, thus avoiding difficult line construction.

1.5 In Australian practice, the largest automatic exchanges are of 10,000 line ultimate capacity. This is decided from the average telephone density conditions and from the point of view of convenient size of buildings. Also the possibility of complete disruption of service in the case of fire or enemy attack is reduced.

2. MAIN, BRANCH AND SATELLITE EXCHANGES.

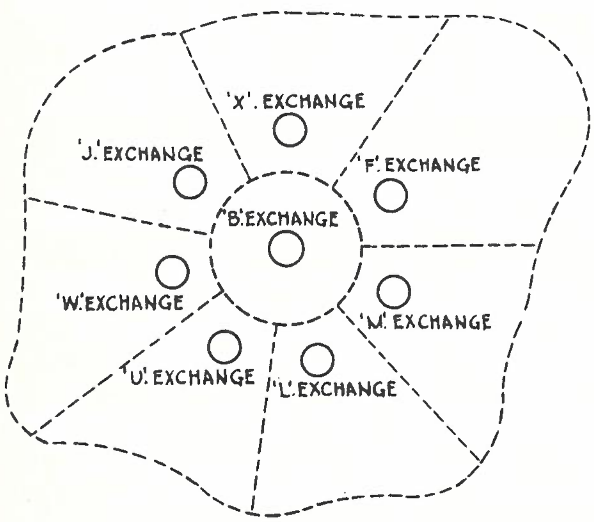
2.1 Main Exchanges. There are 10 numbers on the automatic dial, and a unit fee area may be divided into 10 corresponding exchange areas. If each exchange has a maximum of 10,000 lines, subscribers will dial five digits. The first digit serves to select the required exchange, the last four digits serving to select the required number from the 10,000.

To aid the memorising of numbers, only four figures are used in the subscribers' numbers, any additional digits being represented by letter prefixes. Thus, 43562 becomes J 3562 as the letter J is associated with the figure 4 on the standard dial.

2.2 As explained in Paper No. 2 of this Book, level 1 of the first group selectors is not usually allotted, and level 0 (or Y) is sometimes allotted for the trunk exchange. Fig. 1 shows a multi-exchange area having eight exchanges.

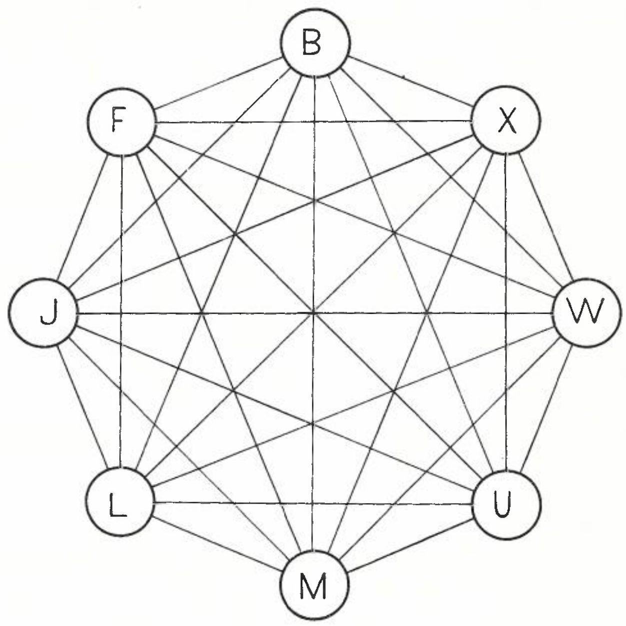
As a subscriber in any of these exchange areas may desire to call a subscriber in any of the other exchange areas, it is necessary to provide junction circuits from each exchange to every other exchange. Under these conditions the exchanges are known as "main" exchanges.

Fig. 2 shows the junction routes necessary between the eight exchanges. Each connecting line represents a group of junctions in each direction, the number of junctions in each group depending on the traffic to be carried.



MULTI-EXCHANGE AREA.

FIG. 1.



JUNCTION ROUTES BETWEEN MAIN EXCHANGES.

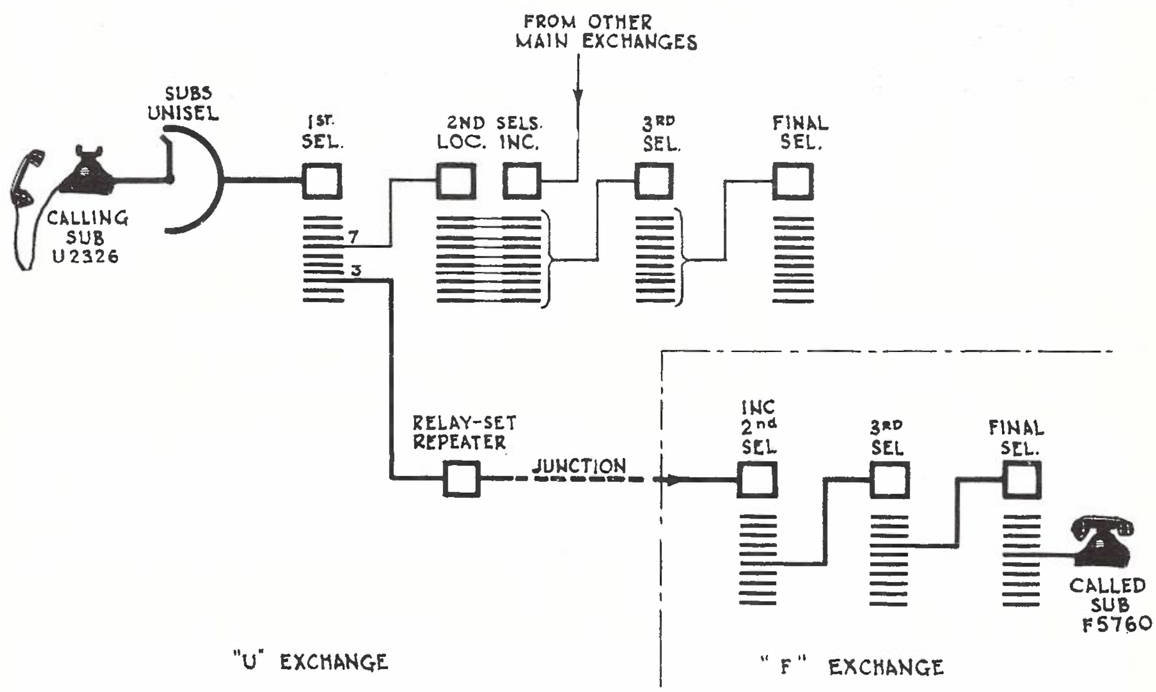
FIG. 2.

2.3 As a five-digit numbering scheme is used in the example quoted there will be 1st, 2nd and 3rd group selectors and final selectors in each exchange as shown in Fig. 3.

In each case the outgoing junctions are trunked from the 1st selector bank levels and terminate on incoming 2nd selectors at the distant exchange. The term "Incoming" selector is used to distinguish them from "Local" selectors, the latter being trunked from the local level of the 1st selectors.

2.4 Relay-Set Repeater. If the outgoing 1st selector levels were connected directly to the junction and thence to an incoming 2nd selector at the distant exchange, it would be necessary to provide three-wire junction circuits so that the holding and guarding functions of the private wire could be fulfilled. Also, for transmission purposes, it is necessary to provide a transmission bridge in the caller's exchange.

A relay-set repeater is connected between the 1st selector and the junction, and enables a two-wire junction to be used. It provides the transmission bridge, performs the necessary metering function and repeats dialled impulses over the junction to operate selectors in the distant exchange. Fig. 3 shows the route taken by a call from a subscriber on the "U" exchange to a subscriber on the "F" exchange.

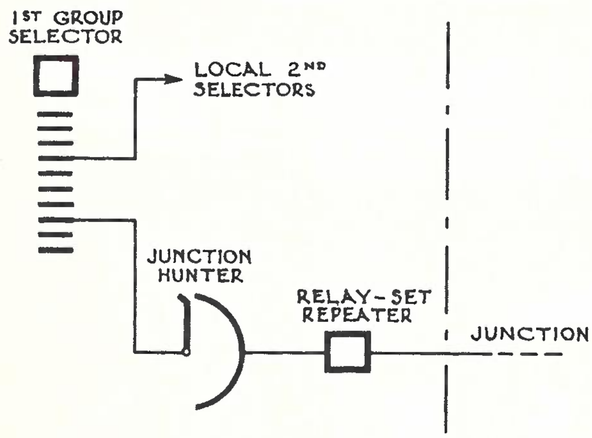


CALL FROM U 2326 TO F 5760.

FIG. 3.

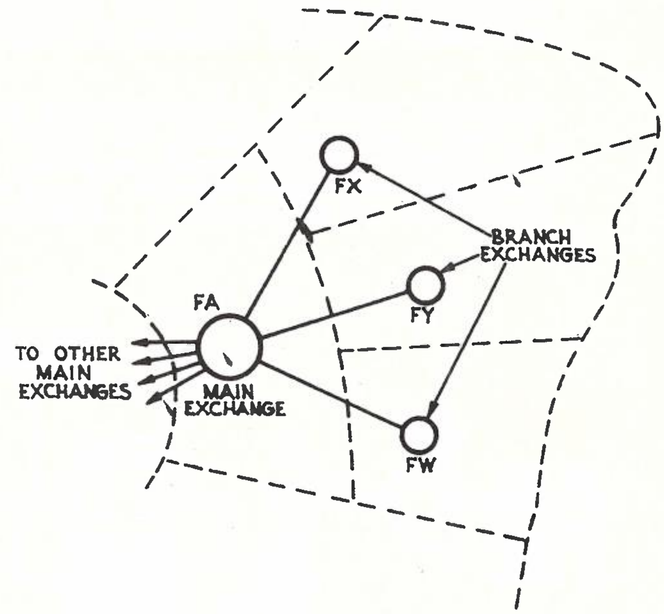
2.5 Junction Hunters. Where exchanges are equipped with group selectors having 10 outlets per level, it is usually the practice to provide a rank of junction hunter switches (previously known as Secondary Outgoing Line Switches or Traffic Distributors) between the group selector bank levels and the relay-set repeaters, as shown in Fig. 4. These switches are 25-point non-homing uniselectors, and increase the traffic carrying efficiency of the junctions.

2.6 Branch Exchanges. If the number of telephones in the area increases, so that six-digit working is necessary, one or more of the main exchange areas may be divided to form up to 10 exchange areas, as shown in Fig. 5, where the "F" exchange area is so divided.



USE OF JUNCTION HUNTERS.

FIG. 4.



MAIN AND BRANCH EXCHANGES.

FIG. 5.

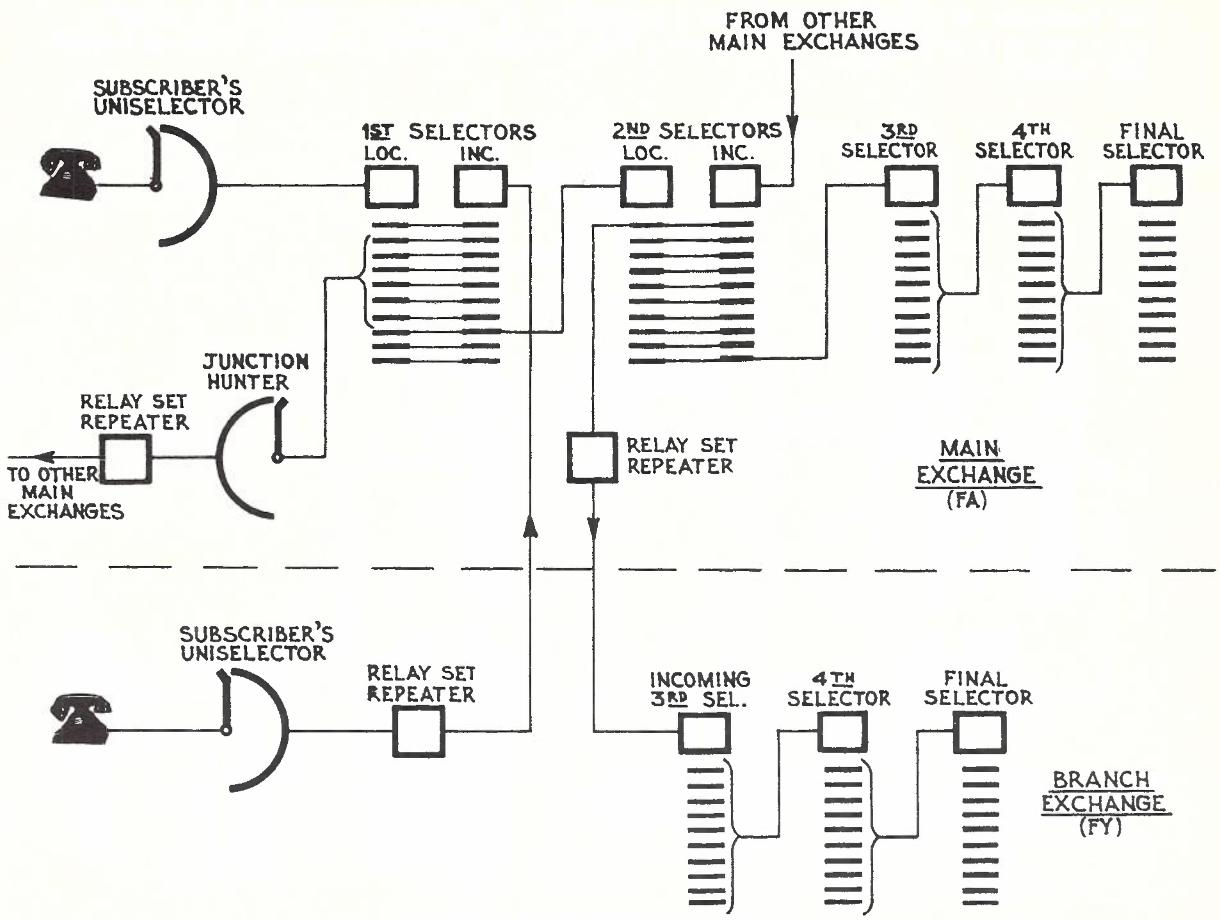
The new exchanges are called "Branch" exchanges as they can be considered to be portions of the main exchange located in separate buildings. The branch exchanges are linked by junctions to their main exchange and an additional letter prefix (FW, FX, FY, etc.), is usually given to the branch exchange subscribers' numbers to raise their individual capacities to 10,000 lines. Similarly, a second letter prefix is required to raise the main exchange capacity to 10,000 lines.

In deciding the numbering scheme for an automatic area, allowance has to be made for the number of lines that will ultimately exist in the area (that is for 20 years ahead). It is, therefore, necessary to adopt a numbering scheme which can easily be expanded to meet the growing needs of the area.

A main exchange with its dependent branch exchanges is known as a main exchange group.

/ Fig. 6

Fig. 6 shows the trunking arrangements for typical main and branch exchanges.



MAIN AND BRANCH EXCHANGE TRUNKING DIAGRAMS.

FIG. 6.

Calls to subscribers on the branch exchanges have "F" as the first digit and are switched to 2nd selectors at the FA main exchange. Upon the second digit being dialled, say it is Y, the call is extended over a junction to the FY branch exchange via a relay-set repeater (and possibly a junction hunter). There an incoming 3rd selector is seized and accepts the third digit. The fourth digit operates a 4th selector and the final two digits serve to select the required number on a final selector.

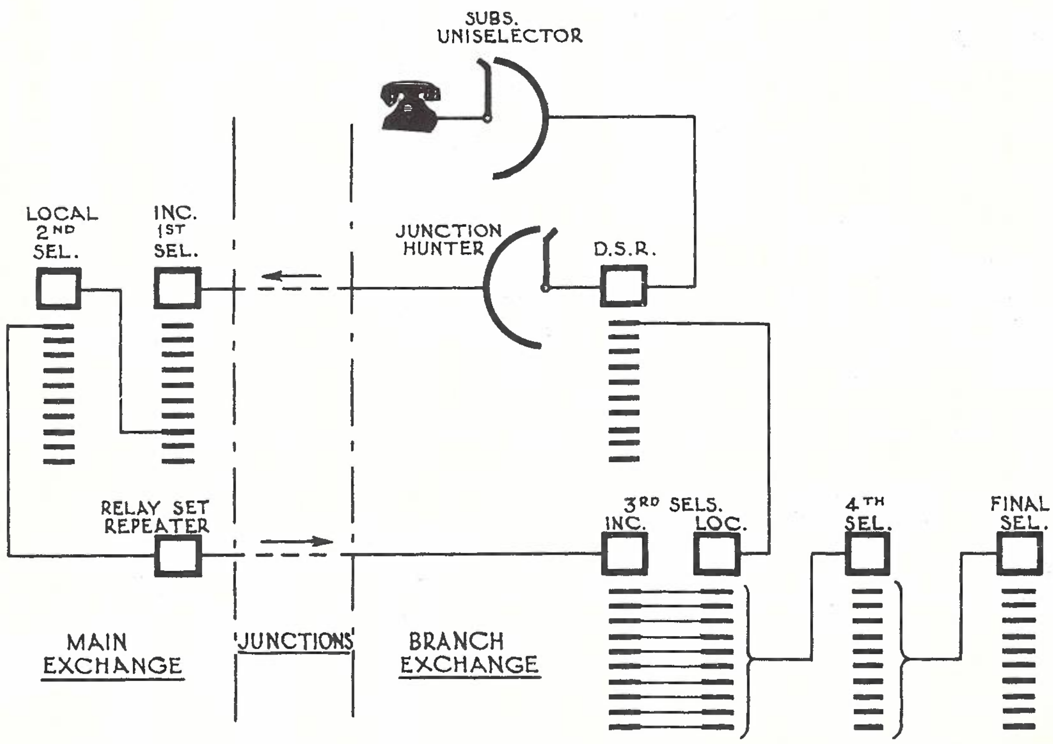
When a branch exchange subscriber lifts the receiver to make a call, a 1st selector at the parent main exchange is seized over a junction and dial tone is given to the caller. The call is set up in the same way as a call made by a main exchange subscriber.

2.7 Discriminating Selector Repeaters (D.S.R.). With the arrangement shown in Fig. 6, a call from a branch exchange subscriber to another branch exchange subscriber passes over an outgoing junction to a 1st selector in the main exchange and back over a second junction to the 3rd selector in the branch exchange; thus, two junctions between the main and branch exchanges are held while a branch exchange local call is in progress.

If the proportion of local calls is comparatively high, or if the distance between main and branch exchanges is considerable, it is generally economical to provide special arrangements which keep the junction requirements down to the lowest possible figure.

/ A

A two-motion selector, known as a Discriminating Selector Repeater (D.S.R.) or Switching Selector Repeater (S.S.R.), was developed to meet this requirement. This switch combines the functions of both a selector and a repeater. It serves as a repeater on outgoing calls and as a selector on local calls. Fig. 7 shows a branch exchange trunking diagram with D.S.R's.



BRANCH EXCHANGE WITH D.S.R's.

FIG. 7.

When a branch exchange subscriber lifts the receiver to originate a local call, a D.S.R. is seized. The associated junction hunter selects a junction to the main exchange, where a 1st selector is also seized. With the transmission of the first train of impulses both the selector and D.S.R. operate and the 1st selector hunts for a free 2nd selector. The D.S.R. shaft and wipers restore to normal after cutting-in on the dialled level, and the D.S.R. is said to have "absorbed" this digit. The second train of impulses operates the 2nd selector at the main exchange, and the D.S.R. at the branch exchange steps vertically, cuts in and seizes a free local 3rd selector. The junction to the main exchange and the switches there are released.

If the call is not for the local exchange, the D.S.R. functions as a repeater, the wipers being disconnected.

2.8 <u>Direct Switching Between Branch Exchanges</u>. The direct distance between adjacent branch exchanges is often far less than the route via the main exchange, and, in many cases, it has been found economical to provide direct junctions. In such cases, the D.S.R. functions as a selector-repeater on calls between adjacent branch exchanges and the junctions to the main exchange, and the 1st and 2nd group selectors, are released and become available for other calls.

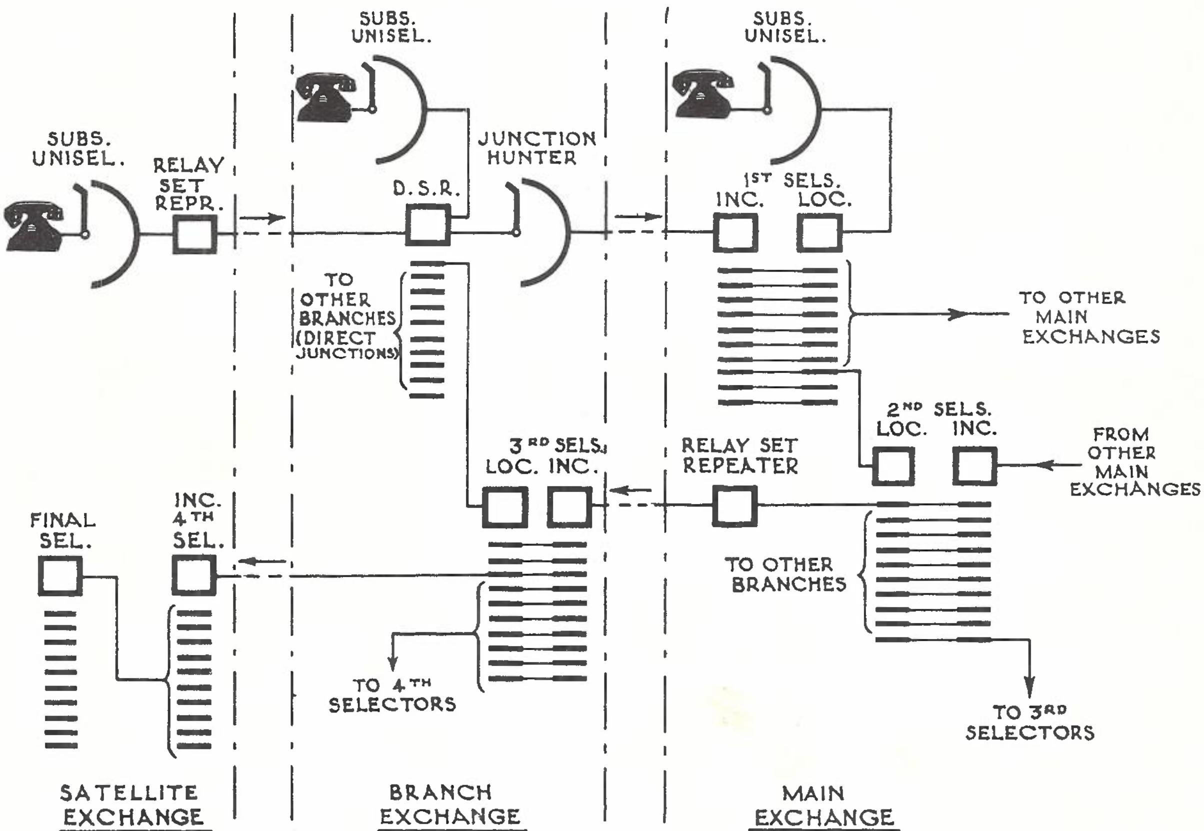
/ 2.9

2.9 Direct Switching from Branch Exchange to Main Exchange. In cases where a large number of calls are made from a branch exchange to its parent main exchange, direct junctions may be trunked from the relevant D.S.R. bank level to incoming 3rd selectors at the main exchange. Such calls are switched over this route, and 1st and 2nd selectors at the main exchange are released and become available for other calls.

2.10 Satellite Exchanges. In areas where the telephone density is relatively low, smaller exchanges may be provided. The outgoing junctions from "Satellite" exchanges do not connect directly to 1st selectors at the parent main exchange, but to relay-set repeaters or D.S.R's. at a branch exchange.

A satellite exchange, depending on its size, is allotted portion of the numbering range of the branch exchange to which its main traffic outlets are connected.

Trunking arrangements are shown in Fig. 8 for a satellite exchange FY8, having 1,000 lines capacity. A satellite having more than 1,000 lines takes up two or more 3rd selector levels at the branch exchange and requires a corresponding number of incoming junction groups. Smaller satellite exchanges may have uniselectors, relay-set repeaters and final selectors only; these latter switches being trunked over junctions from 4th selector levels at the branch exchange.



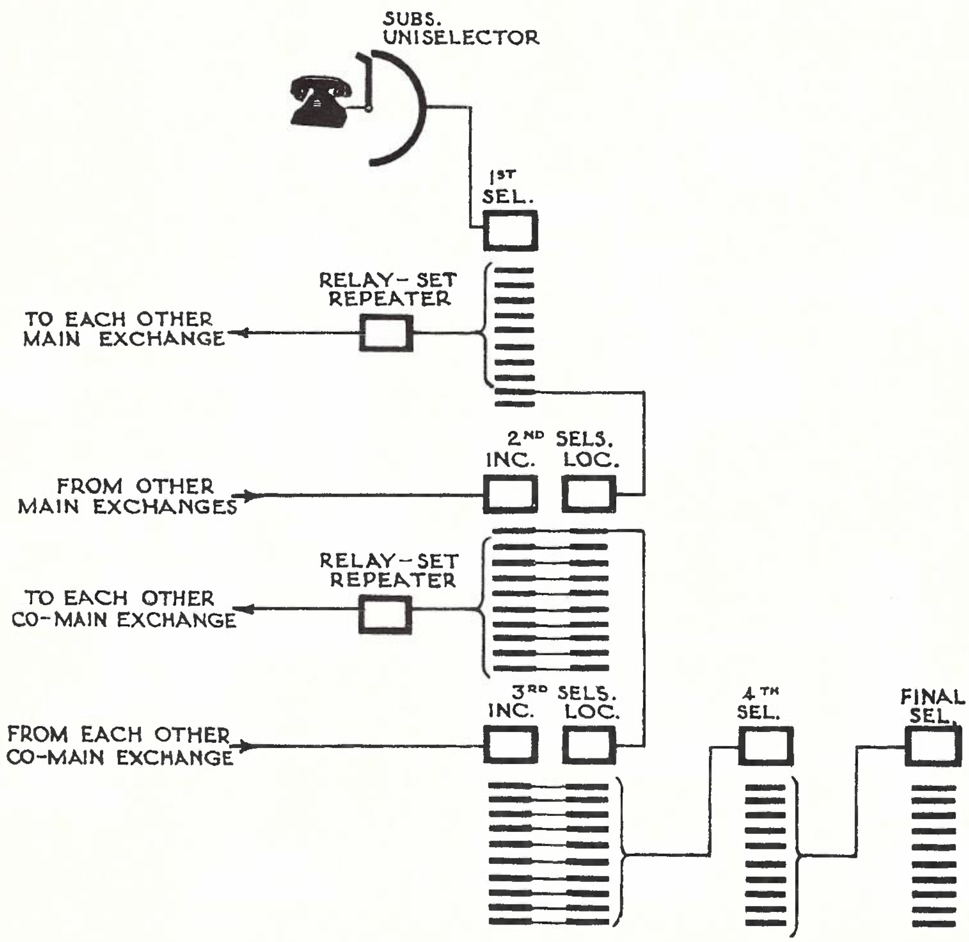
SATELLITE EXCHANGE TRUNKING DIAGRAM.

FIG. 8.

2.11 Co-Main Exchanges. In large cities the incoming and outgoing traffic is usually much heavier in the main exchange group serving the city business centre than in other main exchange groups.

In these cases, a single main exchange for the city group would require a very large number of group selectors to handle the originating and terminating traffic. The exchange building would need to be very large and there would be a heavy concentration of junction cables at the main exchange. This arrangement is inconvenient and very vulnerable in the case of emergency.

A scheme has been developed whereby each of the exchanges in the main city group becomes a "Complementary" main (or Co-main) exchange, and each have junctions outgoing to every other main exchange. Junctions from other main exchanges terminate on incoming 2nd selectors at a convenient co-main exchange, and calls for other co-main exchange subscribers are passed on from the second selector levels over junctions to incoming 3rd selectors. Fig. 9 shows the trunking arrangements at a typical co-main exchange, BY. In this way the traffic, and junction cables, are shared evenly among all the exchanges in the group.



CO-MAIN EXCHANGE TRUNKING DIAGRAM.

FIG. 9.

3. RELAY-SET REPEATERS (AUTO-AUTO).

3.1 From the foregoing, it is seen that, when a call is set up from a subscriber on one exchange to a subscriber on a second exchange, a relay-set repeater is brought into use. Fig. 10 shows the through connections on a typical call between exchanges. Note the method of eliminating the private wire between exchanges. The relay-set also has a polarised relay which operates on the reversal of current on the junction when the called party answers, and gives metering and supervisory conditions to the caller.

3.2 The general functions of a relay-set repeater are as follows -

(i) Connects guarding and holding earth to the P wire to hold preceding switches and so allows the use of two-wire junction circuits.

(ii) Provides a transmission bridge to feed current to the calling party.

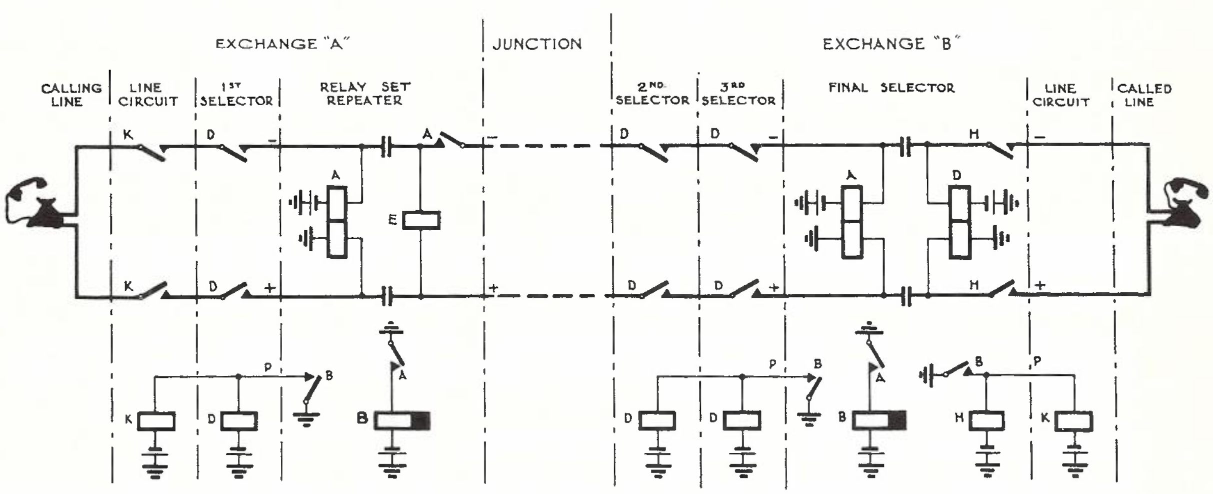
(iii) Repeats dialled impulses from the caller over the junction to operate selectors at the distant exchange.

(iv) When the called party answers -

(a) Operates the calling party's meter.

(b) Reverses the current flow to the calling line for supervisory purposes.

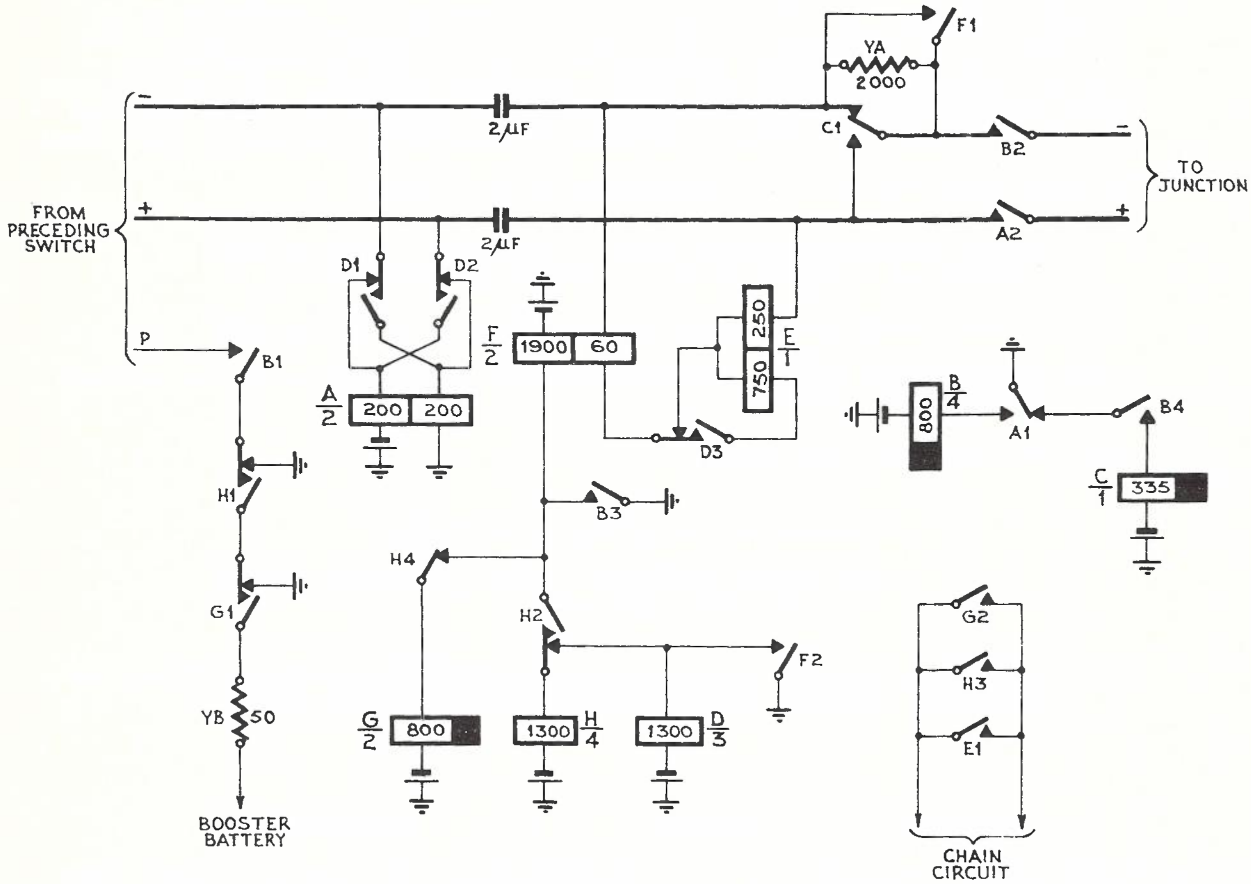
(v) When the calling party clears, releases preceding and succeeding switches, and guards the junction to cover the release of the incoming selector.



TYPICAL CONNECTIONS OF CALL BETWEEN EXCHANGES.

FIG. 10.

3.3 Relay-Set Repeater (Auto-Auto) with Strowger Relays. Fig. 11 shows the circuit of an early type of relay-set repeater, arranged for booster battery metering. The circuit operation is described below -



RELAY-SET REPEATER (AUTO-AUTO).

FIG. 11.

Relay-Set Seized. When the calling subscriber's loop is extended from the preceding selector, relay A operates over the loop via D1 and D2. A1 completes the circuit of relay B which operates.

B1 earths the P wire to hold the preceding switches. B2 and A2 complete a loop circuit to operate the incoming selector at the distant exchange via C1, 60 ohm winding of relay F, D3 and 250 ohm winding of relay E.

E operates and E1 closes the relay-set chain circuit.

B3 closes the circuit of the 1,900 ohm winding of relay F, which does not operate at this stage. Relay F will not operate on the current in either winding alone, or with the current in the 60 ohm line winding in the normal direction. B3 also closes the circuit of relay G, which operates.

G2 further bridges the chain circuit. G1 prepares the metering circuit.

/ Impulsing

Impulsing. On the first impulse being received from the subscriber's dial, relay A restores, but relay B holds, due to its release lag of approximately 300 mS.

A1 completes the circuit of relay C which operates, and remains operated during the impulse train. A2 opens the loop to the distant exchange, and causes the selector to step.

C1 short-circuits the 60 ohm winding of F and the relay E winding to reduce the impedance of the circuit for the distant relay A while impulsing. After the impulse train, relay C releases, reconnecting relays F and E into the holding loop circuit. To avoid making C1 make-before-break, 2,000 ohm resistance YA is connected across its back contacts, and prevents the possibility of a false impulse being delivered when relay C releases. This resistance also prevents the short circuiting of the transmission condensers, which would cause distortion of the repeated impulses.

Subsequent impulse trains are repeated in the same way, relay C operating during the first impulse of each train.

Called Party Answers. When the called party answers, the final selector at the distant exchange reverses the current flowing over the junction loop. The two windings of relay F now assist and F operates. F1 provides an additional short-circuit on the 2,000 ohm resistance YA, while F2 closes the circuit of relays D and H.

Relay D operates and D1 and D2 reverse the current feed to the calling telephone. D3 connects the 750 ohm winding of relay E in series with its 250 ohm winding to increase the impedance of the holding loop, reducing shunt losses.

Relay H operates and locks via H2 to earth at B3. H3 maintains the chain circuit; H1 completes the booster battery circuit to operate the caller's meter, and H4 opens the circuit of relay G.

When G releases, the booster battery is disconnected and replaced with earth. The meter pulse is applied to the P wire for the release time of relay G, approximately 300 mS. The 50 ohm resistance YB prevents short-circuiting of the booster battery while G1 and H1 are changing-over.

Release of Connection. When the calling subscriber replaces the receiver, relay A releases and A1 opens the circuit of relay B. A2 opens the junction loop circuit, allowing the switches at the distant exchange to release.

B releases after its slow release period, covering the release of switches in the distant exchange. B1 removes the earth from the P wire, allowing all preceding switches to release. B2 and B4 release the remaining repeater relays.

3.4 Relay-Set Repeater (Auto-Auto) 3,000 Type Relays. Fig. 12 shows the circuit of a modern relay-set repeater using 3,000 type relays. The functions and principles are the same as those previously described, but the circuit embodies many new features. The circuit operation is described below -

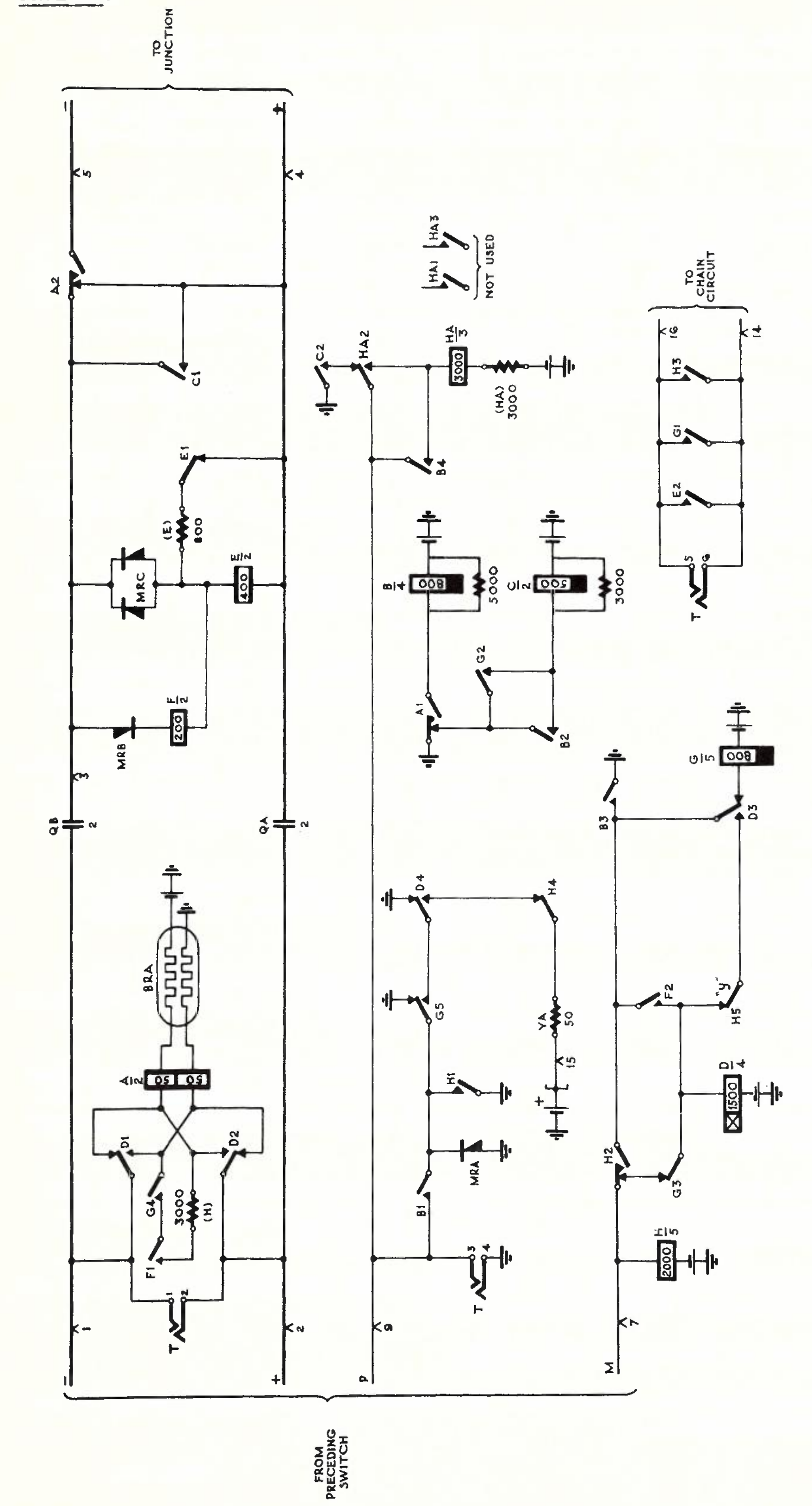
Relay-Set Seized. When seized from the preceding switch, relay A operates via D1 and D2 in series with the ballast resistor. A1 closes the circuit of relay B, whilst A2 completes the junction loop circuit via relay E and rectifier MRC.

B operates and B1 earths the P wire via G5. B2 prepares the circuit for relay C, B3 and B4 close the circuits of relays G and HA respectively.

HA operates and performs no function at this stage.

G operates and G1 closes the chain relay link. G5 transfers the P wire to earth at D4, and prepares the metering circuit.

/ Fig. 12.



RELAY-SET REPEATER (AUTO-AUTO) 3,000 TYPE RELAYS (CE. 59, SHEET 3).

FIG. 12.

E operates over the junction loop in series with the selector relay A. This operation is known as the "initial pick-up". To reduce the impedance of the loop circuit and allow the selector relay A to operate quickly, 800 ohm resistance (E) shunts the relay E winding, and is removed by E1. E2 further bridges the chain relay link.

Impulsing. When the subscriber dials, relay A impulses, A1 completes the circuit of relay C and A2 opens the loop to the distant exchange.

C operates during the first impulse of each train and remains operated for the remainder of the train. C1 short-circuits relay E and rectifier MRC, E releases during each train and, when C releases, is again included in the loop circuit. This is termed the "subsequent pick-up," and E reoperates.

Called Party Answers. When the called party answers, the current over the junction is reversed, and the comparatively low forward resistance of MRB allows relay F to operate in series with relay E. Rectifier MRC, due to its high reverse resistance, no longer shunts relay F. F2 completes the circuit of relay D, which is slow-operating to cover the "flick" operation of F, due to line surges, etc.

On operation, D3 opens the circuit of relay G and closes a temporary locking circuit for D via H5. D1 and D2 reverse the current feed to the calling subscriber's line. To prevent relay A releasing during the reversal of current, a 3,000 ohm resistance is connected across relay A by F1. D4 closes the positive battery metering circuit via 50 ohm YA.

After its release lag (approximately 300 mS), G releases and replaces the positive battery on the P wire with earth at G5. Rectifier MRA maintains an earth on the P wire while G5 and D4 are changing-over. G4 opens the local loop circuit on the A relay. G3 closes the circuit of relay H via H5 and D3 to earth at B3.

H operates, and locks via H2 to earth at B3. H1 connects a parallel earth to the P wire, and H4 opens the positive battery lead, preventing further meter pulses. H3 bridges the chain relay link. H5 opens the temporary locking circuit of relay D, which is now controlled by relay F.

Earth is also extended to the M wire for metering. This is required only in branch or satellite exchanges, where the relay-set repeater is connected directly to subscribers' uniselectors designed for fourth wire metering.

Release of Connection. If the called party restores first, relay F and D release. When the calling party restores first, relay A releases, followed by relays F, E, D, B and H. Relay B has a release lag of 200-250 mS and after the release of D, relay G is operated via D3 to earth at B3. Relay C is operated via B2 (and G2) to earth at A1.

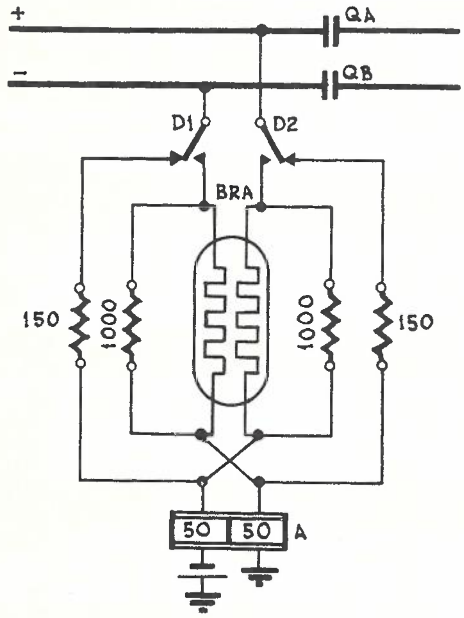
Earth is removed from the P wire when B releases allowing preceding switches to release, and HA releases. After the release time of HA (approximately 15-20 mS) the P wire is re-guarded at C2 until relays G and C release. This allows the selector at the distant exchange to restore to the normal position before the junction is made free.

3.5 Circuit Details. Following the introduction of the 3,000 type relay, various alterations were made to relay-set repeaters, and these are described below -

Impulsing Relay. The A relay is fitted with make-before-break (K) contacts in lieu of change-over (C) units, and stiff back springs are used to reduce the "Bunching" time of these contacts. The coil resistance is 50 ohms/50 ohms, and three nickel-iron sleeves are placed over the core to increase the impedance to voice-frequency currents. The relay is fitted with an isthmus armature and a magnetic shield (see Paper No. 1, paragraph 7.8).

/ Ballast

Ballast Resistor. This limits the current on short lines and gives an increase of current on long lines.



BALLAST RESISTOR.

FIG. 13.

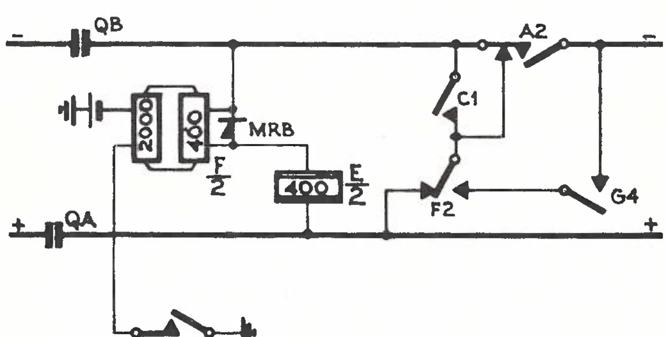
In branch and satellite exchanges where subscribers' uniselectors are trunked directly to relay-set repeaters, considerable trouble has been experienced with the failure of ballast resistors in service, as a result of subscribers' lines contacting with power lines.

At these exchanges the circuit may be altered, as shown in Fig. 13. As the ballast resistor is not generally used for transmission until a current reversal is given, it is replaced by 150 ohm resistors until relay D operates, when the ballast resistor filaments are connected into the relay A circuit.

Should the ballast resistor fail in service, a 1,000 ohm resistor connected across each filament, will prevent the release of relay A when reversal takes place. The conversation may proceed but with lowered transmission efficiency. The reduced speech volume can be detected readily during tests.

Sparking at Relay A Contacts. Sparking at these contacts is quenched by connecting a resistance of 5,000 ohms across the coil of relay B, and one of 3,000 ohms across relay C.

Polarised Relay. The present standard circuit uses a rectifier-polarised relay in lieu of a shunt-field type used in some circuits (see Fig. 14). This arrangement is more reliable in operation as the shunt-field relay has a tendency to "flick" up when the circuit of the polarising winding is closed and, in addition, there is no need for a special relay. The line winding of the shunt-field relay is shunted by a rectifier to reduce the impedance in the junction loop, so reducing "pick-up" troubles on long junction lines. Contacts F2 and G4 shunt A2, preventing the possibility of a false impulse should relay A flick during reversal.



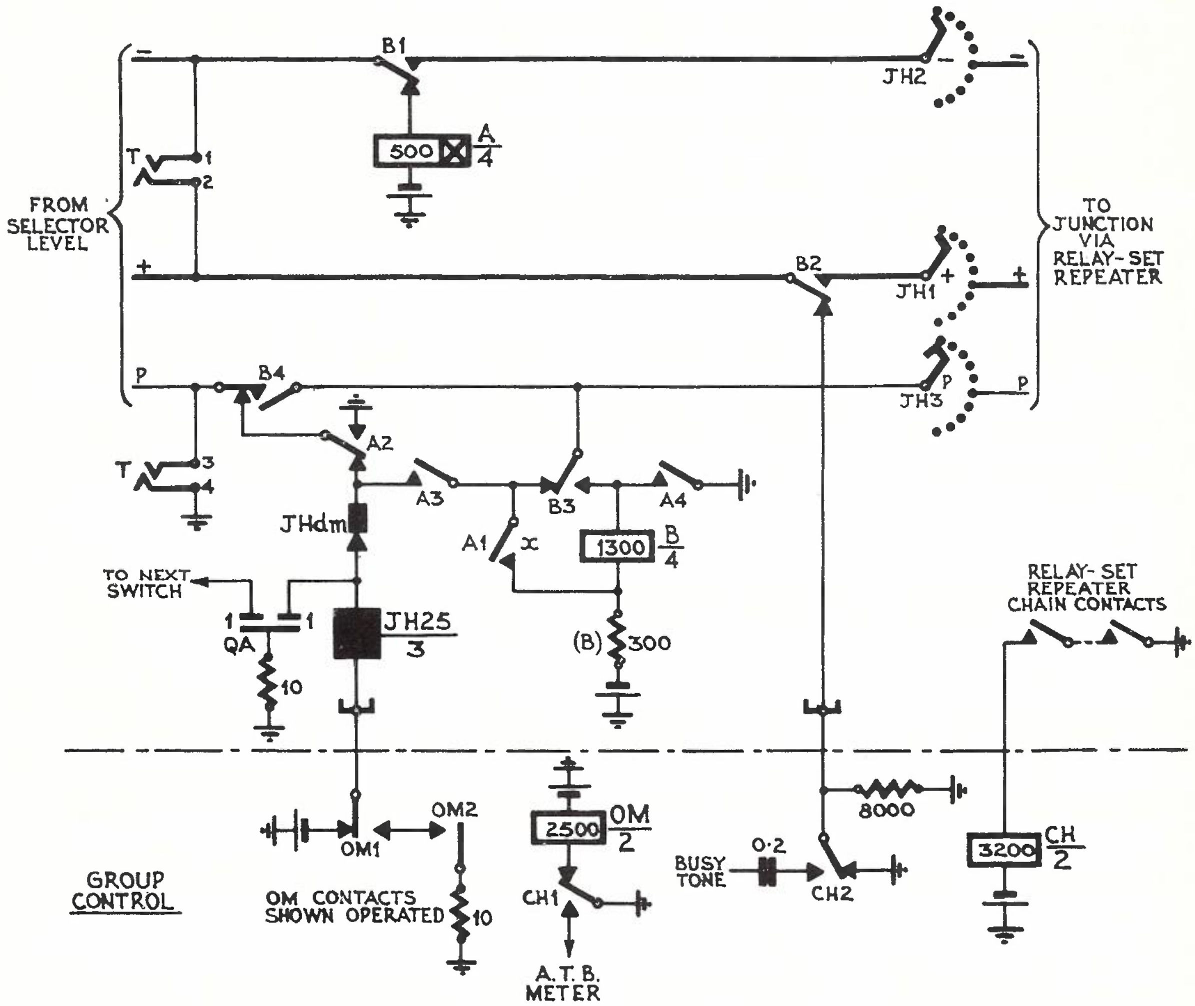
EARLIER CIRCUIT USING SHUNT-FIELD RELAY.

FIG. 14.

4. JUNCTION HUNTERS.

4.1 Junction hunters are connected between group selector bank levels and relay-set repeaters, to increase the traffic carrying efficiency of the junction group. They are similar in operation to subscriber's uniselectors except that traffic is handled in one direction only. These switches must operate during the dial interdigital pause, and are usually of the non-homing type to reduce hunting time.

Fig. 15 shows the circuit of a non-homing type junction hunter. This circuit is arranged to advance the wipers two or three steps when the switch is seized, before testing for a free outlet. In this way successive calls will seize different junctions, preventing a caller continuously engaging a faulty junction.



JUNCTION HUNTER (C.1488).

FIG. 15.

4.2 The functions performed by this circuit are -

Junction Hunter.

(i) Advances the wipers two or three steps when seized.

(ii) Returns guarding and holding earth on P wire.

(iii) Hunts for and seizes the first free junction.

(iv) Prevents interference with circuits passed over while hunting.

(v) When release conditions are applied, disconnects the wipers. (Non-homing.)

Group Control Circuit. When all outlets in the group are busy -

(i) Marks all idle switches in group busy to searching selectors.

(ii) Returns busy tone to callers held in group.

(iii) Prevents continuous rotation of junction hunters.

4.3 The circuit operation is described below -

Switch Seized. Earth is extended by the group selector over the P wire and operates the drive magnet via its interrupter contacts, A2 and B4. At the same time the caller's loop completes the circuit of relay A, which operates slowly. The junction hunter self-drives until A operates, stepping the wipers two or three steps.

A2 opens the stepping circuit and earths the P wire to hold preceding switches and guard the connection.

A1, A3 and A4 complete the circuit for hunting and testing.

Hunting and Testing. A1 makes first to prevent premature operation of relay B. Earth on busy outlets operates the drive magnet via its interrupter contacts, A3 and B3, and the wipers step until a free outlet is reached. Relay B is no longer shunted, and operates from earth at A4 to battery through 300 ohm resistance (B).

Switching Through. B1, B2 and B4 switch the negative, positive and private wires respectively through to the relay-set repeater. B3 connects the P wire to relay B, which is held operated for the duration of the call by earth returned from the relay-set repeater. Relay A releases after its slow release period.

Release. When the calling party restores, earth is removed from the P wire at the relay-set repeater and relay B releases, disconnecting the wipers.

All Outlets Busy. When the last outlet is taken into use, the relay-set repeater chain contacts complete the circuit for the operation of the chain relay CH.

CH1 opens the circuit of relay OM, which is normally operated. The contacts of OM remove battery from all junction hunter drive magnets in the group, preventing continuous rotation, and replace it with earth through a protective resistance to busy all idle switches.

CH2 removes the earth from junction hunter B2 contacts, preventing the operation of relay A should a caller have switched to a junction hunter in the busy group before the operation of the chain relay. Busy tone is given to the caller in this case.

/ 5.

5. DISCRIMINATING SELECTOR REPEATERS.

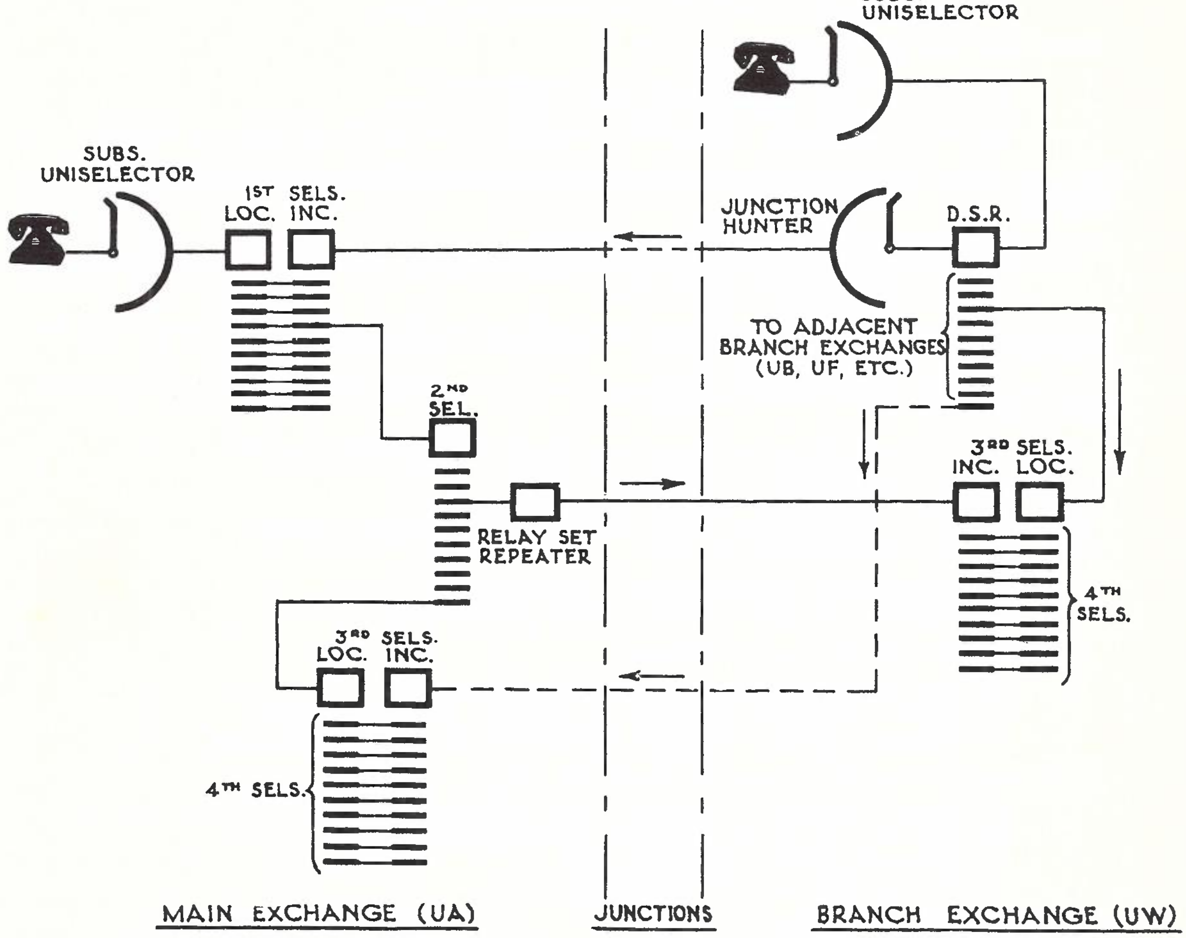
5.1 This switch is used in branch exchanges to provide a means of releasing the junctions to the main exchange, and the selectors there, when a call originating in the branch exchange terminates in the same branch exchange, or an adjacent satellite exchange. By this means, the number of junctions required between the branch exchanges and the parent main exchange is reduced, and there is a saving in the amount of switching plant necessary at the main exchange.

As explained in paragraphs 2.7 to 2.9 the Discriminating Selector Repeater (D.S.R.) provides means of routing a call -

(i) Via the parent main exchange to other main exchange groups.
(ii) Direct to local 3rd selectors at the local branch exchange.
(iii) Direct to incoming 3rd selectors at an adjacent branch exchange.
(iv) Direct to incoming 3rd selectors at the parent main exchange.

A junction hunter is associated with each D.S.R. to enable a saving to be made in the number of junctions required to the main exchange.

Fig. 16 shows the trunking diagram of a typical branch exchange (UW) showing the routes a call may take.



BRANCH EXCHANGE (UW) TRUNKING DIAGRAM.

FIG. 16.

5.2 Digit on which Discrimination Takes Place. In this respect there are three types of D.S.R. One type discriminates whether the call will be completed over the junction to the main exchange or via a direct route, after the first digit has been dialled. These may be used only where no other numbers in the system begin with the same digit as those of the branch exchange. The other two discriminate on the second and third digits respectively.

The switch described discriminates on the second digit, since it is this type which finds most frequent application in practice.

5.3 Functions of D.S.R. Fig. 17 attached shows the circuit of a pre-2,000 type D.S.R., discriminating on the second digit, together with its associated junction hunter. The functions of this circuit are -

(i) When seized, connects a guarding and holding earth to the P wire.
(ii) Causes the junction hunter to operate and seize a junction to the main exchange.
(iii) Steps the wipers to the dialled level, and automatically cuts-in.

When the first digit dialled does not correspond with the first digit of the local branch exchange numbers -

(iv) Repeats the dialled impulses over the junction to the main exchange.
(v) Provides a transmission bridge to feed current to the caller.
(vi) When the called party answers -

(a) operates the calling party's meter, and
(b) reverses the current flow on the calling line.

(vii) When the calling party releases -

(a) allows the preceding switches to release,
(b) releases the junction hunter and junction, and
(c) releases itself, and gives a supervisory alarm if it fails to release.

When the first digit dialled corresponds with the first digit of the local branch exchange -

(viii) Releases the wipers from the bank level.
(ix) When the second digit is dialled, steps the wipers to the corresponding bank level, and automatically cuts-in.

When the call is to be completed over the junction to the main exchange - see (iv) to (vii) above.

When the call is to be switched directly (to local branch, adjacent branch, or parent main exchange) -

(x) Hunts for and seizes the first free trunk in the dialled level.
(xi) Releases the junction to the main exchange.
(xii) Repeats succeeding impulses to group selectors.
(xiii) Provides a transmission bridge to feed current to the caller.
(xiv) When the called party answers -

(a) operates the calling party's meter, and
(b) reverses the current flow on the calling line.

(xv) When the calling party releases -

(a) allows the preceding switches to release,
(b) allows following switches, or junction, to release, and
(c) releases itself, and gives an alarm if it fails to release.

(xvi) When all outlets in dialled level are busy -

(a) steps the wipers to the 11th bank contacts,
(b) releases the junction to the main exchange,
(c) operates an overflow meter, and
(d) returns busy tone to the caller.

Functions of Junction Hunter -

(i) Hunts for and seizes the first free junction when engaged by the D.S.R.
(ii) Prevents interference with circuits over which the wipers are passing.
(iii) Guards the seized junction from intrusion.

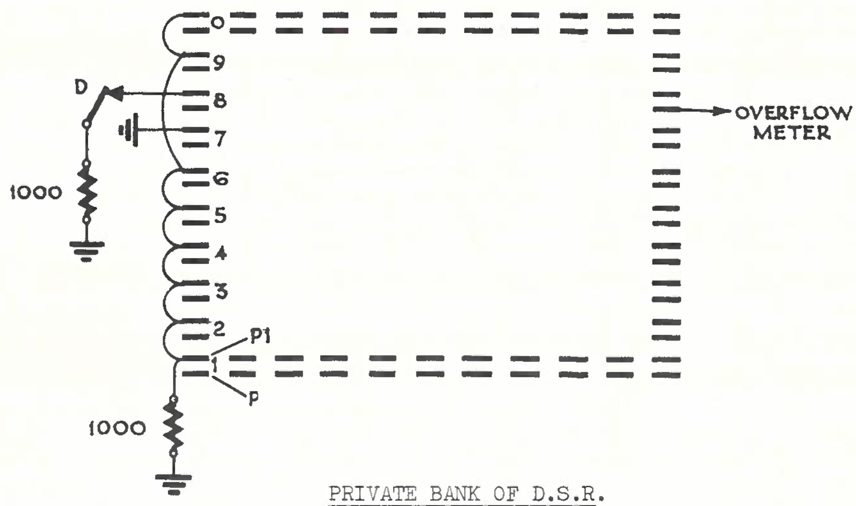
/ (iv)

(iv) If all junction outlets are busy -

(a) returns dial tone to the caller, and
(b) if the call is routed via the main exchange, returns busy tone to the caller after the necessary discriminating digits have been dialled.

(v) Advances the wipers when the switch is released.

5.4 Discrimination between Calls via Main Exchange and Calls Switched Directly. Associated with each normal private contact in the D.S.R. bank is an auxiliary private contact (P1). Discrimination between levels is made by means of the connections to the first P1 contact in each level, enabling the switch to determine the routing of the number being called. Fig. 18 shows the connections to the P1 contacts of D.S.R's. in the case of the branch exchange shown in Fig. 16. If direct junctions are provided to adjacent branch exchanges or to the parent main exchange, the P1 contacts of the corresponding bank levels are strapped to that of the local branch exchange level. The P1 contacts are individual to each switch bank and are not multipled as are normal bank contacts.



PRIVATE BANK OF D.S.R.

FIG. 18.

When the first digit dialled corresponds to that of the local branch exchange, in this case U, the P1 wiper encounters earth, resulting in the operation of relay D and the release magnet. The D.S.R. releases, but the 1st selector at the main exchange is held.

The second digit again steps the D.S.R. wipers and if direct switching is required, no earth is found by the P1 wiper, this being removed by the operation of relay D. This allows the D.S.R. to function as a selector-repeater, and the junction to the main exchange is released.

If the first or second digits dialled do not correspond with those of the local or adjacent exchanges, earth via 1,000 ohms allows relay K to operate (but not the release magnet) and the D.S.R. functions as a repeater, the wipers remaining on the first contacts of the dialled level.

5.5 The operation of the D.S.R. and associated junction hunter (Fig. 17 attached) is described below -

D.S.R. Seized. The subscriber's loop is extended from the line circuit and relay A operates via F1 and F2 in series with 150 ohm resistors YB and YC. A1 completes the circuit for relay B, which operates. B1 earths the P wire via F4. B2 completes the circuit of the polarising winding of shunt-field relay E, and also that of relay J via K3 and D4. J operates and locks via J3 and F3. B3 prepares the vertical stepping circuit. J4 completes the supervisory alarm circuit to indicate permanent loop conditions.

Junction Hunter Seized. A2 loops the junction hunter JA relay from battery via 300 ohms (JB), JB3, H4, 500 ohm (H), E1, line winding of relay E (which does not operate), A2, H5 and JB2. JA operates and JA3 connects the junction hunter drive magnet to the P wiper,

/ causing

causing the junction hunter to step the wipers over busy contacts, which are marked by earth.

During hunting, relay JB is shunted by earth from busy private contacts on one side, and earth from the D.S.R. hold lead via B2, J1, B5, H2 and S2 on the other side, and when a free outlet is reached JB operates in series with the drive magnet. JB1 connects relay JA to the drive magnet, JA and JB both remaining operated.

JB4 operates the CH relay associated with the seized junction, and CH2 guards the junction from intrusion. JB2 and JB3 switch the D.S.R. loop through to the junction and the 1st selector at the main exchange is seized. Dial tone is returned to the calling subscriber from the 1st selector via transmission condensers, QA and QB.

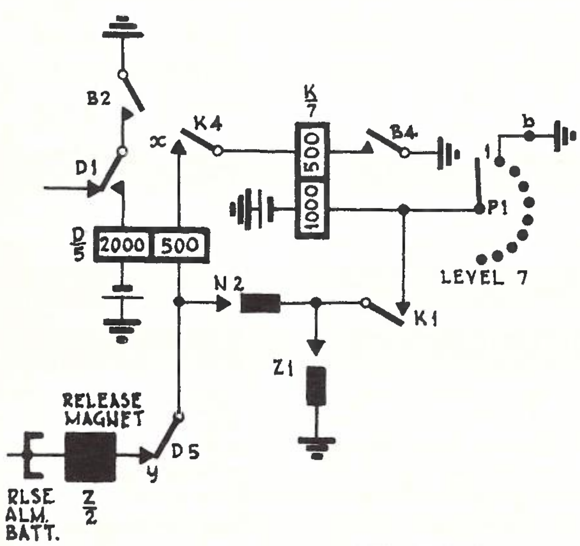
All Junction Hunter Outlets Busy. Should a calling subscriber seize a D.S.R. associated with a junction hunter from which all outlets are busy, relay JA is prevented from operating by the operation of relay ATB when the chain circuit is completed. Relay JB operates in series with the drive magnet to earth from the D.S.R. hold lead, and dial tone is fed to the calling subscriber from the D.S.R. tone lead via D2, JA1, JB3 and H4. This allows the call to proceed although no junction to the main exchange is available. Should the call be routed via the main exchange, the operation of relays D and K give busy tone to the caller after the discriminating digits have been dialled.

First Digit Dialled. Relay A responds to the impulses from the calling subscriber's dial. A1 normal completes the circuit of the vertical magnet and relay C in parallel. A2 repeats the impulses over the junction loop, causing the 1st selector at the main exchange to be stepped in synchronism with the D.S.R. C2 short-circuits the line winding of relay E and 500 ohm (H) to give an impulsing loop of low impedance. C1 prepares a circuit for relay G, which operates from earth at B2 during the first vertical step when the vertical off-normal springs (N) operate. G2 holds G operated when C falls back at the end of the impulse train, and G1 and C1 complete the rotary magnet circuit from earth at B2.

The rotary magnet operates to step the wipers on to the first bank contacts of the dialled level, and opens the circuit of relay G at its interrupter contact R1.

G releases, and G1 releases the rotary magnet.

Discriminating - Local Level. If the digit dialled corresponds to the first digit of the local branch exchange numbers, in this case 0, the wipers will be positioned on the first contacts of level 7. As shown in Fig. 19, the first P1 contact of this level is wired directly to earth and relay K operates over the P1 wiper to this earth. K1 completes an operating circuit for the release magnet from the earth on the P1 wiper via N2 and D5, and K1 provides a locking circuit for the release magnet and relay K until the shaft has restored to normal.



After Rotary Cut-In -

K operates.
Release magnet operates.

When D.S.R. Reaches Normal -

Release magnet releases.
D operates and locks.
K releases.

DISCRIMINATING - LOCAL LEVEL.

FIG. 19.

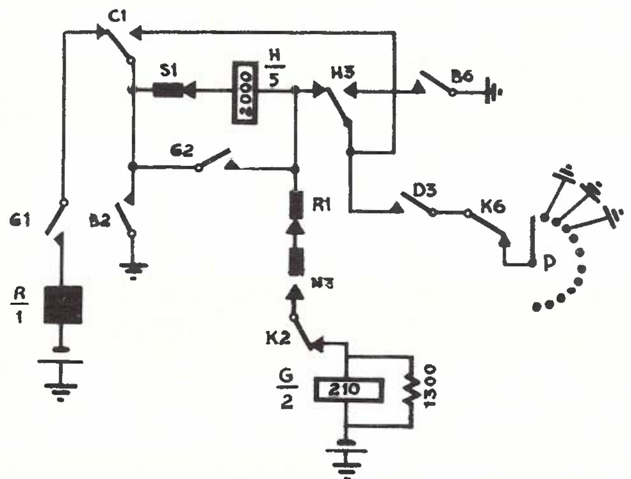
The 500 ohm windings of relays D and K are short-circuited until N2 breaks, when the release magnet releases. D operates and K holds in series with the release magnet. D1 locks D on its 2,000 ohm winding and removes the marking condition from tags "d" and "c". D5 opens the circuit of the 500 ohm windings of relays D and K, and K releases.

Thus, after the first digit of the local number has been dialled, the D.S.R. restores to normal with relays A, B, D and J operated. The first digit is said to have been "absorbed". Junction hunter relays JA and JB are operated, and the junction is held.

Second Digit Dialled. The second train of impulses is repeated over the junction as before, and the D.S.R. steps to the dialled level in synchronism with the main exchange 2nd selector. Relay G again operates when the switch moves off-normal, and, when C releases at the end of the impulse train, the rotary magnet operates and steps the wipers on to the first bank contacts of the dialled level.

Call to Local Branch Exchange. If the digit dialled corresponds to the second letter of the local branch exchange numbers, in this case W, the P1 wiper encounters an open condition, as the marking earth is removed at D1, and relay K cannot operate.

The outlets of this level are trunked to local 3rd selectors (see Fig. 16) and the D.S.R. now hunts over the level and seizes the first free outlet. (Fig. 20.)



On Busy Outlets -

G operates.
Rotary magnet operates.
G releases.
Rotary magnet releases.

On Free Outlet -

H operates.

HUNTING AND TESTING.

FIG. 20.

With K normal, when relay G and the rotary magnet release after the wipers reach the first contacts, a testing circuit for relay G is completed via K2, N3, R1, H3, D3 and K6 to the P wiper. If the first outlet is busy, G operates and holds via G2, and G1 closes the rotary magnet circuit, releasing G when the rotary interrupter contact opens. This cycle of operations continues until a free outlet is found, or the 11th contacts are reached. Relay H is short-circuited by the earth on busy P contacts, and when a free outlet is reached, H operates in series with relay G to earth at B2. (G does not operate.) H1 opens the hold lead to the junction hunter, allowing relays JB and JA to release, and the junction to the main exchange is cleared. H4 and H5 extend the negative and positive wires through to the 3rd selector, and H3 connects a guarding earth to the P contact of the seized trunk. H2 opens the circuit of the vertical magnet to prevent

/ further

further stepping when subsequent impulse trains are transmitted. These are repeated to the local selectors, relay C operating on each train. A small condenser, QD, and resistor YG act as a spark quench on the A2 contacts.

Called Party Answers. When the called party answers, the current feed from the final selector is reversed and shunt-field relay E operates. E1 connects relay F into the holding loop, reducing shunt losses. F operates, and F1 and F2 reverse the current feed to the caller. E2 completes a local loop circuit via 3,000 ohm YF to prevent relay A flicking during the reversal. F4 connects positive battery via protective resistance YA to the P wire to operate the caller's meter. F3 opens the holding circuit of relay J, which releases slowly, and reconnects earth to the P wire at J5. Rectifier MRA maintains earth on the P wire while F4 and J5 are changing-over. J2 opens the local A relay loop.

Release. When the caller restores, relay A releases, followed by relay B, and the release magnet is energised via N1 and B3 to earth at A1. The switch restores, opening the release magnet circuit at N1. During release the switch is guarded by earth from Z2.

All Outlets Busy. If all outlets on the selected level are busy, the wipers are stepped to the 11th bank contacts, and the 11th step contacts S operate. S1 opens the circuit of relay H to prevent its operation. S2 opens the junction hunter hold lead to release relays JB and JA, and free the junction to the main exchange. S3 opens the vertical magnet circuit to prevent its operation should the caller continue to dial. S4 connects busy tone to the calling line via the transmission condenser QA. The overflow meter is operated in series with relay G (which does not operate) via K2, N3, R1, H3, D3, K6 and the P wiper.

Calls to Adjacent Branch or Parent Main Exchange. Where direct junctions exist to incoming 3rd selectors at adjacent branch exchanges, or at the parent main exchange the first P1 contacts of the D.S.R. bank levels corresponding to the second digits of these exchange numbers are treated in the same way as the local branch exchange level, that is, strapped to tag "c". The circuit operation is similar to that described above, the third and subsequent impulse trains being repeated over the direct junction to selectors at the branch or main exchange.

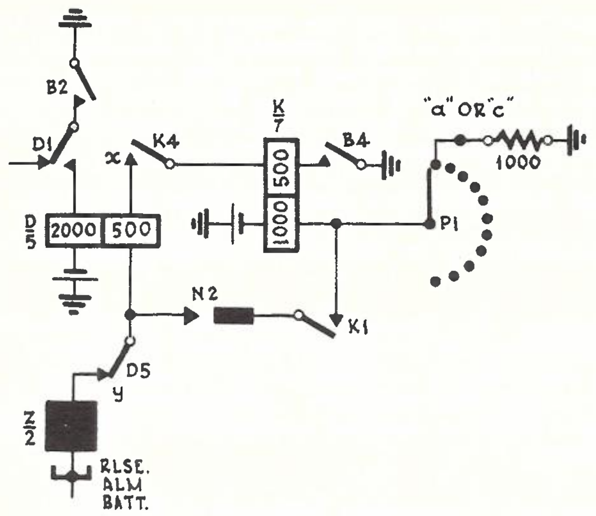
Where the same level corresponds to both first and second digits of local or adjacent exchange numbers, for example, UU, the first P1 contact of that level is strapped to tag "d". Thus, on the completion of the first impulse train the P1 wiper encounters earth via D1 and B2, and the digit is absorbed. Relay D operates when the shaft restores and D1 removes the earth for discrimination on the second digit.

Calls Via Main Exchange. The first P1 contacts of levels other than those corresponding to the first digit of local exchange numbers are connected to earth via 1,000 ohm resistance on tags "a" or "c". On a call routed via another main exchange the P1 wiper encounters this condition on cutting-in after the first impulse train, and relay K operates. K4 connects the 500 ohm windings of relays K and D in series with the release magnet (which does not operate). D operates and locks via D1 to earth at B2. D5 opens the release magnet circuit, but K holds with both windings in series via K1, N2, K4 and B4 (see Fig. 21).

On a call to a branch exchange or the parent main exchange not connected by direct junctions, the first digit is absorbed as described on page 20, and relay D operates and locks. After the second impulse train the P1 wiper encounters earth via 1,000 ohms and relay K operates and locks.

/ Thus

Thus, if a call is to be routed over the junction to the main exchange, relays D and K will have operated when the digits necessary for discrimination have been dialled. D2 and K5 connect busy tone to the junction hunter tone lead and if all junction hunter outlets are busy (see page 20), busy tone is now given to the caller. Assuming that a junction has been seized, subsequent impulse trains are repeated to the main exchange selectors, relay C operating on each train. K7 prevents further operation of the vertical magnet. K2 opens the circuit of relay G to prevent it operating via C1 during impulsing. K3 provides an alternative circuit to hold the junction hunter when J1 releases later.



After Rotary Cut-In -

K operates and locks.
D operates and locks.

CALL VIA MAIN EXCHANGE.

FIG. 21.

Thus, the D.S.R. wipers remain on the first contacts of the level dialled and the switch functions as a repeater during the call. The operation when the called party answers is similar to that described on page 22.

Release of D.S.R. When the calling party replaces the receiver, relay A releases, followed by relay B. A2 opens the junction loop, allowing the selectors at the main exchange to restore. B1 removes the earth from the P wire, allowing preceding switches to release. A1 and B3 close the release magnet circuit and the D.S.R. restores, being guarded during release at Z2. N1 opens the release magnet circuit when the switch reaches the normal position, and the switch is free to accept the next call.

Release of Junction Hunter. The release of the junction hunter takes place when the earth on the hold-lead is removed, allowing relay JB to release. JB1 opens the circuit of relay JA and closes a circuit for the operation of the junction hunter drive magnet from earth at CH2 via JB1 and JA3. The wipers are stepped to the next outlet ensuring that different junctions are seized on successive calls. This reduces the possibility of a calling subscriber continually engaging a faulty junction.

The circuit of relay CH is opened at JB4, and CH releases slowly. CH2 guards the junction during the release time of CH to allow the main exchange selectors to restore fully before the junction is freed.

6. JUNCTIONS TO MANUAL EXCHANGES.

6.1 It has been considered, for the sake of convenience, that all exchanges in a network are of the automatic type. As it is impossible to convert all the exchanges simultaneously to automatic working, there will be a "transition period" when automatic and manual exchanges will exist side by side. It is necessary, therefore, to provide means for completing calls in either direction between automatic and manual exchanges.

As the metering system used in Australia permits only one operation of the calling subscriber's meter for each call, subscribers are not permitted to dial directly to exchanges outside the unit fee area, and it is necessary to provide a manual switchboard to deal with trunk calls, and to provide for Inquiries, Phonograms and similar services. Automatic junctions to and from these switchboards are considered in the Papers dealing with Trunk Exchanges. Within a network calls may be made -

(i) From an automatic exchange subscriber to a manual exchange subscriber.

(ii) From a manual exchange subscriber to an automatic exchange subscriber.

6.2 Calls from Automatic to Manual Exchanges. The automatic subscribers are instructed to dial a special number, consisting of one or two digits, to reach the desired manual exchange, where the call is completed by an operator who ascertains the desired number. This procedure is called "dialling-out". Arrangements are usually made whereby the calling subscriber's meter is operated automatically when the manual subscriber lifts the receiver to answer.

The circuit conditions depend on the type of equipment installed at the manual exchange, which may be C.B., Magneto Multiple, or Magneto Non-multiple. Details of the automatic exchange circuits will be given, together with the principles of working at each type of manual exchange.

Outgoing junctions to manual exchanges are trunked from the relevant selector bank levels, and relay-set repeaters must be inserted at the outgoing end to allow two-wire junction circuits to be used. These relay-sets provide the same facilities as the repeater (Auto-Auto) described in paragraph 5.2. In addition the relay-set must perform the following functions.

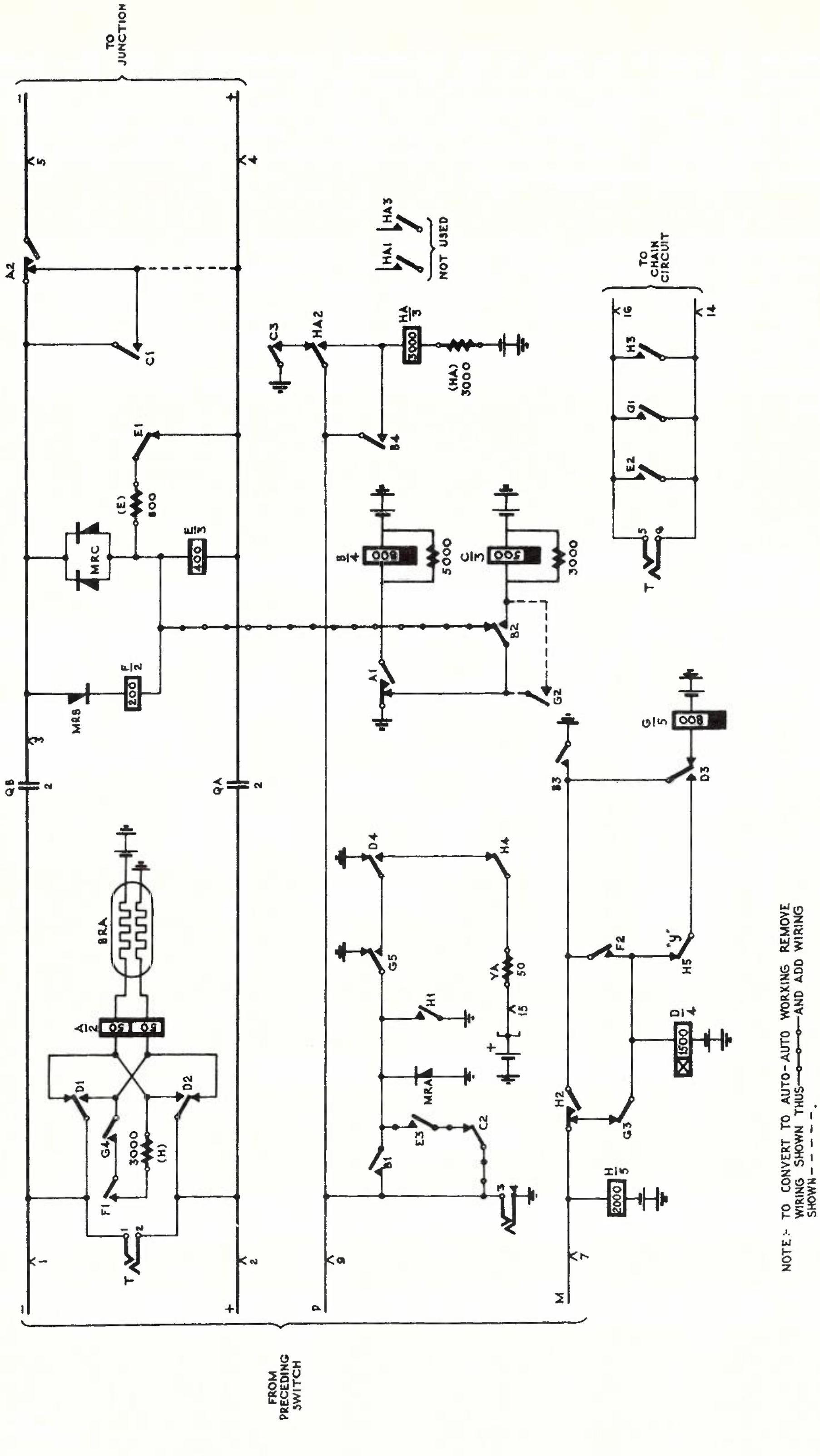
(i) Light a calling lamp in the distant manual exchange.

(ii) Light the supervisory lamp in the cord circuit at the manual exchange when the calling subscriber replaces the receiver.

In an auto-auto connection, both ends of the junction are released simultaneously when the calling subscriber hangs up, whereas in an auto-manual connection only the outgoing end is released. The incoming end is not released until the cords are cleared by the telephonist, so that the relay-set must guard the junction as long as a cord is connected to the incoming end at the manual exchange.

6.3 Relay-Set Repeater (Auto-Manual Convertible to Auto-Auto). As it is anticipated that the manual exchanges will eventually be converted to automatic, an interchangeable circuit is generally used. (Fig. 22.) When the manual exchange is converted to automatic a slight modification in the wiring will enable the circuit to function as a repeater (auto-auto).

/ Fig. 22.

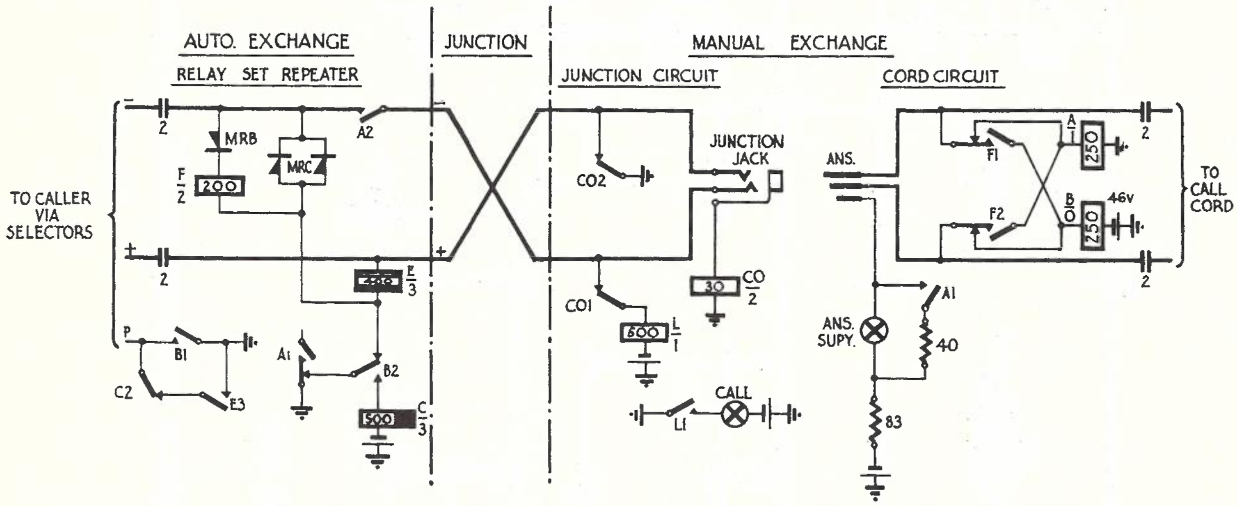


RELAY-SET REPEATER (AUTO-MANUAL CONVERTIBLE TO AUTO-AUTO). (CE. 53, SHEET 2.).

FIG. 22.

The circuit operation is similar to that of the relay-set (auto-auto) of Fig. 12. Earth to hold the preceding switches is applied to the P wire by B1, and A2 extends a loop over the junction to the manual exchange, operating a line relay there, and causing a calling lamp to glow. (See Fig. 23.) The current on the junction is reversed when the called subscriber answers, and relays F and D operate. The conditions are the same as in the repeater (auto-auto) until release takes place.

On the calling subscriber hanging up, relay A releases to operate relay C during the release time of relay B. A2 opens the loop to the manual exchange to give a clearing signal. When B releases, relay E is held via B2 from earth at A1 over the positive wire of the junction line to negative battery via retard B in the manual exchange cord circuit. B1 removes earth from the P wire to release preceding switches and relay HA releases. After the release time of HA, approximately 15-20 mS, the P wire is re-guarded via C3 and HA2, until C releases, when earth via E3 and C2 maintain the guarding earth so long as E remains operated.



ELEMENTS OF AUTOMATIC-MANUAL CONNECTION.

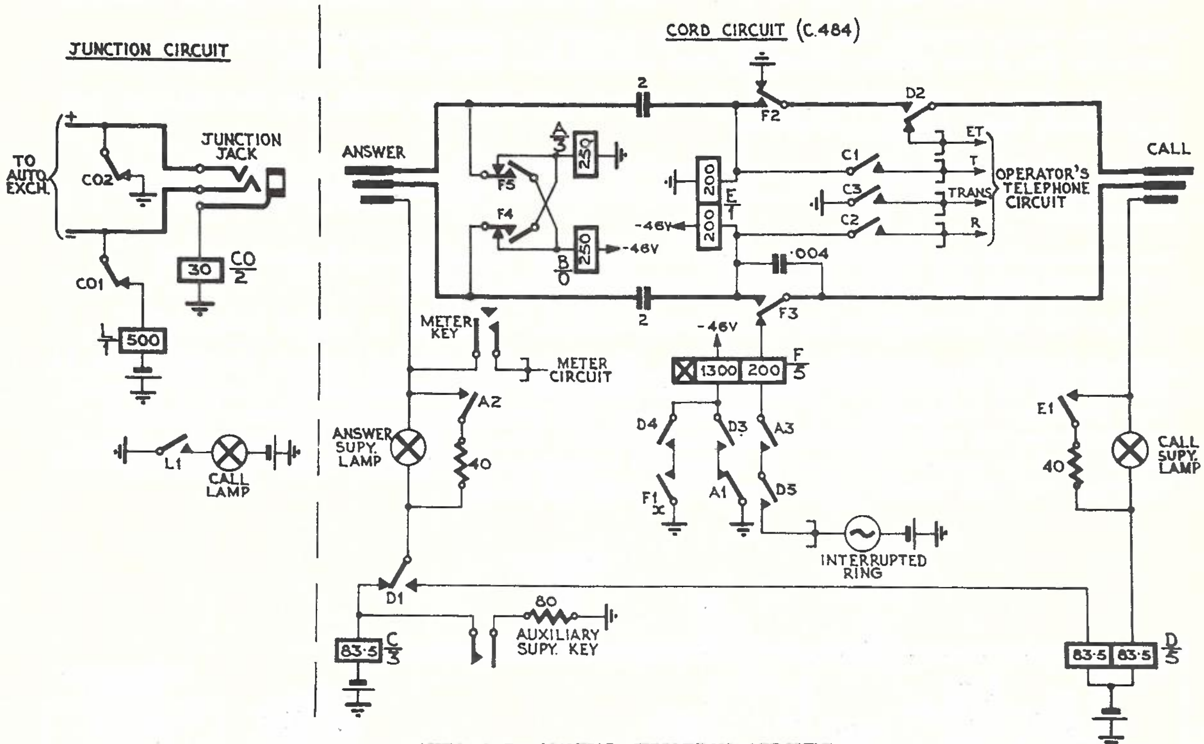
FIG. 23.

Thus the junction is guarded against intrusion until the cord circuit is cleared at the manual end, when negative battery on the positive wire is removed, and relay E releases.

A small 46 volt battery is usually installed at the manual exchange to supply the current over the junction. This enables the circuit to function over long junction lines.

6.4 Junction Circuits - Automatic to C.B. Manual. The circuit of a typical incoming junction and cord circuit at a C.B. Manual Exchange is shown in Fig. 24. The junction circuits terminate on special "Auto. A" positions, and calls are completed by the telephonist via the multiple jack field. The cord circuit gives the following facilities -

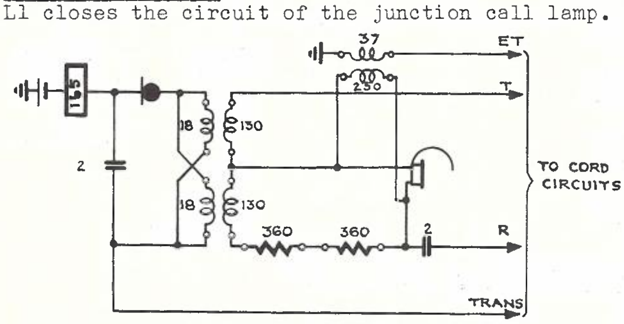
- (i) May be used for local or junction calls. (Universal cord circuit.)
- (ii) Gives normal supervision on all calls.
- (iii) Keyless ringing, and ring tone given to caller while ringing conditions are applied.
- (iv) Gives reversal of current on junction line for supervision and metering, when called party answers.
- (v) Guards junction until cords are cleared by telephonist.



AUTO-C.B. MANUAL JUNCTION CIRCUIT.

FIG. 24.

Circuit Operation. The loop from the relay-set operates relay L over the junction, and L1 closes the circuit of the junction call lamp.



"AUTO A" POSITION OPERATOR'S TELEPHONE CIRCUIT.

FIG. 25.

The telephonist answers by placing an answering plug in the junction jack, operating relay CO in the line circuit and C in the cord circuit in series. CO1 and CO2 open the circuit of relay L, and the call lamp is extinguished. The current to the junction is fed from the cord circuit via relay A and retard B, and A operates. A2 shunts the answering cord supervisory lamp. The contacts of relay C connect the operator's telephone circuit to the cord circuit and the required number is requested of the caller. (Fig. 25).

Before inserting the calling plug into the multiple jack an engaged test is made, the circuit being from the tip of the calling plug, via D2 and the 37 ohm winding of the

/ engaged

engaged test induction coil to earth.

Relay D operates in series with the called subscriber's CO relay when the calling plug is inserted. D1 opens the circuit of relay C, disconnecting the operator's circuit. D5 and D2 complete the ring and ring return circuits. A small condenser allows a portion of the ring current to be fed back to the caller to give a ring tone. The calling cord supervisory lamp is energised in series with the sleeve circuit.

When the called party answers, relay F operates on its 200 ohm winding, locking up on its 1,300 ohm winding via F1 and D4. F2 and F3 disconnect the ringing circuit and connect the called party to the transmission bridge, when relay E operates, and shunts the calling cord supervisory lamp at E1. F4 and F5 reverse the current flow on the junction.

When the caller clears, the junction loop circuit is opened and relay A releases, removing the shunt on the answering cord supervisory lamp, which glows.

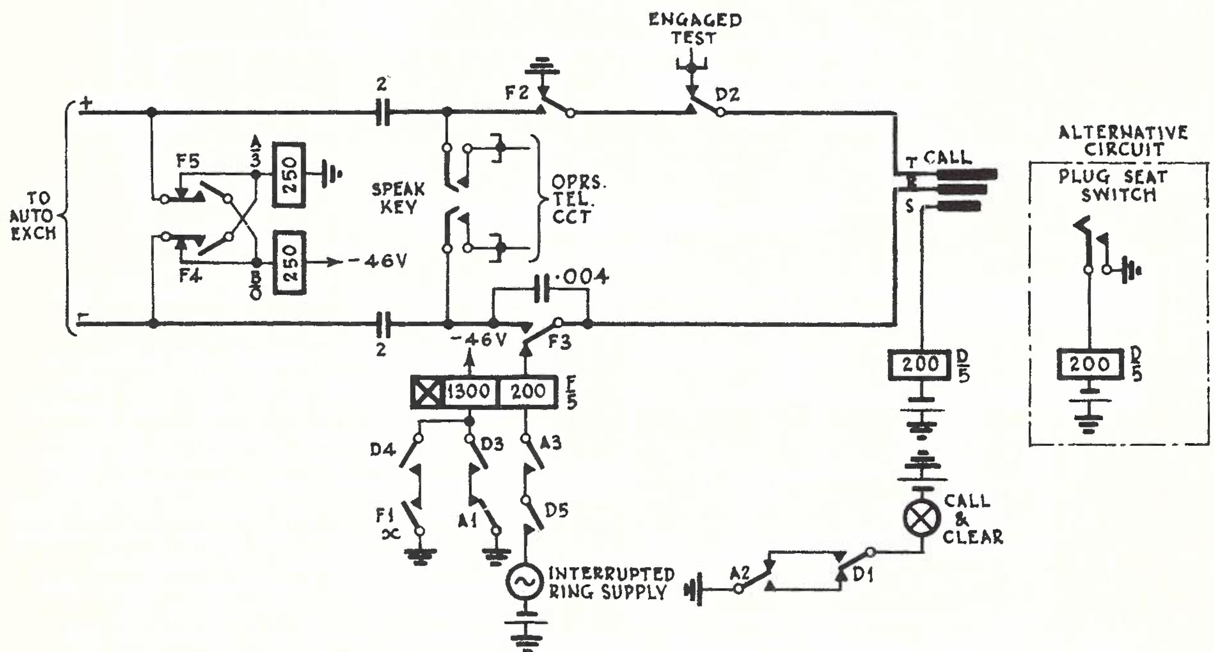
When the called party clears, relay E releases, removing the shunt from the calling cord supervisory lamp, which also glows.

If the caller clears before the called party has answered, relay F is operated on its 1,300 ohm winding via D3 and A1, tripping the ring and guarding the junction from intrusion.

The telephonist may supervise the call by operating the Auxiliary Supervisory key associated with the cord circuit, allowing relay C to operate.

A meter key is provided to enable the cord circuit to be used to answer local calls.

6.5 Junction Circuits - Automatic to Magneto. (Multiple.) A similar circuit to that shown in Fig. 24 may be installed at large magneto exchanges for the completion of calls incoming from automatic exchanges. It is necessary to fit condensers in the magneto telephone bell circuits to give the necessary supervision. Fig. 26 shows the circuit of a plug-ended junction circuit for use in a magneto branching multiple exchange, where relay D is operated over the sleeve conductor of the junction plug.



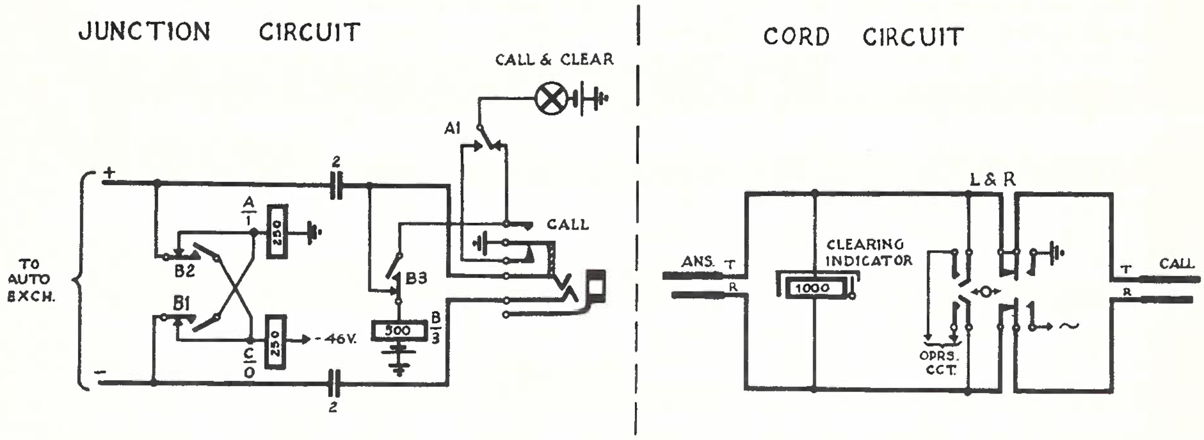
AUTO-MAGNETO JUNCTION CIRCUIT (C.485).

FIG. 26.

Relay F operates when the called party answers, tripping the ring, and giving a current reversal on the junction.

In other types of magneto exchanges, relay D may be operated by means of a plug seat switch operating when the junction plug is lifted.

6.6 Junction Circuits - Automatic to Magneto (Non-Multiple). Smaller non-multiple exchanges generally have simpler junction circuits, with manual ringing. The incoming junctions may terminate on jacks on the A positions, and calls are answered with regular cord circuits. Fig. 27 shows a typical circuit. This circuit has a serious disadvantage in that reversal of current is given when the ringing key is operated, even though the called party may not answer, and these calls must be rebated to the caller.

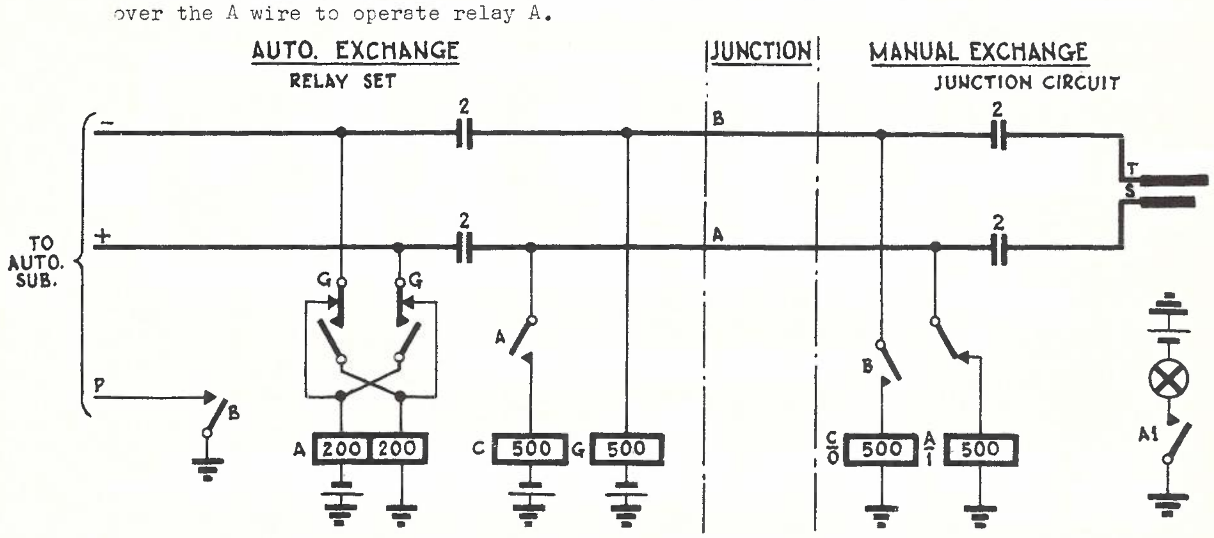


AUTO-MAGNETO JUNCTION CIRCUIT (C.505).

FIG. 27.

An alternative circuit has a metering key associated with each junction circuit, and this is pressed by the telephonist after the called party has answered, operating relay B.

6.7 Junction Circuits - Automatic to Magneto (Earth Return Signalling). Various relay-set (auto-manual repeater) circuits are in use in the earlier automatic exchanges. Generally speaking, these were designed to work on auto-manual junctions with a minimum alteration to plant at the manual end. One type uses "Earth Return" signalling, the elements of which are shown in Fig. 28. The manual exchange is called by connecting negative battery over the A wire to operate relay A.



ELEMENTS OF EARTH RETURN SIGNALLING.

FIG. 28.

When the call matures, earth through a reactance is applied to the B wire and operates relay G in the automatic exchange relay-set. The contacts of G reverse the current feed to the calling subscriber.

6.8 Junction Circuits, Automatic to Magneto (Trapping of Follow-on Calls.) A circuit has been developed (CE-139) which does not guard the incoming junction after the calling subscriber clears, but gives an indication to the manual telephonist by means of a flashing lamp in the case of the junction being re-seized before the cords are cleared.

This scheme is slightly more economical as regards junctions, since there is practically no ineffective time at the end of a conversation. Moreover, standard auto-auto relay-sets may be used at the automatic exchange. The circuit, however, is rather complex and its use will be limited to new installations to avoid extensive alterations at existing manual exchanges.

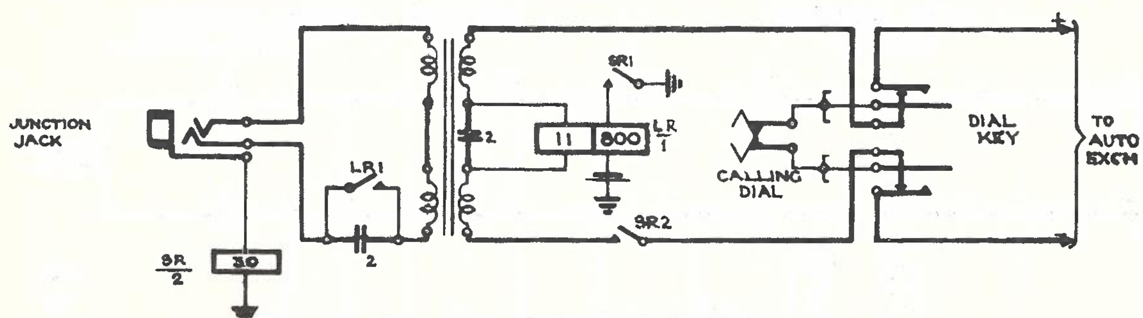
6.9 Calls from Manual to Automatic Exchanges. Junctions from manual exchanges usually terminate on 1st selectors at an adjacent main automatic exchange.

Both-way junctions are provided when traffic conditions determine such an arrangement to be the most economical. When this type of circuit is provided the automatic exchange end is generally terminated on a uniselector, through which access to a group of selectors is given.

At the manual board, the junctions terminate on jacks in the outgoing junction field, and, to enable the telephonist to reach the automatic subscribers, a dial (or its equivalent) is installed on each position.

A manual exchange telephonist can complete a call by plugging into a junction to the automatic exchange and dialling the number of the subscriber required. This process is called "dialling-in". The telephonist must be able to distinguish free junctions from busy ones and this discrimination may be given by the normal engaged test in a multiple exchange, or by lamp signals. Of the latter scheme, one method indicates all busy lines by a lighted lamp above the jack, the other indicates the next free line by a lighted lamp. If a group of junctions is small, then the first method (busy lamps) is favoured because of its simplicity, but if a large group is involved the second method (free line lamps) is used to reduce battery consumption to a minimum.

6.10 Junction Circuits - C.B. Manual to Automatic. A typical junction outgoing to automatic from a small C.B. manual exchange is shown in Fig. 29. A dial is provided on each position and is connected in circuit by a dial key in each junction circuit.



C.B. MANUAL-AUTOMATIC JUNCTION.

FIG. 29.

On calls for automatic subscribers the telephonist plugs the calling cord into a junction jack, and, on the receipt of dial tone, operates the dial key and dials the required number.

/ Relay

Relay SR is operated (and the junction marked busy) by the negative battery via the cord circuit sleeve conductor, and SR2 gives a loop to the automatic exchange, seizing a 1st selector. SR1 energises the polarising winding of relay LR which does not operate, as the current in the line winding is in opposition.

The operation of the dial key connects the dial to the junction and the required number is dialled. The contacts of the dial key are make-before-break to avoid giving a false impulse on operation.

When the called party answers, the current on the junction is reversed and relay LR operates. LR1 completes a loop for the cord circuit supervisory relay and the supervisory lamp is dimmed.

6.11 Keysenders. When a large number of junctions is involved the above method becomes unwieldy and expensive because -

(i) The time to operate a dial is too long for a busy telephonist.

(ii) The associated apparatus requires too much space on the face of the A positions.

(iii) The maintenance on dials is expensive due to the heavy use.

One method of overcoming these difficulties is by the use of "keysenders". A keysender consists of a desk and associated apparatus. On these desks the required number is "set up" by depressing push keys with which is associated a machine which stores the impulses and sends them out to the automatic equipment once a free junction has been seized.

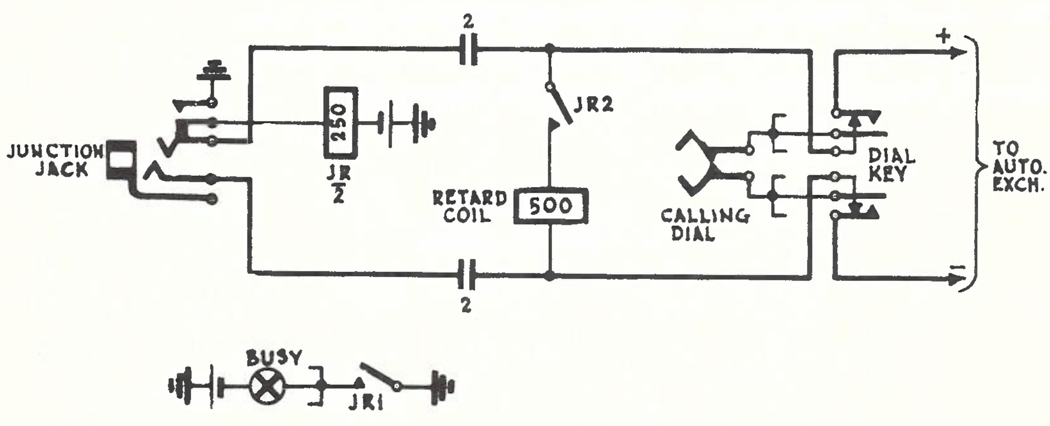
The method of operation is as follows -

(i) The A position telephonist presses an order-wire key and passes the required number to the operator at the keysender desk.

(ii) The keysender operator allots a junction to the A telephonist and sets up the required number, then presses the junction key which connects the keysender to the allotted junction for the transmission of impulses.

(iii) The A telephonist meanwhile plugs the calling cord into the allotted junction jack, appearing in the outgoing junction multiple.

6.12 Junction Circuits - Magneto to Automatic. A typical circuit is shown in Fig. 30.



MAGNETO-AUTOMATIC JUNCTION CIRCUIT.

FIG. 30.

The telephonist plugs the calling cord into a junction jack, operating relay JR. JR1 causes the busy lamps associated with that junction to glow. JR2 loops the junction and dial tone is returned from the first selector at the automatic exchange. The operation of the dial key connects the position dial to the junction and the required number is dialled.

When conversation is finished, the magneto subscriber rings off and the telephonist removes the plugs, restoring the circuits to normal.

7. TEST QUESTIONS.

1. In a multi-exchange area the allocation of subscribers numbers is -

Main exchange	... ...	BA1000-7999
Branch exchange (with D.S.R.)	...	BJ1000-2199
Satellite exchange	... ...	BJ6100-6699

Give a simple sketch showing the trunking scheme that would be employed.

2. In the case of the branch exchange in (1), explain what happens when a local number is dialled.

3. What functions are performed by a relay-set repeater (auto-auto)?

4. Why is it usual to install auto-manual relay-sets which are convertible to auto-auto? What are the different requirements? State briefly how these requirements are provided.

8. REFERENCES.

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Volume 3, No. 5 - "Direct Switching Between Auto. Branch Exchanges" by D. J. Mahoney.

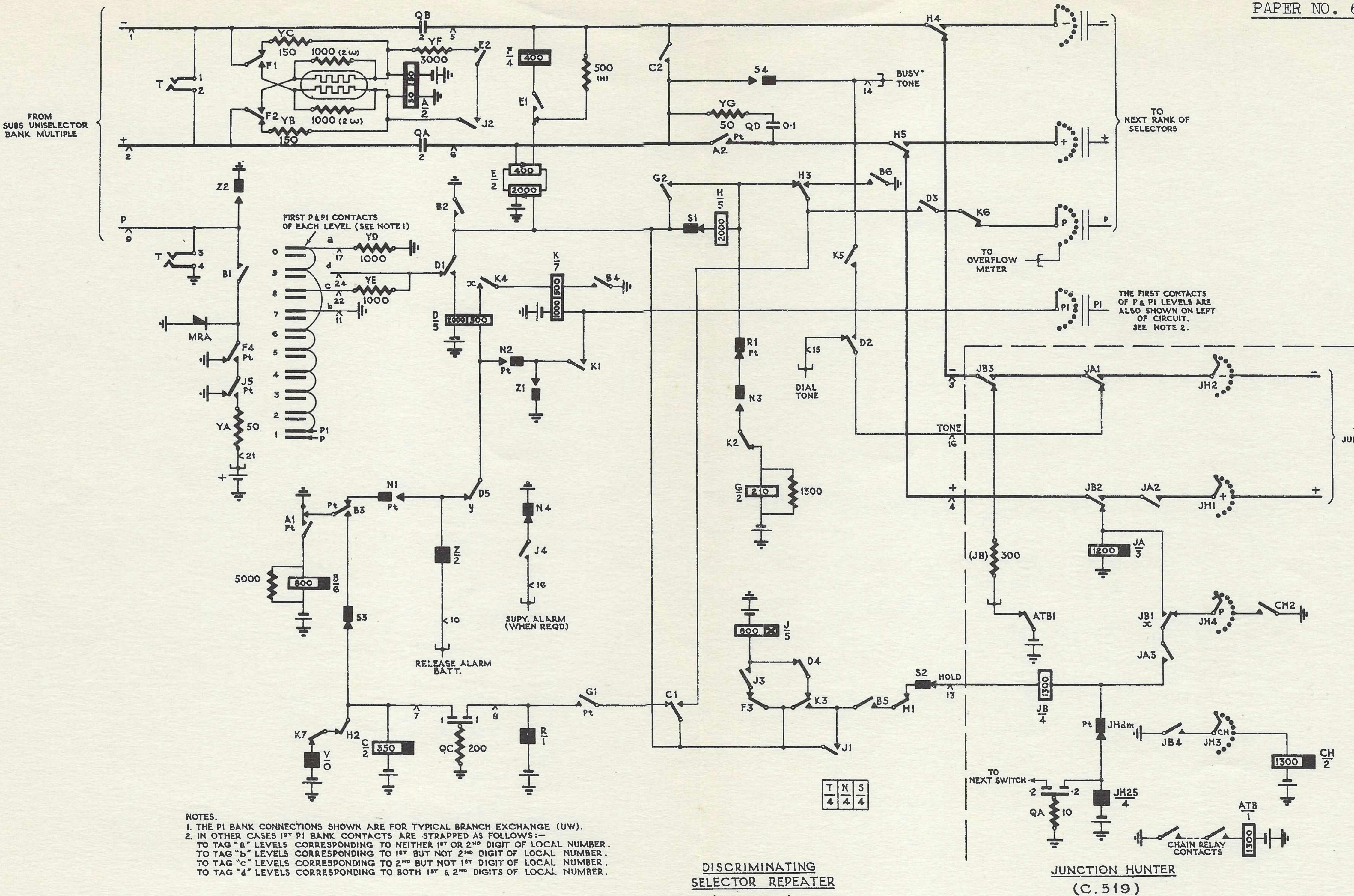
Volume 5, No. 1 - "The Melbourne Telephone Network Plan" by C. J. Prosser.

Volume 5, No. 6 - "Relay-Set Repeaters" by O. C. Ryan.

Volume 7, No. 2 - "Impulsing in Multi-Exchange Networks" by W. King.

"Telephony" by Herbert and Proctor. Volume II, Chapter IX.

END OF PAPER.



NOTES.
1. THE P1 BANK CONNECTIONS SHOWN ARE FOR TYPICAL BRANCH EXCHANGE (UW).
2. IN OTHER CASES 1ST P1 BANK CONTACTS ARE STRAPPED AS FOLLOWS:—
TO TAG "a" LEVELS CORRESPONDING TO NEITHER 1ST OR 2ND DIGIT OF LOCAL NUMBER.
TO TAG "b" LEVELS CORRESPONDING TO 1ST BUT NOT 2ND DIGIT OF LOCAL NUMBER.
TO TAG "c" LEVELS CORRESPONDING TO 2ND BUT NOT 1ST DIGIT OF LOCAL NUMBER.
TO TAG "d" LEVELS CORRESPONDING TO BOTH 1ST & 2ND DIGITS OF LOCAL NUMBER.

DISCRIMINATING SELECTOR REPEATER AND ASSOCIATED JUNCTION HUNTER.

FIG. 17.

COMMONWEALTH OF AUSTRALIA.

Engineering Services,
Postmaster-General's Department,
Treasury Gardens,
Melbourne, C.2.

COURSE OF TECHNICAL INSTRUCTION.

STROWGER AUTOMATIC EXCHANGES.

CONTENTS.

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1. MOUNTING OF APPARATUS.

1.1 In previous Papers, information has been given regarding the individual switches in a Strowger exchange, and trunking schemes, showing how the various switches are used to set up calls between subscribers, have been shown. This Paper deals with the methods in which switches are mounted, cabled and interconnected.

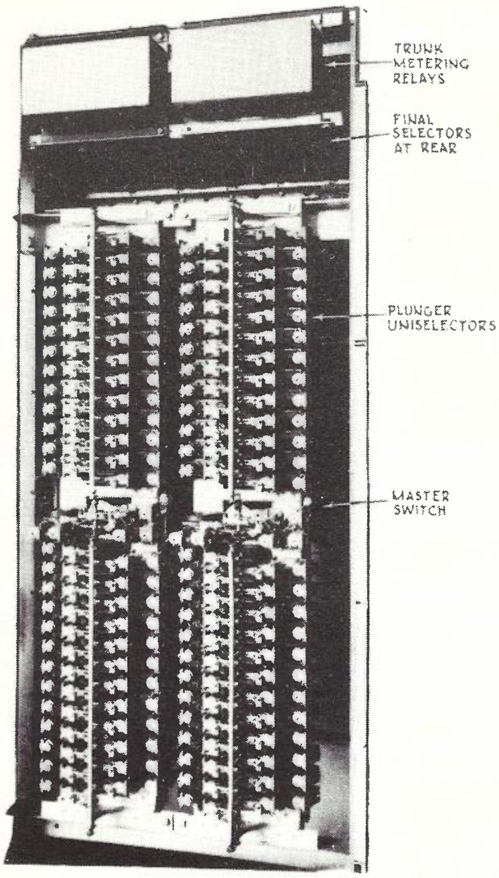
1.2 Subscribers' Uniselectors. In Strowger type exchanges, 100 uniselectors are mounted in a group on a "Primary Unit". Fig. 1 shows a group of 100 plunger type uniselectors. (A side view of this unit is shown in Paper No. 4, page 12.) The switches are arranged in two vertical rows of 50, each row being controlled by a master switch mounted in the centre. The plunger guide shafts of the two rows may be coupled to allow one master switch to serve the 100 switches. This would only apply where the outgoing traffic from the group was relatively light. Under heavy traffic conditions, the rows of 50 may be divided and additional master switches provided, one for each 25 uniselectors.

Rotary uniselectors are mounted, as shown in Fig. 2. Fifty switches and associated relays, in 5 rows of 10, are mounted on each half of the board or "gate". The gate may be swung out to give access to the rear wiring. The bank contacts of the 50 switches on a gate are multipled and wired to the terminal assembly at the top of the unit.

1.3 Secondary Uniselectors. These may be of the plunger or rotary type, and are mounted in a similar way to primary uniselectors. In this case, both sides of the unit are used giving a total of 200 switches per unit.

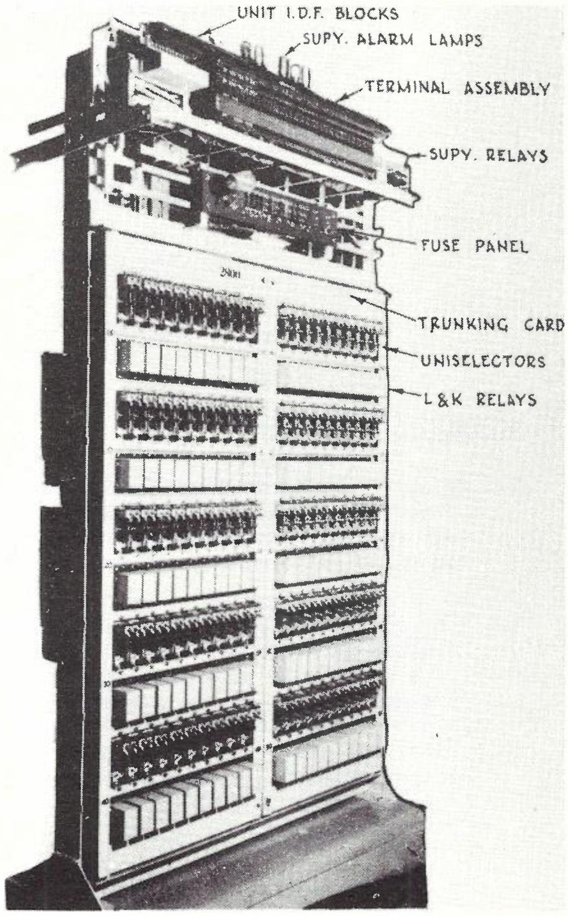
1.4 Final Selectors. These are mounted on shelves at the rear of the uniselector units. Up to four shelves may be fitted, with six or seven switches per shelf for plunger type units, and eight per shelf for the rotary type, giving up to 24, 28 and 32 final selectors per group, respectively. The banks are multipled in two sections, and these are normally strapped together on the terminal blocks.

For testing purposes, a special "Test Final Selector" is provided, and is placed on the end position of the bank multiple so that the multiple wiring is included in the tests.



GROUP OF 100 PLUNGER UNISELECTORS.

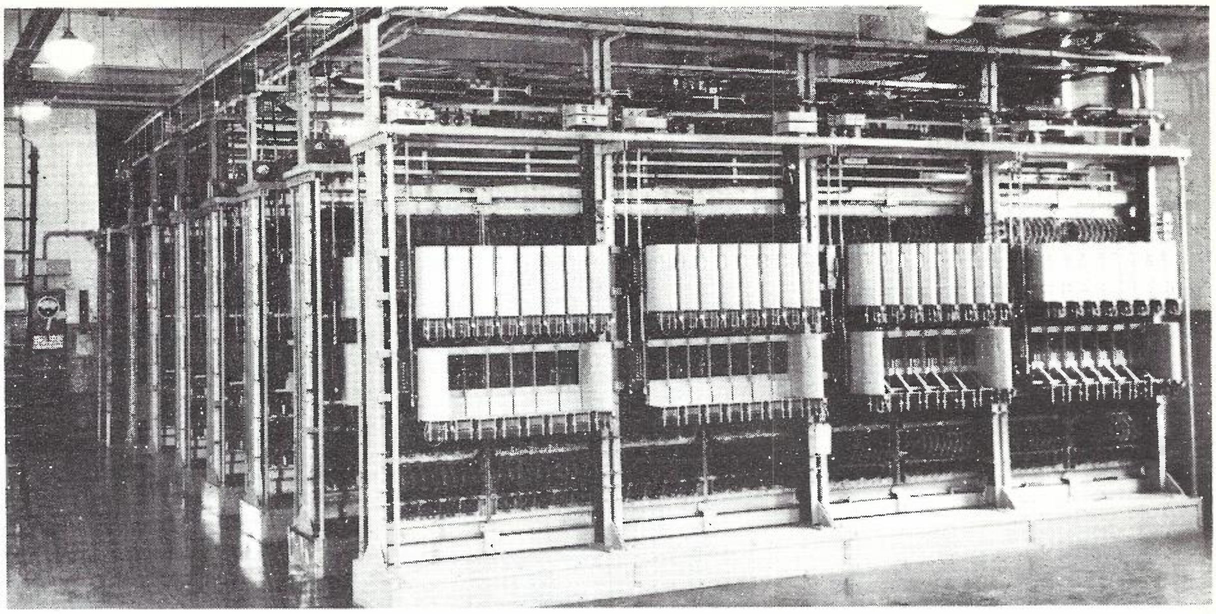
FIG. 1.



GROUP OF 100 ROTARY UNISELECTORS.

FIG. 2.

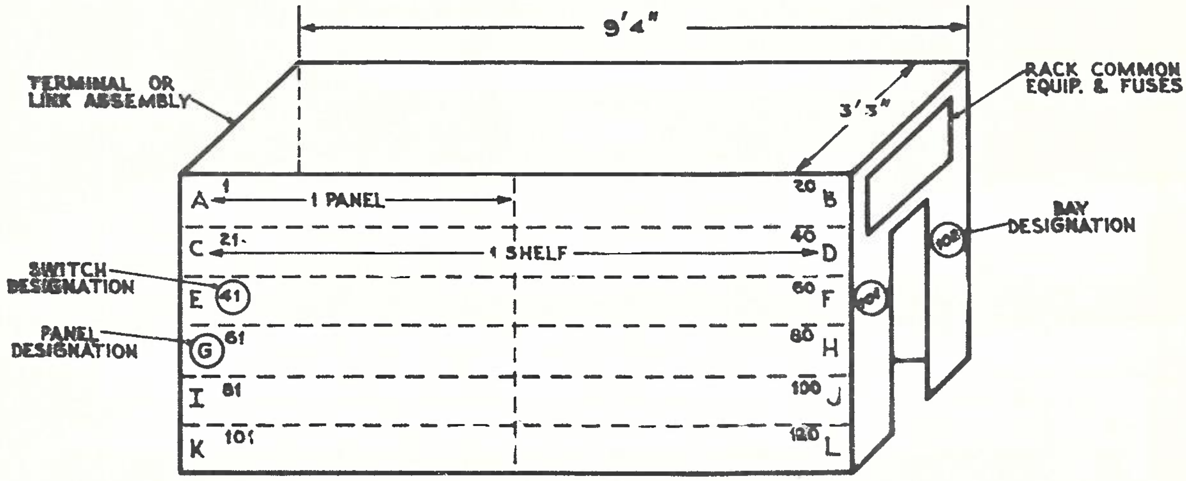
Primary units are mounted side by side to form a "suite", generally of five units. Fig. 3 shows part of an exchange using four units to form a suite.



SUITE OF PRIMARY UNITS.

FIG. 3.

1.5 Group Selectors. Group selectors are mounted on shelves in two panels, each of ten switches. A panel of switches is a group of switches in which the bank multiple wiring is taken direct from switch bank to switch bank. Shelves of group selectors are mounted horizontally in racks or bays on trunk boards. The capacity of a trunk board is generally six shelves per side or a total of twelve shelves, giving a total of 240 selectors. The bank multiple of each panel of switches is extended by means of a bank tail to a frame at one end of the trunk board. This frame is known as a "terminal assembly" or "link frame", and it enables the banks to be multipled together or graded in any desired grouping, and cabled to the switches in the next rank. Fig. 4 shows diagrammatically the lay-out of a group selector trunk board.

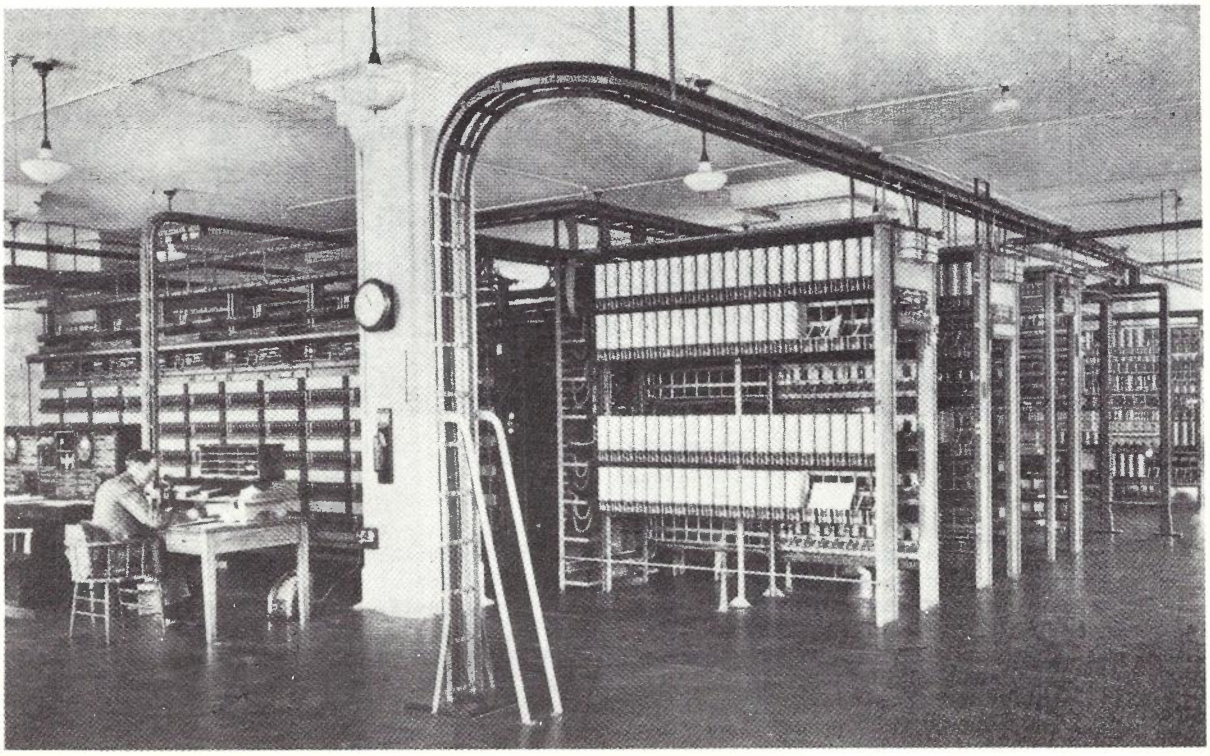


GROUP SELECTOR TRUNK BOARD.

FIG. 4.

Bays are designated according to the group selector rank, for example, first selector bays number 101, 102, etc., second selector bays number 201, 202, etc., and so on. Access to the shelf wiring, etc., is obtained from the interior of the board.

Part of an exchange showing a selector trunk board is shown in Fig. 5.



GENERAL VIEW - HOBART CENTRAL EXCHANGE.

FIG. 5.

1.6 Relay-set Repeaters. These are mounted on trunk boards, on shelves of twenty, in a similar manner to group selectors. Due to the smaller size of a relay-set, up to eight shelves may be fitted on each bay, giving a total of 160 relay sets per bay or 320 per trunk board. Relay-set bays are designated R1, R2, etc.

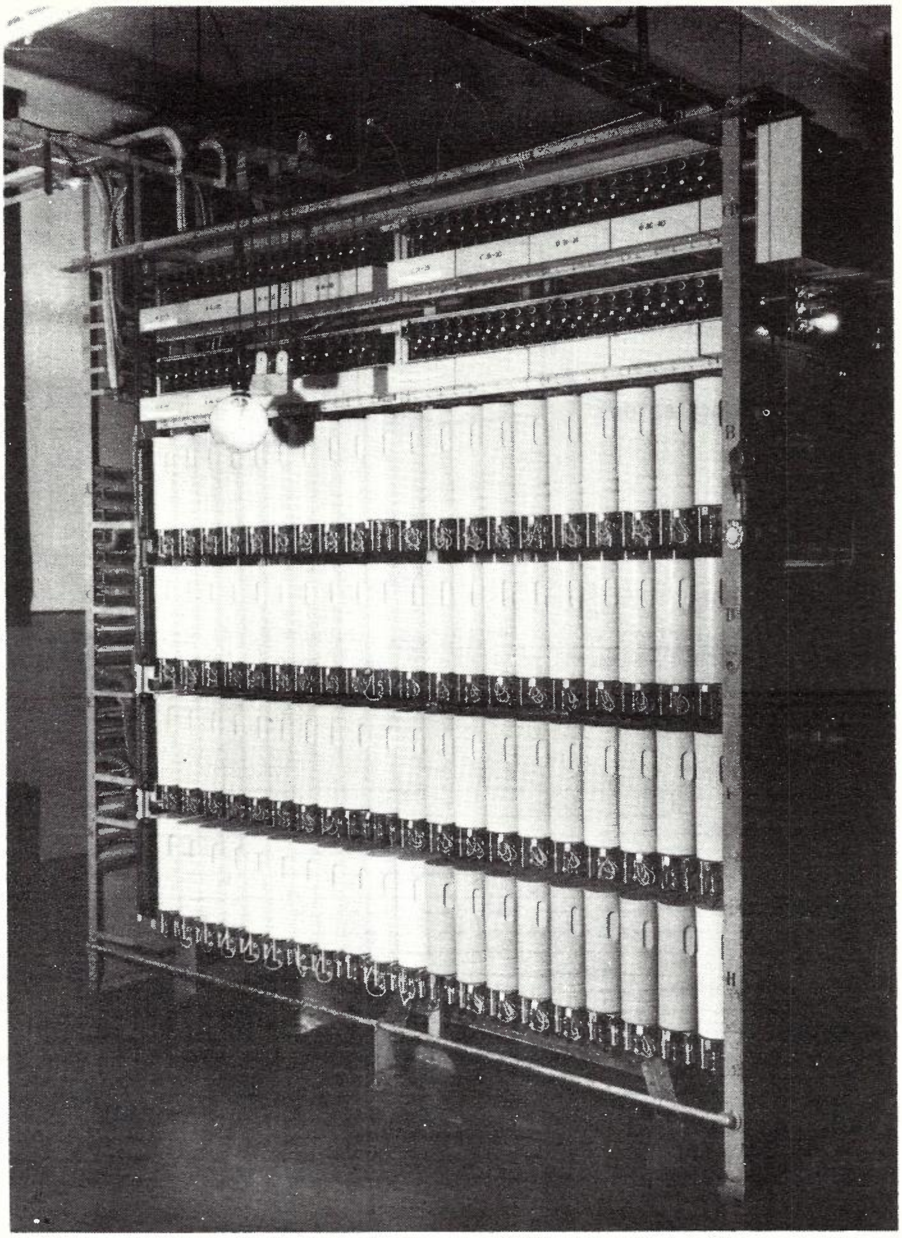
1.7 Junction Hunters. Where junction hunters are used, these may be mounted on one bay of a trunk board, and the associated relay-set repeaters on the adjacent bay, forming a composite trunk board. The junction hunter uniselectors and associated relays are mounted in shelves, each taking two groups of 20 switches. Eight shelves may be mounted on a bay, giving a total of 320 switches per bay. The bays are designated T1, T2, etc.

/ 1.8

1.8 Discriminating Selector Repeaters. These are considerably larger than a group selector and only five shelves may be fitted on a bay, giving a total of 100 switches or 200 per trunk board. The associated junction hunters are mounted separately in this case.

A later method mounts only four shelves of D.S.R's. and the associated junction hunters on a composite bay. (See Fig. 6.)

D.S.R. bays are usually designated 101, 102, etc.

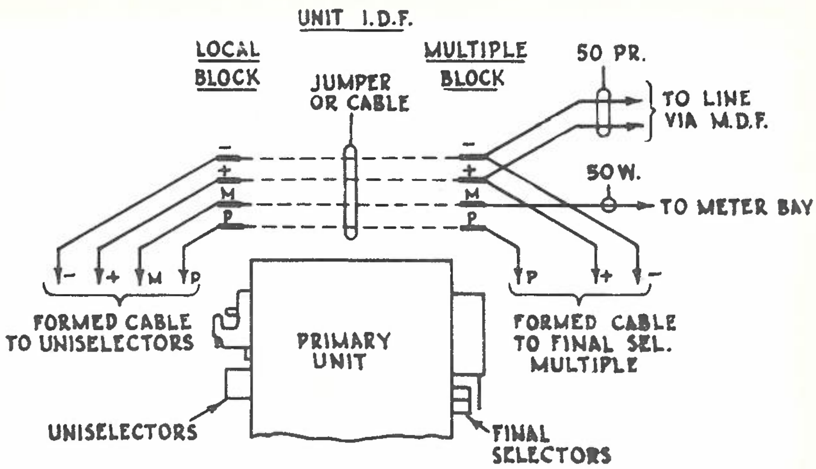


COMPOSITE D.S.R./JUNCTION HUNTER BAY.

FIG. 6.

2. TRUNKING BETWEEN SWITCH RANKS.

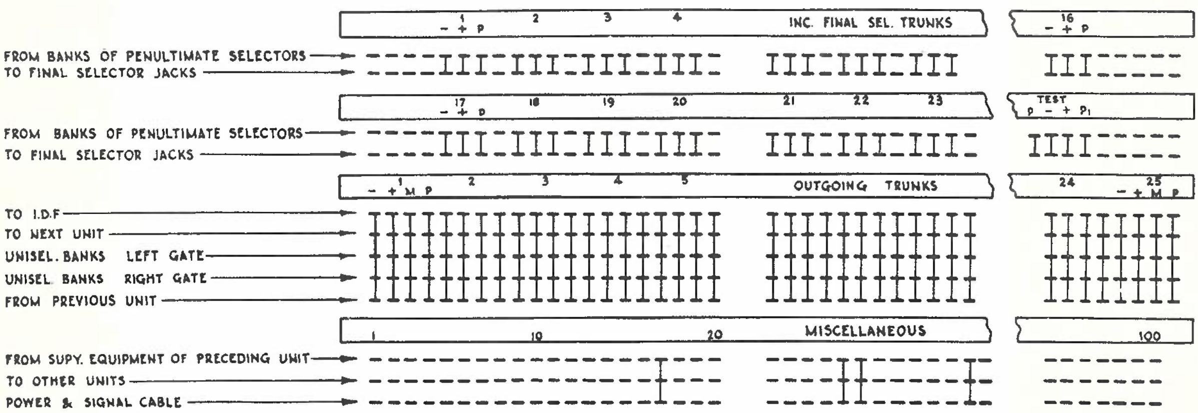
2.1 Primary Unit Local I.D.F. Terminal blocks mounted on the top of each primary unit give the facilities of an I.D.F. and serve as a convenient cabling point. A diagram of typical cabling arrangements is shown in Fig. 7. Jumper wires, or a formed cable, connect the local and multiple side of subscribers' lines.



PRIMARY UNIT LOCAL I.D.F.

FIG. 7.

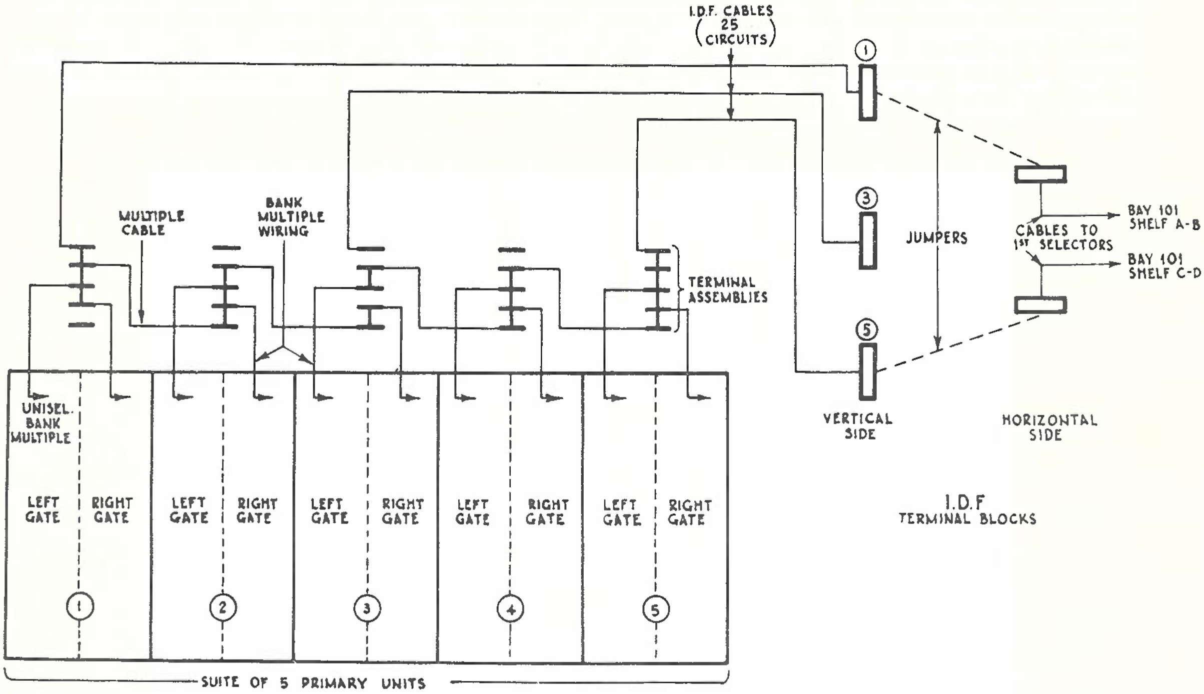
2.2 Trunking from Uniselectors to 1st Selectors. Subscribers' uniselectors are mounted on two gates per unit, with 50 switches on each gate. The banks of all uniselectors on a gate are multipled and terminated on terminal strips in the terminal assembly mounted on the unit. (Fig. 8.)



TYPICAL PRIMARY UNIT TERMINAL ASSEMBLY.

FIG. 8.

The terminal assembly provides a convenient and flexible arrangement of adding, subtracting and multipling the uniselector outlets. A typical trunking arrangement is shown in Fig. 9, where 25 outlets are provided for each 250 subscribers on straight line units (10 per cent. trunking).



TRUNKING OF UNISELECTOR OUTLETS.

FIG. 9.

The multipling of trunks from one unit to another is arranged by multiple cables between the terminal assemblies of adjacent units. A number of cables, in this case three, is taken from each suite to the vertical side of the I.D.F. The first cable feeds to the first primary unit and is multipled over the second unit and the right gate of the third unit. A second cable feeds to the fifth unit, and is multipled over the fourth unit and the left gate of the third unit. The third cable feeds to the third unit and is left idle. This cable will provide additional outlets when an increase in the calling rate demands them. On P.B.X. line units the calling rate is usually heavier, and a cable from each unit is taken to the I.D.F.

The first selectors (or relay-sets or D.S.R's.) are cabled to the horizontal side of the I.D.F. and connected to the uniselector outlets with jumper wires. This provides a flexible means of evening up the traffic loading on first selectors.

A trunking card (Fig. 10) on each gate gives the location of each uniselector outlet.

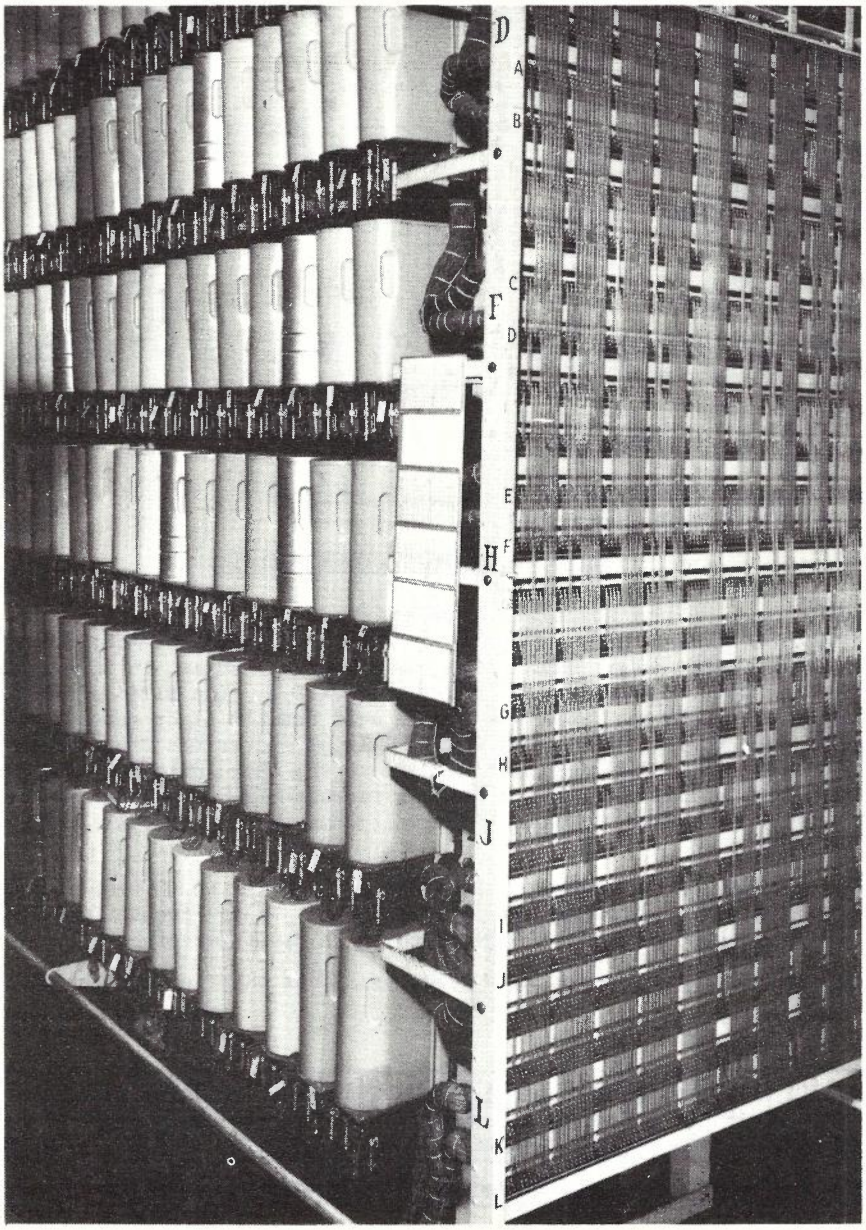
TRUNK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
IS SWITCH	1	11	21	31	41	51	61	71	81	91	101	111	1	11	21	31	41	51	61	71	81	91	101	111	1
IN BAY	101	101	101	101	101	101	101	101	101	101	101	101	102	102	102	102	102	102	102	102	102	102	102	102	103

UNISELECTOR TRUNKING CARD.

FIG. 10.

2.3 Trunking Group Selector Outlets. A terminal assembly, or link frame, on each group selector trunk board allows multipling and grading of the group selector outlets. Fig. 11 shows a typical link frame.

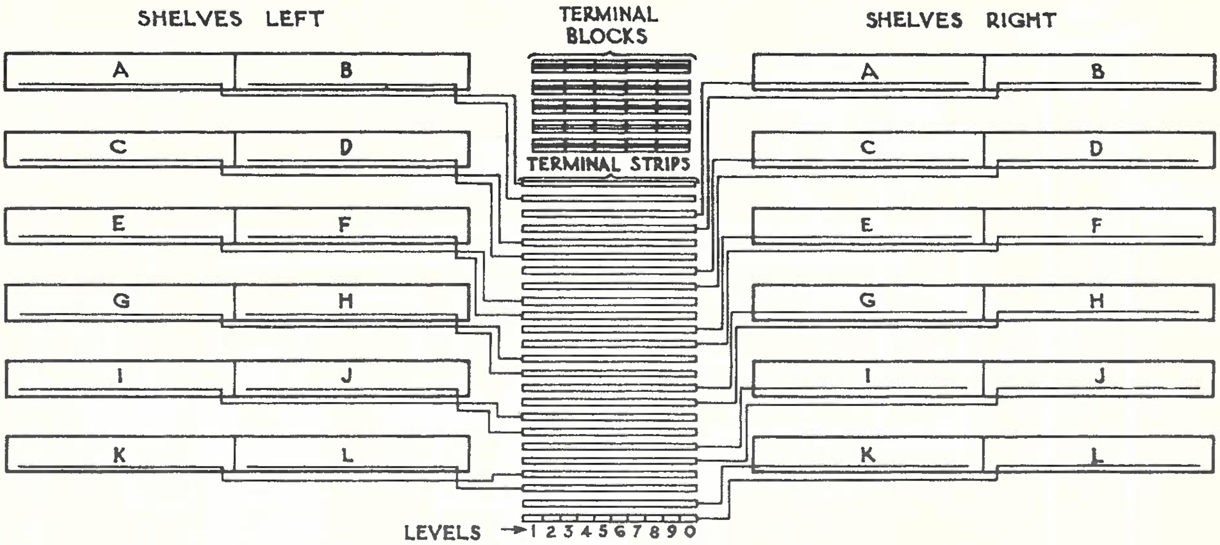
Grading is carried out by commoning vertical rows of tags on the link frame by means of bare cadmium-copper wire straps. From the tag connected to the lowest point of each common, a jumper wire is run at the rear of the link frame to the terminal blocks mounted at the top, and terminates there on the particular tag to which the required outgoing trunk is cabled.



GROUP SELECTOR LINK FRAME.

FIG. 11.

If the outgoing trunk is cabled from another board, the jumper is terminated on a tag connected to a tie circuit to the adjacent board, and the circuit may be extended over several boards in this way. On reaching the board from which the outgoing trunk is cabled, a jumper is run from the tie circuit to the tag to which the required outlet is cabled. Fig. 12 shows the arrangement of terminal strips and terminal blocks on a link frame.



ARRANGEMENT OF LINK FRAME.

FIG. 12.

A trunking card (see Fig. 13) for each shelf gives the required information regarding group selector outlets, and by observing on which contacts the wipers of a switch are standing, and then referring to the card, the call may be traced through the exchange.

In addition, to facilitate tracing calls backwards through the exchange, that is, from final selector to uniselector, a small card on each selector gives the necessary information regarding the selectors from which that particular switch is trunked.

BAY (101) SHELF K

	1	2	3	4	5	6	7	8	9	10	Level
	—	—	N	U		TONE			—	—	10
T5	3	43	82	142	162	201	241	281	2	42	9
R7	75	61	44	48	72	68	—	—	—	—	8
	—	—	N	U		TONE			—	—	7
	—	—	N	U		TONE			—	—	6
R8	75	97	58	113	140	21	121	61	62	102	5
T1	7	47	84	124	164	202	242	281	2	42	4
201	1	11	21	31	41	51	61	71	81	91	3
T6	1	41	81	121	161	201	241	281	2	42	2
	—	—	N	U		TONE			—	—	1

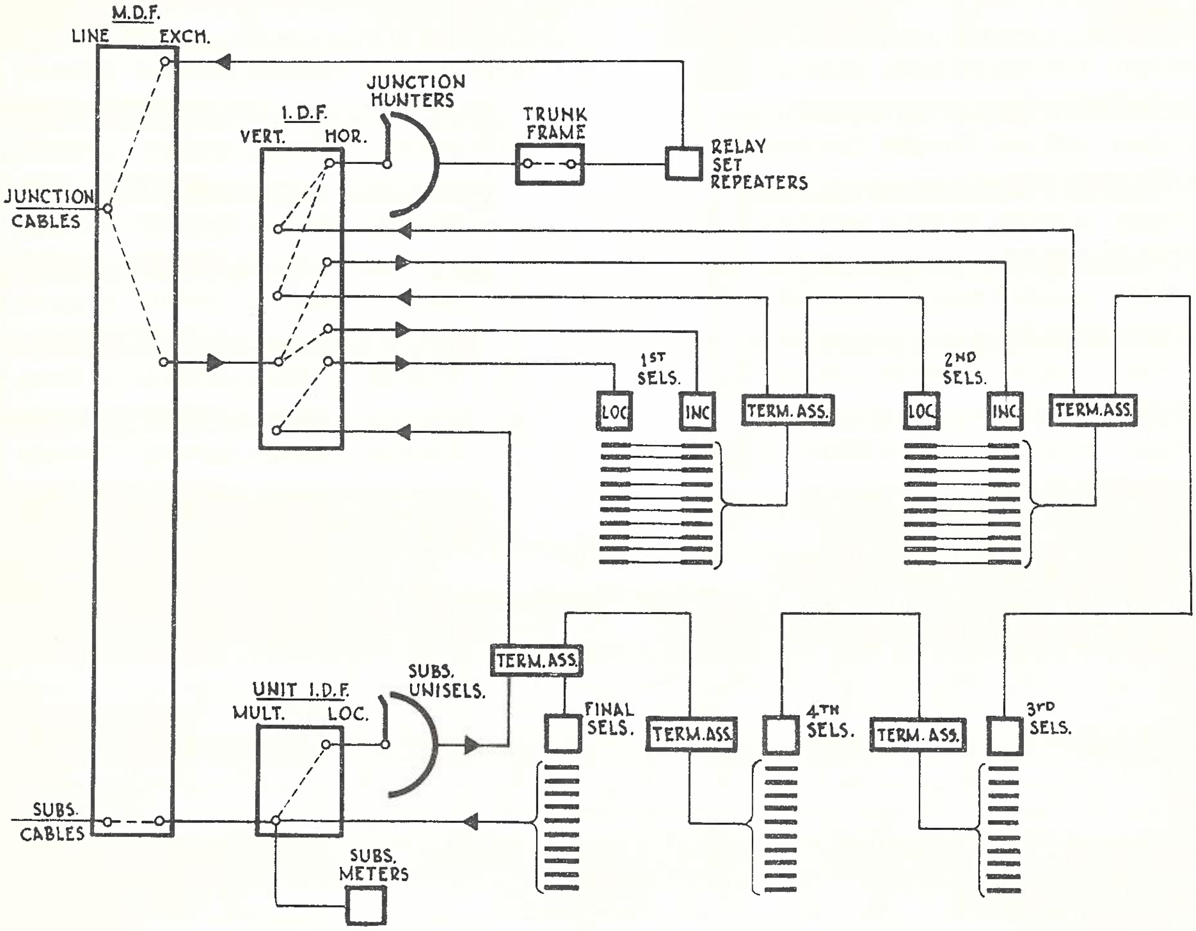
BAY (101) SHELF L

	1	2	3	4	5	6	7	8	9	10	Level
	—	—	N	U		TONE			—	—	10
T5	3	43	82	142	162	201	241	281	2	42	9
R7	75	61	44	48	72	68	—	—	—	—	8
	—	—	N	U		TONE			—	—	7
	—	—	N	U		TONE			—	—	6
R8	75	97	58	113	140	21	121	61	62	102	5
T1	7	47	84	124	164	202	242	281	2	42	4
201	1	11	21	31	41	51	61	71	81	91	3
T6	1	41	81	121	161	201	241	281	2	42	2
	—	—	N	U		TONE			—	—	1

GROUP SELECTOR TRUNKING CARD.

FIG. 13.

2.4 Trunking Outlets to Junctions. Group selector outlets from levels trunked to junctions are distributed via an I.D.F., where cross-connections are made to relay-set repeaters, or to junction hunters where the latter are installed. A trunking diagram of a typical main exchange, showing the cabling arrangements, is shown in Fig. 14.



TYPICAL MAIN EXCHANGE CABLING DIAGRAM.

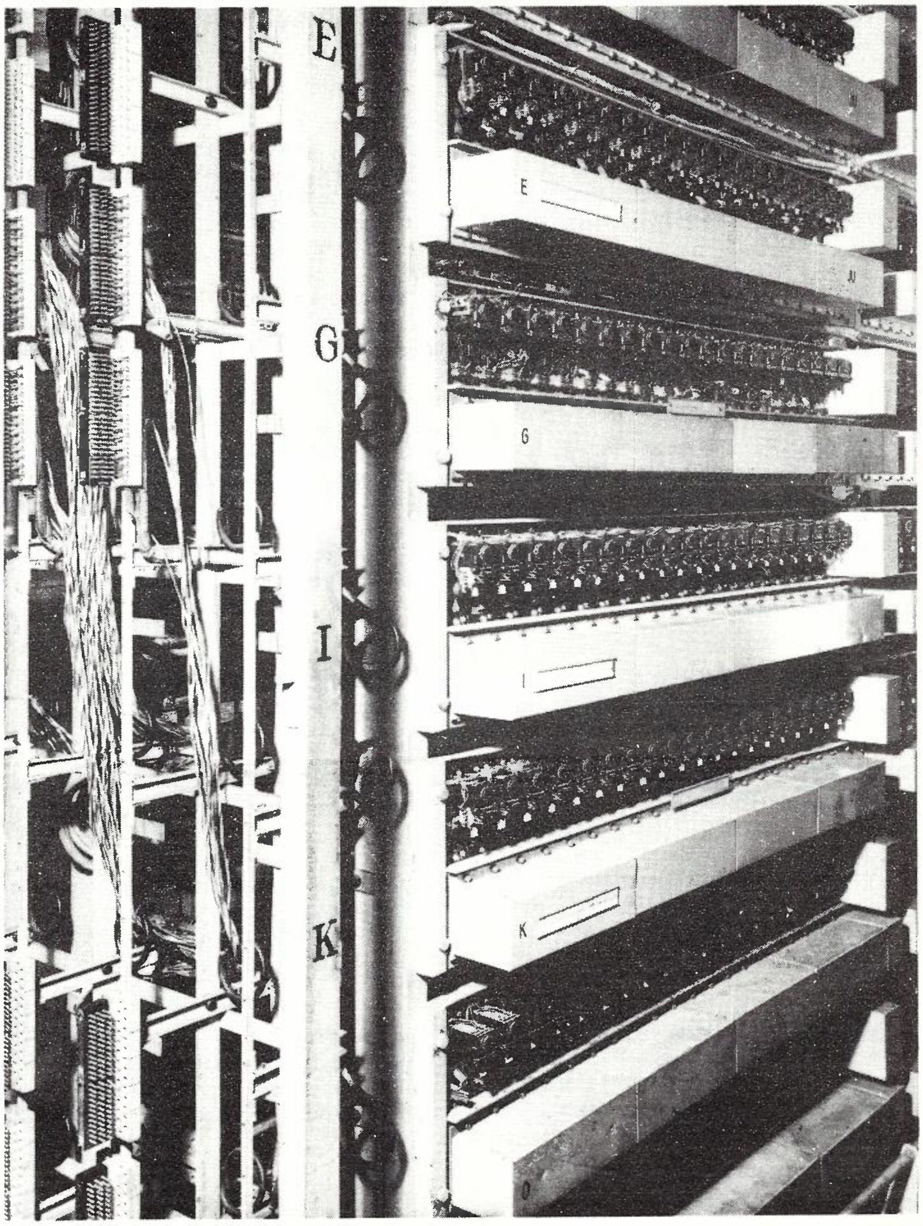
FIG. 14.

Where junction hunters are installed, they are cabled to the horizontal side of the I.D.F. Their banks are multipled and wired to terminal blocks mounted on a "trunk frame" at the end of the trunk board. Jumper wires are run from these blocks to adjacent terminal blocks which are cabled to the relay-set repeaters. The outgoing sides of the relay-set repeaters are cabled directly to the M.D.F. The private wire may be cabled to the M.D.F. with the negative and positive line wires and busying strips installed on the protectors. Thus, by inserting a busying plug at the M.D.F., a junction may be "busied out", when required.

The I.D.F. also forms a convenient point for distributing traffic from incoming junctions to incoming 1st and 2nd selectors. Note that local group selector levels are cabled directly from the terminal assembly, and do not pass through the I.D.F.

/ Fig. 15

Fig. 15 shows part of a junction hunter bay, including the method of cross-connecting junction hunter outlets to relay-set repeaters. The reverse side of the trunk board carries the relay-set repeaters.



JUNCTION HUNTER BAY.

FIG. 15.

3. LAY-OUT OF EXCHANGE SWITCHING EQUIPMENT.

3.1 The lay-out of the plant in an exchange will differ according to the building. The shape of the building space is determined by the land available, existing buildings and other facilities which have to be provided, such as postal, etc. Consequently, it is not possible to have a standard plan for all exchange buildings and a standard lay-out of apparatus is therefore not possible.

3.2 The space required by the switching equipment, the main distributing frame and cable tunnel (the position of which is usually fixed by other factors), the battery room and the power room, are calculated on the estimated requirements at the 20 year date. A store room, office and air-conditioning room may also be required. Attention must also be given to amenities such as luncheon rooms, lavatories, etc.

3.3 Dominating all considerations of lay-out of switching plant are natural lighting facilities, ease of maintenance and economy of cabling. The relative positions of the various units is determined by these factors. Some of the special considerations which will apply are given hereunder -

(i) The M.D.F. In most cases, it will be found that the position of the M.D.F. is determined by considerations affecting external cables, and the position adopted may be taken as a starting point for the exchange equipment lay-out. A clear space of 5 ft. is usually allowed in front of the protector side of the frame, the length of which depends on the ceiling height and the number of lines to be accommodated. Usually the verticals, which are on 6-3/4 in. centres, mount 200 lines, and the frame is approximately 4 ft. 6 in. in width.

(ii) The Test Desks are placed so that the testing officer has a clear view of the M.D.F. Each position occupies a floor space of approximately 3 ft. x 2 ft.

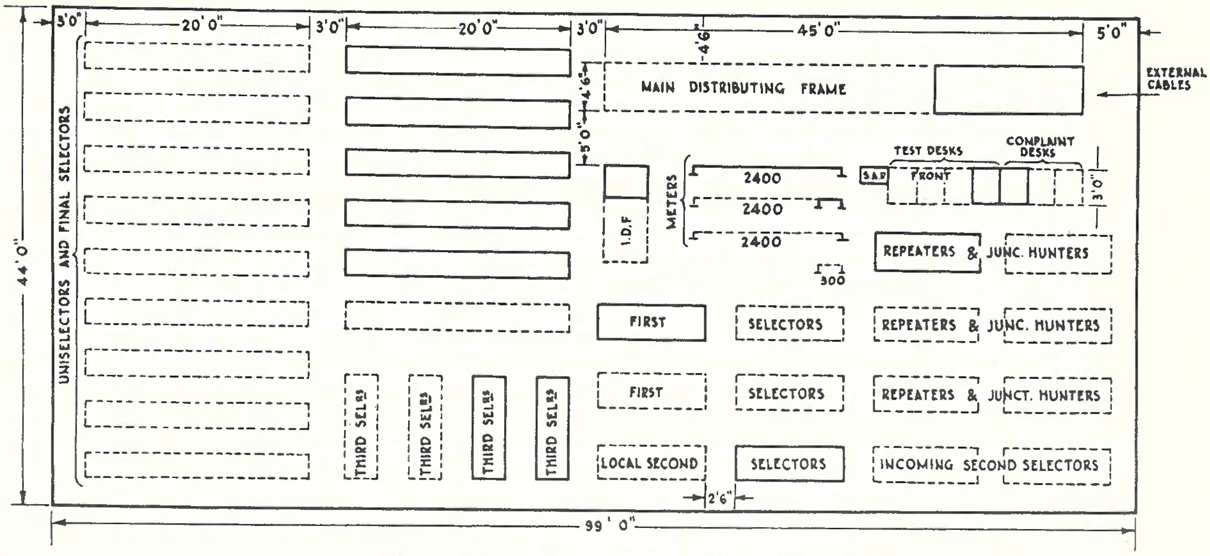
(iii) Subscribers' Meters are mounted in bays of 300, 400 or 600 per bay of 1 ft. 8 in. width.

(iv) Trunk Boards have accommodation for 240 group selectors and a corresponding number of other switches, as described earlier in this Paper. The floor space occupied by a board is 9 ft. 4 in. x 3 ft. 3 in., and 2 ft. 6 in. is usually allowed between boards.

(v) Primary Units, mounting 100 uniselectors and the associated final selectors, are usually arranged in suites of five. Each unit occupies a floor space of 4 ft. x 2 ft. and a space of 2 ft. 6 in. is usually left between rows. In order to economise in cabling, the units should be erected as near as possible to the M.D.F.

/ 3.4

3.4 Fig. 16 shows a typical lay-out for the exchange switching plant only, the full lines representing initial equipment, while the dotted lines show the extension to the ultimate.



TYPICAL EXCHANGE SWITCHING EQUIPMENT LAY-OUT.

FIG. 16.

The data on which this lay-out is based is given below -

Item.	To be Installed Initially.	To be Installed Ultimately.
Main distributing frame cable pairs	3,500	16,000
Main distributing frame ironwork (5 years)	5,000	16,000
Subscribers' uniselectors	2,500	7,500
Trunk boards, local 1st selectors	1	4
Trunk boards, local 2nd selectors }	1	2
Trunk boards, incoming 2nd selectors }		2
Trunk boards, local 3rd selectors	2	4
Trunk boards, relay-set repeaters and junction hunters	1	6
Test desks	1	4
Complaint desks	1	3
Subscribers' meters	2,500	7,500

3.5 Air-Conditioning. Air-conditioning plants are used in certain places for the comfort of the staff and to protect the equipment from the effects of humidity and dust. Full air-conditioning consists of dust extraction and the control of temperature and relative humidity, the air thus dealt with being forced into the exchange through large ducts. Exit ducts are also provided and a constant movement of air maintained in a definite direction. Automatic exchange equipment is comparatively delicate, and is largely composed of metal parts which normally are subject to corrosion. Various forms of zinc plating on ironwork, lacquer on brass, etc., give reasonable protection, yet in the humid parts of Australia there would be distinct possibilities of corrosion if the air conditions in the exchange were uncontrolled. Insulation resistance may be adversely affected by highly humid conditions, and dust is a prolific source of contact trouble.

Vacuum cleaning plants are provided in the larger automatic exchanges for cleaning the walls and floor of the building. In all cleaning operations, care must be taken to ensure that, as far as possible, dust is removed from the switch room instead of being dispersed into the atmosphere to settle elsewhere. A cocoanut fibre or coir mat must be provided outside each entrance to the automatic switch room.

/ 4.

4. SUPERVISORY ALARMS.

4.1 In the circuit descriptions given in previous Papers, various supervisory alarm conditions have been mentioned, such as Release Alarm, Called Subscriber Held (C.S.H.) Alarm, etc. The purpose of the exchange alarm system is to call the attention of the maintenance staff to the condition causing the alarm, and to indicate the item of equipment causing the fault. Alarm conditions may be "Prompt" or "Deferred", the former requiring immediate attention, while the latter may be temporarily deferred without affecting the service of a group of subscribers.

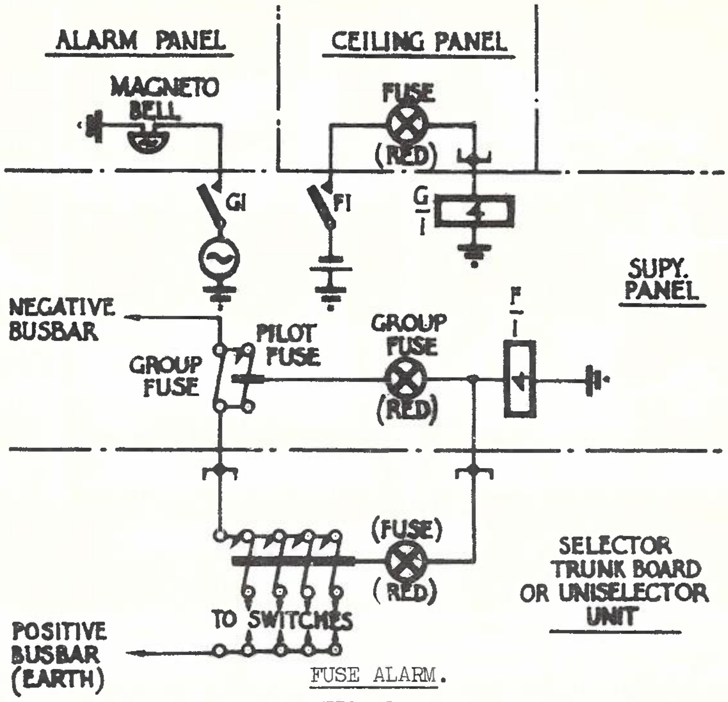
4.2 Delayed Alarms. Some normal conditions constitute a fault if they persist beyond a certain period of time. For example, the release magnet is energised during the release of a selector, but, if it remains energised for long periods, it will overheat and possibly cause a fire. A delayed alarm circuit gives an alarm only if the alarm condition is maintained for a certain minimum time. To obtain this delay period (generally, 9 seconds), a "dash-pot" relay is often used in Strowger exchanges. This relay, together with other methods of obtaining delay periods, is described in Paper No. 1, paragraph 7.7.

4.3 The following alarms are generally provided in a Strowger exchange -

Alarm.	Delay Period.	Prompt or Deferred.	Cause of Alarm.
Fuse alarm	Nil	Prompt	Operation of a fuse.
Condenser alarm	Nil	Prompt	Breakdown of uniselector spark quench condenser.
Release alarm	9 seconds	Prompt	Failure of selector to restore to normal when its release magnet is energised.
Supervised earth alarm	9 seconds	Prompt	Failure of uniselector to switch through, or foreign battery on positive line wire.
Permanent loop alarm (1st selectors)	Nil	Deferred	First selector held without receiving impulses.
C.S.H. alarm (Final selectors)	Nil	Deferred	Calling or called subscriber holding the connection after the other party has cleared.
Ring fail alarm	Nil	Prompt	Failure of ringing current.
Charge fail alarm	Nil	Prompt	Operation of circuit breaker during battery charging.
Voltage alarm	Nil	Prompt	Voltage at busbars outside prescribed limits.
Meter battery fail alarm	Nil	Prompt	Failure of meter battery voltage.

/ 4.4

4.4 Fuse Alarm. Negative battery is distributed via group fuses on the supervisory panel to the various selector and uniselector groups. Final distribution on the trunk board or unit is made via alarm type fuses. (Fig. 17.)

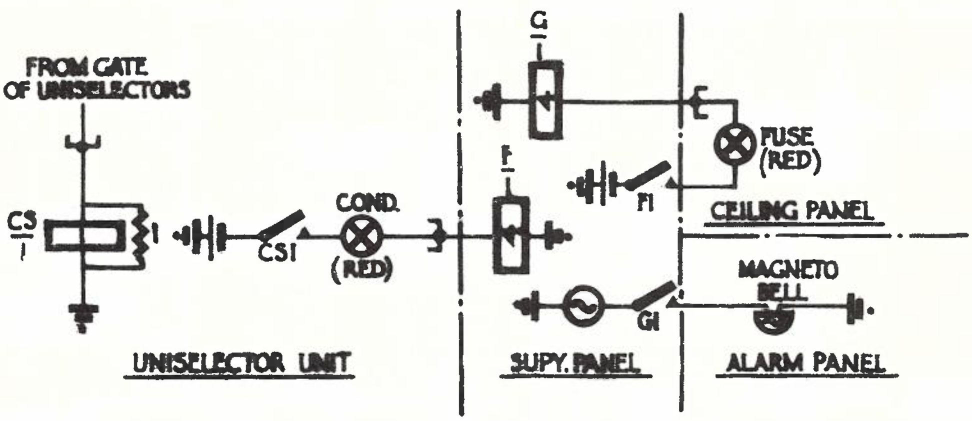


FUSE ALARM.

FIG. 17.

Operation of a fuse allows the alarm spring to bridge the battery and alarm busbars, energising the board fuse lamp in series with relay F. F1 completes the circuit of the group ceiling lamp in series with relay G. The operation of relay G connects ringing current to the exchange alarm bell.

4.5 Condenser Alarm. Earth to uniselector spark quench condensers is fed via a condenser supervisory relay, CS, for each gate of 50 switches. (Fig. 18.)



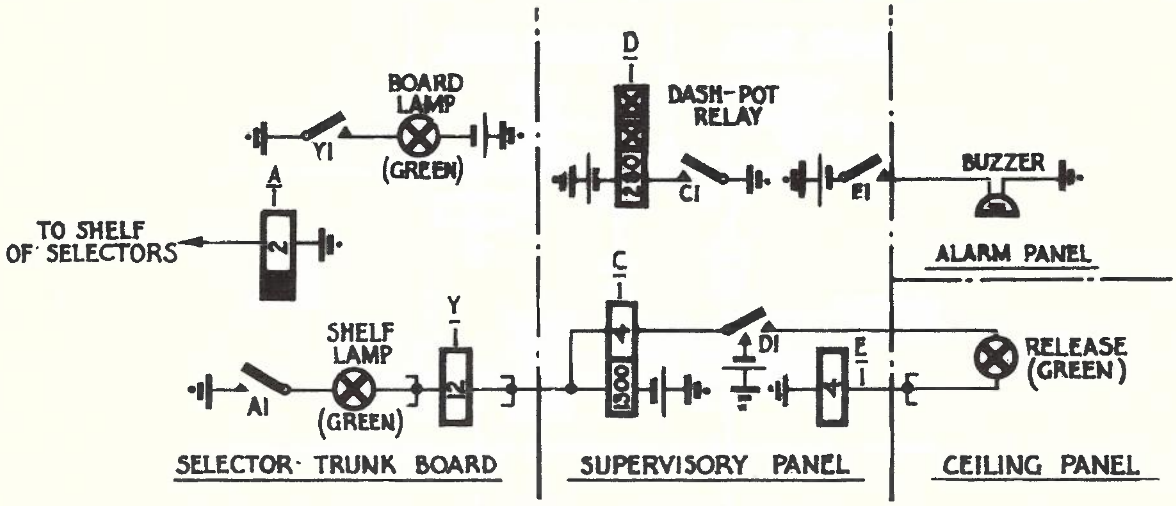
CONDENSER ALARM.

FIG. 18.

Breakdown of the insulation of a condenser allows relay CS to operate in series with the associated uniselector drive magnet, CS1 completing the circuit of the condenser alarm lamp. The battery feed to the lamp is taken via the fuse alarm relay F, operating the group ceiling lamp and magneto bell.

/ 4.6

4.6 Release Alarm. The battery supply to group selector release magnets is fed via a relay A for each shelf. (Fig. 19.)



GROUP SELECTOR RELEASE ALARM.

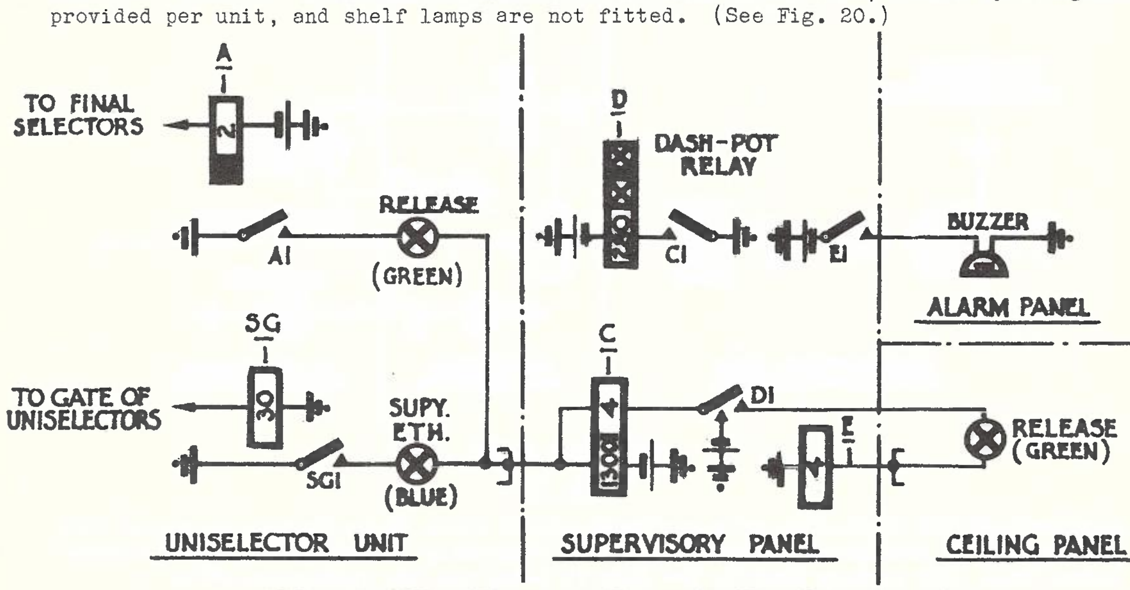
FIG. 19.

Relay A operates in series with the release magnet and completes a circuit, via the shelf lamp and relay Y, to operate relay C on its 1,300 ohm winding. The shelf lamp does not glow, nor relay Y operate, in series with 1,300 ohms.

C1 completes the circuit of the dash-pot relay D, which is very slow operating. If the selector fails to restore within 9 seconds, relay D operates completing the circuit of the ceiling lamp and relay E. E1 closes the alarm buzzer circuit.

D1 also connects the 4 ohm winding of relay C in parallel with its 1,300 ohm winding, allowing relay Y to operate and the shelf lamp to glow. Y1 completes the circuit of the board lamp.

The final selector release alarm circuit is similar to the above, one relay being provided per unit, and shelf lamps are not fitted. (See Fig. 20.)



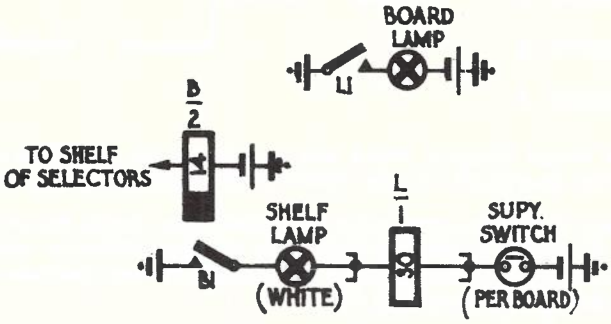
FINAL SELECTOR RELEASE ALARM AND SUPERVISED EARTH ALARM.

FIG. 20.

4.7 Supervised Earth Alarm. (Fig. 20.) Earth to line circuit relay K contacts is fed via a supervisory relay for each gate of 50 switches. A foreign battery on the positive wire of a line operates the relay, closing the circuit of the delayed alarm circuit relay C in series with the board lamp. The alarm is delayed to ensure that intermittent contacts and the extension of a normal calling loop do not give false alarm signals.

After 9 seconds, the dash-pot relay operates, completing the ceiling lamp and buzzer circuit, and allowing the board lamp to glow in series with the 4 ohm winding of relay C.

4.8 Permanent Loop Alarm. Supervised battery is fed to 1st group selectors via a relay B for each shelf. (Fig. 21.)

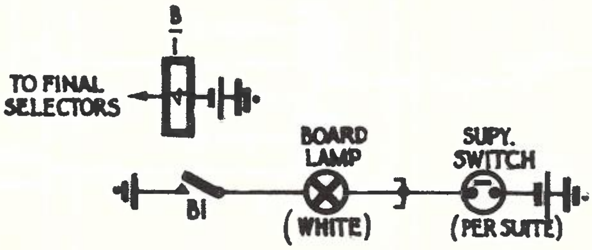


PERMANENT LOOP ALARM.

FIG. 21.

With the supervisory switch in the "On" position, the operation of relay B energises the shelf lamp in series with relay L. L1 closes the circuit of the board lamp. Lamps provided on each switch further assist in the location of the faulty circuit.

4.9 C.S.H. Alarm. The supervisory lamp on each final selector is fed through a common board relay, B. Operation of this relay completes the circuit of the board lamp. (Fig. 22.)



C.S.H. ALARM.

FIG. 22.

The permanent loop and C.S.H. alarms are not urgent and are attended to periodically as a routine test. Switches are provided to allow these alarms to be switched off at other times.

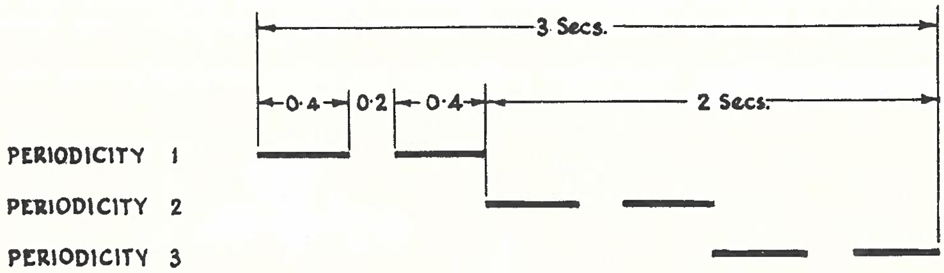
4.10 Power Room Alarms. The Ring Fail, Charge Fail, Voltage and Meter Battery Fail Alarms are similar to the corresponding circuits for a 2,000 type exchange, and are described later in this Course.

/ 5.

5. RING AND TONE DISTRIBUTION.

5.1 Ringing current and service tones are generated by a ringing machine, and cam driven interrupters on the machine give the required periodicities.

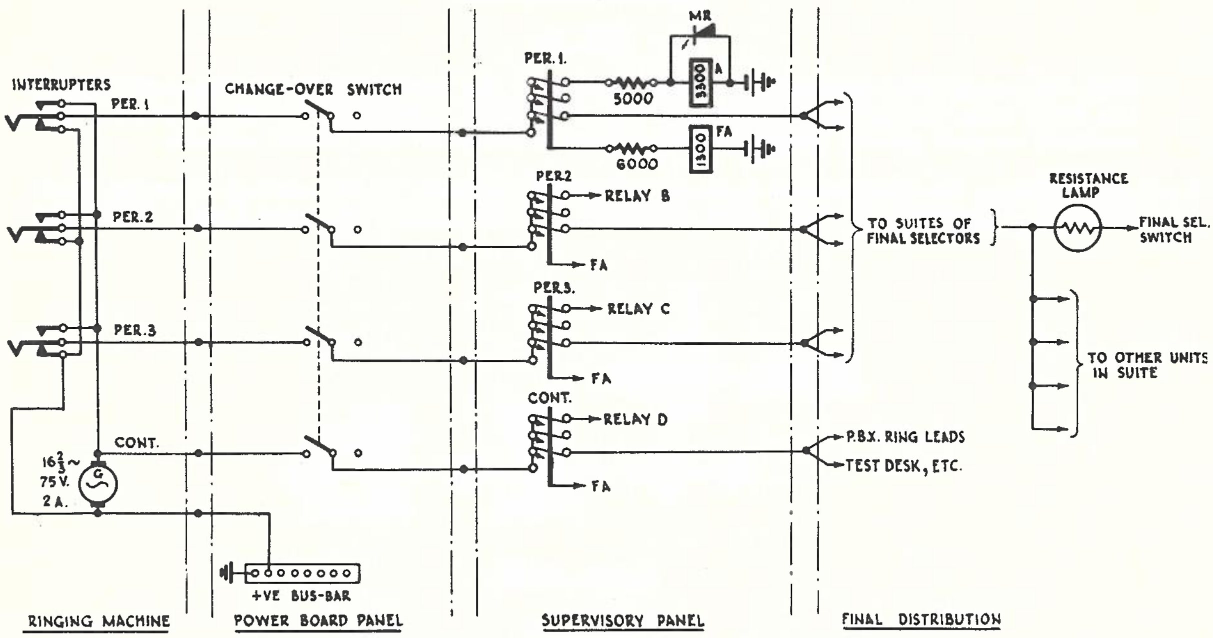
5.2 Ringing Current. Alternating current of 16-2/3 c/s is provided (sometimes 33-1/3 c/s) and is broken up into three periodicities as shown below -



Note that the three ringing feeds are staggered so that the actual load on the ringing machine is only one-third of the total load on the exchange.

Two ringing machines are generally provided, the first mains driven, the second battery driven. The circuit is usually arranged to automatically start the second machine and change over the load, if failure of the mains driven machine occurs. Details of the machines are given in Telephony V.

Fig. 23 shows typical arrangements for distribution of ringing current in a Strowger exchange.



RING DISTRIBUTION, STROWGER EXCHANGE.

FIG. 23.

Each suite of final selectors is fed from the supervisory panel terminal strip, and a resistance lamp on each unit prevents a fault on one unit from seriously affecting the ringing on other units.

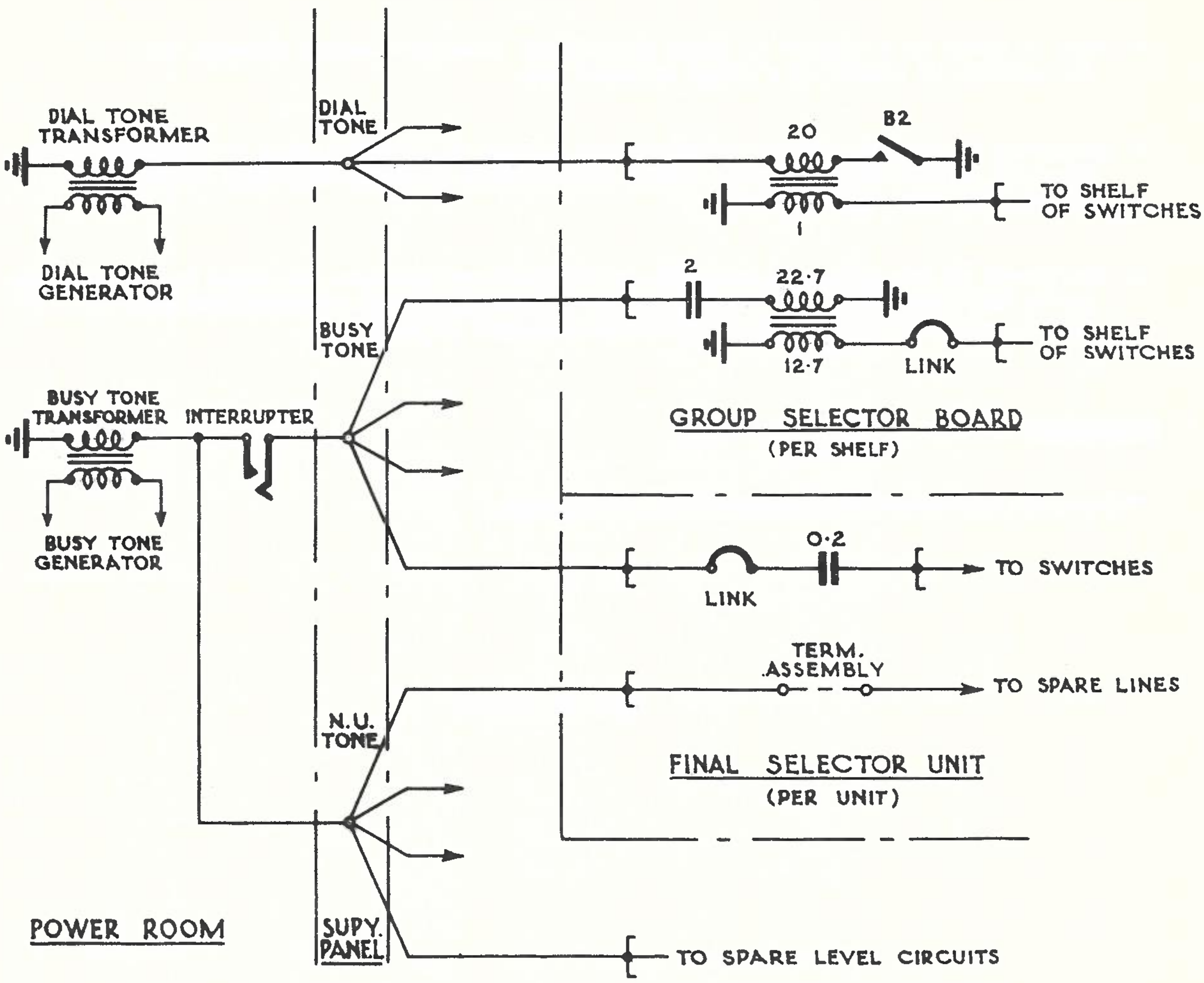
Failure of ringing current on any of the four leads will allow the associated ring fail relay to release and complete an alarm circuit. This may also cause the changeover circuit to function.

/ 5.3

5.3 Tones. The characteristics of the standard service tones are summarised below -

Tone.	Frequency.	Periodicity of Interruptions.
Dial	33 c/s	Continuous.
Ring	133 c/s (superimposed on ringing current)	Same as ringing current.
Busy	400 c/s	0.75 seconds ON, 0.75 seconds OFF.
Number Unobtainable (N.U.)	400 c/s	Continuous.

Typical arrangements for distribution of tones in a Strowger exchange are shown in Fig. 24.



TONE DISTRIBUTION, STROWGER EXCHANGE.

FIG. 24.

6. TEST QUESTIONS.

1. What alarms are provided in an automatic exchange, and what is the purpose of each?

2. In a Strowger exchange a release alarm operates -

   (i) What indications are given?

   (ii) How would you locate the group selector causing the alarm?

3. What equipment is mounted on a composite D.S.R./Junction Hunter bay in a Strowger exchange?

4. What is meant by a "panel" of group selectors? Show by a simple diagram the designation of panels on a group selector bay.

5. Referring to the uniselector trunking card on page 7, a uniselector is observed to be standing on the 12th contacts. Which switch would be taken into use? Give the switch, bay and panel numbers.

6. The wipers of the 1st group selector in the previous question are found to be standing on the 4th contacts of the second level. Referring to the trunking card on page 9, give the switch and bay to which the call is routed.

7. REFERENCES.

"Principles of Automatic Telephony" - H. P. Mahoney.

END OF PAPER.

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Postmaster-General's Department,
Treasury Gardens,
Melbourne, C.2.

TELEPHONE TRAFFIC IN AUTOMATIC EXCHANGES.

CONTENTS.

1. INTRODUCTION.

1.1 In previous Papers, details have been given of apparatus which allows a call to be set up between any two subscribers in an Automatic system. In any exchange, there will generally be many conversations in progress simultaneously and it is, therefore, necessary to provide sufficient apparatus for all these calls to be made.

2. TELEPHONE TRAFFIC.

2.1 The amount of switching plant provided in an exchange depends upon the calls to be handled and, therefore, to study the exchange plant requirements, it is necessary to consider the number and routing of calls going through the equipment.

Any particular subscriber will originate a call as the result of some such circumstances as the receipt and nature of the mail, the needs of the household on the matter of retail shopping, maturing plans for social functions and many other incidents that will readily come to mind. The causes for making a call are so numerous and so varied that the time a call is made may be regarded as a matter of pure chance, that is, a call is as likely to be made at any one moment as at any other. Although individual calls are made at random, the factors which cause them to be made are of reasonably regular occurrence. Moreover, these factors apply to most of the subscribers at a particular exchange. Take, for instance, an exchange in a business area. The incidents such as mail times, etc., recur regularly each day and also they are much the same for each business subscriber. Therefore, one would expect that the number of calls made at certain times will be greater than at others and that the rise and fall of the number of calls will occur regularly each day.

It is a matter of experience that the number of calls through an exchange varies widely over the 24 hours of the day as well as varying from day to day. In an exchange serving a business area there are marked peaks in the number of calls during the forenoon and afternoon, while the traffic during the remainder of the 24 hours is comparatively small. In exchanges serving a residential area there is often a heavy peak in the evening due to social calls as well as a peak in the morning due to shopping and other suburban business. In addition, there will be variations due to fixed events in certain seasons. Besides these regular changes there will be peaks caused through accidental events such as a severe railway break-down.

The number of calls coming into an exchange is therefore a quantity which ebbs and flows, generally in a fairly regular manner. This is known as telephone traffic. The quantity and disposition of the exchange switching plant is determined from the amount of telephone traffic. The quantity of plant at the exchange must be sufficient to switch through the number of calls at any one time and, if sufficient switches are provided to cope with the peaks of traffic, there will be no fear of blocking traffic at any other time. The calls take different routes in the exchange so that the number of switches and trunks on each route will depend on the calls going that way. To determine the number of switches on each route, it is sufficient to know the maximum number of simultaneous calls and to provide that number of switches. It is possible, of course, for half the subscribers to wish to call the other half at the one time, but it would be uneconomical to provide for this eventuality and, similarly, short peaks of traffic are not provided for. Some arbitrary measure must be set down to balance the economical considerations and the high traffic handling capacity. The amount of traffic in the busiest hour of the day is used to determine the amount of switching equipment required.

2.2 Busy Hour. We have referred above to the period of the day during which the traffic is heaviest as being the basis for the determination of the various kinds of switches required. This period is called the "busy hour" and the traffic during this time is called the busy hour traffic. Although the actual period of an hour during which most traffic flows might be from 10.39 to 11.39 a.m., the limits of the busy hour are usually determined to the nearest quarter hour, 10.30 to 11.30 a.m. or 10.15 to 11.15 a.m. It is found that the average duration of a call does not vary greatly from hour to hour in the same exchange and therefore, besides the greatest average of simultaneous calls, it is generally the hour during which the greatest number of calls originate.

2.3 The total traffic during the day is of importance in the design of the batteries and associated power plant, which must have sufficient capacity to cover all the traffic between successive charging periods as well as sufficient size to cover the busy hour traffic without overloading it.

2.4 The Traffic Unit. Telephone traffic can be measured by the number of switches or trunks occupied, and from this a unit to measure telephone traffic has been derived. As the traffic carried by automatic apparatus depends both on the number of calls and upon the average holding time, the unit in which traffic is measured must contain both factors. The unit of traffic flow is called the Traffic Unit (T.U.) and the traffic flow for a specified period (usually the busy hour) is said to be unity when the average number of simultaneous calls is unity.

Take, as an example, a group of ten selectors which are observed at 20 regular intervals of 3 minutes during the busy hour and the number found busy are -

5, 2, 0, 7, 3, 8, 1, 5, 5, 3, 0, 9, 7, 6, 2, 3, 1, 6, 4, 3.

Then the average number of selectors simultaneously in use is $\frac{80}{20} = 4$, hence the traffic flow is 4 T.U., it being supposed that each call lasted exactly 3 minutes.

With a single circuit continuously occupied, the average number of simultaneous calls is obviously one, therefore, it can be said that a traffic unit is equivalent to the traffic flow in one circuit continuously occupied.

A traffic unit may be made up of one call lasting for an hour, or of 100 calls per hour, each call lasting for 1/100 hour. Thus if "C" calls are originated in an hour and the average holding time is "T" hours (expressed as a fraction), then if "A" is the traffic flow in traffic units -

$$A = C \times T.$$

For example, if 100 calls are originated in an hour and the average holding time of each call is 3 minutes, then the traffic flow is -

$$A = 100 \times \frac{3}{60} = \underline{5\ \text{T.U.}}$$

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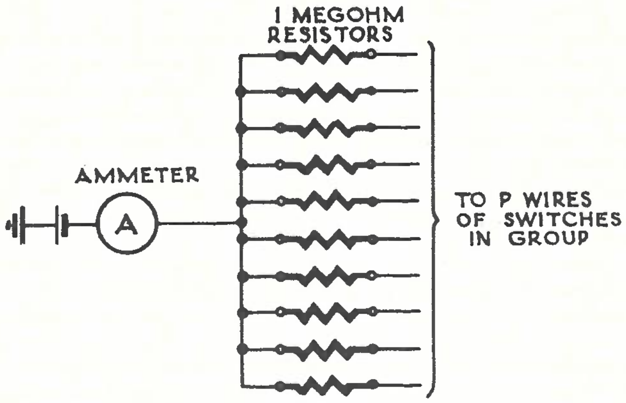
2.5 Traffic Recording. Measurement of the traffic flow in a group of switches may be made by counting the number of switches that are in use at regular short intervals (say, three minute intervals) throughout a given period (usually the busy hour), and the average traffic flow in traffic units is then obtained by averaging these readings. Visual observation of switch groups is tedious and other arrangements are usually made whereby the observations are made electrically, that is, by testing the P wires of the switches in the group. Two methods are in common use -

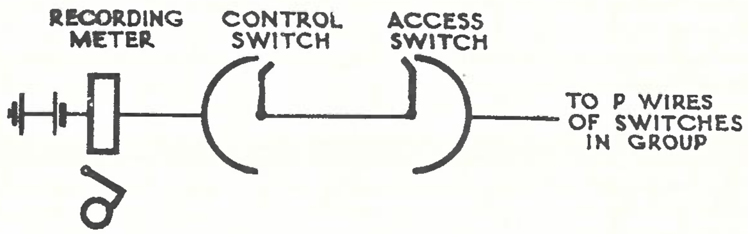
(i) Traffic Recorder (Resistor Type). Each P wire in the group to be tested is connected via a 1 megohm resistor, and suitably switched to an ammeter. Each busy circuit (earthed P wire) contributes 0.05 mA to the current through the meter, which is directly calibrated to read traffic units in various ranges by suitable shunting (see Fig. 1).



RESISTOR TYPE TRAFFIC RECORDER.

FIG. 1.

(ii) Automatic Traffic Recorder. In this recorder, the switches in a group may be tested at intervals of 30 seconds, the number of switches in use being recorded on subscribers' type meters. The P wires of the switches are connected in turn via a uniselector switching arrangement to the meters (see Fig. 2). Details of the automatic traffic recorder are given later in this Course.



AUTOMATIC TRAFFIC RECORDER.

FIG. 2.

3. GRADE OF SERVICE.

3.1 It has been mentioned that the remote possibility of simultaneous calls being made by one half of the subscribers to an exchange for the other half is discarded in the design data. It has also been stated that no provision is made for other peaks. The average traffic flow for the busy hour is the basis of calculating the switch quantities and it will be realised that for considerable periods during the busy hour the traffic flow will be substantially in excess of the average. At other times, of course, it will be below the average. If the number of switches were determined exactly in accordance with the average requirements during the busy hour, many calls would be lost through insufficient switches. Lost calls through this source could not be allowed to exceed certain limits. Calculations are made to ascertain the proportion which will be lost, and a number of switches is provided to ensure that these are kept within the required limits. Such calls will, of course, be repeated after a short interval and practically all will be successful the second time.

3.2 In the previous example, we observed 5 T.U. passing through a group of switches, that is, an average of five simultaneous calls. This could be made up of five calls lasting an hour or 30 calls lasting 10 minutes each, one call commencing just as a previous call releases. In practice, of course, calls will be coming in and dropping out at odd times, giving a fluctuating demand for switches and obviously to average five, at times there must be many more switches in use and at times less. In order to get 5 T.U. through, more than five switches must be available, but how many more? If eight are provided, this will be sufficient for most times but now and then there will be a demand for more than eight even if only for a short interval, and some calls will be unable to get through. If nine switches were available some of these calls would be saved but still on an odd occasion calls would be lost and if there were 10 some traffic would reach the 10th switch and still a few calls would be lost. As switches are added, the traffic carried by these last switches would become smaller and smaller but on odd occasions there would be insufficient switches and calls would be lost. A point is reached where the traffic carried by the last switch is so small that the arrangement is uneconomical and it would be wasteful to provide them just to put through one odd call the moment it was originated. It is, therefore, standard practice not to install switches beyond an economical limit knowing that calls will thereby be allowed to fail purely on account of shortage of switching plant. The proportion of calls which thus fail to mature on the first attempt is known as the grade of service, that is, a grade of service of 1 in 500 means that 1 call in every 500 originated is lost through shortage of switching plant. This loss may occur wherever a search takes place. Thus, a subscriber's uniselector hunts to find a free 1st selector when a call is originated. If all outlets are busy, the call fails to mature immediately. Similarly, when the first digit has been dialled, the selector hunts over its bank contacts to find a free outlet to the next rank. Here again is another chance for a call to be lost, as, if there is no free outlet, busy tone is passed back to the caller.

3.3 The Standard Grade of Service laid down by the B.P.O. and adopted by the A.P.O. is that at each switching stage during the busy hour an average of 1 call in 500 may be lost. This is subject to the proviso that the grade of service shall not fall below 1 lost call in 100 if the traffic increases by 10 per cent. It is of interest to note that the latter condition does not affect smaller groups of circuits, but it leads to a small increase in the number of trunks in certain cases where large blocks of traffic are concerned. For line finders employing partial secondary working (see Telephony IV) the grade of service is 1 lost call in 1,000. Fig. 3 shows the grade of service as applied to each rank of switches in a typical automatic exchange.

A grade of service of 1 lost call per 1,000 calls may be written as 1/1,000 or 0.001. That is, when a subscriber originates a call during the busy hour the chance or probability that the call will be ineffective owing to all switches being engaged is 1 in 1,000, that is, 1/1,000 or 0.001. Similarly, 1 lost call per 100 is 1/100 or 0.01. At each switching point there will be a probability of loss and the aggregate probability over all switching points in setting up a call is termed the Over-all Grade

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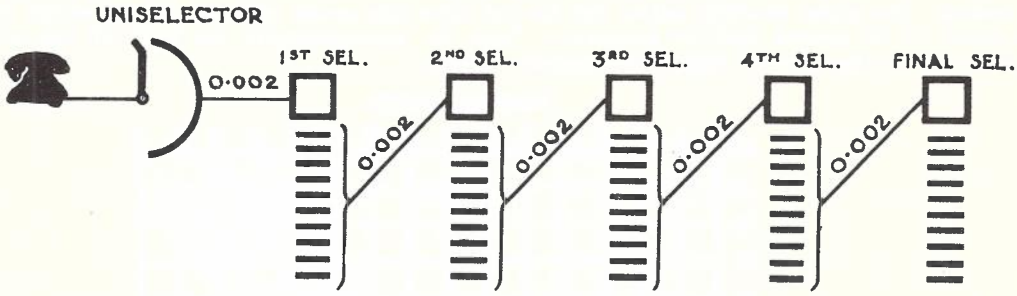
of Service. Thus, in Fig. 3, local calls have an over-all grade of service of 10 in 1,000 or 0.01. If all the calls passing through the different switching points have been grouped to find the busy hour then the over-all grade of service is the sum of the losses at each switching point but, if there is a combination of calls from various sources, the busy hours of the different sources may not occur at the same time. Then the over-all grade of service would be better than the sum of the losses at each switching point since they would not all be at their busiest at the one time.



GRADE OF SERVICE IN AN AUTOMATIC EXCHANGE.

FIG. 3.

3.4 Owing to the variation of traffic density, it is not possible to maintain the grade of service at all times exactly at the standard level. Consequently, under normal conditions in a working exchange, the grade of service on any one group is allowed to deteriorate to 1 lost call in 200 (0.005), at which stage sufficient additional switching equipment is provided for the estimated two year requirements at the standard grade of service.

3.5 Experience and observation have shown that the actual proportion of lost calls in trunk groups carrying a given amount of traffic per hour is closely in accordance with the results obtained from a mathematical calculation based on the Theory of Probabilities. This theoretical calculation, therefore, is used as far as it can be usefully applied in the determination of the number of switches required.

For example, if a group of subscribers originating a given amount of traffic can be given access to a group of 1st selectors in such a way that each subscriber can reach any of the 1st selectors, the application of the theory in order to determine the resulting grade of service is trustworthy and comparatively simple.

3.6 Switch Provision. Fig. 4 shows switch provision curves, based on the theory of probabilities, used in the design of simple trunk groups.

The number of outlets or trunks required to carry a given amount of traffic with a given grade of service may be determined from these curves, assuming that all the trunks in the group are available to the subscriber originating the call, as referred to in paragraph 3.5 above.

Ten traffic units is the equivalent of the traffic carried by 10 trunks if these trunks are fully occupied throughout one hour. From Fig. 4, it will be seen that to carry 10 T.U. with a grade of service of 0.10, 12.4, say 13 trunks, would be required as compared with 10 trunks required if the calls are put through one after the other in regular order. That is, three extra trunks are required in the group to allow for the calls being distributed throughout the hour on a chance basis instead of being put through one after the other. So that with 13 trunks, then during the busy hour 1 call in 10 would be lost because of insufficient trunks.

To carry 10 traffic units with the standard grade of service of 0.002, 20 trunks would be required. That is, where we allowed three extra trunks to provide a grade of service of 0.1, we now require to allow 10 extra trunks, making a total trunk group of 20, expecting that 1 call out of every 500 will fail to get through because of insufficient trunks. Similarly, 22 trunks would be required to carry 10 T.U. with a grade of service of 0.0005, that is, 1 lost call per 2,000.

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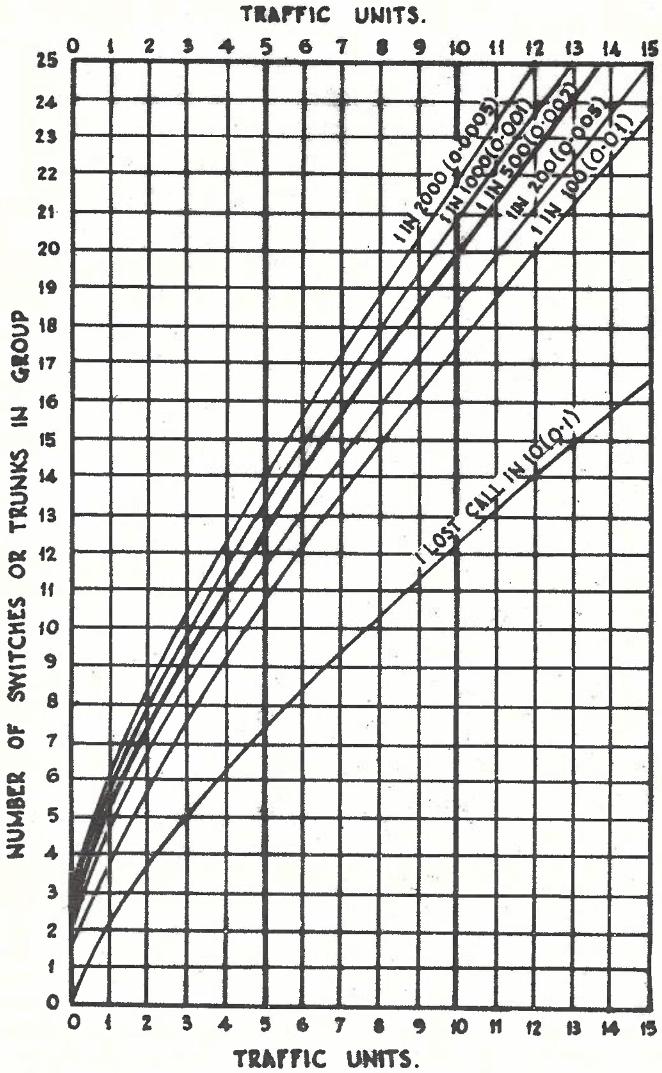
It will be appreciated, therefore, that the grade of service to be given in automatic exchanges must be very carefully determined so that only the number of switches, cabling, etc., will be provided that are economically justified.

Another interesting and important point in regard to the probability curves shown in Fig. 4 is the increased efficiency resulting from an increase in the size of the group. For instance, to carry two traffic units with a grade of service of 0.002, a group of eight trunks is required. If there were four similar groups, eight trunks would be required in each group, or 32 trunks in all, carrying eight traffic units, two in each group. If, however, the eight traffic units can be fed into one group of trunks, the curve shows that a total of 18 trunks will be required. That is, approximately one half of the number required in the case of the four separate groups.



AUTOMATIC EXCHANGE SWITCH PROVISION CURVES.

FIG. 4.

3.7 In most exchange installations, the problems are more complicated and their solution by theory becomes somewhat involved.

Each subscriber may in actual practice, obtain access to the first rank of selectors by means of a uniselector having a limited number of outlets, for example, 24. The number of 1st selectors required in the exchange may, however, be 1,000 or more and the problem is

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to arrange the trunking of uniselectors and selectors in such a way that, while any particular line can reach only 24 selectors, the traffic of the exchange will be carried at the specified grade of service by a minimum total number of selectors.

Fundamentally, the calculation and design of trunk groups in automatic exchanges is based on the theory of probabilities and traffic capacity tables have been prepared from which can be read the number of switches required to meet various conditions.

3.8 Pure Chance and Smooth Traffic. Pure chance traffic may be defined as traffic such that a call is as likely to originate at any one moment as at any other. This carries with it the implication that the number of sources from which calls can originate is infinite, and means that the traffic at any given instant will vary widely from the average traffic measured over a period of time.

Smooth traffic, on the other hand, is such that the traffic at any given instant will not differ greatly from the average traffic measured over a period of time. Smooth traffic conditions apply when the number of sources from which the calls can originate is small and the traffic is large, since, in such circumstances, the chance of a further call being originated diminishes as the number of calls already in progress grows larger. Smooth traffic also occurs at a certain stage in the switching process owing to the fact that traffic peaks in any previous group have been spread over a number of groups due to the interconnection arrangements.

(i) Traffic Offered to 1st Selectors. Normally, subscribers are not influenced by any common factor and, therefore, originate calls quite independently of each other. As the number of subscribers on the exchange is large and each originates only a small amount of traffic, calls are as likely to originate at any one moment as at any other, independent of the number of calls already in progress. Therefore, the traffic on the 1st selectors is assumed to be "pure chance".

(ii) Traffic Offered to 2nd Selectors. Due to the manner in which the outlets from one group of subscribers' uniselectors are connected to the 1st selectors, the traffic on individual shelves of 1st selectors is smoother than pure chance traffic. This smoothing of the traffic in individual groups is noticeable even when the traffic is divided among the various levels of the 1st selectors according to the digit dialled, hence the traffic offered to 2nd selectors is regarded as "smooth". With the proviso that -

(a) At least 70 first selectors serve the uniselector grading.

(b) Where a group of 1st selectors serves both subscribers and dialling junctions from manual exchanges, the traffic offered to the 2nd selectors is only regarded as "smooth" if the number of shelves of 1st selectors serving the subscribers' uniselector grading is greater than half of the total number of shelves.

(iii) Traffic Offered to 3rd, 4th and Final Selectors. Although the smoothing effects noted in (ii) are present, the splitting up of the traffic into small groups means that the traffic in any group is generally too small to effect any noticeable reduction in the number of selectors required. This traffic is, therefore, regarded as "pure chance".

At each switching stage, sufficient switches are provided to carry the traffic with the required grade of service. With "pure chance" traffic, the number of switches provided will be influenced by the size of the traffic peaks, so that for long periods a large number of switches will be idle. With traffic which is 100 per cent. smooth, the number of switches provided will be sufficient only to carry the average traffic. This degree of smoothness, however, is not achieved in practice, but the degree of smoothness obtained in the case of 2nd selectors is such that for a given amount of traffic, less switches are required than for pure chance traffic.

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4. TRUNKING.

4.1 Trunking is the name given to the branch of automatic telephony which deals with the determination of the amount of plant required in an automatic exchange, its arrangement and cabling. It also concerns the methods of rearranging and adding to that plant as circumstances require. From a knowledge of the amount of traffic, the quantity of switching apparatus is determined. In designing exchanges, it is necessary to determine the precise quantities of apparatus required at each switching stage so that calls will be set up in the most economical manner. There is a big difference in the cost of a good and a badly designed exchange. The design must take into account the capacity of the switches and the way a call is routed, both inside an exchange and over junctions in the network to other exchanges so that the maximum traffic can be handled by the plant available. Trunking can be divided into two sections -

(i) Switch provision based on the traffic, and
(ii) Trunking or routing of calls, as shown in the trunking diagrams already referred to in previous Papers.

The great bulk of the exchange switching equipment consists of apparatus such as group selectors, final selectors, etc., provided for the common use of subscribers. The quantity of the equipment depends upon the volume of traffic to be carried and not upon the number of subscribers and junction lines connected.

There are many ways in which the number of trunks or outlets involved may be grouped and very careful calculation and planning are needed in order to arrive at the best economic layout and to ensure that the amount of switching plant at all points in the system shall be adequate to the requirements of the traffic without wasteful over-provision anywhere.

It is necessary, therefore, in the first place to prepare data regarding the estimated traffic of all classes such as local calls, and outgoing and incoming junction calls to the various exchanges. The average probable duration of the calls, that is, the holding time, has also to be determined for each class of call. This data is prepared for the busy hour of the particular exchange trunk group under consideration.

4.2 Simple trunking diagrams for various types of exchanges and networks have been given in previous Papers in this Course. An outline will now be given of the various methods of connecting the switches in one rank to their associated bank multiples of the previous rank. Consider a 1,000 line exchange equipped with 10 contact uniselectors in which 10 first group selectors are sufficient to carry the traffic from each 100 lines. Obviously, 100 group selectors would be required to carry the traffic offered by the 1,000 lines. It would be found, however, that each group of 100 lines would originate its maximum traffic at different periods during the busy hour, whilst several groups were busy the remainder would be comparatively slack and at any time during the busy hour we may find only 80 first selectors simultaneously engaged. Each group of 100 needs 10 switches at some time, but all do not need the maximum number at the same time. It follows, therefore, that if we were to make every 1st selector available to every subscriber in the exchange, the number of 1st selectors required would be 80 and not 100 as would be necessary by basing the number of 1st selectors on the busy hour traffic offered by each individual group.

This condition is known as Full Availability and exists where all of the sources of traffic have access to every trunk to the next stage. Another way of stating the condition is that all switches are accessible to calls from the previous rank. We see, then, that the minimum number of 1st selectors in the next rank occurs under full availability conditions.

One method of obtaining full availability, is to employ a switch which has a bank capacity equal to the number of outlets required to carry the traffic offered. Thus, in the case chosen, a uniselector with 80 outlets would give full availability. The searching time and the cost must be taken into account, for any saving in 1st selectors might be more than counterbalanced by the increase in the cost of the uniselectors and banks.

4.3 Secondary Working. A second method of achieving full availability is to use a 2nd uniselector between the subscriber's uniselector and the first rank switches. An instance of this is the Siemens No. 16 system. (See Fig. 5.) Taking the figures used

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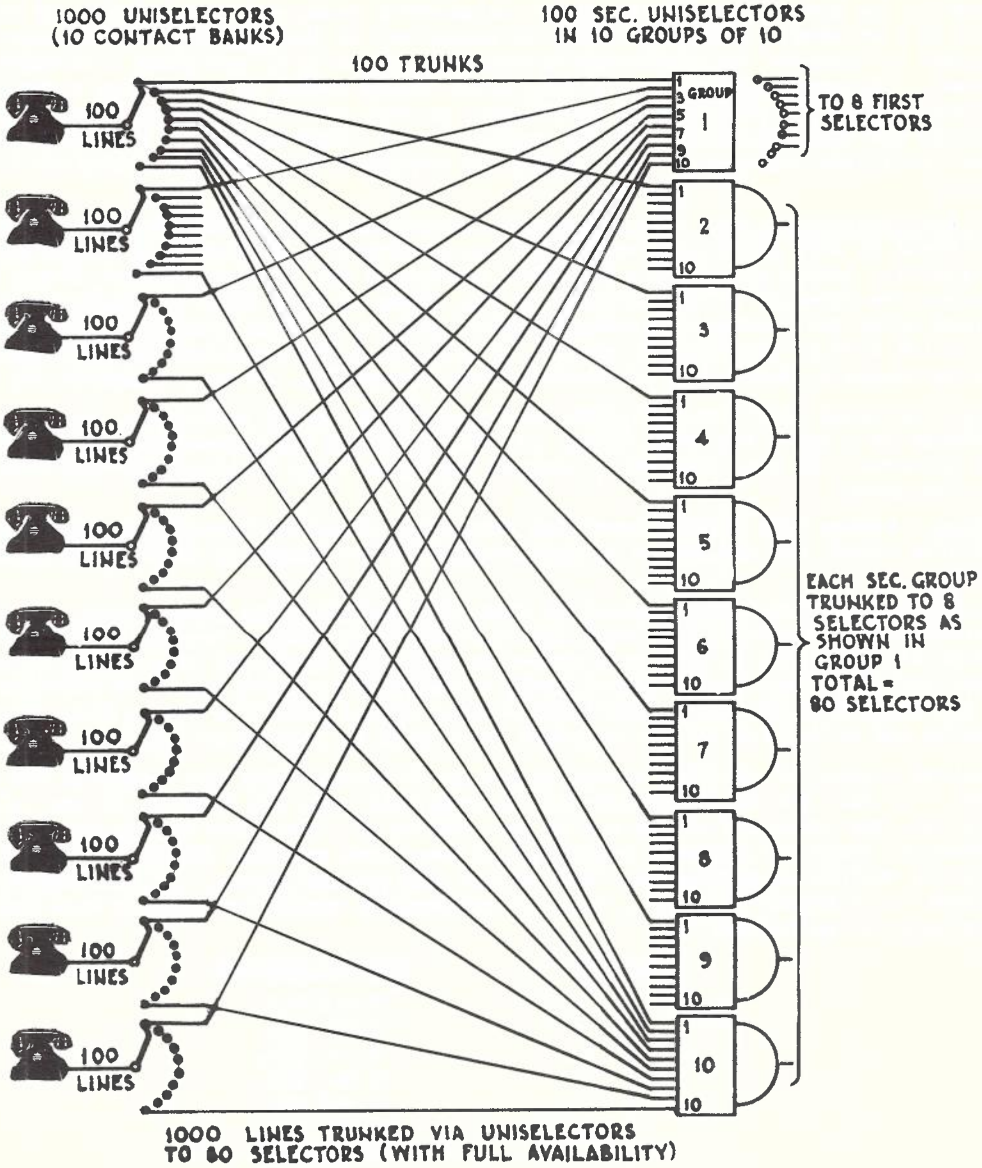
previously, that is, 80 first selectors for a 1,000 exchange under full availability conditions, the secondary trunking scheme is as follows - 100 second uniselectors are installed in 10 groups of 10. Each group of 10 second uniselectors has access to 8 trunks to 1st selectors. The 10 trunks from the first group of subscriber's uniselectors are trunked to the 1st uniselector in each secondary group, for example, the first trunk to the 1st uniselector in secondary group No. 1, the second trunk to the 1st uniselector in secondary group No. 2, and so on. The 10 trunks from the second group of subscriber's uniselectors are trunked to the 2nd uniselector in each secondary group, the 10 trunks from the third group to the third uniselector in each secondary group, and so on. Thus, every subscriber has access to every 1st selector, and this will be apparent if a few of the routes are followed in Fig. 5.



SECONDARY TRUNKING SCHEME.

FIG. 5.

For the purposes of simplicity, only 28 of the 100 trunks from the subscribers' uniselectors to the secondary uniselectors are shown in Fig. 5. All subscribers' uniselector groups of 100 lines are trunked in a similar manner to the two shown at the top of Fig. 5. It is important to realise that the efficiency of full availability applies whatever the trunking scheme. It has been shown that 10 point 1st and 2nd uniselectors give full availability from 1,000 subscribers to about 80 first selectors, but the results would be equally effective if a line finder system were used, and the 80 line finders, with associated 1st selectors, searched for calls amongst the 1,000 subscribers.

4.4 Limited Availability. Full availability, however, can rarely be given in practice. In most applications in exchanges the availability is limited. For example, in the case of group selectors trunked direct from uniselectors, the availability is limited to the number of contacts on the uniselector bank. Thus, a uniselector has access to a number of selectors equal to the number of contacts on the uniselector bank, and if all these are busy, the call is lost even though other group selectors may be disengaged. Various means have been adopted to increase the efficiency without the necessity of providing a secondary trunking scheme. "Interconnecting" is the name given to any method of connecting together level multiples when the availability is limited, so that sets of trunks available from different shelves are partially common to one another, or in other words, any method of connecting level multiples together so that trunks are available from different sections in different order.

4.5 Full Availability Groups. Non-homing type uniselectors may be divided into simple groups, the banks of each group being multipled and connected to a group of 25 first selectors. Twenty-five trunks are usually more than sufficient for 100 subscribers' lines, so these outlets are arranged to be available to two, three or more units of subscribers' uniselectors, depending on the average originating traffic per line. Each group of 25 first selectors is called a "full availability group", as they are fully available to the uniselectors having access to them. The switch provision curves (Fig. 4) may, therefore, be employed.

Note. Although "full availability" conditions occur inside each group, regarding the exchange as a whole the availability is limited, since any uniselector cannot reach any 1st selector. Do not, therefore, confuse the terms "full availability" and "full availability group".

4.6 Grading. Homing type uniselectors, and two-motion selectors search over their outlets in a definite order, and the method of interconnecting the trunks in these cases is termed grading.

One advantage of full availability is that it distributes the total traffic over all the switches and, therefore, uses each one to a high efficiency. Grading is another method of distributing traffic to give each switch an efficient load, and is a system of connecting level multiples together so that a group of switches is given access to individual trunks on the early choices, but in the later choices shares access to trunks with other groups. Grading can be applied only to switches which give an invariable order of search.

Consider a group of switches having access to 10 trunks which are tested in the invariable order 1 to 10. The second outlet will be used only when the first is in use, the third only when the first and second are in use, and so on. The first choice outlets will, therefore, carry the greatest percentage of the total traffic, the later choices carrying only the traffic originated when the earlier choices are in use. If the total traffic offered to 10 trunks is 5 T.U., then the approximate traffic carried by each individual trunk will be as follows -

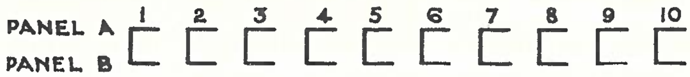
Trunk No.	Traffic Carried.
1	0.815 T.U.
2	0.79 T.U.
3	0.73 T.U.
4	0.66 T.U.
5	0.565 T.U.
6	0.47 T.U.
7	0.36 T.U.
8	0.28 T.U.
9	0.17 T.U.
10	0.1 T.U.

TOTAL = 5 T.U. (Nearly).

From this table, it will be seen that the later choices carry very little traffic. The later choice trunks only carry the peak traffic originated by the group of lines which the 10 trunks serve. As the demand for 10 trunks from one switch group rarely coincides with a similar demand from other groups, the later choice trunks could be made accessible to a number of groups. This is the principle of grading.

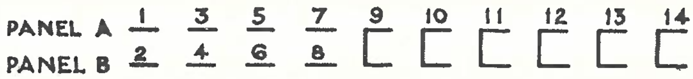
To simplify the description, the case of outlets from group selectors will be considered. As has been explained, group selectors are arranged in panels, the bank contacts of the switches in a panel being multipled together. Consider the second level of two panels (A and B) of 1st selectors. From each panel there will be 10 sets of multipled contacts on this level, and these contacts may be represented as shown below -

Each short horizontal line represents a set of negative, positive and private contacts. If it is desired to connect these contacts to 10 second selectors, the corresponding contacts can be joined together and taken to a selector, as shown below -



This is a full availability condition, as each 1st selector has access to any 2nd selector.

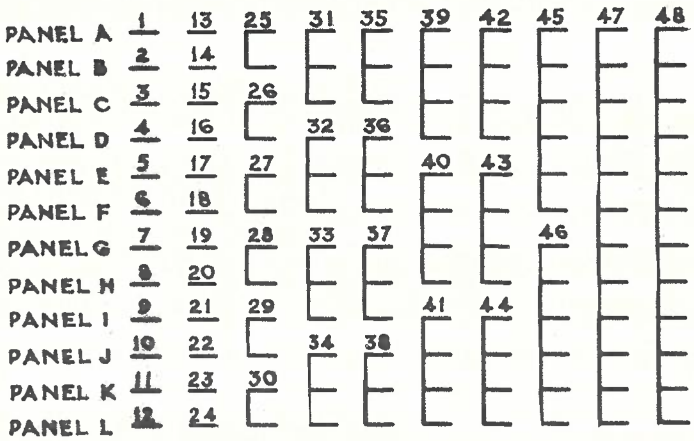
If it is necessary to increase the number of 2nd selectors to 14, contacts 1-4 of panel A may be connected to a different set of 2nd selectors to those available to contacts 1-4 of panel B, as shown below -



Full availability conditions no longer occur.

Second selectors Nos. 1, 3, 5 and 7 can receive traffic only from panel A, and are said to be "individual" to panel A. Similarly, 2nd selectors 2, 4, 6 and 8 are individual to panel B. Second selectors Nos. 9-14 can receive traffic from either panel and are called "common". As selectors hunt over the banks from left to right, 2nd selectors Nos. 1 and 2 are called "first choice", 2nd selectors Nos. 3 and 4 are "second choice", 2nd selectors Nos. 5 and 6 are "third choice", and so on.

Fig. 6 shows the same principle extended to show how the contacts from one level of 12 groups of selectors may be connected to 48 selectors in the next rank -



12 GROUP GRADING WITH 48 TRUNKS - AVAILABILITY 10.

FIG. 6.

The first two contacts in each group are given access to individual 2nd selectors. The third contacts of each group are connected in "pairs", each pair being connected to a separate 2nd selector. The next two contacts are arranged in "threes", after this come two sets of "fours" and one set of "sixes". The nineth and tenth contacts of each group are connected together and taken to "common" selectors.

This arrangement is called a "grading", and it is evident that a large variety of gradings is possible. The number of groups and the number of outlets may vary, and tables have been prepared to give the most efficient formation of the grading in each case. The arrangement is very flexible and in practice enables trunking alterations to be made with very little difficulty.

The principal advantage of grading, however, is not that it is flexible, but that the average traffic capacity of the rank of selectors reached by the grading is increased. For a given volume of traffic and grade of service, a fewer number of switches is required <u>in the next rank</u> when the outlets are graded than when they are arranged in separate groups, the availability being the same.

In considering the switch saving effected by grading, it may be pointed out that, but for grading, it would be necessary in the example shown in Fig. 6 to "tee" the contacts from the panels in pairs to form six full availability groups of 10 selectors. The traffic capacity of these 60 selectors is approximately the same as that of the graded group of 48 selectors. Thus, in this example, the use of grading has resulted in a 20 per cent. saving in the number of 2nd selectors required.

4.7 <u>Limitations to Size of Grading</u>. Although there is no theoretical limit to the size of a grading, practical considerations make it desirable to limit size for the following reasons -

(i) To facilitate tracing of calls.

(ii) To lessen congestion of tie cable circuits.

(iii) To minimise crosstalk caused by exchange equipment.

For the above reasons, limitations are laid down as to the maximum size of gradings as follows -

(i) <u>Double-sided trunk boards</u> (as described in Paper No. 7). The maximum number of trunks from a grading should not exceed the capacity of a bay, that is, 120 group selectors.

(ii) <u>Single-sided Racks</u> (described later in the Course for Siemens No. 16 System and 2,000 type equipment). The maximum number of trunks from a grading should not exceed the capacity of 3 racks.

Crosstalk via bank contacts is due to capacity unbalances via -

(i) Adjacent contacts in adjacent levels.

(ii) Adjacent contacts in the same levels.

The limitations imposed are -

(i) The maximum number of selector bank contacts to be multipled is 2,400.

(ii) When two levels are adjacent, the number of contacts which may be multipled must not exceed 1,250 when the number of contacts multipled for the same choice in the adjacent level exceeds 1,250.

(iii) The maximum number of uniselector bank contacts to be multipled is 2,000.

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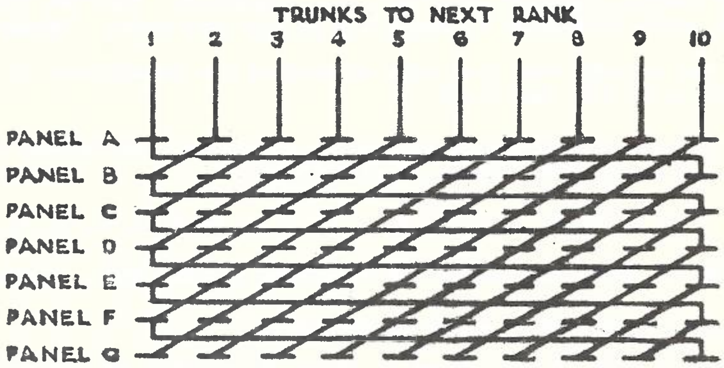
4.8 Straight and Slipped Banks. Present practice is for selector banks to be multipled in "straight" fashion, that is, No. 1 contacts of every bank is commoned, likewise No. 2, etc. As previously mentioned, this condition is necessary whenever grading is used.

In full availability groups (not graded), it is desirable that each trunk should carry an equal share of the total traffic. This condition is achieved only by non-homing type switches. By using "slipped" banks, the same effect may be obtained on switches which search over their outlets in an invariable order. Slipped banks are connected in such a way that No. 1 contact of a level of the first bank is connected to No. 2 of bank 2 and No. 3 of bank 3, etc. The principle is shown in Fig. 7.



SLIPPED BANK MULTIPLE.

FIG. 7.

This arrangement reduces hunting time to a minimum and reduces mechanical wear on the switches. The main disadvantages of the scheme are that uneven wear may be realised on bank contacts and mechanical portions of the switches, and the added complexity introduced into call tracing.

4.9 Trunking of Outgoing Junctions. In this case, the economic advantage of securing the most efficient trunking arrangements is greatly increased by the fact that the next rank of selectors is located in another exchange, and the connecting circuits may traverse many miles of underground cable.

In the case of small groups, say 10-30 junctions, selector outlets to outgoing junctions are graded.

Where the number of outgoing junctions to one particular exchange is large, say over 30, the increased traffic efficiency attending the selection of circuits in large groups has led to the practice of installing in these cases 25 point secondary uniselectors (junction hunters) between the selector banks and the relay-sets installed on the outgoing junctions.

The decision as to whether junction hunters should be installed is made after taking into consideration all the relevant costs (including maintenance of the exchange equipment and line plant) to provide the standard grade of service -

(i) With junction hunters; and

(ii) Without junction hunters.

The charges involved in each scheme are considered as at the present time and at the end of the 5 year and 20 year periods and junction hunters are only installed if the installation in the light of the above costs is economically sound.

Normally, any one selector has access to 10 trunks on any particular level. By connecting each one of these trunks to a secondary uniselector equipped with a 25 point bank and then connecting the 25 outlets of this secondary uniselector bank to the outgoing junctions, it is possible to arrange that one particular selector will have access

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to any one of a number of junctions up to 10 x 25 = 250. The junctions function as one simple group. The full benefit of junction hunters can only be obtained if the junction hunters are equipped with a "group busying" feature, which prevents selectors from seizing a hunter in a congested group.

5. TEST QUESTIONS.

1. (a) State what is meant by the term "traffic unit".

   (b) A group of 100 subscribers originate an average of 1.5 calls each during the busy hour and the average duration of a call is 2.5 minutes. Find the total number of traffic units originated by the group in the busy hour. (Answer 6.25 T.U.).

   (c) What is the average busy hour calling rate of the subscribers in the group. (Answer 0.0625 T.U. per line).

2. A row of 10 selectors is observed at regular intervals. The number of selectors engaged at the successive periods is as follows -

   3, 1, 0, 2, 2, 4, 5, 3, 4, 2, 7, 9, 5, 8, 2, 3, 1, 2, 0, 1.

   Find the traffic units carried by the selectors in that hour. (Answer 3.2 T.U.)

3. (a) What do you understand by grade of service?

   (b) When observed over 10 busy hours, a group of switches carries an average hourly traffic of 10 T.U., the average duration of a call being 3 minutes. If the total calls lost during the 10 hours, owing to all the switches being engaged, is 20, what is the grade of service? (Answer 1 in 101, say 1 in 100 = 0.01.)

4. What is meant by "grading" and what are the principal advantages of grading?

5. What do you understand by "individual" and "common" outlets as applied to gradings? Which should be tested first in order to obtain the best effect from a grading?

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END OF PAPER.