COURSE OF TECHNICAL INSTRUCTION

CROSSBAR SWITCHING I.

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CROSSBAR SWITCHING 1.

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Contents:—

INTRODUCTION TO CROSSBAR SWITCHING

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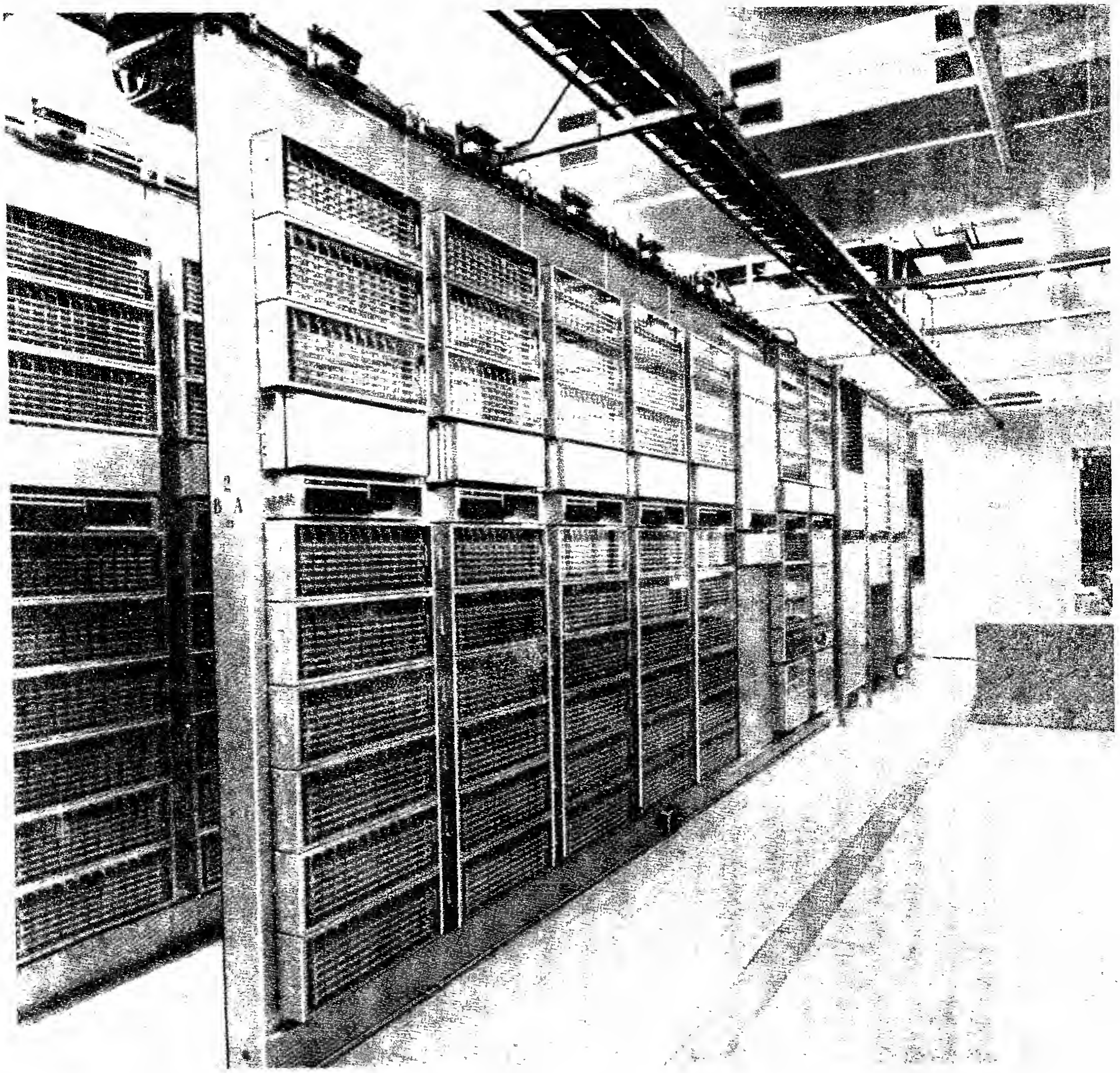
1. INTRODUCTION.

1.1 Development studies of the Sydney and Melbourne networks indicated that a new approach to telephone switching was necessary to overcome problems brought about by rapid expansion. In 1956 it was recognised that the introduction of a seven figure numbering scheme could no longer be postponed and that a register or common control system should be used to avoid the addition of a further rank of switches for the extra digit. A common control system allows a call to be switched by the most economical route and the number of switching stages is no longer decided by the number of digits dialled.

1.2 As a result of recommendations which followed the intensive study by the Engineering Division of the requirements of the Australian telephone networks, it was decided, in April 1959, that the A.P.O. would adopt as its new standard a common control switching system incorporating crossbar switches. The system adopted is that developed by the L.M. Ericsson Company.

1.3 This paper describes the components, together with a basic outline of the principles of operation of a crossbar automatic exchange.



VIEW OF A TYPICAL CROSSBAR EXCHANGE.

FIG. 1.

2. CHARACTERISTICS OF A CROSSBAR SYSTEM.

2.1 Step-by-step automatic system. In the step-by-step system, using bimotional switches, each selector stage is provided with an impulse receiving device. As the impulses are received from the dial, they are translated into D.C. pulses which operate relays and magnets controlling the movement of the wipers to the selected outlet. This operation is referred to as the "setting" of the selector.

Fig. 2 shows that in every call through a step-by-step system using bimotional switches, and employing six digit working, there are four group selector stages and one final selector stage.

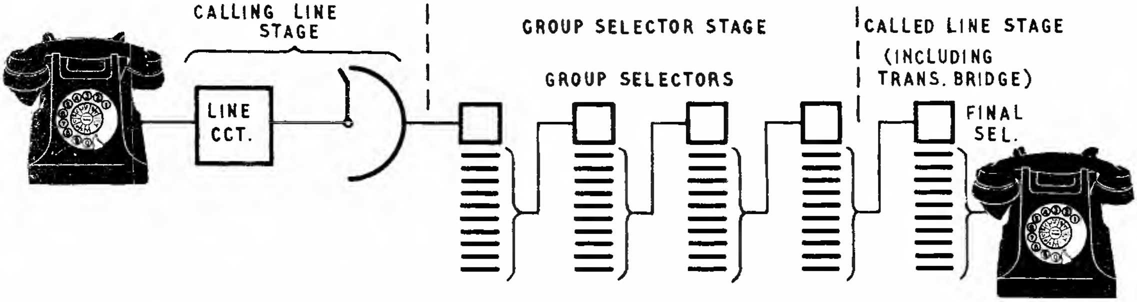


FIG. 2. EXAMPLE OF STEP-BY-STEP SYSTEM.

As the impulse receiving and setting section of each group selector is in use for the duration of only one impulse train, a considerable amount of equipment is idle during the major part of each call.

2.2 Common Control of Selectors. When using common control, as the setting devices for each selector are idle after a call has been established, a reduced number of setting devices is necessary. These are provided in control units called "markers" and are connected to the selectors only during the setting time. (Fig. 3.)

Systems built up in this way are called "common control systems" or "bypath" systems. The term bypath indicates that connection between the control devices and to the selectors is made via a separate path to the actual speaking path.

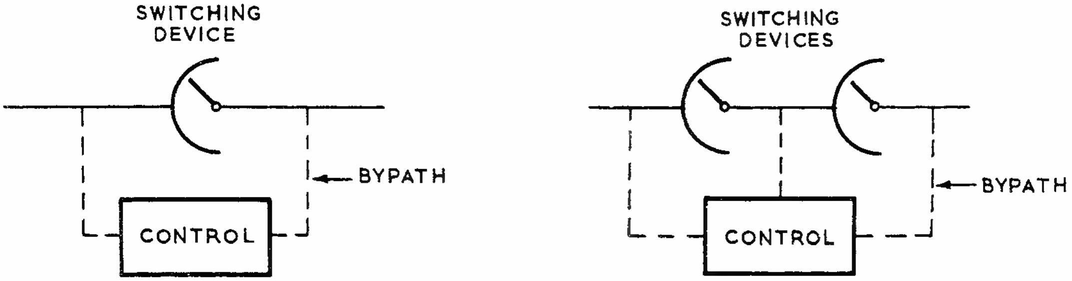


FIG. 3. USE OF CONTROL DEVICES.

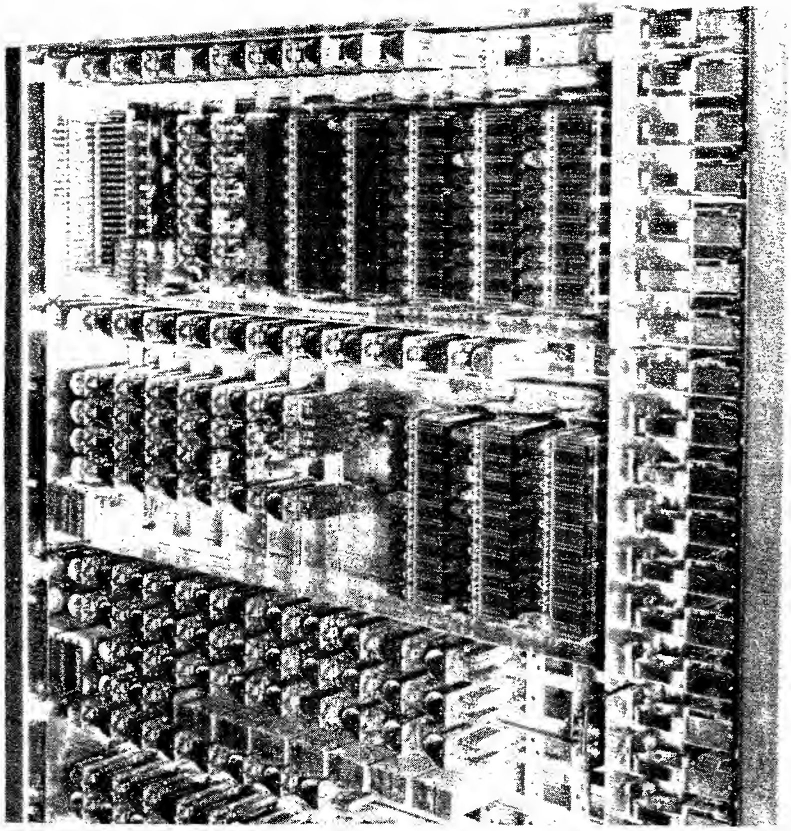


FIG. 4. SECTION OF A CROSSBAR CONTROL DEVICE.

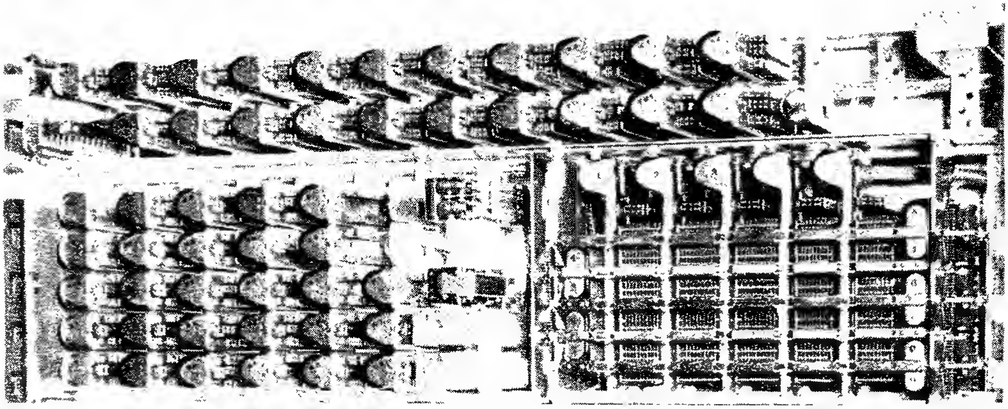


FIG. 5. CROSSBAR CENTRAL REGISTER.

2.3 A central register is connected between the linefinder stage and the group selector stage (Fig. 6).

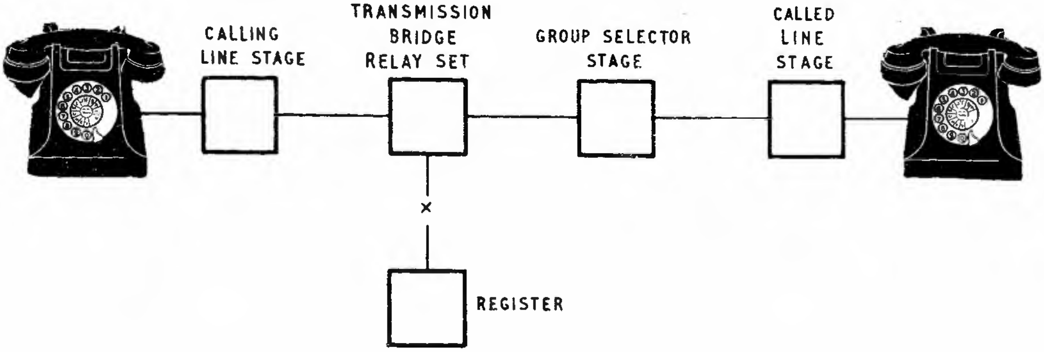


FIG. 6. USE OF A CENTRAL REGISTER.

When a call is originated, the caller is connected to a central register and receives dial tone. The digits dialled are stored in the register, which then initiates the forwarding of the necessary information to the markers.

2.4 The crossbar system adopted for Australia is the L. M. Ericsson system which incorporates the following main characteristics :-

(i) Centralised register control of all calls.

(ii) Common marker control of switching stages.

(iii) Switching stages made up of combinations of 10 inlet/20 outlet crossbar switches.

(iv) High speed signalling employing multi-voice frequency code for digit forwarding and control signals.

2.5 The central registers have the following main functions :-

(i) With favourable line conditions receive dialled digits correctly at speeds between 8 and 22 impulses per second, and dial ratios from 30% make and 70% break to 50% make and 50% break.

(ii) Store up to 10 digits simultaneously and operate in a cyclic manner if more than 10 digits are dialled. This means that the register must commence signalling before the eleventh digit is received.

(iii) Transmit the digits to the crossbar selector stages or to a distant crossbar exchange using a high speed multi-frequency code.

(iv) Transmit dial pulses at normal speed and ratio to step-by-step exchange equipment.

2.6 The common markers have the following main functions :-

(i) Receive coded digits from the registers.

(ii) Analyse the digits received to determine the route required, the number of digits to be expected and the next digit to be sent.

(iii) Test for a free outlet on the route required.

(iv) Select a free path through the selector stage to the free outlet in the route required.

(v) Send control signals to the register in multi-frequency code.

2.7 The use of high speed signalling allows :-

(i) Alternate routing of traffic with multiple choices.

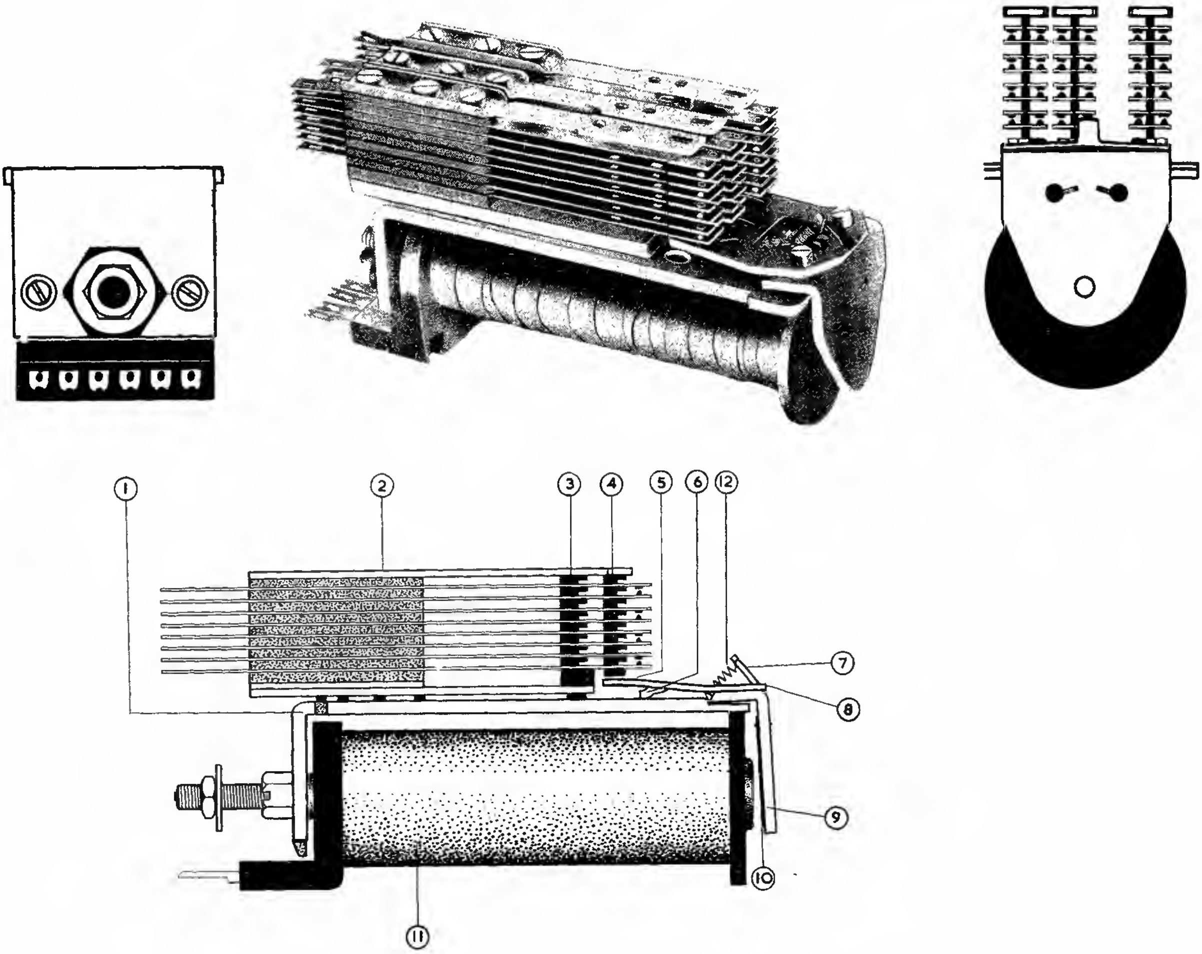
(ii) Faster setting up of calls and earlier release of ineffective calls.

3. CROSSBAR SWITCHING COMPONENTS.

3.1 The chief switching components in use in the crossbar system are :-

- (i) Relays -
  - (a) General purpose relays, types RAB and RAF.
  - (b) "Triple" relay type RAH.
  - (c) Double-coil line relays (early installations).
  - (d) Polarised relays.
  - (e) Miniature relays.
  - (f) Thermal relays.
- (ii) The Crossbar switch.

3.2 The standard general purpose relay used in crossbar systems is the RAF type as shown in Fig. 7.



(1) Relay yoke.
(2) Springset.
(3) Supporting card or comb.
(4) Lifting comb.
(5) Lifting tongue.
(6) Tongue for Stroke adjustment.
(7) Armature bracket.
(8) Armature plate.
(9) Armature.
(10) Nylon Residual plate.
(11) Coil.

FIG. 7. RAF TYPE GENERAL PURPOSE RELAY.

3.2 Coils. As in 3000 type relays, several types of coil are provided :-

(i) A plain core for general use;

(ii) Cores fitted with armature or heel end slugs, or copper sleeves, when slow operate or release characteristics are required.

A maximum of six coil tags may be provided on each relay.

The coil is fixed to the relay yoke by a nut. Two mounting screws attach the complete relay to the mounting frame. In earlier RAF relays the threaded extension of the core served to attach the core to the yoke and the complete relay to the mounting. The use of the two separate mounting screws on the later relays makes it possible to change a relay coil without removing the relay from its mounting.

3.3 Armature. The rear part of the armature forms a knife edge which pivots on a step in the front part of the yoke. Attached to the front end of the armature is the armature bracket. The armature is held and restored by a spiral spring, one end of which is connected to the yoke via a spring support, and the other end of which is attached to the armature bracket. Side movement of the armature is prevented by the spring support, which projects from the yoke through a slot in the armature.

Armature stroke may be adjusted by bending a tongue projecting downward from the armature plate. Adjustment of armature restoring spring pressure is arranged by bending the end of the armature bracket to which the spring is attached.

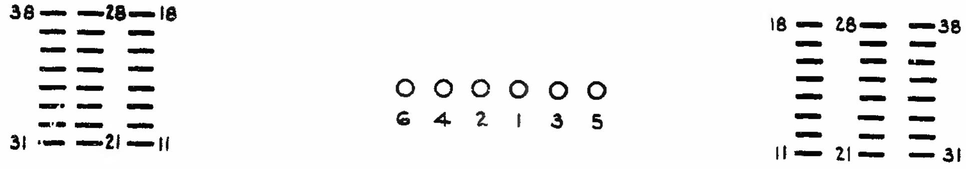
The residual on later relays is provided by a strip of nylon wired to the inside face of the armature, different colours being provided for different thickness requirements.

Colour	Thickness
Transparent	.05mm or approx. 2 mil.
Rose	.10mm
Green	.15mm
Blue	.20mm
Transparent	.25mm.

3.4 Springsets. Each relay is able to accommodate up to three springsets, each containing a maximum of eight springs. Each springset is fixed to the relay yoke by one screw, and is kept in position by a stud in the front end of the springset fitting into a matching hole in the yoke. The fixed springs rest on steps on a supporting card which is rigidly held by a metal plate at top and bottom. The moving springs are supported in positions by a lifting card or comb which is operated by lifting tongues at the rear of the armature plate.

A bending adjustment is possible on each individual lifting tongue, making it possible for one springset to operate before or after all others.

The numbering of the springs and relay coil tags is shown in Figs. 8a, b and c.



(a) Contact Numbering.
Viewed from Armature.

(b) Coil Tags.

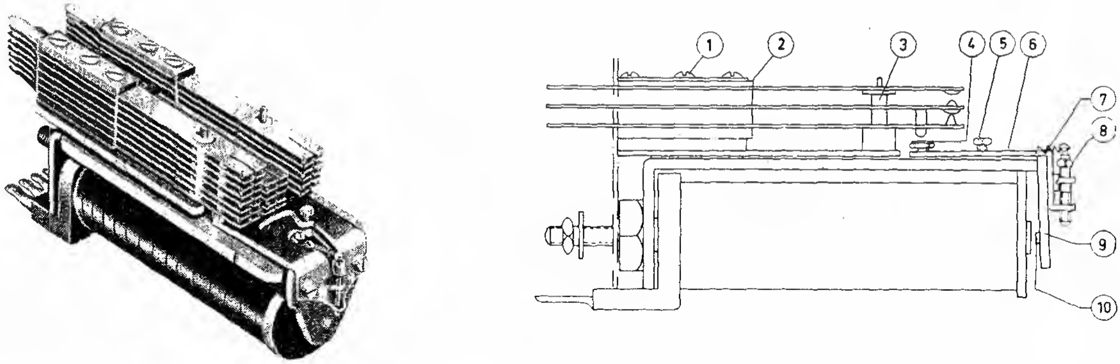
(c) Spring Tags.

Viewed from Rear.

FIG. 8.

3.5 In addition to the type RAF, general purpose relay type RAB is also used. This relay is designed for low contact loads and fast operation. The armature pivots on pins at the front end of the yoke.

Screw adjustments are provided for varying the armature travel, spring lift and armature restoring spring pressure. In early types the moving springs were operated by lifting studs, while the fixed springs were supported by steps on a cylindrical buffer block. Later models use a springset similar to that of the RAF type. Fig. 9 shows a typical RAB type relay.



(1) Springset mounting screw.
(2) Contact springset. (3) Buffer.
(4) Screw adjusting spring lift.
(5) Screw adjusting armature travel.
(6) Armature bracket.
(7) Spiral spring.
(8) Screw adjusting armature pressure.
(9) Armature. (10) Residual.

FIG. 9. GENERAL PURPOSE RELAY TYPE RAB.

A special relay type RAH (Fig. 10) has been developed to obtain a space saving relay where only simple relay functions are required. This relay has three separate coils each with its own springset and armature, the whole being mounted on a common yoke.

The springsets used are the same type as those used on relay type RAF, and the complete RAH relay with its three coils occupies the same space as the RAF relay.

Generally it can be said that relay RAH can be used when up to 8 contact springs are sufficient, and when the requirements are simple.

The main use of relay RAH in Australia is in the line circuits in ARK systems. However, RAH relays will also be used in SR and FIR relay sets.

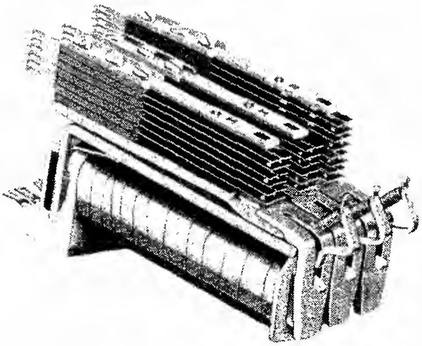
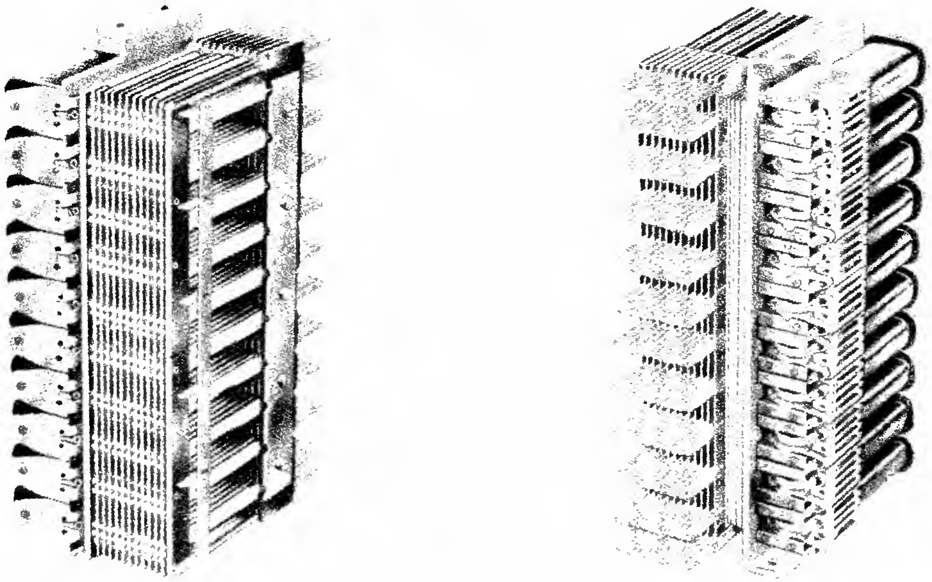


FIG. 10. RELAY RAH.

3.6 Multicoil relay. This relay (Fig. 11) is used to save space and simplify wiring when the multipling of contacts over many relays is required, as in the provision of bypath circuits.



(a) Front View.

(b) Rear View.

FIG. 11. MULTICOIL RELAY.

The multicoil relay consists of a contact field of ten springsets under the control of ten armatures and relay coils, all mounted on a common yoke.

The contact field consists of a number of twin contacts of the make type. The fixed contacts are made in the form of thin silver contact strips mounted on strips of insulation, each contact strip being common to all sections of the relay. The movable springs are individual and under the control of the associated armature. Each springset consists of a maximum of twelve contact units.

The common contact strips are provided with soldering tags at both ends, so that if necessary the strips may be divided into two completely separate units each with five springsets. To facilitate the division, a small gap is left in the centre of the insulation strip on which the contact strip is mounted. The combination of common contact strips and individually operated units is shown in Fig. 12. Springset No. 2 is shown operated.

(1) Contact strip.

(2) Movable spring.

(3) Solder tags.

(4) Armature.

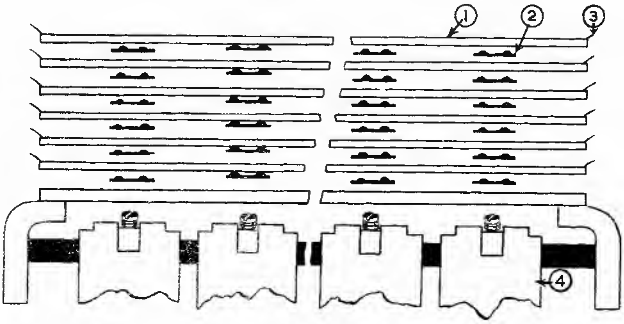


FIG. 12. CONTACT ARRANGEMENT - MULTICOIL RELAY.

3.7 Double Coil Line Relay. A special type of line relay has been used in early crossbar installations. This relay has two coils on a common yoke, two individual armatures and a common springset. Each armature operates its own lifting card, causing the operation of different spring combinations in the common springset. By operating the armatures individually or simultaneously various contact combinations can be obtained. (Fig. 13.)

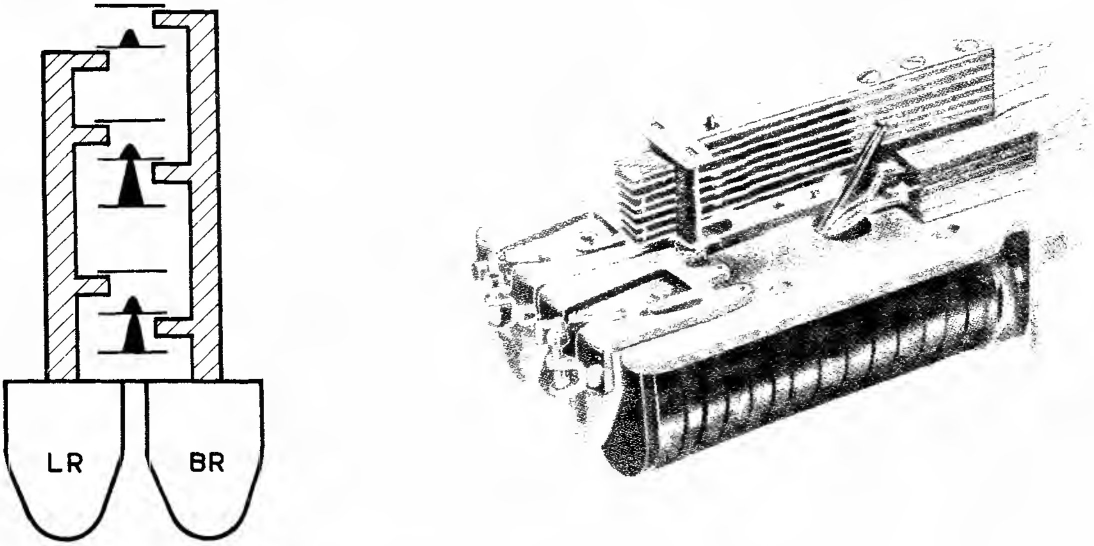


FIG. 13. DOUBLE COIL LINE RELAY.

3.8 Polarised relays. Two types of polarised relays are used, types RAG and RAE (Figs. 14 and 15).

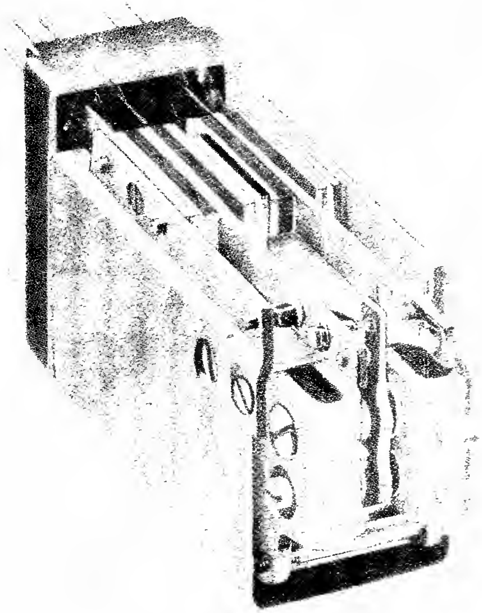


FIG. 14. POLARISED RELAY TYPE RAG.

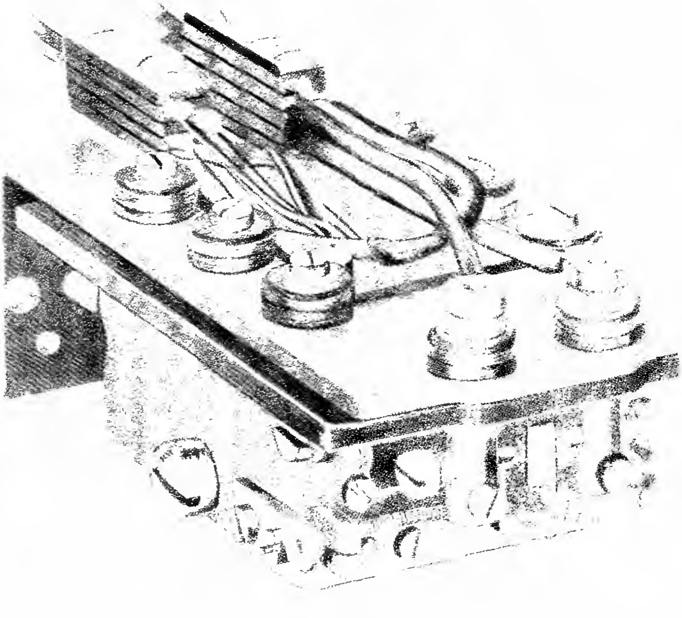


FIG. 15. POLARISED RELAY TYPE RAE.

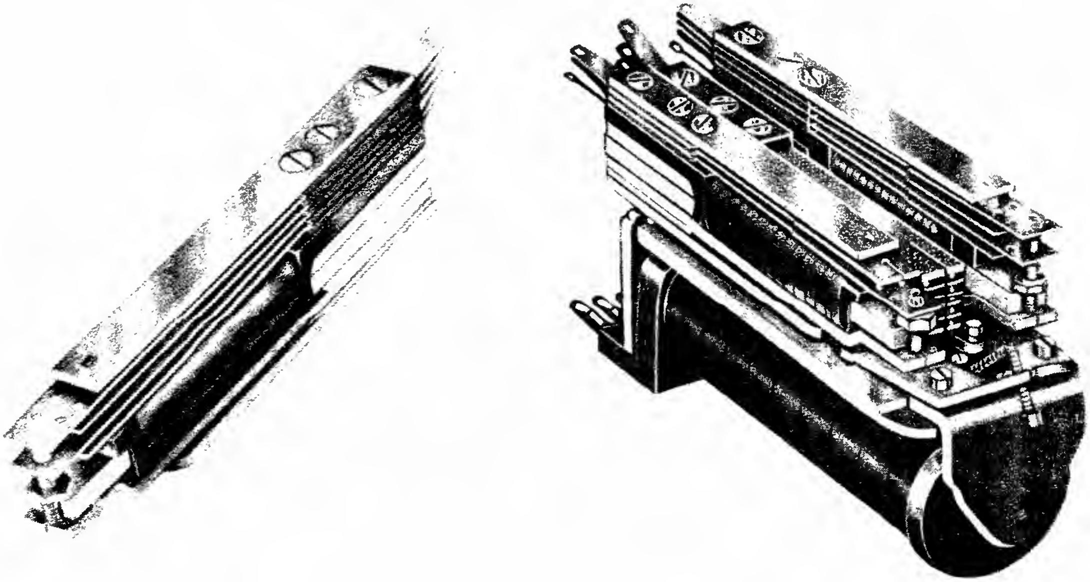
In both types of relay the armature passes through the centre of the coil and operates contacts or contact springs by its movement in one or the other direction. The movement is obtained by two magnetic fields, one from a permanent magnet and the other from an electromagnetic field obtained from the relay coil.

If the armature is adjusted centrally between the two side contacts, the relay is termed "centre-stable" and will operate in either direction depending on the direction of current through the coil.

If the armature is adjusted so that it normally rests on one contact, it is referred to as "side-stable". The relay will then only operate when the current through the coil is in a particular direction.

These relays are also used in some circuits where a particularly sensitive relay is required.

3.9 Miniature Relay. For crossbar circuits where a relay is required to have only one springset, a miniature relay has been designed (Fig. 16a). This relay is of such a size that six units can be mounted in the space required for a general purpose relay. A miniature relay can also be mounted on the yoke of a regular relay which does not have its full complement of three springsets. (Fig. 16b.)



(a) Miniature Relay.

(b) Miniature relay mounted on a general purpose relay.

FIG. 16.

3.10 Thermal Relay. A thermal relay is used to provide the long supervisory times which are beyond the capacity of slugs on regular relays. This relay unit, which consists of a coil wound on a bimetal strip, is the size of a springset and is designed to be mounted in the space normally occupied by the right hand springset of a general purpose relay in a similar manner to that used when mounting a miniature relay.

When current passes through the coil the bimetal strip is heated, causing the two metals to expand at different rates. This bows the bimetal strip and operates the contact unit.

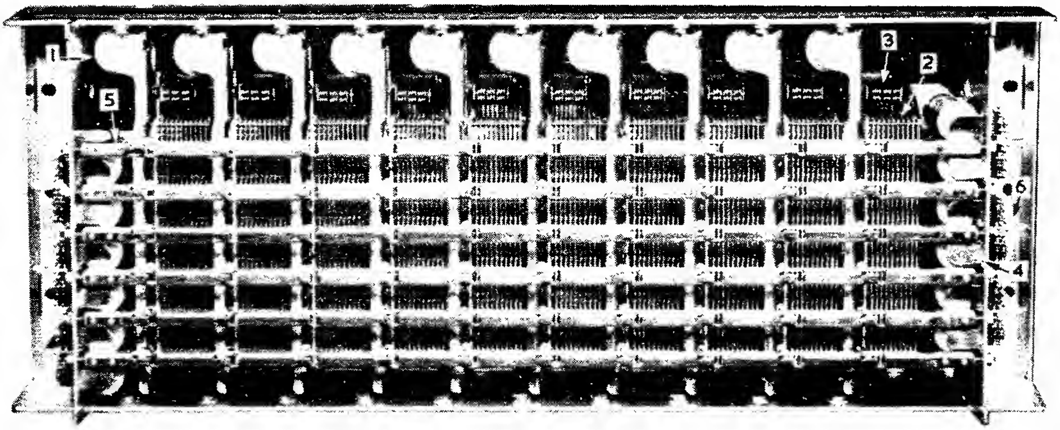
3.11 The Crossbar Switch. The crossbar switch is only a switching device and has no facilities available for testing outlets. Any necessary testing is performed by the associated control devices.

The switch consists of a welded rectangular frame, inside which is fitted :-

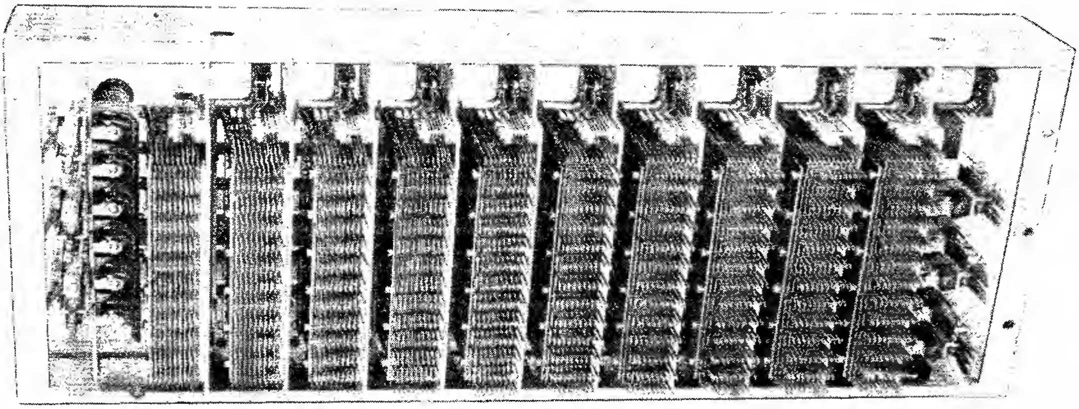
(i) a number of multi-contact arrangements called verticals,
(ii) vertical holding bars and controlling magnets (1 per vertical),
(iii) 5 or 6 horizontal bars and controlling magnets.

Fig. 17 shows a typical crossbar switch and Fig. 18 shows an exploded view of a vertical unit.

(1) Vertical armature.
(2) Vertical contact unit.
(3) Vertical off-normal springs.
(4) Horizontal armature.
(5) Horizontal selecting bar.
(6) Selecting bar restoring buffer.

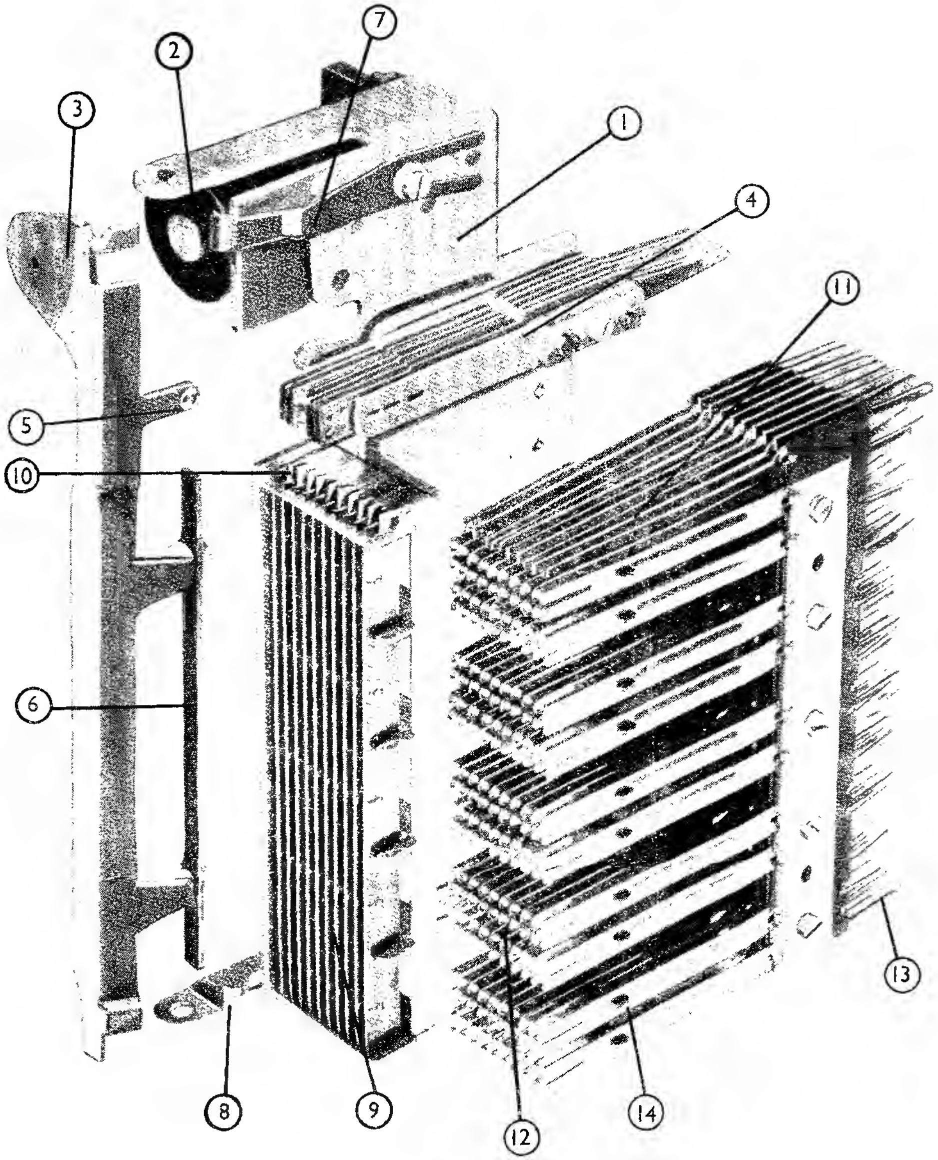


(a) Front View.



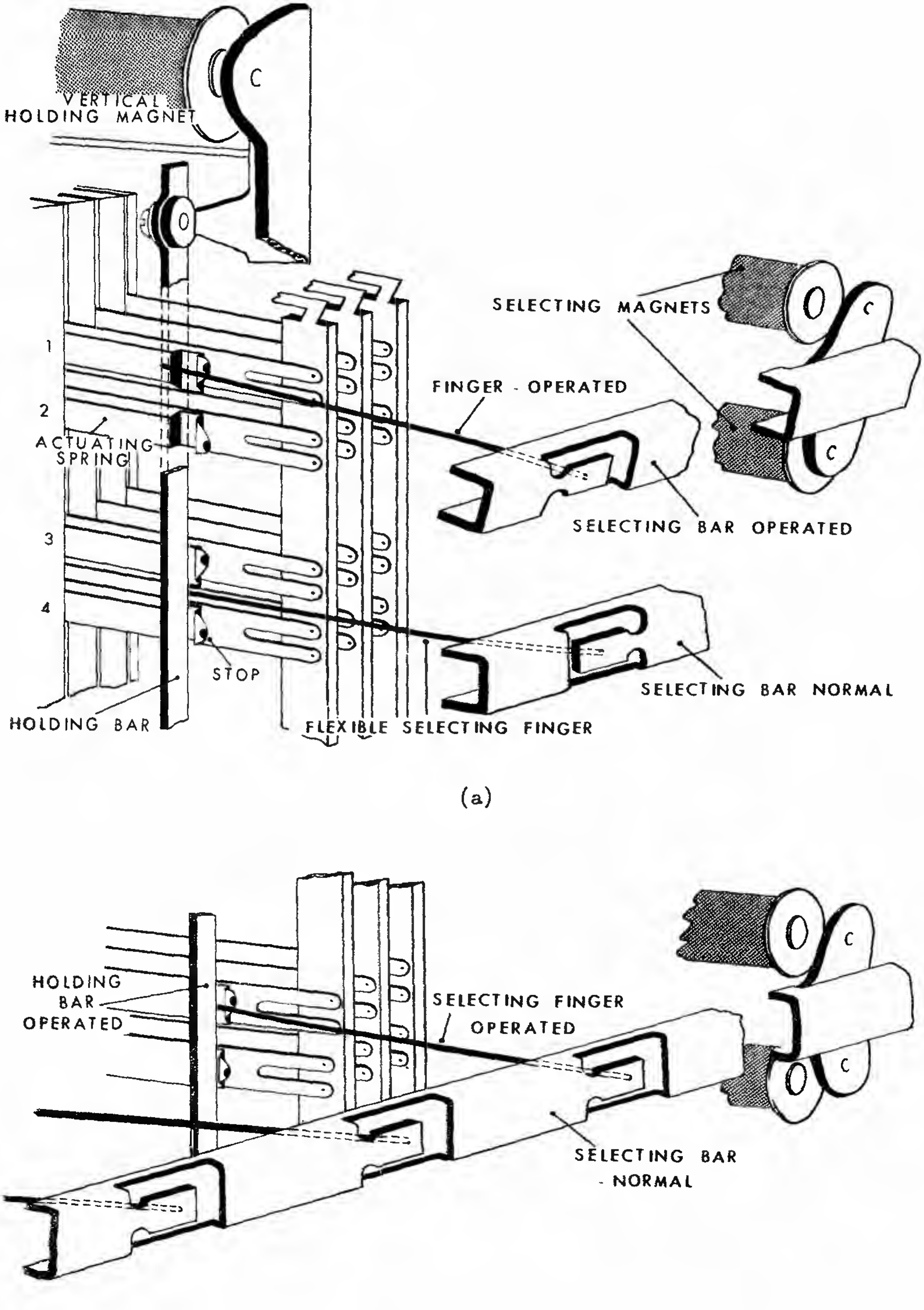
(b) Rear View.

FIG. 20. CROSSBAR SWITCH.



(1) Vertical unit base.
(2) Vertical unit magnet.
(3) Vertical armature.
(4) Vertical unit springset.
(5) Stud for vertical unit springset.
(6) Vertical holding bar.
(7) Upper locking spring.
(8) Lower locking spring.
(9) Contact strips.
(10) Strip extended tabs.
(11) Strip connecting bars.
(12) Multiple springset.
(13) Springset soldering tabs.
(14) Operating comb.

FIG. 18. EXPLODED VIEW - VERTICAL UNIT.



(a)

(b)

FIG. 19. PRINCIPLE OF CROSSBAR MECHANISM.

3.13 Each vertical can be considered as the basic selector of the crossbar system. It consists of a multi-contact field arranged in a similar manner to the multicoil relay contacts. The fixed contacts are arranged in the form of contact strips which extend over the complete vertical. The moving springs are arranged as ten individual units, the particular unit to operate being determined by the operation of a horizontal selecting magnet.

Each horizontal selecting bar has attached to it a number of flexible rods or fingers, the number corresponding to the number of verticals on the crossbar switch. Under normal conditions each finger occupies a central position between two springsets. Each horizontal bar is capable of being tilted up or down under the control of an upper or lower selecting magnet so that the associated fingers are moved up or down against projecting stops.

3.14 Fig. 19a shows a selecting bar normal, with an attached finger occupying a central position between springsets 3 and 4. When a vertical magnet is energised with all horizontals normal, the vertical holding bar moves into a U shaped depression in the actuating springs without operating any springset pile.

The upper selecting bar in Fig. 19a is shown in the operated position, with the attached finger moved against the upper stop, bridging the U shaped depression in the actuating spring of springset 1. When a vertical magnet is energised while the finger is in this position, the vertical holding bar presses against the finger, causing the actuating spring to operate springset 1. When the finger is tilted down instead of up, the operation of the vertical bar causes the operation of springset No. 2.

3.15 Once the connection has been made, the vertical magnet remains energised for the duration of that call. Each vertical, therefore, can be used for only one call at a time. The vertical holding bar remains operated, keeping the flexible finger wedged in position. The horizontal selecting magnet releases after switching, allowing the selecting bar to restore to normal, while the selecting finger is held by the vertical holding bar until the vertical magnet releases at the end of the call. The selecting bar can be used again to switch calls on other verticals.

The holding condition is shown in Fig. 19b. Fig. 20 shows the standard contact numbering of a crossbar switch.

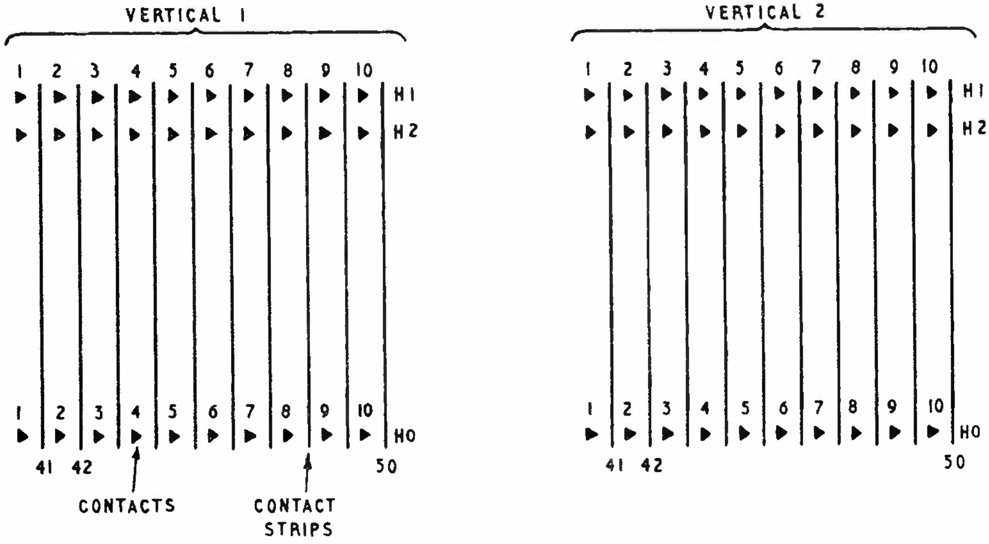


FIG. 20. CONTACT NUMBERING OF CROSSBAR SWITCH.

4. CROSSBAR SYMBOLS.

4.1 The introduction of crossbar automatic switching systems has made it necessary to introduce symbols for devices not previously encountered. In addition, many devices such as relays are represented on crossbar circuits by symbols which differ from A.P.O. standard symbols. The following chart of relay symbols does not include all types, but includes those in general use. Other types will be included as required in other papers of the course.

4.2 Crossbar circuits are drawn using a "Semi-detached method" in which the contacts are shown with their associated relay, but not necessarily in the same order that they are mounted on the relay. The relay coil and associated contacts are arranged in a line either vertically or horizontally, being linked together by a broken line as shown in the example in Fig. 21. When a contact is detached, it is also drawn in its usual position associated with the relay, and a reference written beside this normal appearance indicates the position on the circuit where the detached contact appears.

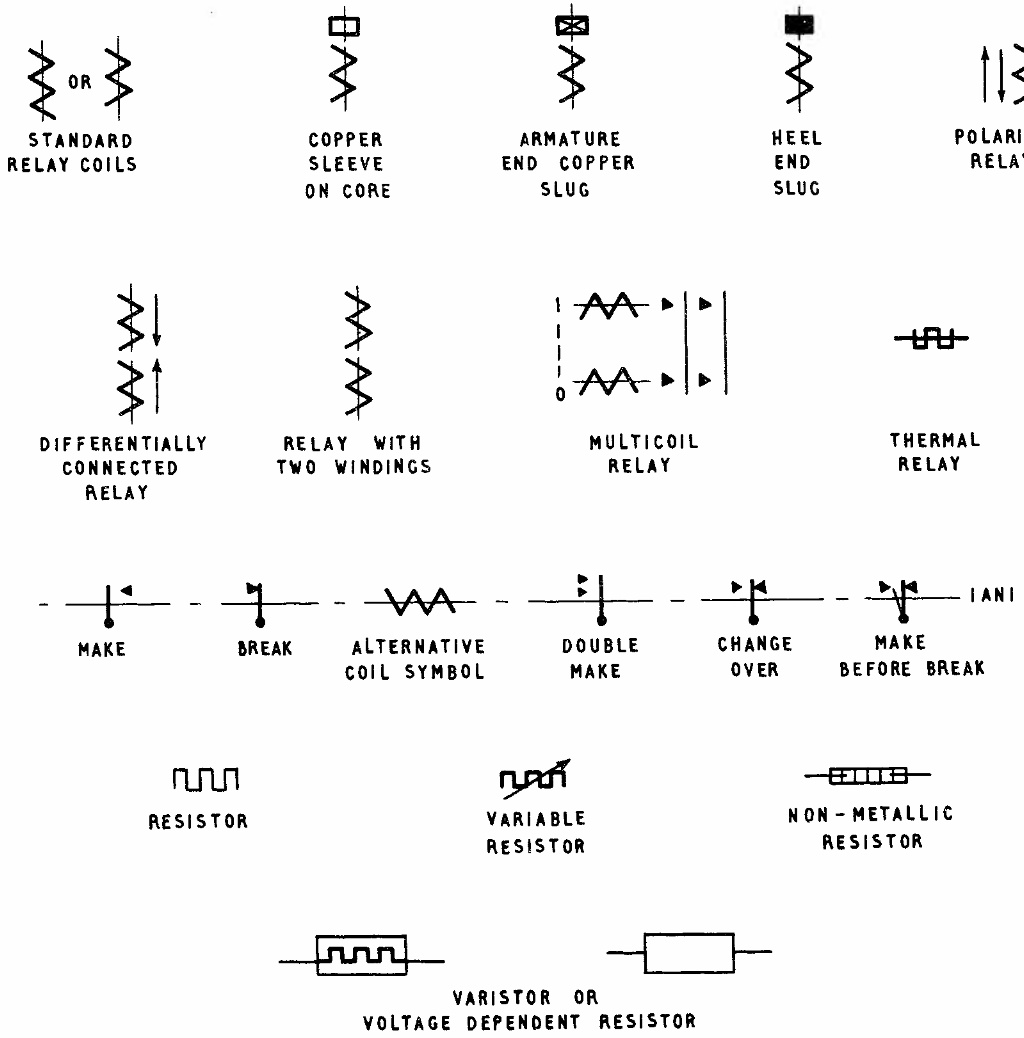


FIG. 21. CROSSBAR SYMBOLS.

4.3 Relay designations. The designation for any particular relay is shown at the end of the broken line linking the coil and its associated contacts. The designation does not give any indication of the number of contact units on the relay, as is the case with normal A.P.O. standards.

In the example 1 AN1 as shown on the symbol chart in Fig. 21, the letters AN designate the relay, while the first figure is an indication that there are other relays 2 AN1, 3 AN1 etc. which assist 1 AN1 to perform a particular circuit function. The figure after the letters indicates that there are other identical relays (1 AN2, 1 AN3 etc.) which perform identical functions with other relay groups.

4.4 Polarised relays are distinguished by two arrows facing in opposite directions placed alongside the coil symbol. A differentially connected relay is one in which the two coils set up opposing fields. This is indicated by an arrow placed beside each coil symbol, the two arrows facing in opposite directions.

4.5 When miniature relays are mounted on general purpose relays, the miniature relay is designated on the circuit in such a manner that the designation indicates the general purpose relay on which the miniature relay is mounted. For example, the designation "R3X" indicates by the "X" that the relay is a miniature relay, while the "R3" before the "X" means that this particular miniature relay is mounted on the yoke of a general purpose relay designated "R3".

4.6 The crossbar switch may be represented by three different symbols as shown in Fig. 22. The symbol shown in Fig. 22a is used only on block diagrams, that shown in Fig. 22b is mainly associated with trunking diagrams, while the symbol shown in Fig. 22c is used to represent a switch or part of a switch in a schematic circuit.

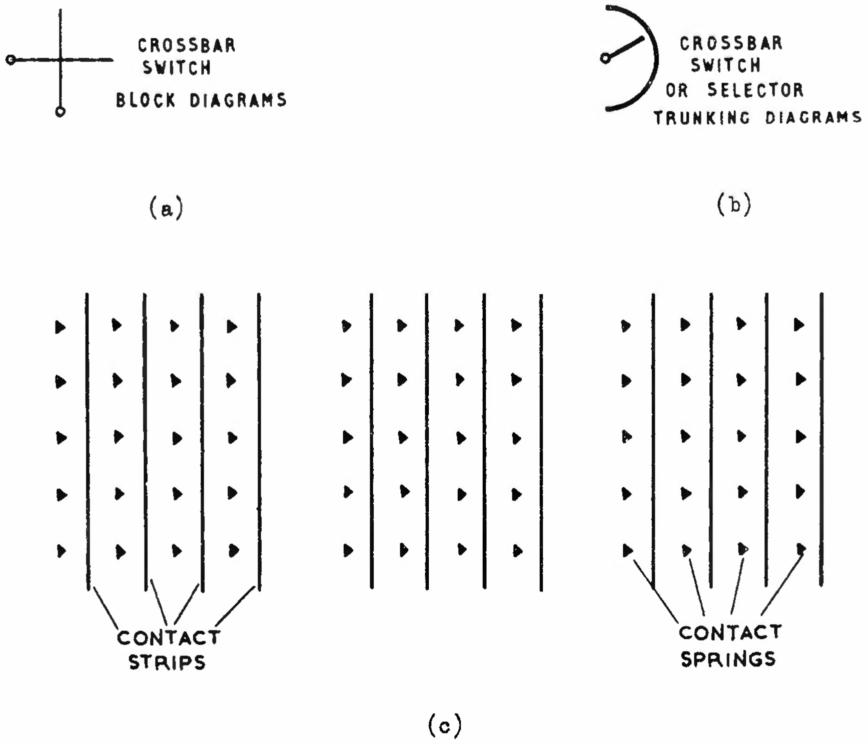


FIG. 22. CROSSBAR SWITCH SYMBOLS.

5. CROSSBAR SWITCH CONNECTING ARRANGEMENTS.

5.1 Fig. 18 shows that each vertical consists of a number of contact spring groups built up by make contact units in which the fixed contacts are arranged as a contact strip common to all spring groups. The moving contacts are individual to each contact group, making contact on the common contact strip when operated.

5.2 When the switch is fitted with five horizontal bars, as each bar may be tilted up or down, ten contact groups are available for each vertical.

5.3 Fig. 23 represents two verticals of a typical crossbar switch using five selecting bars (indicated by ten magnet coils at the extreme left, two for each selecting bar). In this example each of the verticals is fitted with four fixed contact strips (indicated by vertical lines) against which four spring contacts make contact when operated. This switch is therefore known as a four-pole switch.

5.4 Crossbar switches are fitted with varying numbers of poles per vertical to suit different circuit requirements but each switch is designed to accommodate a maximum of ten poles per vertical.

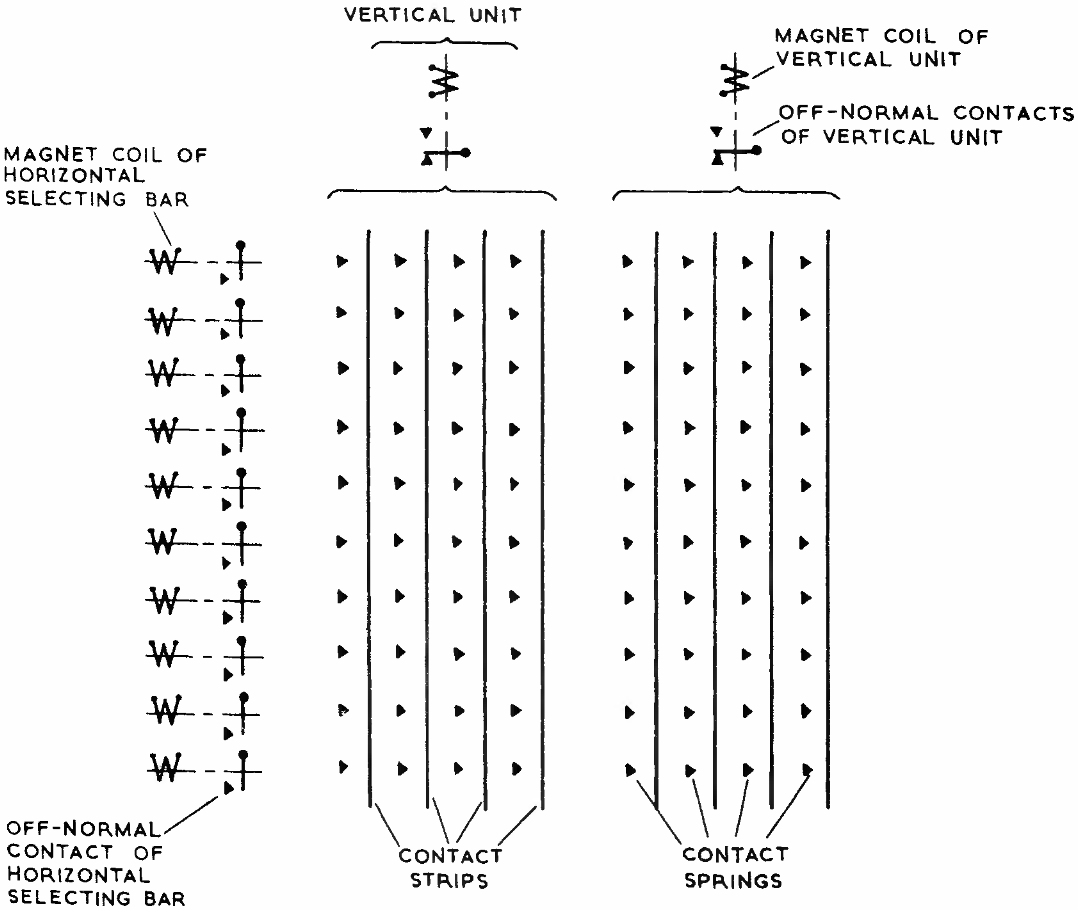


FIG. 23. SECTION OF CONTACT FIELD.

5.5 A crossbar switch containing 10 verticals and 5 horizontal bars contains 100 sets of springs. One hundred subscribers can be connected to the switch as shown in Fig. 24, one subscribers line being connected to each set of individual moving springs. To simplify the diagram, only one pole is shown for each vertical, so that each contact shown can be taken as representing a complete springset.

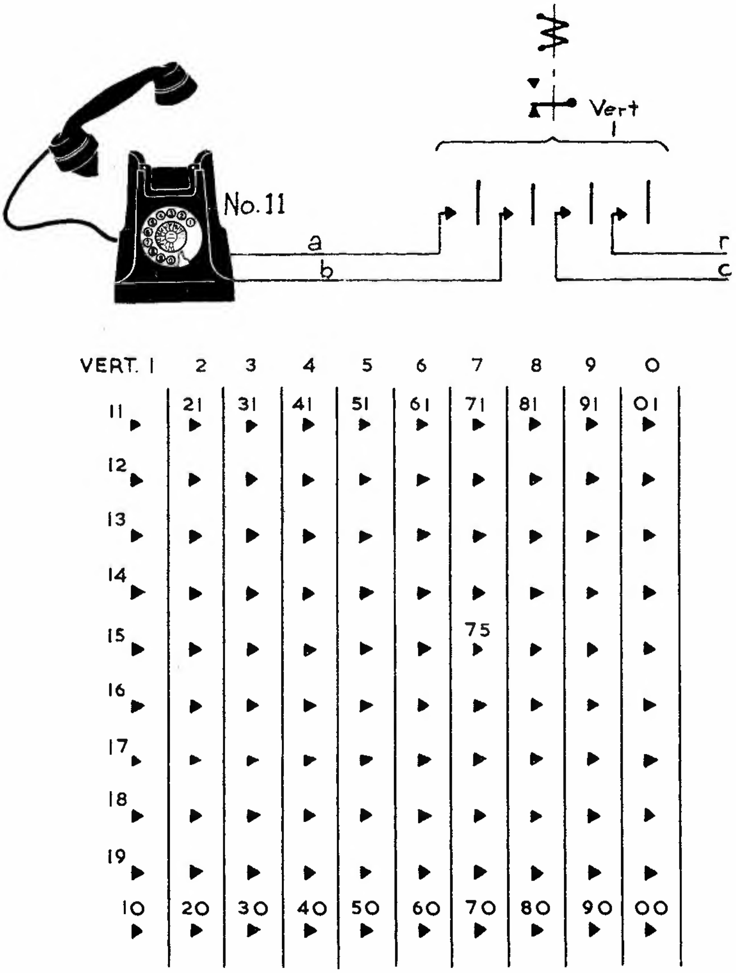


FIG. 24. ARRANGEMENT OF 100 LINES ON A CROSSBAR SWITCH ("SLA" STAGE).

5.6 The numbering in Fig. 24 shows that the vertical row represents the "tens" figure of the subscriber's number, while the horizontal row in that vertical indicates the "units". For example, subscriber 75 is connected in the 5th horizontal springset of the 7th vertical row.

When the 5th horizontal magnet is operated, followed by the 7th vertical holding magnet, the resultant springset operation will connect subscriber 75 to the 7th vertical contact strip.

Similarly, any other number can be connected to the vertical strip in its own row.

The switching stage to which subscribers are connected in this manner is referred to as the "SLA" switching stage. As all available springsets on switches in this stage are connected to subscribers lines, it is not possible to switch together two subscribers lines in a 100 line system by only using an SLA switching stage.

5.7 To facilitate the switching together of two subscribers in a 100 line exchange, another switching stage "SLB" is introduced. This consists of another crossbar switch in which the individual moving springs in each horizontal row are multipled together, i.e. the 1st contact in Vertical 1 is connected to the 1st contact in each other vertical. The other contacts are connected together as shown in Fig. 25.

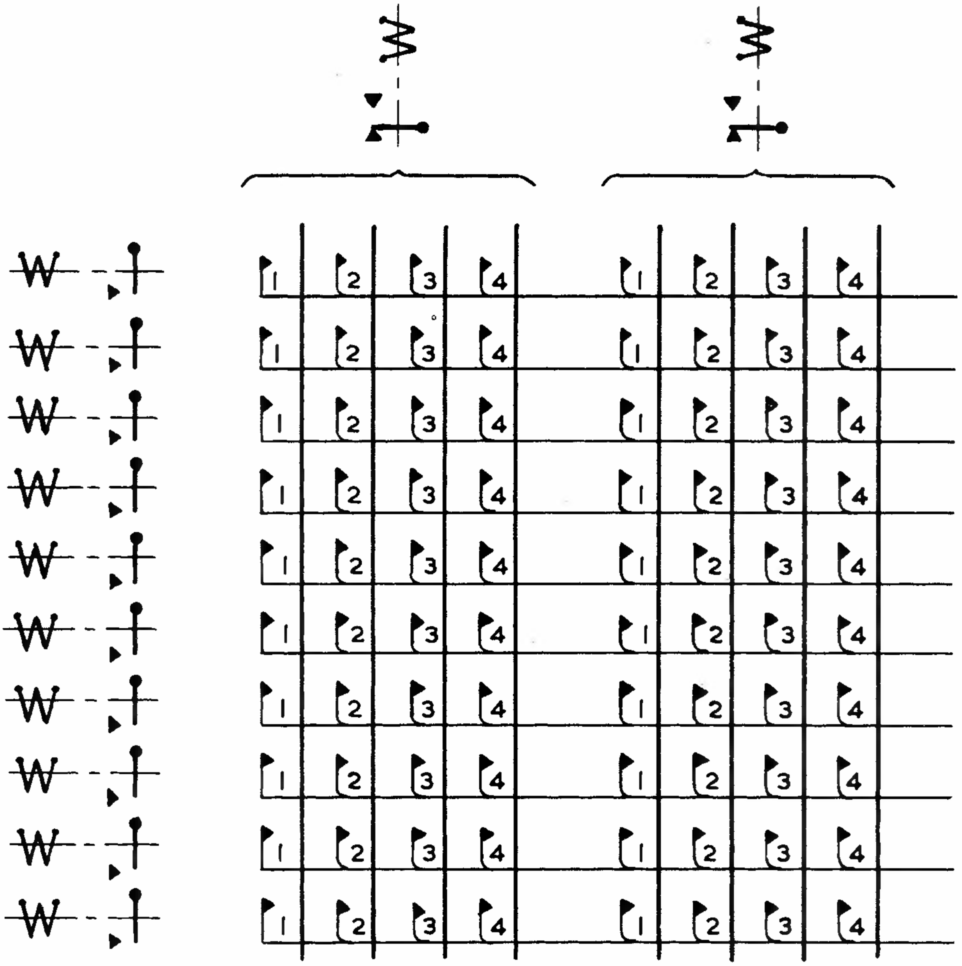


FIG. 25. MULTIPLE CONNECTION OF "SLB" STAGE HORIZONTAL CONTACTS.

5.8 Each of the "SLB" horizontal rows is connected to a vertical contact strip in the SLA switch. Using the previous example of subscriber No. 75, the operation of the 5th horizontal and 7th vertical caused the subscribers line to be connected to the contact strips of the 7th vertical. As the 7th SLA vertical is connected to the 7th SLB horizontal row, subscriber No. 75 has now been extended to the SLB stage and can be reached from any SLB vertical. This may be seen by referring to Fig. 26.

The verticals in the SLB stage are divided into two groups, half the verticals being used to connect to the calling subscribers, while the other half are used to complete connections via relay sets to the called subscribers.

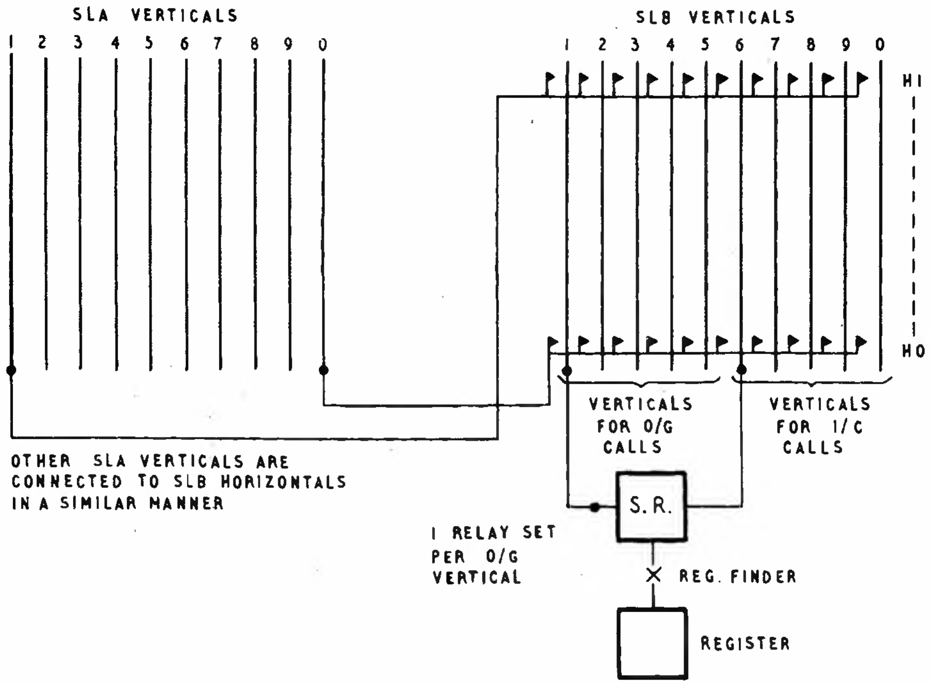


FIG. 26. CONNECTIONS IN THE SLA AND SLB STAGES. 100 LINE EXCHANGE.

5.9 The impulses dialled by the subscriber are stored by the register. This information is then passed on to a control set called a "marker", which determines the correct horizontal and vertical magnets and causes their operation at the correct stage of the call.

5.10 The SR relay set shown in Figs. 26 and 27 acts in a similar manner to a final selector, providing ringing current, ring tone, transmission battery and metering facilities. Fig. 27 shows how two subscribers may be connected together in a 100 line exchange.

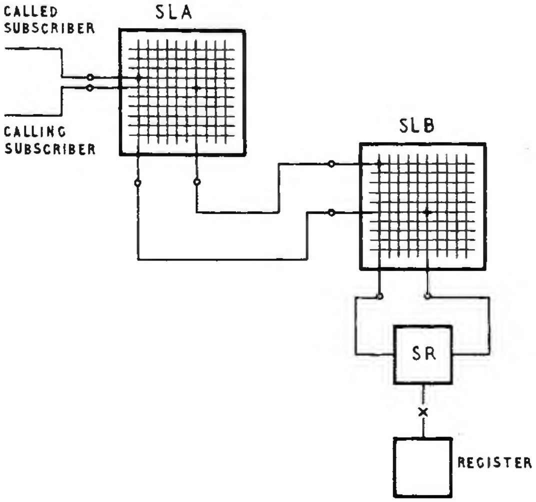


FIG. 27. CALL THROUGH A 100 LINE EXCHANGE.

5.11 The marker control set is only in use during the setting of the call. It is then disconnected and made available for use by other callers. In the trunking diagram of the 100 line exchange (Fig. 28), the dotted lines between the marker and the switching devices represent connections used only during the setting of a call.

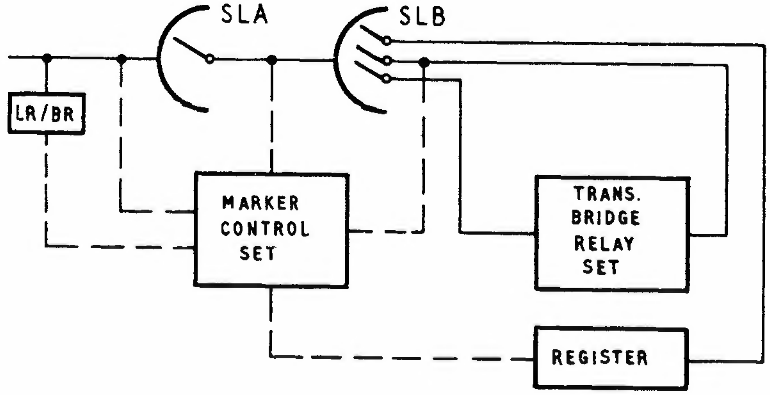


FIG. 28. TRUNKING DIAGRAM OF 100 LINE EXCHANGE.

5.12 Subscriber 75 calling subscriber 14. When subscriber 75 lifts his receiver, his loop causes the operation of his individual line relay. A signal is sent to the marker, which begins to identify the calling line and at the same time a free switching path via SLB to a disengaged register.

The marker then operates the necessary magnets in the SLA and SLB crossbar switches to switch the calling subscriber through to a free register. As the marker is only used during the setting period, it releases as soon as the connection is made, and the subscriber receives dial tone from the register.

5.13 When dial tone is received, subscriber 75 dials the number 14 which is stored in the register. The register signals the marker and passes on the dialled number information in the form of a high speed multi-frequency code. When the marker receives this information it tests the line 14 and, if it is free, operates the necessary SLA and SLB magnets to connect both lines together via the relay set and releases the register.

5.14 The marker releases again after switching has taken place, while the relay set connects ringing current to the line of subscriber 14, and ring tone to the caller. When subscriber 14 answers, the ring and ring tone are disconnected, a metering circuit is prepared and the two subscribers are connected together through a Stone type transmission bridge.

5.15 At the completion of the call, all switches restore to normal when the calling subscriber replaces his receiver.

5.16 Multiple connection of lines. If only one SLA switch were provided, only one subscriber out of each vertical row of ten could make a call at any one time. To overcome this, several SLA switches are provided (the number depending on the calling rate) and the 100 lines are multipled over each of these switches.

6. EXTENSION BEYOND 100 LINES.

6.1 Extension to 200 Lines. Fig. 24 showed four contacts used to switch one subscriber. In various applications the number required varies from three to five contacts. The crossbar switch can accommodate up to ten contacts in each spring pile.

The provision of extra contacts in each spring pile and the fitting of a 6th horizontal selecting bar extends the capacity of each switch to 200 lines.

Fig. 29 shows the principle of doubling the switch capacity.

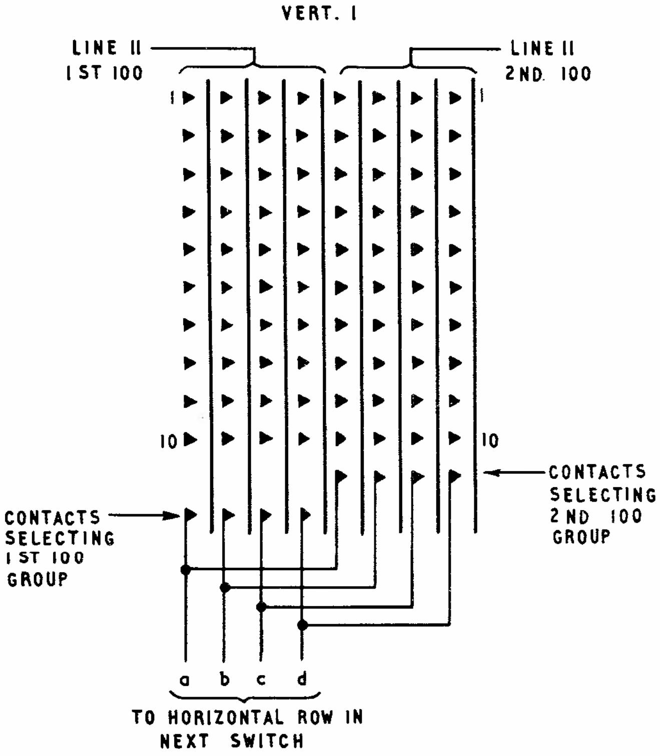


FIG. 29. VERTICAL 1 OF A 200 OUTLET SWITCH (SLA STAGE).

6.2 To connect a line through this type of switch, it is necessary to operate two horizontal bars and the vertical holding bar. The line number (tens and units) is selected as before, while the direction of operation of the 6th horizontal bar decides which 100 line group is selected.

6.3 Both horizontal bars must be operated before the vertical holding bar. When switching has taken place the horizontal bars are restored to normal, but the selecting fingers remain held by the vertical holding bar as previously described. Fig. 29 shows that the outlet to the next stage (SLB) is wired from the contacts controlled by the 6th horizontal bar. The vertical contact strip now serves as a means of connecting together the two sets of operated contacts.

In practice, although the 6th selecting bar may be situated at either the top or the bottom of the switch, its function remains the same. Fig. 29 shows that the operation of the top springset connects 8 contacts to 8 contact strips. However, only 4 of these contacts are connected to each subscriber's circuit. The operation of one or the other group selecting springset, determined by the direction of operation of the 6th selecting bar, decides which set of 4 contacts will be switched to the next stage.

6.4 Extension to 1000 lines. A 1000 line crossbar system is made up of 5 basic groups, each of 200 lines. Each 200 line group is connected to an individual rack of SLA switches. Fig. 30 shows the distribution of line groups.

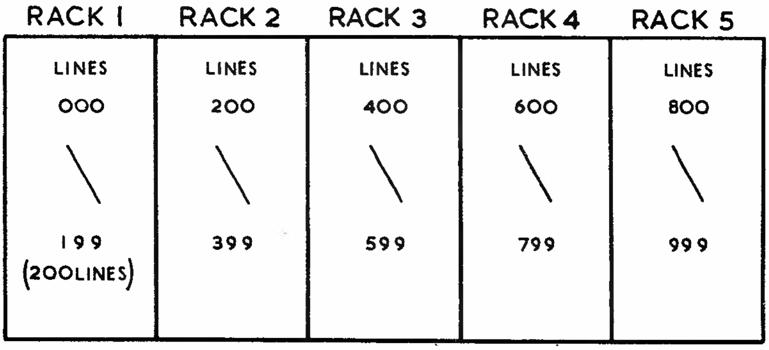


FIG. 30. LINE GROUP DISTRIBUTION.

The arrangement of each 200 line group on a particular SLA switch is the same as that shown in Fig. 29. The group is then multipled or connected to identical contacts on other SLA switches on the same rack. In practice there are exceptions to this arrangement which will be dealt with in other papers.

6.5 To extend the system to 1000 lines it is necessary to add two more stages of crossbar switches, referred to as the SLC and SLD stages. These additional stages are shown in Fig. 31, which shows the trunking of a 1000 line crossbar system.

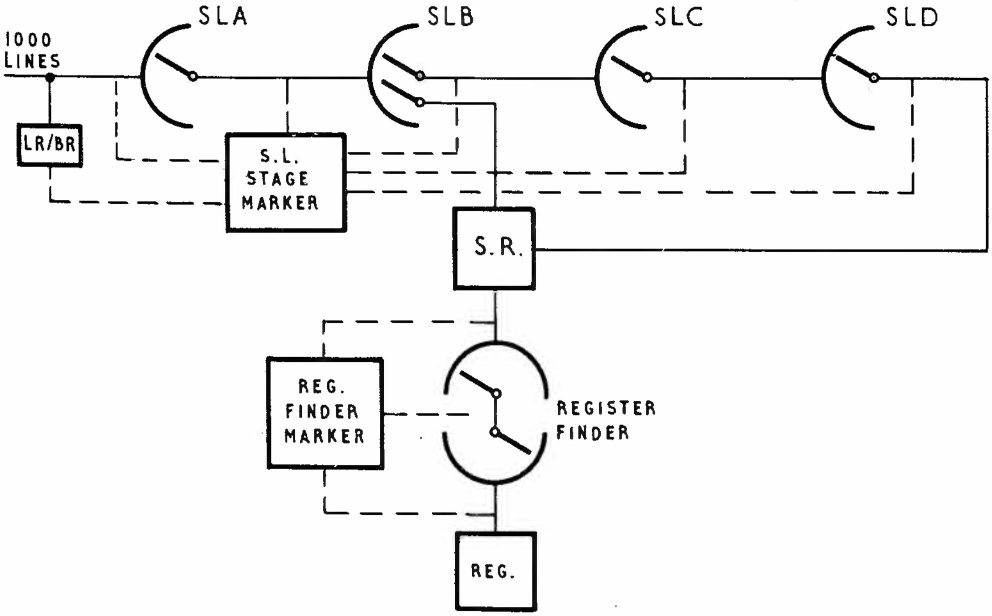


FIG. 31. TRUNKING DIAGRAM 1000 LINE SYSTEM.

As in the simpler 100 line example the SLA stage is used for both outgoing and incoming calls. Some verticals in the SLB stage are used for outgoing calls while others are reserved for incoming calls. However, the SLC and SLD stages are only used for incoming calls.

6.6 A call through this exchange follows the same procedure as before. The calling subscriber lifts his receiver, operates his line relay and supplies a signal to the SL marker to indicate an outgoing call. This marker control set finds the calling line and a free path to a SR relay set in a group which has access to a free register. The SL marker and the Register Finder marker cause the operation of the necessary magnets to connect the caller through the SLA/B stages and SR relay set to the register. The markers then release.

6.7 The caller receives dial tone from the register and dials the three digits necessary to identify the required number. The register signals the marker again and passes on the three digits in code form. The SL marker tests the called number and advises the register of the line conditions.

6.8 <u>When the line tests free</u>, the marker causes the operation of the necessary magnets to complete a path from the selected SR relay set through stages SLD, SLC, SLB and SLA to the called number. The register releases and the remainder of the call functions as described in paragraph 5.14. The SR relay set is connected between an outgoing vertical of SLB and a vertical of SLD.

6.9 <u>When the called number is busy</u> the whole connection is released and the calling subscriber receives busy tone from his line circuit.

6.10 <u>Extension beyond 1000 lines</u>. When the exchange has more than 1000 lines, or is part of a network with a capacity of more than 1000 lines, one or more group selector stages of crossbar switching are added. However, it is not necessary to add a switching stage for every extra digit dialled as is the case with step-by-step systems. Fig. 32 shows a typical trunking diagram of an exchange with a capacity of more than 1000 lines.

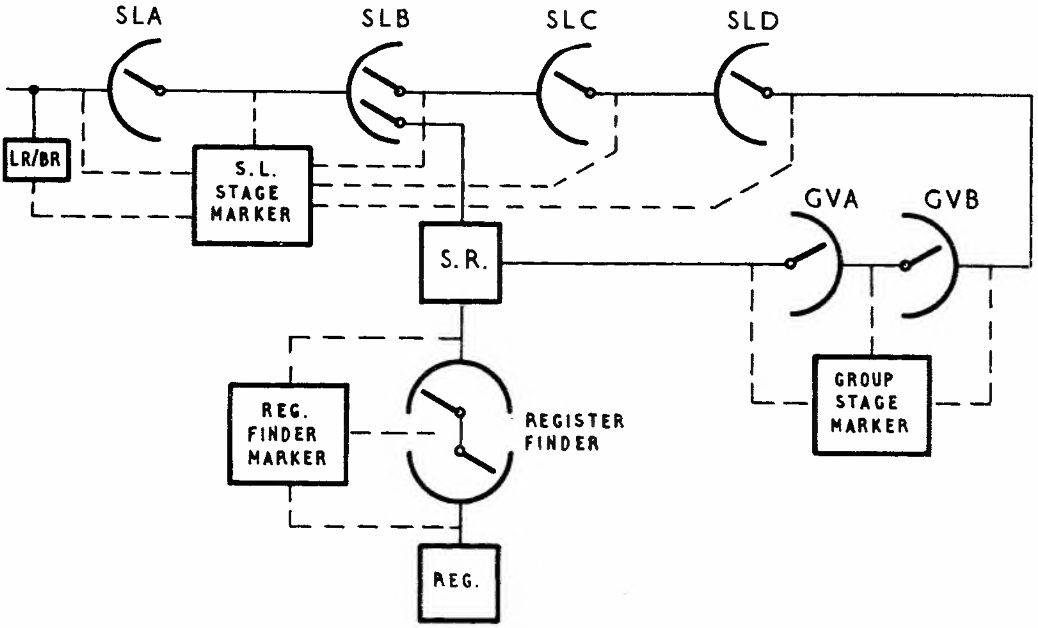
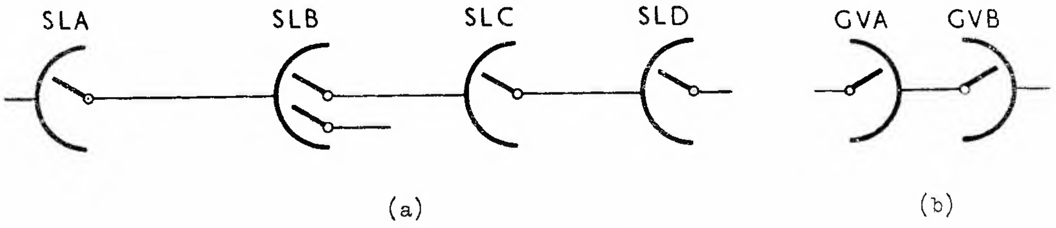


FIG. 32. SIMPLIFIED TRUNKING DIAGRAM OF A TYPICAL CROSSBAR EXCHANGE.

6.11 Previously, SLA, SLB, SLC and SLD have been referred to as separate stages. In practice, however, they are collectively referred to as one combined line-finder and final selector stage, and individually, SLA, SLB, SLC and SLD are referred to as "partial stages" (Fig. 33). Similarly, each group selector stage is made up of two partial stages connected in tandem or in series as shown in Fig. 33b.



PARTIAL STAGES IN TANDEM.

FIG. 33.

The maximum of 20 outlets from one crossbar vertical (using 6 horizontal selecting bars) is insufficient for trunking requirements. By connecting the two partial stages in tandem each inlet to the first partial stage is given a choice of 400 possible outlets.

6.12 The SR relay set shown in the previous diagrams has the following main functions :-

(i) Supply of transmission battery for both A (caller) and B (called) subscribers on a local call and caller only on an outgoing call.

(ii) Metering of effective calls.

(iii) Supervision.

(iv) Holding.

(v) Connection of ring and ring tone.

(vi) Disconnecting ring and ring tone when called subscriber answers.

The trial installations of L.M.E. crossbar in Australia at Templestowe, Sefton and Toowoomba distributed the above functions in two relay sets, the SR and the LKR. Future installations will use only the SR containing all functions.

6.13 A subscribers stage marker (SLM) is provided for each group of 1000 lines and a separate marker (GVM) is provided for the group stage.

In a purely crossbar network the register would wait until it had received all digits before signalling the GV marker. However, for Australian requirements the register will only wait until it has received enough digits to decide when to signal the next stage.

Each SR relay set is directly connected to an inlet to the group selector stage and it is over this path that the register signals the GVM, sending forward enough information for the GVM to identify the group of 1000 lines containing the desired number. The number of coded digits required will vary with the local numbering scheme.

The GVM selects a free outlet to the wanted 1000 group and operates the GVA and GVB magnets. The register is now connected through to an SLD inlet which calls in the SL marker. SL marker receives the last three digits of the called number in code from the register and the further operation is as described for the 1000 line exchange.

7. TYPES OF CROSSBAR EQUIPMENT TO BE USED IN AUSTRALIA.

7.1 The three types of L.M.E. crossbar exchanges to be used in Australia are as follows:-

(i) ARF - City and larger country exchanges.

(ii) ARK - Smaller country exchanges.

(iii) ARM - Trunk switching exchanges.

These crossbar exchange types use similar relays and switches, but differ considerably in internal trunking and control techniques.

7.2 The trial exchanges installed at Templestowe in Victoria and Sefton in New South Wales used a design known as ARF 51, which functioned as a step-by-step employing crossbar switches. A central register was not used but very simple registers were associated with each switching stage. No additional exchanges of this type will be purchased.

The trial exchange at Toowoomba is a design known as ARF 10, using a central register and employing a DC code for high speed internal signalling.

This design has been modified to incorporate a method of high speed signalling using multi-voice frequency code, and all future supplies for Australian use will include multi-frequency signalling between registers, and between registers and marker control sets.

7.3 Two types of ARK exchange are to be used in Australia:-

(i) ARK 51 is designed in the form of a 30 line unit. It may be extended by further 30 line units up to a maximum of 90 lines.

(ii) ARK 52 has an initial capacity of 100 subscribers and can be extended to 2000 subscribers.

These exchanges are designed for normal operation with an ARM parent exchange where the control registers are centralised. However, operation with other types of parent exchange equipment is possible.

7.4 ARM exchanges are of two types, ARM 50 for smaller installations and ARM 20 for very large switching centres.

Separate explanations of the various exchange types will be given in other papers of the course.

8. TEST QUESTIONS.

1. Explain briefly the meaning of the term "setting" as applied to selectors.
2. State how the use of register control reduces the amount of idle equipment.
3. Which apparatus in a crossbar system receives the pulses from the subscriber's dial?
4. Sketch the symbol used for each type of relay employed in crossbar working.
5. Show by sketches the contact numbering and coil tag numbering on a general purpose relay used in a crossbar system.
6. Describe the construction of a multicoil relay.
7. State three methods of using polarised relays.
8. Describe the mechanical operation of a crossbar switch.
9. State the vertical and horizontal magnets operated to switch the following numbers - 11, 67, 83, 46 in a 100 line system.
10. Sketch the various symbols used for a crossbar switch and state where each symbol is used.
11. Draw a trunking diagram for a 100 line crossbar exchange.
12. Describe the operation that occurs when subscriber No. 81 calls subscriber No. 10.
13. Explain the method of extending the capacity of an exchange from 100 lines to 200 lines.
14. List the facilities provided by the SR relay set when no LKR relay set is provided.
15. Explain how these facilities are divided when SR and LKR are both provided.
16. List the subscribers lines connected to each rack in a 1,000 line exchange.
17. State the magnets operated to switch the following numbers - 234, 761, 893, 024 in a 1000 line system.
18. Draw a trunking diagram of a 1,000 line exchange.
19. List the three main types of crossbar systems to be used in Australia.
20. State the maximum number of simultaneous calls that can be in progress on one 200 outlet crossbar switch.
21. Show with a sketch the numbering of the contact strips on a crossbar vertical.

END OF PAPER

CROSSBAR TRUNKING

1. INTRODUCTION.

1.1 In the paper "Introduction to Crossbar Switching", we studied a basic outline of the principles involved and the switching apparatus necessary for a simple crossbar exchange.

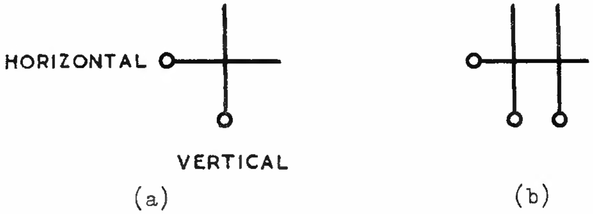
1.2 The reasons for the adoption of the crossbar automatic switching system were mainly to reduce the costs of the future development of the Sydney and Melbourne networks and to facilitate the introduction of subscriber dialling of trunk traffic, ultimately on a nationwide basis. An important factor in both cases is the provision for alternate routing of traffic.

1.3 To enable a full understanding of the principles involved in providing these additional facilities, it is first necessary to study in more detail the trunking methods employed in a typical crossbar exchange.

1.4 This paper compares the trunking of crossbar and step-by-step exchanges, and provides a basic description of crossbar trunking with its associated symbols. An introduction to the use of "chicken" symbols is followed by a description of typical interworking between crossbar and step-by-step equipment. Finally, a brief outline is given of the main features of the scheme for nationwide subscriber dialling.

2. TRUNKING SYMBOLS.

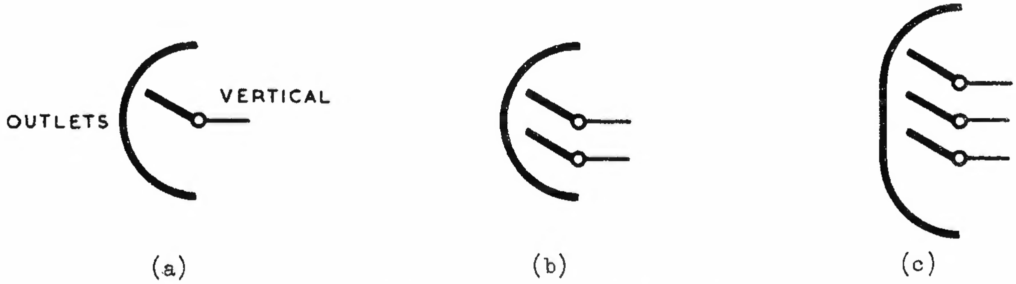
2.1 Figs. 1-3 show symbols which are commonly used in crossbar trunking diagrams. Fig. 1 shows a symbol for a crossbar switch. This symbol is generally used when representing a crossbar switch in a block diagram. The inlets to each vertical are represented by a vertical line, while the outlets are represented by a horizontal. It is not essential to show the exact number of verticals or horizontals as the symbol is used only to convey an impression of verticals and horizontals. Generally only one vertical and one horizontal is shown (Fig. 1a) but if it is important to show that verticals from one switch are connected to various types of apparatus, then several verticals may be shown (Fig. 1b). An example of this is the SLB switch in which half the verticals are used for outgoing calls while the other half are used for incoming traffic.



(a) (b)

FIG. 1. CROSSBAR SWITCH SYMBOLS - BLOCK DIAGRAMS.

2.2 Fig. 2a shows the symbol used to indicate a partial switching stage. Figs. 2b and 2c show how this symbol can be varied when indicating that several verticals from the one partial stage are connected to different types of apparatus.



(a) (b) (c)

FIG. 2. PARTIAL STAGE SYMBOLS - TRUNKING DIAGRAMS.

2.3 A simple form of block diagram (Fig. 3) is sometimes used to indicate either switching stages or connections between various groups of apparatus.

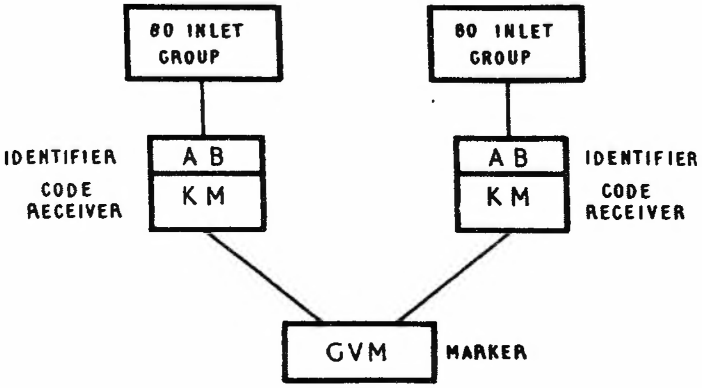
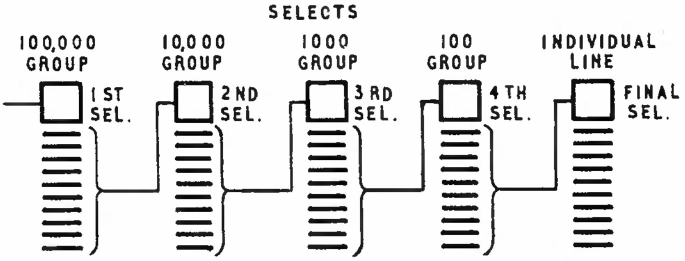


FIG. 3. BLOCK DIAGRAM USED TO SHOW INTERCONNECTION OF APPARATUS.

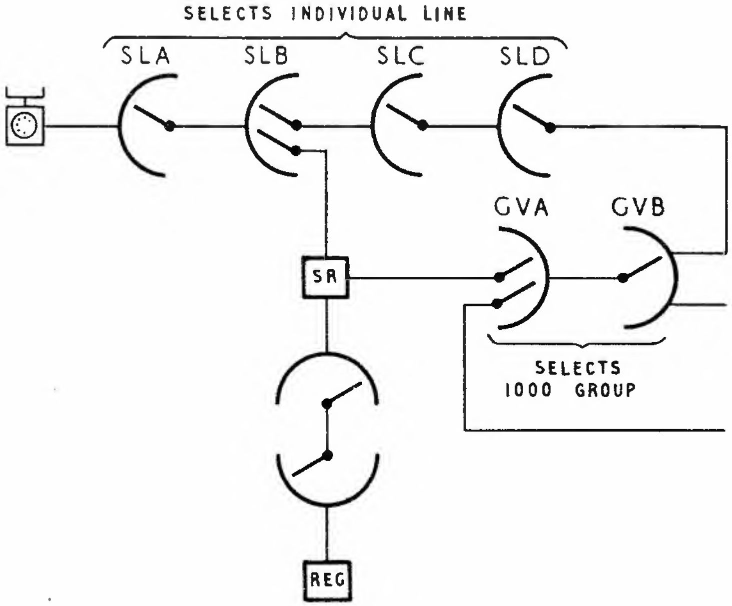
3. CROSSBAR SWITCH AS A SELECTOR.

3.1 In step-by-step automatic switching systems, a number of group selector stages are used during the progress of each call. In the case of a system using a 6 digit numbering scheme, four group selector stages are provided to narrow the selection to the final stage of 100 or 200 lines. A final selector stage then uses the last two digits to select the required number.

3.2 The crossbar system, by using a central register control system, provides a more flexible method of trunking. On a local call in a crossbar exchange, all the digits are received in the register before switching takes place. The register is able to forward sufficient information for the GV marker to determine the route required. Although one group selector stage is usually sufficient to switch a local call, a second GV stage (para. 7.3) may be fitted to provide sufficient routes. Figs. 4a and 4b compare the group selector requirements of typical step-by-step and crossbar exchanges.



(a) Selecting stages in a Step-by-step exchange.

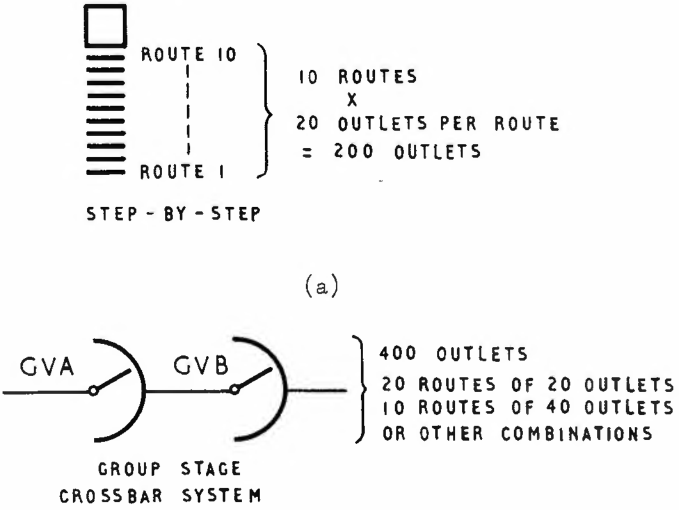


(b) Crossbar Selecting Stages.

FIG. 4. COMPARISON OF TRUNKING SCHEMES.

3.3 In a step-by-step switching system, the call is steered in the correct direction by the digits received from the dial. These digits cause the wiper assembly to be stepped to a level corresponding to the digit dialled. On each level there are twenty outlets, and the group selector must choose one free outlet from this group of twenty if the call is to proceed. As each group selector is under the direct control of the dial, it is possible to provide only ten traffic routes from one switch.

3.4 In the crossbar system, it is possible to provide 400 possible outlets, which may then be divided into varying numbers of routes. As the crossbar group selector is not directly controlled by the dial, the outlets may be arranged in the manner best suited to the traffic requirements. Figs. 5a and 5b compare one group selector stage in each system.



(a)

(b)

FIG. 5. COMPARISON OF GROUP SELECTOR STAGES.

3.5 Fig. 5a which represents a step-by-step first selector stage, shows that as there are ten levels on a bimotional switch, it is only possible to provide ten different routes from each stage.

When one or more levels are not in use, it is not possible to use these levels for other routes and so a number of outlets are idle.

3.6 The 400 outlets from a crossbar group selector stage may be divided so that routes with a low calling rate may have only 5 outlets, while routes with a high calling rate may have up to 40 or more outlets. This flexibility reduces the possibility of idle outlets.

3.7 We saw in the paper "Introduction to Crossbar Switching" that where a crossbar switch contains five horizontal selecting bars, each vertical has ten individual springsets. When this type of switch is used as a group selector, each vertical has a choice of ten outlets.

This number is not sufficient for trunking requirements.

3.8 One method of increasing the number of outlets from each vertical is by using a 6th horizontal selecting bar controlling two group selecting springsets HA and HB. The use of these additional springsets enables the number of outlets from each vertical to be doubled.

To select a particular outlet it is necessary to operate two springsets, a normal horizontal springset and either HA or HB springset.

Table 1 indicates the horizontal springsets which must be operated to connect the inlet to various selected outlets.

Required Outlet	Horizontals		Required Outlet	Horizontals	
	H1 - HO	HA or HB		H1 - HO	HA or HB
1	H1	HA	11	H1	HB
2	H2	HA	12	H2	HB
3	H3	HA	13	H3	HB
4	H4	HA	14	H4	HB
5	H5	HA	15	H5	HB
6	H6	HA	16	H6	HB
7	H7	HA	17	H7	HB
8	H8	HA	18	H8	HB
9	H9	HA	19	H9	HB
10	HO	HA	20	HO	HB

TABLE 1.

3.9 This method used for doubling the outlets is identical to that described in the paper "Introduction to Crossbar Switching" para. 7.1, where the capacity of the SLA switch was increased from 100 lines to 200 lines.

Fig. 6 shows that each horizontal unit consists of 6 contact units, although only 3 units are needed for switching 1 circuit. The inlet to each vertical is connected to both the HA and HB springsets, which are under the control of the 6th horizontal selecting bar.

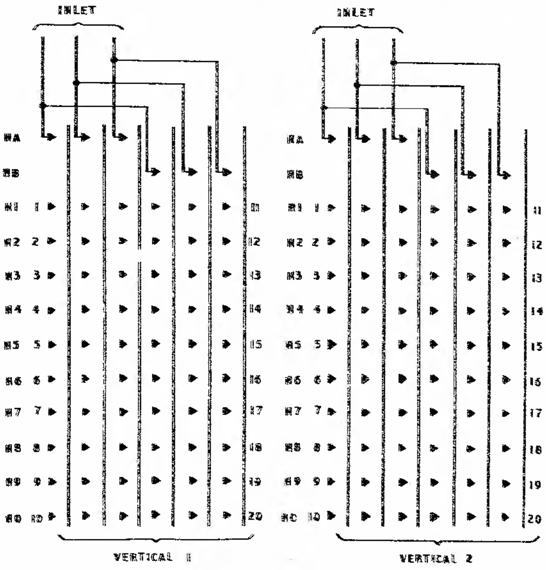


FIG. 6. VERTICALS WITH 20 OUTLETS.

The operation of the HA springset connects the inlet to the three left hand side contact strips. This restricts switching to an outlet in the 1-10 group.

The operation of the HB springset connects the inlet to the three right hand side strips, so that the inlet can now only be connected to an outlet from the 11-20 group.

4. PARTIAL STAGES IN TANDEM.

4.1 To extend the number of outlets to more than the twenty obtained by use of the 6th horizontal bar, two or more partial stages are arranged in tandem. Fig. 7 shows that the outlet from a vertical in the first partial stage is connected to the inlet of the second partial stage. As each vertical in the second partial stage also has access to twenty outlets, an inlet to the first partial stage can be connected through both partial stages in tandem to any one of 400 possible outlets.

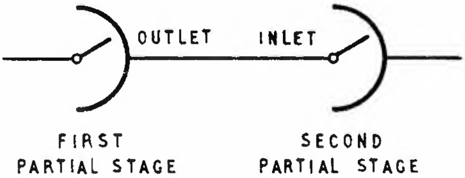


FIG. 7. PARTIAL STAGES IN TANDEM.

4.2 The Link Principle. The circuits connecting two partial stages are referred to as "links" and the method of connection is regarded as a link system. Fig. 7 shows two partial stages connected by links and under the control of one group selector marker. This allows the two partial stages to be grouped together as one stage in which the choice of links and outlets takes place simultaneously.

4.3 Conditional Selection. For any connection to be established between an inlet and an outlet in a link system, the following conditions must be fulfilled :-

- (i) There must be a free outlet available in the desired route.
- (ii) There must be a free link circuit between the partial stages, and this link must have access to the free outlet.
- (iii) The free link must be accessible from the inlet to the first partial stage.

This method of switching is called conditional selection.

4.4 Congestion. A state of "congestion" is said to occur when :-

- (i) the links are engaged
- (ii) the outlets are engaged, or
- (iii) certain combinations of engaged outlets and engaged links prevent a connection.

Fig. 8 shows an example of congestion.

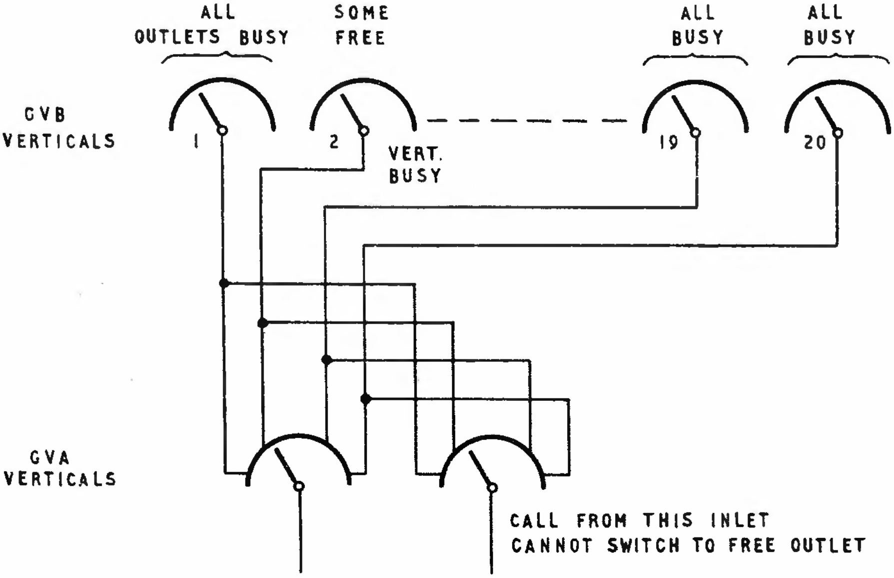


FIG. 8. CONGESTION.

5. GROUPING PLANS.

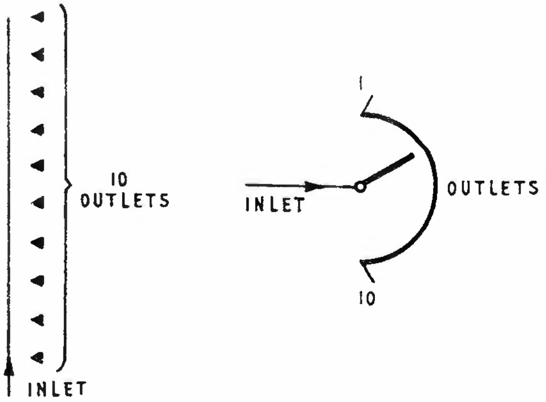
5.1 In crossbar grouping plans, which are a special type of trunking diagram designed to show the connections between partial switching stages, special grouping plan symbols are used. Fig. 9a represents a crossbar vertical, with the number of the vertical shown inside the circle and the line connected to the circle pointing to the available outlets. These are often represented by a circle, with the number of the outlet shown beside the symbol (Fig. 9b). As the vertical symbol resembles a chicken's head it is often referred to as a "chicken" symbol, while the grouping plans containing these symbols are referred to as "chicken" diagrams.

(a) (b)

FIG. 9. VERTICAL AND OUTLET SYMBOLS.

5.2 In grouping plans chicken symbols are arranged in varying group combinations according to the type of exchange and the switching stage concerned. Therefore, in the maintenance of crossbar exchanges, it is essential to understand the meaning of these symbols in the grouping plans.

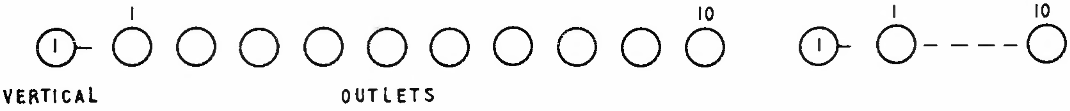
5.3 Figs. 10a and 10b show common methods of representing a crossbar vertical having 10 outlets. Fig. 10a is the mechanical symbol of the vertical, and Fig. 10b is the standard trunking symbol.



(a) (b)

FIG. 10. SYMBOLS OF A 10 OUTLET CROSSBAR VERTICAL.

5.4 In Fig. 11a the same vertical is represented using the chicken symbol, showing that vertical 1 has access to 10 outlets. Fig. 11b shows a method of simplifying the drawing. Where a number of outlets are available from the same vertical, only the first and last outlets need to be drawn, the intermediate ones being shown by a broken line.



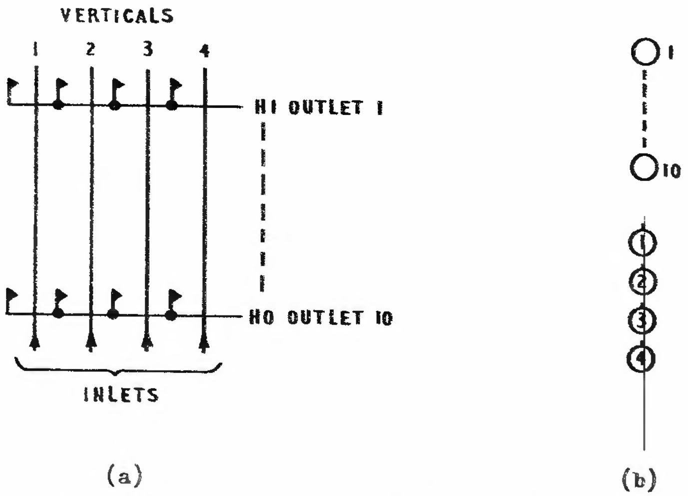
(a) (b)

FIG. 11. CHICKEN SYMBOL OF 10 OUTLET VERTICAL.

5.5 In many of the practical applications of the grouping plan, two or more verticals have access to the same group of outlets. To illustrate this condition using chicken symbols, the symbols representing the verticals are placed so that their "beaks" point in a line towards the group of common outlets. Fig. 12 shows a condition in which either of two verticals may be switched to any one of ten outlets.

FIG. 12. TWO VERTICALS WITH ACCESS TO THE SAME 10 OUTLETS.

5.6 To give a number of verticals access to the same group of outlets, the outlets are commoned together with a multiple wiring form. For example, when four verticals are to be given access to the same outlets, the outlets are commoned together as shown in Fig. 13a. The 1st horizontal springset on the 1st vertical is connected to the 1st horizontal springset on each of the other verticals. The other horizontal springsets are multipled in a similar manner. Fig. 13b shows the equivalent chicken diagram.



(a) (b)

FIG. 13. VERTICALS WITH ACCESS TO COMMON OUTLETS.

5.7 In Fig. 14a ten verticals all have access to the same ten outlets. This diagram is simplified in Fig. 14b by showing the first and last verticals and connecting them with a broken line.

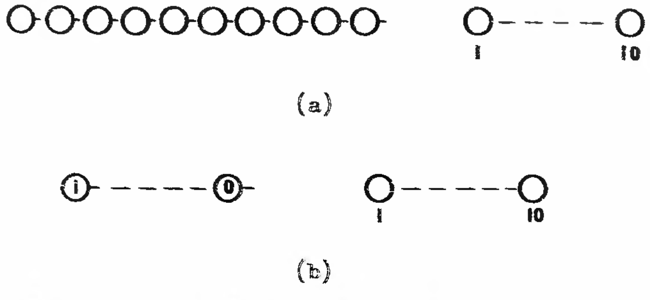
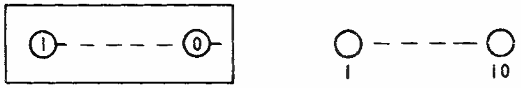


FIG. 14. TEN VERTICALS WITH COMMON OUTLETS.

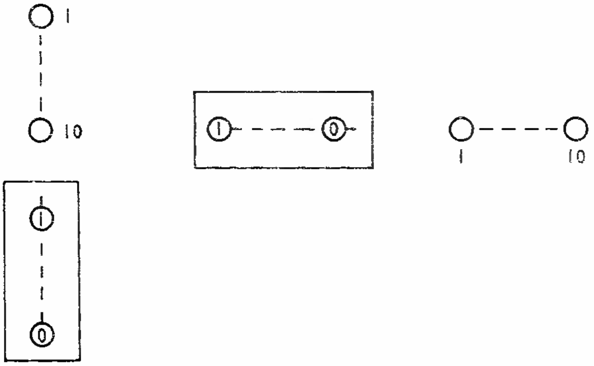
5.9 When all the verticals shown are part of the same crossbar switch, the chicken symbols are enclosed in a rectangle (Fig. 15). As before, the number enclosed within the symbol indicates the number of the vertical on the switch.



VERTICALS IN THE SAME SWITCH WITH ACCESS TO THE SAME 10 OUTLETS.

FIG. 15.

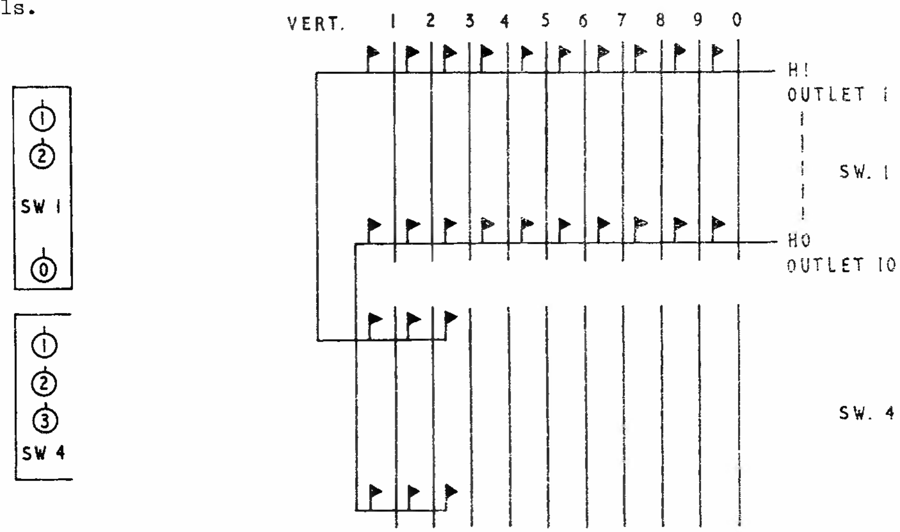
5.10 It is important to understand that the symbols can be shown either vertically or horizontally and still have the same meaning. For example Figs. 16a and 16b both indicate that the ten verticals of one crossbar switch all have access to the outlets shown.



(a) (b)

FIG. 16. ALTERNATIVE METHODS OF USE OF SYMBOLS.

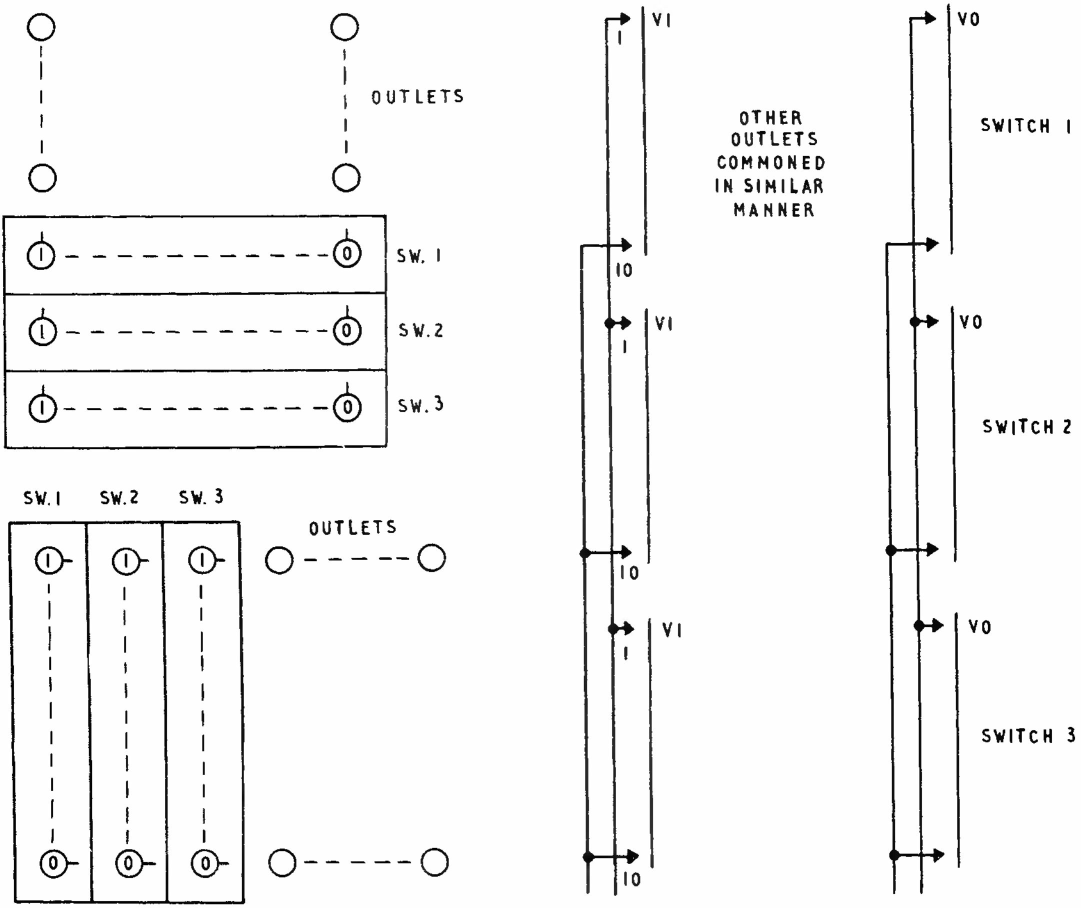
5.11 Fig. 17a indicates that ten verticals on one switch and three verticals on another switch all have access to the same outlets. Fig. 17b shows the commoning on the verticals.



(a) (b)

FIG. 17. MULTIPLE BETWEEN SWITCHES.

5.12 Fig. 18a shows another alternative arrangement of chicken symbols. Each rectangle indicates that the verticals enclosed within that rectangle all belong to the same switch. The direction of the "beaks" indicates that vertical 1 in switch 1 has access to the same outlets as vertical 1 in switches 2 and 3. The outlets from other verticals would be multipled in the same manner. (Fig. 18b.)



(a) Symbols indicating multipling between switches.

(b) Method of commoning.

FIG. 18. MULTIPLING BETWEEN SWITCHES.

5.13 As in Fig. 16, the switch vertical symbols can be shown either vertically or horizontally, so that both illustrations in Fig. 18a have the same meaning.

5.14 It is possible to summarise these examples under two rules :-

(i) When the vertical symbols are all enclosed in a rectangle and the beaks point in the same line, all the verticals in that switch have access to the same outlets. The horizontal springsets on vertical 1 are multipled to the same numbered springsets on each of the other verticals.

(ii) When vertical 1 in one rectangle points in the same line as vertical 1 in other rectangles, these verticals have access to the same outlets. The horizontal springsets on vertical 1 in switch 1 will be multipled to the same numbered horizontal springs on vertical 1 in each of the switches.

Other springsets on each vertical will be multipled in a similar manner.

5.15 Partial Stages in Tandem. When two partial stages are combined, the outlets from one partial stage are connected to the inlets of the next partial stage (Fig. 19).

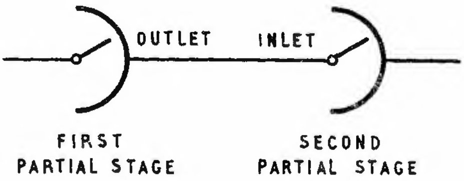


FIG. 19. TRUNKING DIAGRAM TWO PARTIAL STAGES IN TANDEM.

5.16 When representing two such partial stages on a grouping plan, the circle symbol indicating the outlets is not used. Instead, the verticals of the first partial stage now point towards the verticals of the second partial stage (Fig. 20).

5.17 The number of the vertical is included in the usual manner inside the symbol, while the figure placed adjacent to it represents the number of the outlet from the previous partial stage which is connected to that vertical.

5.18 When grouping plans consist of a number of partial stages, there is a 90° change in the direction of the beaks at each partial stage.

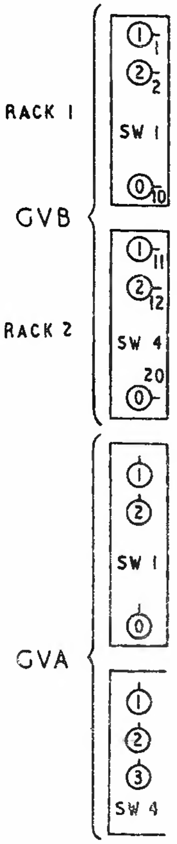
5.19 Fig. 20 represents a section of a typical GV stage grouping plan. Each switch in the GVA stage has twenty outlets from each vertical. This is indicated by the numbers adjacent to the verticals in the second partial stage extending from 1 to 20. The first ten outlets from switch verticals in the GVA stage are connected to the ten verticals on switch 1 in the GVB stage, while the outlets 11 to 20 are connected to the ten verticals on switch 4 in the GVB stage.

5.20 As each vertical in the second partial stage has access to twenty outlets, there is a total of 400 outlets available from the complete stage. The trunking of the combined GV stage is arranged in such a way that an inlet to any vertical in the first partial stage can be switched to any of the 400 outlets from the second partial stage.

5.21 A total of twenty links is necessary to connect the twenty outlets from the first partial stage to the twenty verticals in the second partial stage.

5.22 The 400 outlets from the GVB stage are divided into routes. The route to be taken is determined by the digits received into the register from the subscriber's dial. The register passes this information to the group stage marker, which arranges for the circuits in that route to be tested and also tests to ensure that there is a path by which the calling subscriber can be connected to the selected free circuit.

Complete grouping plans of each switching stage are explained in other papers of the course.



SECTION OF GV GROUPING PLAN.

FIG. 20.

6. TRUNKING SCHEMES.

6.1 The crossbar trunking diagram shown in Fig. 4 has no provision for calls other than those intended for the local exchange. In practice, a number of originated calls will be for subscribers in other exchanges, and a number of received calls will originate in other exchanges.

6.2 When junction cable pairs connect two crossbar exchanges, calls leave the originating exchange via an outgoing junction relay set FUR and enter the other exchange via an incoming junction relay set FIR (Fig. 21).

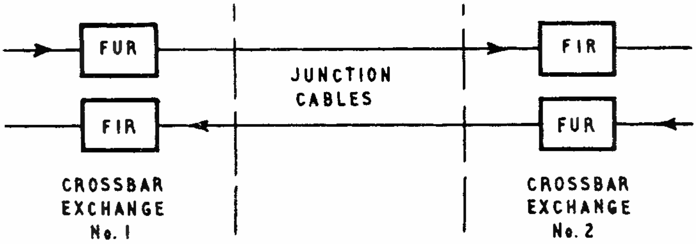


FIG. 21. JUNCTION WORKING BETWEEN CROSSBAR EXCHANGES.

6.3 After passing through the FIR, all incoming calls must be connected to a group selector stage to enable the required 1000 line group to be selected. The call is then connected to the SL stage, where the particular subscriber is selected from the 1000 group in the manner previously described in the paper "Introduction to Crossbar Switching". The method of connecting two crossbar exchanges is shown in Fig. 22.

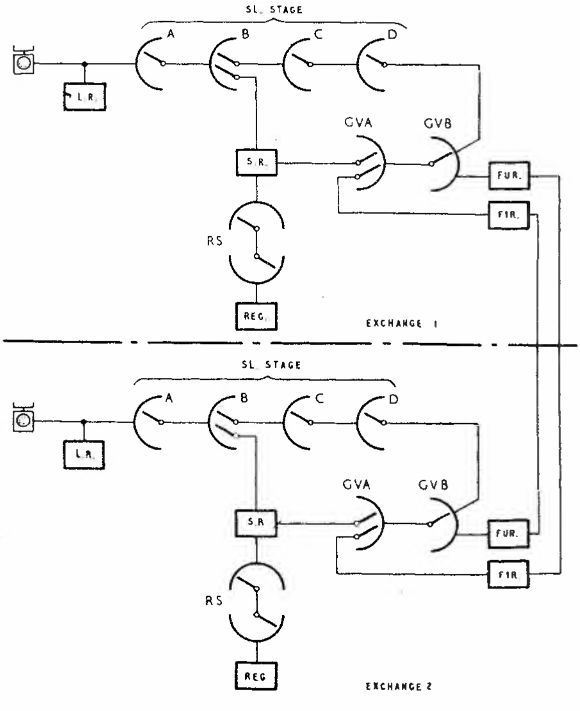


FIG. 22. TRUNKING BETWEEN TWO CROSSBAR EXCHANGES.

6.4 Call between two Crossbar Exchanges. When a subscriber in exchange No. 1 lifts his receiver, the operation of his line relay indicates to the SL marker that a subscriber wishes to make an outgoing call. The SL marker has three main functions to perform for each outgoing call. These functions are :-

(i) to identify the calling line and test for class of service.

(ii) to test for a free path from the calling line to a free SR and, in conjunction with a register finder marker, test for and complete the connection to a free register.

(iii) to cause the operation of the correct horizontal and vertical magnets in the SLA and SLB partial stages, switching the calling line to a free SR relay set and to advise the register of the caller's class of service.

6.5 The SL marker signals the register finder marker, which also has three main functions to perform. These functions are:-

(i) to identify the calling SR relay set;

(ii) to select a free register;

(iii) to cause the operation of the correct horizontal and vertical magnets in the register finder crossbar switch, switching the calling line through to the register.

The SL marker and the RS marker now release.

6.6 The calling subscriber receives dial tone from the register and dials the complete number of the required subscriber. This number is counted and stored in the register. Fig. 23 shows the equipment in use at this stage of the call.

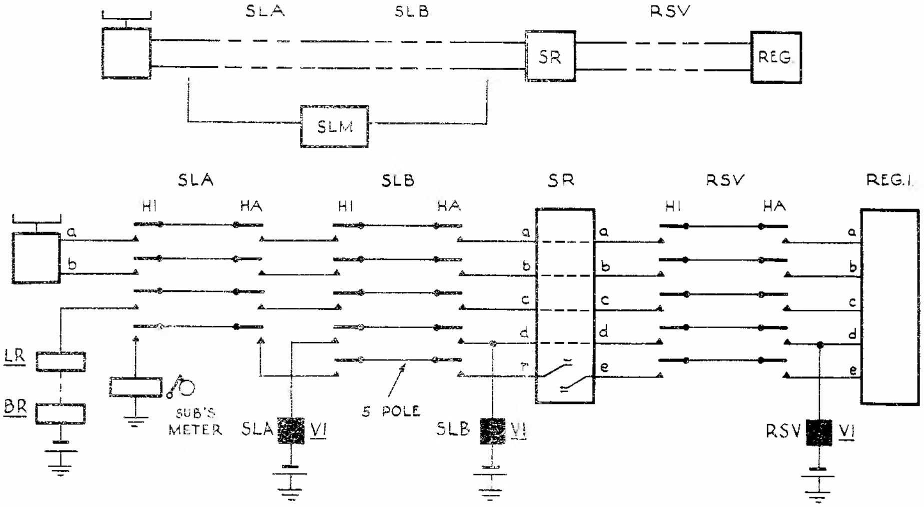


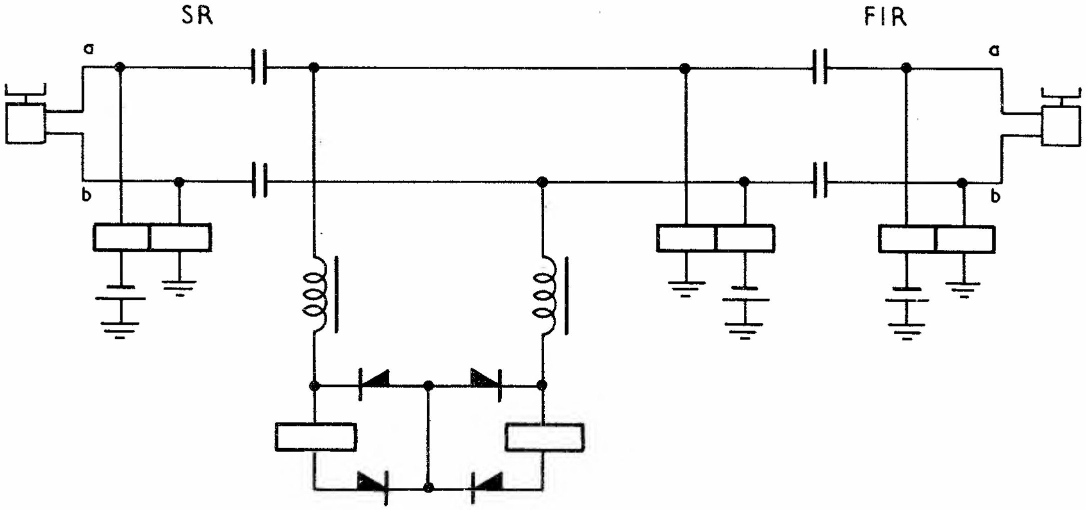
FIG. 23. SCHEMATIC CONDITIONS - SUBSCRIBER TO REGISTER.

6.7 The register calls the group selector marker (GVM) and transmits by code the digits necessary for deciding the route from the group selector stage. The GVM chooses a free circuit on the desired route via a testing bypath, and operates the horizontal and vertical magnets necessary to switch the call to the free circuit. When the call is to another crossbar exchange, it is connected via a relay set FIR to the group selector stage in that exchange.

6.8 The register in exchange 1 now transmits digits by code to the GVM in exchange 2, enabling it to select, test and switch to a free circuit to the required 1000 number group. This marker then releases.

6.9 The register in exchange 1 now sends the remaining information to the SL marker associated with the desired 1000 line group. This marker is able to select the individual line from the 1000 group, test this line, and, if it is free, cause ring to be applied to that line from the FIR relay set.

6.10 The SL marker in exchange 2 and the register in exchange 1 now release. The two subscribers are connected together via an SR relay set in exchange 1 and an FIR relay set in exchange 2. (Fig. 24)



BASIC CONNECTION BETWEEN TWO CROSSBAR SUBSCRIBERS DURING CONVERSATION.

FIG. 24.

6.11 Alternate routing. For the economical development of both local and trunk networks it is necessary to have a flexible routing scheme incorporating alternate routing. Fig. 25 shows how this principle can be applied to the trunking between three crossbar exchanges and Fig. 26 shows a trunking diagram of three exchanges using alternate routing.

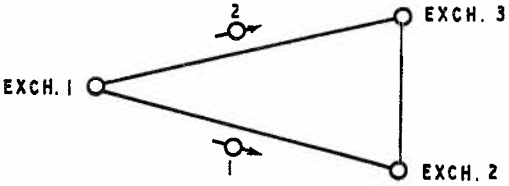


FIG. 25. PRINCIPLE OF ALTERNATE ROUTING.

6.12 When a subscriber in exchange No.1 wishes to call a subscriber in exchange No.2, he lifts his receiver and the SL stage marker arranges for the line to be connected through the SLA and SLB partial stages to a free SR. The register finder completes the connection through to a free register and the calling subscriber receives dial tone.

6.13 The calling subscriber now dials the complete number of the required subscriber. This number is counted and stored in the register of exchange No.1. The forwarding of information from the register to control sets at switching stages is determined by a series of signals which pass between the various marker control sets and the register. The complete list of these signals and the method by which they are sent are described in detail in other papers of the course.

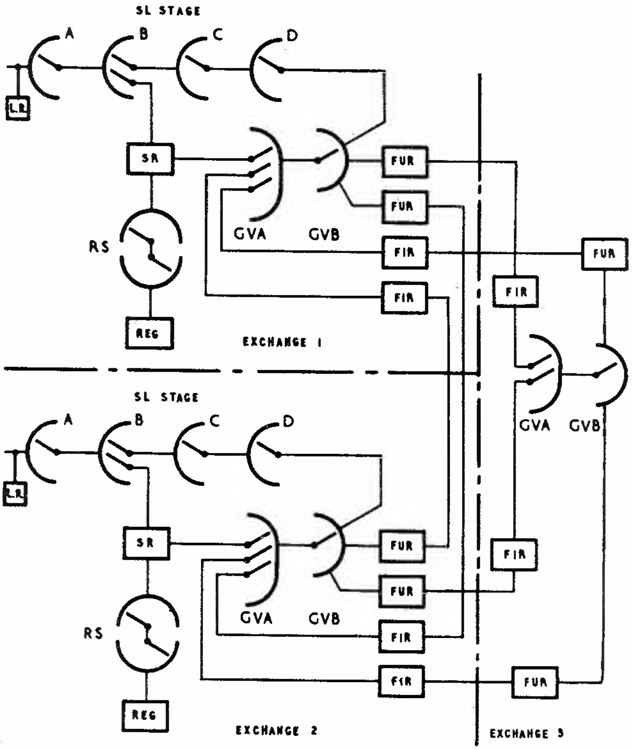


FIG. 26. ALTERNATE ROUTING BETWEEN CROSSBAR EXCHANGES.

6.14 After the register has received the dialled information, it then passes on information about the first impulse train in the form of code to the GV stage marker in exchange 1. If this information is not enough for the marker to decide the route that the call must take, the marker returns a signal to the register, which now forwards information about the next impulse train. This procedure is continued until the GV stage marker in exchange 1 has sufficient information to decide that the route required for that call is to exchange 2.

6.15 The marker first tests the direct junctions between exchanges 1 and 2. If any junctions are free, the marker selects a free circuit, connecting the caller to exchange 2 as described in paragraphs 6.4 to 6.10.

6.16 When all direct junctions are busy, the marker tests the junctions on the alternative route to exchange 3. If a free junction is available, the caller is then connected to the GV stage in exchange 3. The GV marker in exchange 1 releases, but before releasing it sends a signal back to the register, informing it that all code information previously sent must be repeated.

6.17 The register in exchange 1 repeats the information about the route to the GV marker in exchange 3. The marker then tests the direct junctions between exchange 3 and exchange 2. A free junction is selected and the caller switched via the selected junction to the GV stage marker in exchange 2. The marker in exchange 3 signals the register to send more information and then releases.

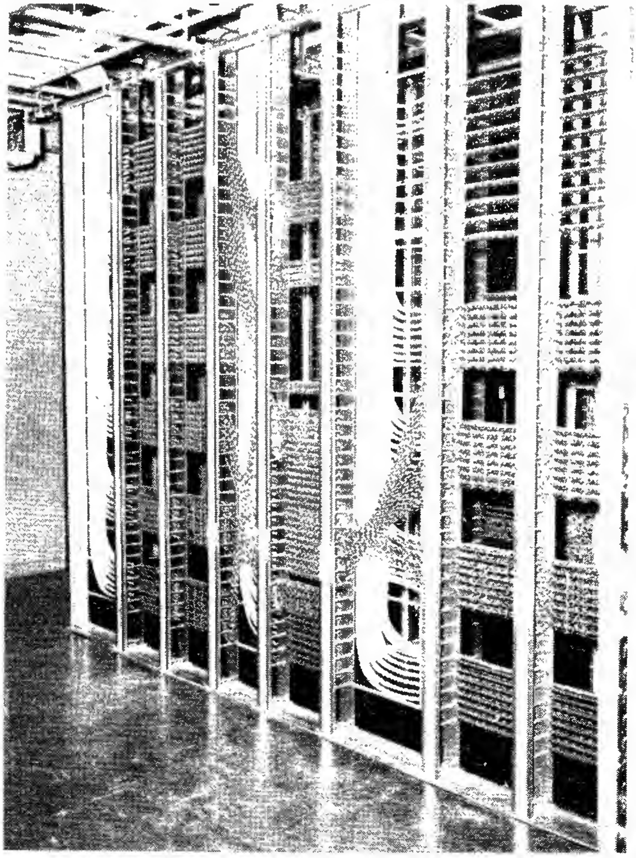
6.18 Information is sent to the GV marker in exchange 2, enabling it to determine the 1000 group required. The remainder of the call proceeds as described in paragraphs 6.9 to 6.10, all information about the dialled number being sent from the register in the originating exchange.

7. INTERMEDIATE DISTRIBUTION FRAMES.

7.1 In the ARF crossbar system, connections to the I.D.F. are made between the following points:-

- (i) the SR relay set and the 1GV;
- (ii) the RS and the Reg.-L
- (iii) the 1GV and the GIV;
- (iv) the 1GV and the FUR relay sets;
- (v) the FIR relay sets and the GIV;
- (vi) the RS-I and the Reg.-I;
- (vii) the GIV and SLD verticals;
- (viii) the Reg.-L and SS;
- (ix) the Reg-I and SS;
- (x) the SS and the KS;
- (xi) MFC tone generators to KS and KM;
- (xii) step-by-step group selector to FIR;
- (xiii) GIV to step-by-step group selector.

7.2 The use of an I.D.F. between these points provides flexibility for re-arrangements of, and additions to, the various exchange devices to meet changing distribution of traffic. The I.D.F. consists of a rack with strips to which the various devices are cabled. The connection between the devices is completed with jumper wire. Fig. 27 shows a section of a typical crossbar type I.D.F.



CROSSBAR INTERMEDIATE DISTRIBUTION FRAME.

FIG. 27.

7.3 Use of a second GV stage. The number of routes to be provided will decide whether a second GV stage must be provided. Each selector has a capacity of 400 circuits, and these may be arranged so that the number of trunks available in a route can vary between 5 and 400 and the number of routes between 1 and 80. Where additional routes are required, a further GV stage is added. Fig. 28 shows a diagram of a typical exchange using a second GV stage and indicates the position of the I.D.F. connections between the various devices. The term "1GV" is used to designate the first originating selector stage. The term "GIV" refers to the incoming or terminating group selector stage.

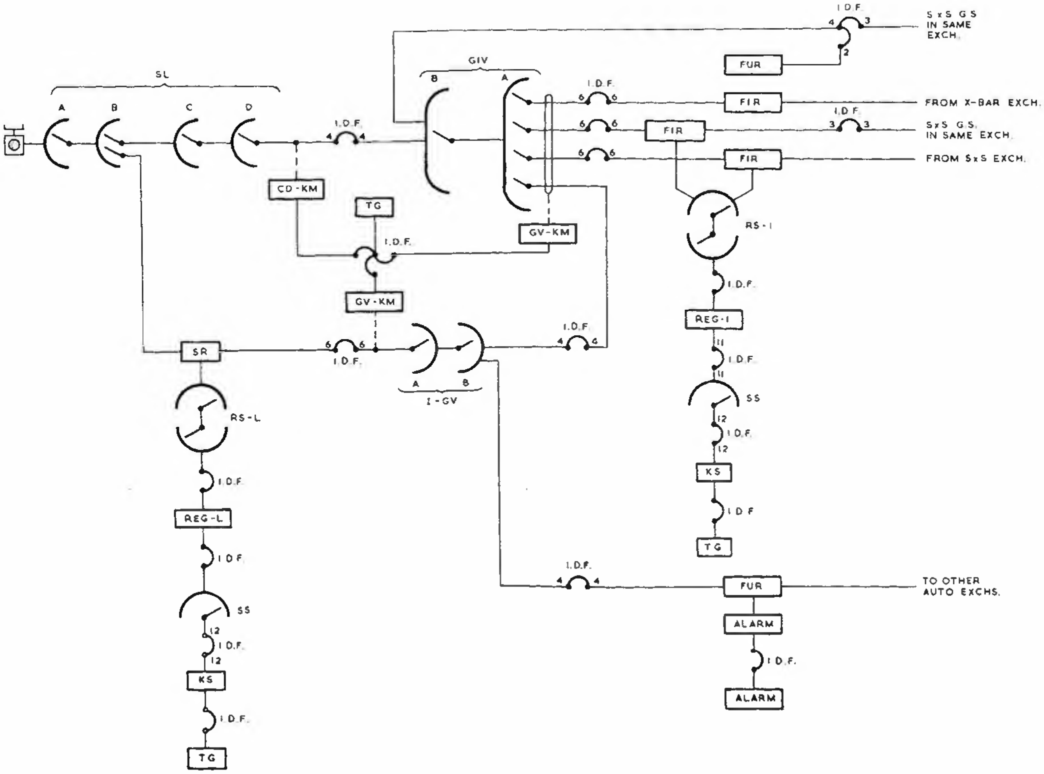


FIG. 28. DIAGRAM OF EXCHANGE USING TWO GV STAGES.

7.4 All inlets and outlets from a group selector stage are connected to an I.D.F. When outlets of a GV stage are connected to inlets of another selector, a four wire circuit is used (1GV to GIV, GIV to SLD). Where the inlets to a GV stage are wired from a relay set (SR to 1GV, FIR to GIV) a six wire circuit is used.

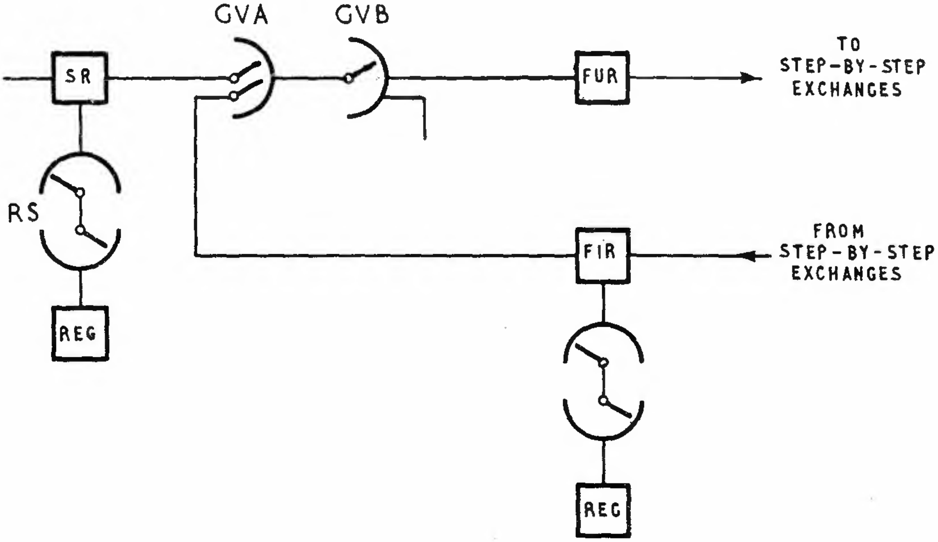
7.5 The cables between the register finders and registers are cross-connected at the I.D.F. The number of incoming circuits to the register finders will always exceed the total number of registers in the exchange as each register is connected to several register finders.

7.6 Crossbar exchanges using MFC signalling require connections between MFC tone generators and code receivers, and tone generators and registers. As the signalling apparatus is only needed on each call for a limited period, this equipment is placed in a common "pool" and is only connected to the various devices when required.

7.7 Where an exchange has two selector stages as shown in Fig. 28, the SLD verticals for the 1,000 groups are connected to outlets of the GIV stage. The routes to other exchanges have been taken from the 1GV stage, while the incoming routes from other exchanges are connected via FIR relay sets to inlets of the GIV stage.

8. INTERWORKING CROSSBAR AND STEP-BY-STEP EQUIPMENT.

8.1 Calls to Step-by-step exchanges. When a call is made from a crossbar exchange to a step-by-step exchange the local register (REG-L) receives the impulses from the dial in the usual manner. Immediately the register receives enough digits to determine that the call is to a step-by-step exchange it signals the GV marker, which selects a free FUR relay set associated with a junction to the required exchange (Fig. 29).



TRUNKING BETWEEN CROSSBAR AND STEP-BY-STEP EXCHANGES.

FIG. 29.

8.2 The remaining digits are sent at normal speed and ratio to the step-by-step equipment, after which the register releases.

When the called subscriber is busy, busy tone is returned to the caller from the final selector in the step-by-step exchange.

8.3 Calls from Step-by-step exchanges. When calls are received from step-by-step exchanges it is necessary to connect the incoming junction and FIR relay set to an incoming register (REG-I) via a register finder. The purpose of this register is to convert the impulses received over the junction to the code signalling necessary to operate marker equipment. The FIR is connected to a GV inlet, enabling the required 1,000 group to be selected.

8.4 Hybrid exchanges. The term "hybrid exchange" is applied to an exchange using both crossbar and step-by-step equipment. Fig. 30 shows an example of an exchange in which the original equipment was of the step-by-step type while the later extensions use crossbar equipment.

The step-by-step section in this example uses 6 digit working and the crossbar section uses 7 digit working, the first 2 digits in each case being the same.

8.5 Incoming traffic of Step-by-step origin. Incoming step-by-step traffic may be connected to either section of the exchange. Calls of this type entering the crossbar section are connected via an FIR to an incoming register. From this point calls to a subscriber in the crossbar section are connected as described in para. 8.3.

A call to a subscriber in the step-by-step section is trunked from the GIV stage to the bimotional 4th selectors. For this call the register must provide standard pulses to operate the step-by-step equipment.

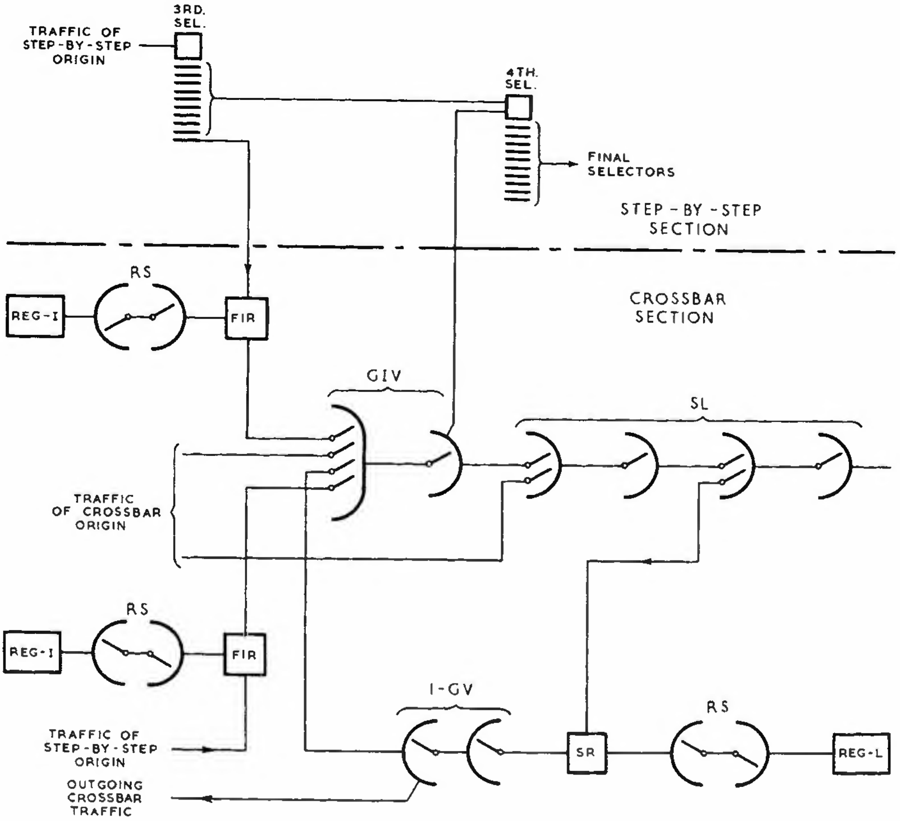


FIG. 30. TRUNKING DIAGRAM OF A HYBRID EXCHANGE.

8.6 Incoming step-by-step traffic connected to the 3rd selector will step this switch under the control of the dialled impulses. In this example calls to the 1st level are trunked to the crossbar section via an FIR. An incoming register converts the dialled impulses to code, and in this case inserts digit 1 as the first code to be sent to the GVM. This is necessary because calls from crossbar origin will send the 3rd digit to the GVM as the first coded signal. Calls to levels other than 1 on the 3rd selector pass to the subscriber via bimotional 4th and final selectors.

8.7 Incoming traffic of crossbar origin. The GIV marker will know from the first coded digit received whether the call is for the crossbar or step-by-step section of the exchange. If the call is for the step-by-step section then the first digit received (3rd digit of number) will indicate which 1,000 group is required. A call to the crossbar section will need another coded digit (4th digit of number) to determine the individual 1,000 group.

8.8 Incoming traffic from external step-by-step origin. The FIR's for these routes are arranged in a separate group since the first digit to be received will be the 3rd digit of the number and the incoming register will not be required to insert an extra digit as in the case of a call from the step-by-step selector in the same exchange. However, in these cases call may be intended for subscribers in either the step-by-step or the crossbar section of the exchange. On calls intended for the step-by-step section the incoming register must provide the last three digits at 10 p.p.s. to operate the bimotional switches.

8.9 Provision is made for incoming crossbar traffic to be connected directly to the required 1,000 group. In this case the selection of the 1,000 group would be done in the previous exchange.

8.10 In practice, hybrid exchanges will consist of many different combinations of crossbar and step-by-step equipment and each installation must be considered separately.

8.11 First Stage Crossbar Switching in Step-by-Step Branch Exchanges. One of the uses of crossbar equipment is the introduction of a crossbar first switching stage in step-by-step branch exchanges.

The subscribers lines are connected to uniselectors in the normal manner. The outlets from the uniselectors are connected to SR-U relay sets, which are a special type of SR relay set fitted with back-busying facilities.

Associated with the relay sets are register finders, registers and a GV stage.

Fig. 31 shows the trunking of a typical crossbar first stage in a step-by-step branch exchange.

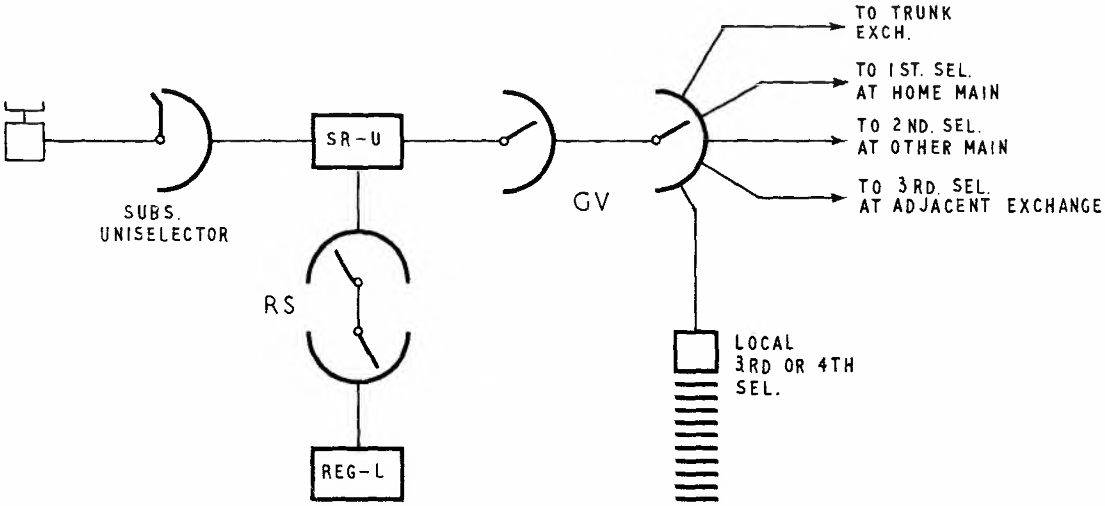


FIG. 31. CROSSBAR FIRST STAGE SWITCHING.

8.12 When a subscriber originates a call the calling line is switched by the uniselector to a free SR relay set. The register finder stage (RS) completes the switching to a free register.

The dialled impulses are counted and stored in the register in the usual manner.

When the digits are received the register forwards the information to the crossbar first switching stage in the form of a high speed code.

The switching stage serves a similar purpose to the DSR but has a wider application.

8.13 Outlets from the GV stage can be arranged to provide direct trunks to any destination where the quantity of traffic justifies the provision of the route. For example, trunks to:-

(i) local 3rd selectors
(ii) local 4th selectors
(iii) 3rd selectors at other exchanges
(iv) 2nd selectors at main exchanges
(v) the trunk exchange

In addition, an "overflow" route is provided to 1st selectors at the local main exchange. This route is used when no direct trunks are available on the desired route.

8.14 Calls to step-by-step switching stages cause the register to send pulses at the normal speed and ratio. On calls to crossbar exchanges or to the trunk exchange, the necessary information is forwarded from the register in the form of a high speed code

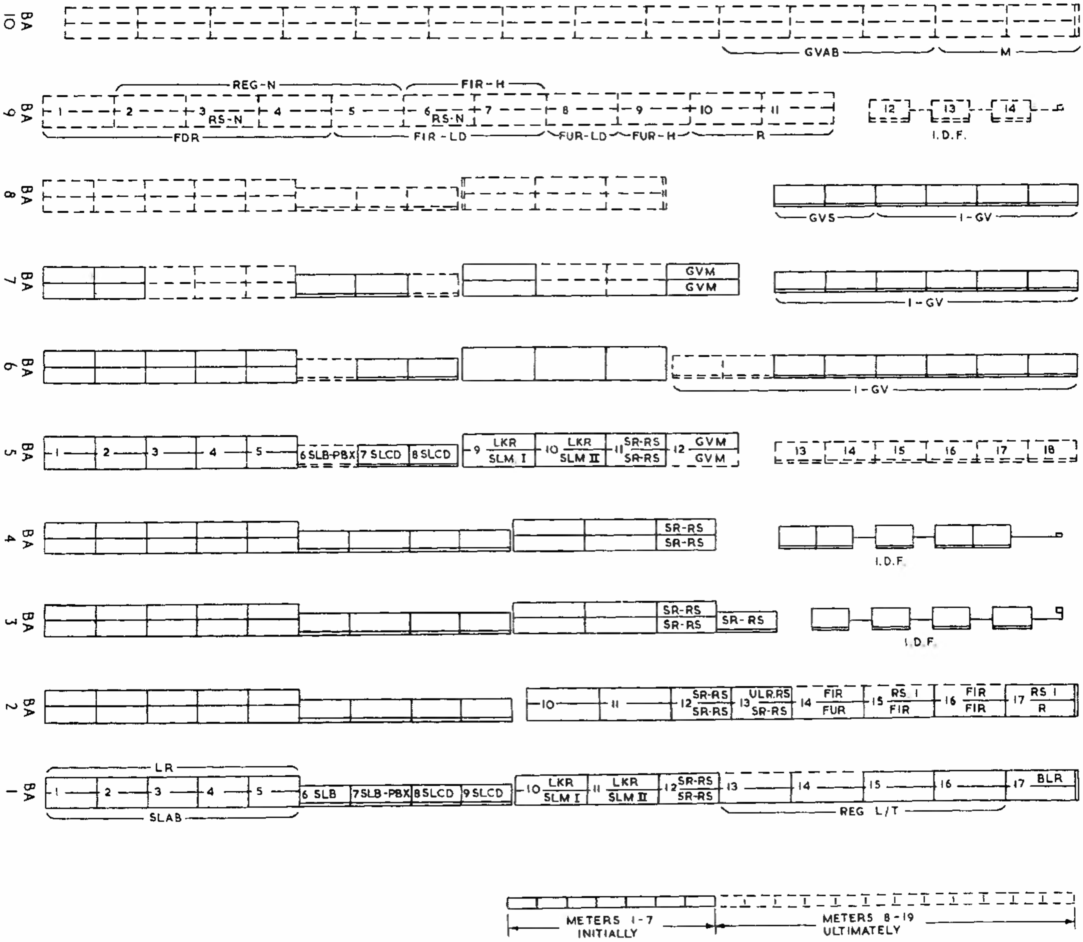


FIG. 32. EQUIPMENT LAYOUT - CROSSBAR EXCHANGE.

9. THE NATIONAL SWITCHING NETWORK.

9.1 The nation-wide subscriber dialling plan includes the following features:-

- (i) A national "Closed" numbering scheme with a maximum of 9 digits.
- (ii) Standard service codes.
- (iii) Multi-metering on trunk calls.
- (iv) Use of register controlled, high speed switching systems using automatic alternate routing.

9.2 Numbering Scheme. A closed numbering scheme is one in which each subscriber's service is identified by a unique telephone number, the same number being dialled to reach a subscriber regardless of the point of origin of the call.

9.3 Australia is divided into a number of numbering plan areas. Each numbering plan area is designated by a unique area code which, together with the subscribers' directory number, forms the national number. For example, a Sydney subscriber's national number may be 02-537 6426 and a subscriber's number in Shepparton, Victoria may be 0582-32516. The area codes are the digits before the dash and the numbers after the dash are the directory numbers used for local calls within the numbering plan area.

All calls other than local calls must be prefixed by "0" followed by the remainder of the area code. Fig. 33 shows how the first figure after the "0" guides the call to the correct part of Australia. This digit is referred to as the "A" digit.

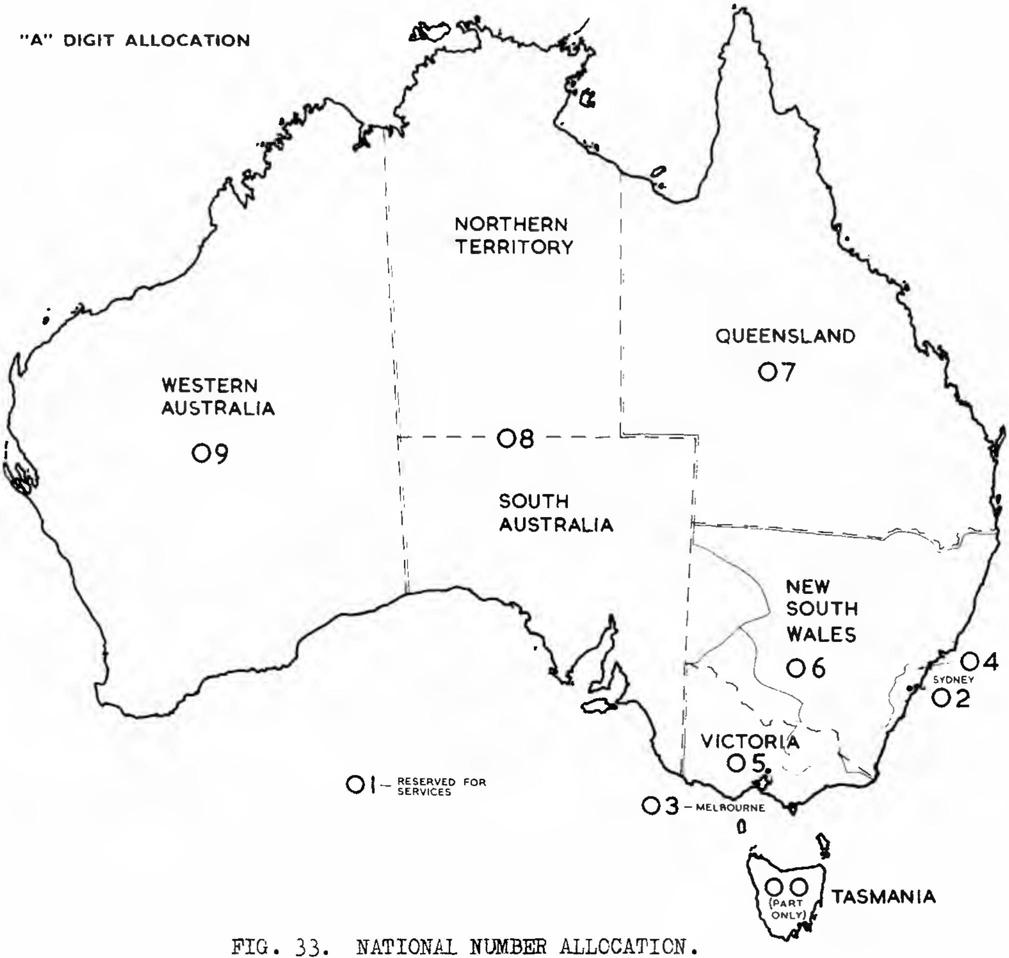


FIG. 33. NATIONAL NUMBER ALLOCATION.

9.4 Service Codes. Standard codes for the Department's special services are designed so that subscribers obtain access to them readily. The range of codes selected provides for:-

(i) the use of the same codes by all subscribers;

(ii) short codes, with the important services such as "Emergency" and "Manual Assistance" having easily remembered codes;

(iii) ample capacity to incorporate new services.

These requirements are met by reserving the "A" digit 1 for services.

The codes for access to the services in the national telephone system will be:-

000 - Emergency - for Fire, Police and Ambulance.

010 - Complaints.

011 - Manual assistance for trunk line calls.

012 - Trunk enquiry.

013 - Directory information.

014 - Time.

015 - Phonograms.

016 - Recorded announcements, e.g. 0164 - weather forecast.

017 - Miscellaneous services requiring an operator.

    0171 - Overseas calls.
    0172 - Mobile radio calls.
    0173 - Early morning and reminder calls.
    0174 - Phonogram enquiries.

018 - Manual assistance for interstate trunk line calls at centres where intrastate and Interstate calls terminate on different suites. Ultimately this code will become spare.

019 - Spare.

At large country centres most of the codes will be used, but in the smaller country exchanges, one code only - 011 - may be used to cover all calls requiring the attention of an operator.

9.5 Directory Instructions. In the ultimate scheme, standard directory instructions will apply throughout the Commonwealth. Each subscriber's telephone service will have its own national number consisting of two parts, an area code and a directory or local number.

Since each numbering plan area will be assigned its own area code, the national numbers of all subscribers who may inter-dial by using only the number listed in the directory will commence with the same area code.

To make a call, subscribers will have to select one of two dialling procedures, namely:-

(i) the dialling only of the directory number shown against the called subscriber's name for calls within the numbering plan area;

(ii) the dialling of the area code plus the called subscriber's directory number for all other calls.

9.6 Metering. On a local crossbar call, the subscriber's meter is operated once at the end of each effective chargeable call. On trunk line calls a system of multi-metering is adopted. The subscriber's meter is operated once immediately the called subscriber answers and is then operated at regular intervals during the call. The frequency of these regular operations is determined by the particular tariff rate applying to the call. In all cases of multimetering the first of the regular operations is suppressed to avoid any possibility of overcharge due to the random arrival time of the first regular pulse.

9.7 Australia's trunk line network is divided into switching centres which are classified as follows:-

(i) ○ T A Terminal Exchange is an exchange which performs no through switching of inter-exchange circuits.

(ii) m A Minor Switching Centre switches the final routes for terminal exchanges only.

(iii) S A Secondary Switching Centre switches the final routes for Minor switching centres and also, if required, Terminal exchanges.

(iv) P A Primary Switching Centre switches the final routes for Secondary switching centres and also, if required, Minor switching centres and Terminal exchanges.

(v) M A Main Switching Centre switches the final routes for Primary switching centres and also, if required, Secondary switching centres, Minor Switching centres and Terminal exchanges.

9.8 Final routes form the foundation of the switching network and interconnect all exchanges. They are defined as routes for which no later choice alternate routes are provided. They are equipped with sufficient circuits to ensure that there is only a small proportion of lost calls during the busy periods.

9.9 Early-choice routes. Superimposed on the system of final routes is a network of early-choice routes. An early-choice route is one for which one or more alternate routes are provided. It provides a preferred direct link between any two centres. The proportion of final routes and early-choice routes is determined by economic considerations which are beyond the scope of this paper. Fig. 34 shows a typical routing pattern between trunk switching centres.

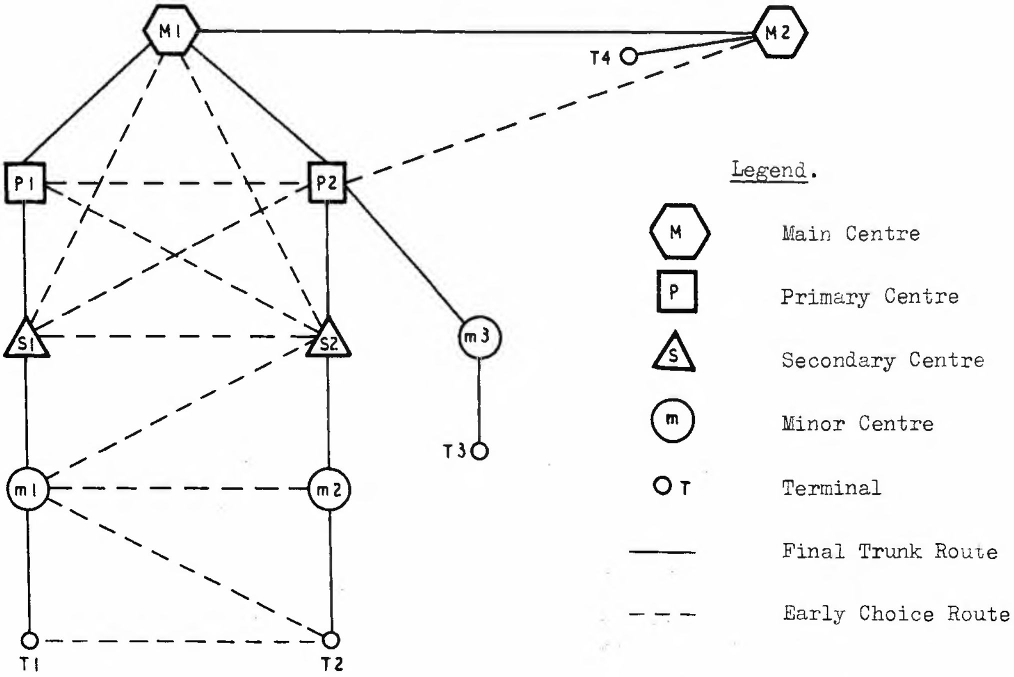


FIG. 34. TYPICAL ROUTING PATTERN.

9.10 When a call is made between two centres, a test is made for a free circuit in the most direct route between these centres. If no free circuit is available on this route, a similar test is made on the next alternate path. If no free circuit is available on any of the alternate routes, the call is switched via a final route to the next higher centre, where a similar testing process is performed, commencing each time with the most direct route.

9.11 A call from Terminal 1 to Terminal 2. First preference is given to direct links between Terminal 1 and Terminal 2. If these are busy, a trunk is chosen to Minor Centre 1. Tests are now applied in the following order of preference:-

(i) direct link between Minor Centre 1 and Terminal 2;
(ii) direct link between Minor Centre 1 and Minor Centre 2;
(iii) direct link between Minor Centre 1 and Secondary Centre 2.

If all trunks on each of these routes are busy, the call is switched to Secondary Centre 1.

Tests are applied to trunks from Secondary Centre 1 in the following order of preference:-

(i) trunks between Secondary Centre 1 and Secondary Centre 2;
(ii) trunks between Secondary Centre 1 and Primary Centre 2;
(iii) trunks between Secondary Centre 1 and Main Centre 1.

If all trunks on these routes are busy, the call is now switched to Primary Centre 1. A similar testing process now takes place, and if direct links are busy the call is switched to Main Centre 1. The final route is shown via the full line. Sufficient circuits are provided along this route to maintain a Standard Grade of Service. However the probability of any call being forced to proceed through all stages is very low.

9.12 Fig. 35 shows how this system of alternate routing may be applied to an actual call between Albury and Wagga.

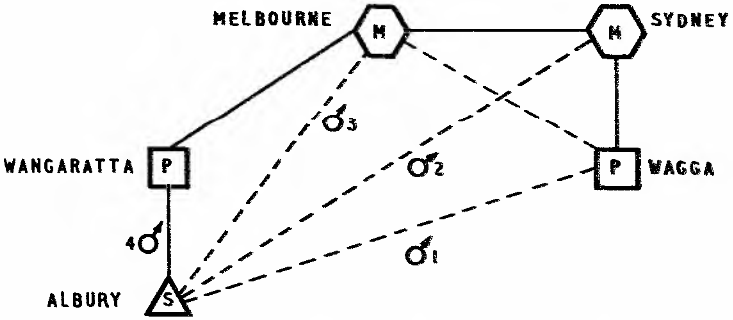


FIG. 35. EXAMPLE OF ALTERNATE ROUTING.

9.13 Under the national switching system, Melbourne and Sydney have been designated Main Centres, Wangaratta and Wagga are designated Primary Centres, while Albury is a Secondary Centre. The arrows shown on Fig. 3 indicate the order of priority given to the testing of routes for this call.

First preference is given to direct trunks between Albury and Wagga, the call being switched to any free trunk available in this route. If this direct route is busy, the second choice is the route from Albury to Sydney.

When all routes on this route are also busy, a test is made on the third choice between Albury and Melbourne. If all trunks on this route are busy, a test is made on the final route from Albury to Wangaratta. If the call is trunked via the final route it will be switched via Wangaratta, Melbourne and Sydney to Wagga.

Final routes are arranged in such a manner that every call may be completed without exceeding 9 links between switching centres. The majority of calls would use a lesser number.

10. TEST QUESTIONS.

1. Compare the purpose of each selecting stage in -
   - (i) a call through a step-by-step exchange;
   - (ii) a local call in a crossbar exchange.
2. How many outlets are available from -
   - (i) a 2000 type bimotional switch;
   - (ii) a crossbar switch using ten verticals and six selecting bars.
3. Explain how crossbar switching is able to provide a more flexible means of trunking than that employed in step-by-step working.
4. Explain the method adopted to increase the number of outlets from each GV vertical from 10 to 20.
5. State the horizontal magnets that must be operated to switch to the following outlets :- 8, 11, 1, 16, 20.
6. (i) Explain the conditional selection method of switching;
   - (ii) When does a state of congestion occur?
7. A crossbar vertical has access to ten outlets. Illustrate this with -
   - (i) Trunking symbols;
   - (ii) The mechanical symbol of the vertical.
8. (i) Use "chicken" symbols to represent ten verticals of one switch, all having access to the same ten outlets;
   - (ii) Sketch the commoning on the switch under these conditions.
9. What indication is given on a grouping plan to enable a call on a particular vertical to be traced back to the outlet from the preceding partial stage.
10. State the three main functions performed by the SL marker for each outgoing call.
11. Describe the progress of a call between two crossbar exchanges stating the stage of the call at which the following items of equipment release -
    - (i) SL marker in the originating exchange;
    - (ii) SL marker in the second exchange;
    - (iii) the register;
    - (iv) GV marker in the originating exchange;
    - (v) SR.
12. Sketch a trunking diagram of a call between subscribers in two crossbar exchanges.
13. Explain the principle of alternate routing when applied to the trunking between three crossbar exchanges.
14. What additional apparatus is necessary for interworking between a crossbar exchange and a step-by-step exchange.
15. List the points in the trunking of a crossbar exchange which are connected to the I.D.F.
16. When is a 11 GV stage used in a crossbar exchange.
17. Why is a register necessary on incoming calls from a step-by-step exchange.
18. What is meant by the term "hybrid exchange".
19. Sketch a trunking diagram of a hybrid exchange.
20. Describe the progress of an incoming call at the exchange sketched in Q.19.
21. Under the nation-wide subscriber dialling plan, state the procedure for -
    - (i) Calling a subscriber within the same numbering plan area.
    - (ii) Calling an interstate number.
22. In what way does the metering differ on each of the two calls in Q.21.

END OF PAPER.

CROSSBAR SWITCHING STAGES

---

1. INTRODUCTION.

1.1 The use of common control switching methods reduces to a minimum the number of relays permanently associated with each switch, but the circuits of the common control apparatus contain a very large number of relays. As an example, an SL marker contains over 300 relays and a large proportion of these relays is used each time a call is originated. Such circuits require a different approach by the technical staff compared to that adopted for the simpler individual circuits of step-by-step exchange apparatus.

1.2 To assist in the understanding of these very large circuits, a system of functional block diagrams has been evolved. The control equipment for each switching stage is divided into a number of functional sections, each section represented by a block. The blocks are connected together in such a manner that the relationship between them can be clearly seen. The progress of a call can be traced through these blocks without reference to the circuits.

1.3 This paper deals with each switching stage in the order normally encountered when originating a local call. The control equipment for each switching stage is shown grouped together, although in some cases sections of the equipment are mounted on different racks.

1.4 Functional block diagrams are not intended to eliminate circuits, but a careful study of these diagrams will aid future circuit reading.

2. SL STAGE.

2.1 The subscriber stage (SL stage) is a common name for the switch equipment dealing directly with the subscriber's line.

Each exchange is divided into groups of 1,000 lines. One SL stage is built up of units for the connection of 1,000 lines, and is divided into four partial stages of crossbar switching called SLA, SLB, SLC and SLD.

2.2 The number of crossbar switches provided for each partial stage is decided by traffic requirements. Table 1 lists some typical combinations available. In this table the letter "m" is used as a symbol for the maximum number of connecting routes through the SLA stage which are available to each subscriber. This number also corresponds to the number of SLA switches over which each subscriber's line is multipled.

TYPE	m	SLB VERTICALS		SLD VERTICALS
		OUT G.	IN C.	
ARF 101/6A	6	75	75	80
ARF 101/6B	6	100	100	120
ARF 101/8A	8	100	100	120
ARF 101/8B	8	100	150	120
ARF 101/8C	8	125	175	160
ARF 101/8D	8	125	125	120
ARF 101/10A	10	125	175	200
ARF 101/10B	10	150	200	200

TABLE 1.

2.3 Functions of the SL stage. For outgoing traffic, the functions of the SL stage are:-

(i) To identify the calling line.

(ii) To connect the calling subscriber to a free SR relay set, checking that the SR concerned has access to an idle register.

Partial stages SLA and SLB are used to switch outgoing traffic.

For incoming traffic the functions of the SL stage are :-

(i) To identify the calling inlet.

(ii) To receive information about required number.

(iii) To test the condition of the required subscriber's line (busy or free).

(iv) To connect the calling circuit to the desired number.

(v) To return information regarding the called number to the originating register.

Partial stages SLA, SLB, SLC and SLD are all used for switching incoming traffic.

2.4 The hunting and selection of routes through the partial stages is performed by a control device known as a marker. The ultimate "setting" of the switches for a connection is directed from the marker.

The subscriber's stage can be served by one or two identical markers, which can perform identification, bypath hunting and subscriber testing simultaneously and independently of one another, with the following exceptions :-

(i) Two markers cannot operate simultaneously in the same 200 line group.

(ii) Two markers cannot test simultaneously over outlets from the same SLB switch.

2.5 The selection of a marker to control a call is arranged in a random manner by a centre-stable polarised relay which is connected to a low frequency A.C. The direction of operation of this relay is decided by the direction of current at the moment of connection. This in turn decides which marker will be used for that particular call.

2.6 When a call is already in progress from the same 200 line group, the polarised relay is short-circuited and cannot operate until the marker has completed switching the first call. The marker takes approximately 500 mS to switch each call. Fig. 1 shows the racks of switching equipment used for a 1000 line group when m = 8.

SLA / B					SLB	SLB / PBX	SLC / D	
SLA 1	SLA 1	SLA 1	SLA 1	SLA 1		PBX EQT.	SLC 1	SLC 1
" 3	" 3	" 3	" 3	" 3			" 2	" 2
" 5	" 5	" 5	" 5	" 5			" 3	" 3
" 7	" 7	" 7	" 7	" 7			" 4	" 4
RELAYS	RELAYS	RELAYS	RELAYS	RELAYS			RELAYS	RELAYS
JACK BOX	JACK BOX	JACK BOX	JACK BOX	JACK BOX			SLD 1	SLD 1
SLA 2	SLA 2	SLA 2	SLA 2	SLA 2			" 2	" 2
" 4	" 4	" 4	" 4	" 4	SLB 11	SLB 16	" 3	" 3
" 6	" 6	" 6	" 6	" 6	" 12	" 17	" 4	" 4
" 8	" 8	" 8	" 8	" 8	" 13	" 18	CODE RECR.	CODE RECR.
SLB 1	SLB 3	SLB 5	SLB 7	SLB 9	" 14	" 19		
" 2	" 4	" 6	" 8	" 10	" 15	" 20		
RK1 SUBS 000-199	RK2 200-399	RK3 400-599	RK4 600-799	RK5 800-999			RK1	RK2

FIG. 1. EQUIPMENT FOR 1000 LINES.

2.7 SLA Stage. The SLA switches for each 1000 line group are distributed over 5 racks, with one rack for each group of 200 lines. The number of SLA switches on each rack corresponds to the "m" number of the group, in accordance with Table 1 in this paper.

2.8 The subscriber's lines are cabled from the M.D.F. to a plug and jack connection at the top of each SLA rack. From the plug and jack the lines are extended to -

(i) the SLA switch contacts;
(ii) line relay sets.

Fig. 2 shows the points to which a subscriber's line is connected.

A proportion of lines (5%) is prepared for possible use with public telephones by extending the C and R wires from the rack to a spare jack in the field above the rack. From this point they are extended as required to MR relay sets associated with public telephone lines.

The numbers allocated for public telephones in each 200 group follow this pattern -

019	037	055	073	091
120	148	166	184	102

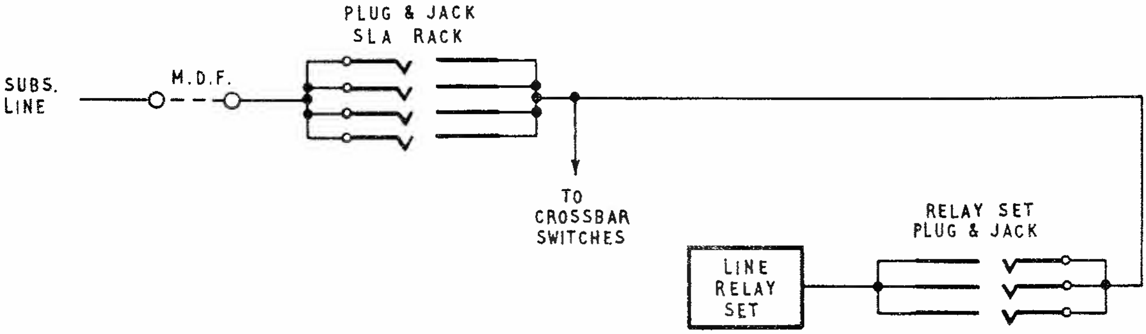
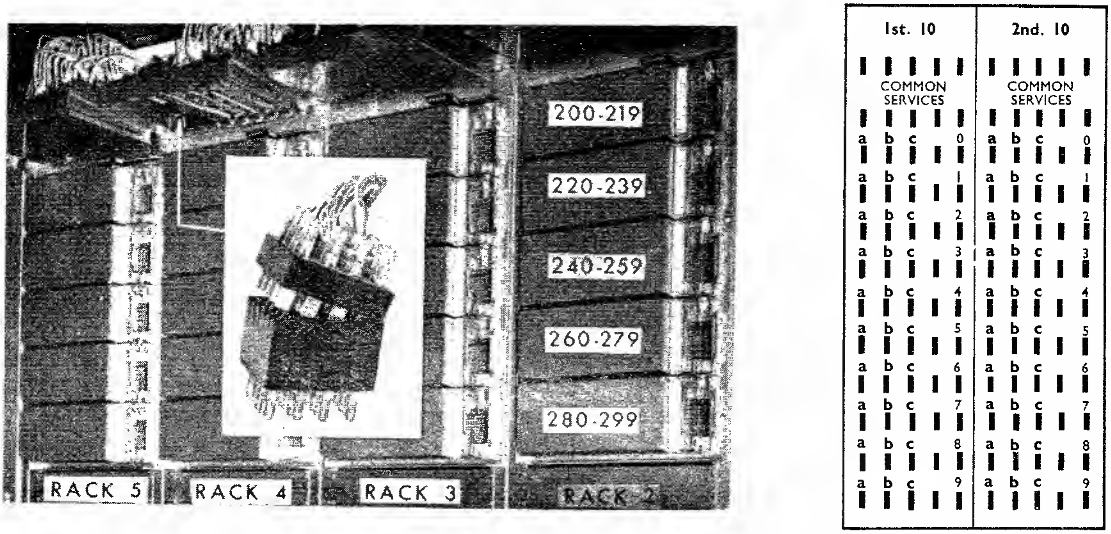


FIG. 2. LINE CONNECTING POINTS.

2.3 The rear of each SLA rack is provided with two swing-out frames in which the line equipment for the 200 subscribers is mounted. The upper frame contains equipment for subscribers in the even hundred group, and the lower frame contains the line equipment for subscribers in the odd hundred group. Fig. 3a shows the arrangement of line equipment on the upper half of several SLA racks. Fig. 3b shows the numbering of each group of twenty lines on its associated relay set jack.



(a) Line relay allocation.

(b) Line Relay Set jack terminations.

FIG. 3. LINE EQUIPMENT.

"Trays" containing the plug and jack connections can be seen at the top of Fig. 3a. The five relay sets shown on each rack provide the line relays for the lower or even numbered 100 group. Five similar relay sets mounted on the bottom half of each rack provide the line relays for the odd numbered 100 group. Fig. 4 shows a typical relay set which contains the line relays for 20 lines and a supervisory relay. Also shown is a strip of five supervisory lamps which are associated with 100 lines. Two such strips are provided, one near the centre of the rack and one at the top of the rack.

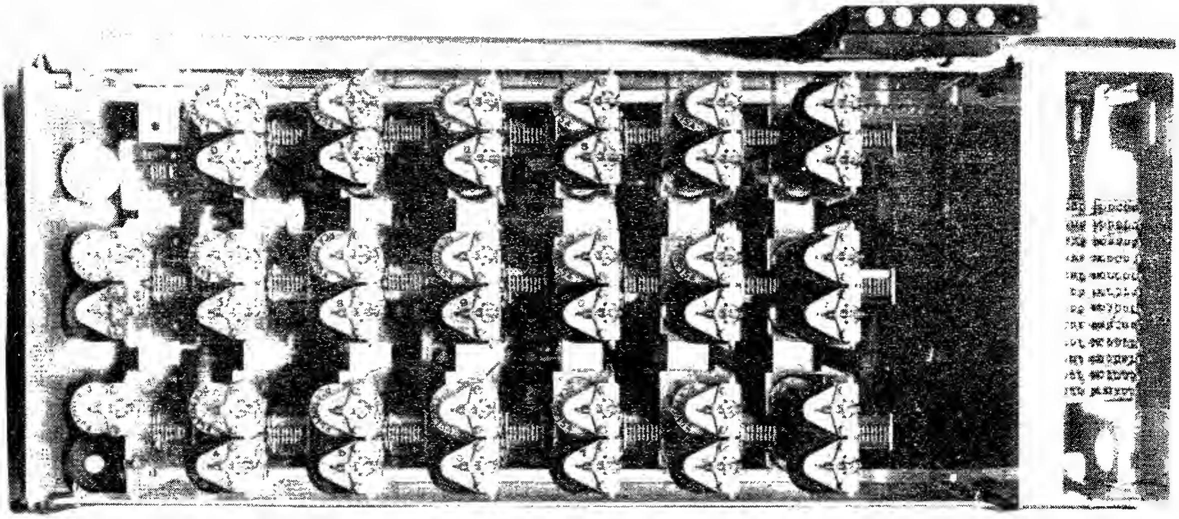


FIG. 4. LINE RELAY SET.

2.10 In the paper "Introduction to Crossbar Switching" para. 5.6, the method of connecting subscriber's lines to the SLA switch was described. We saw that the "tens" figure indicated the vertical of the switch, and the "units" figure indicated the horizontal springset of that vertical. For example, a subscribers whose number ends in 75 is connected to the 5th Horizontal springset in the 7th vertical.

2.11 This method of locating the line is correct when considering the odd numbered SLA switches, or those appearing on the upper half of the rack. In practice however, there is a transposition of the multiple between the upper and lower halves of the rack so that on all even numbered SLA switches, or those on the lower half of the rack, the "tens" figure indicates the horizontal springset, and the "units" figure indicates the vertical on which that subscriber's line is situated.

This transposition is done to distribute the traffic evenly over available devices and decrease the possibility of internal congestion.

Table 2 shows the location of the subscribers' lines on switches in each half of the rack. By plotting on Table 2 the lines to be modified for possible public telephone operation (para. 2.8), it will be seen that they form a diagonal pattern, indicating an even distribution over the available devices which reduces the possibility of internal congestion. A similar arrangement should be made where possible when allocating lines for use with P.B.X. services.

ABOVE JACK BOX
ODD SWITCHES 1,3,5,7.

	V1		V2																V0	
	HA	HB	HA	HB															HA	HB
H1	011	111	021	121	031	131	041	141	051	151	061	161	071	171	081	181	091	191	001	101
H2	012	112	022	122															002	102
H3	013	113	023	123															003	103
H4	014	114	024	124															004	104
	015	115	025	125															005	105
	016	116	026	126															006	106
	017	117	027	127															007	107
	018	118	028	128															008	108
	019	119	029	129															009	109
HO	010	110	020	120	030	130	040	140	050	150	060	160	070	170	080	180	090	190	000	100

BELOW JACK BOX
EVEN SWITCHES 2,4,6,8.

H1	011	111	012	112	013	113	014	114	015	115	016	116	017	117	018	118	019	119	010	110
H2	021	121	022	122															020	120
	031	131	032	132															030	130
	041	141	042	142															040	140
	051	151	052	152															050	150
	061	161	062	162															060	160
	071	171	072	172															070	170
	081	181	082	182															080	180
	091	191	092	192															090	190
HO	001	101	002	102	003	103	004	104	005	105	006	106	007	107	008	108	009	109	000	100

TABLE 2.

3. SUBSCRIBER'S STAGE - OUTGOING TRAFFIC.

3.1 Call Indicator. When a calling subscriber originates a call, his loop operates the line relay associated with his line.

Contacts of this line relay connect the call indicator for that rack to a low frequency A.C. The call indicator, a centre-stable polarised relay, operates to the half cycle of A.C., and, depending on the direction of operation, selects either Marker 1 or Marker 2 for that particular call. Fig. 33 (attached) shows a block diagram of the SL stage apparatus used in an outgoing call. The basic explanatory figures in this section should be related to Fig. 33, to gain an overall picture of switching paths and equipment.

3.2 Identification of the 200 line group. A call indicator (Rack Equipment, Fig. 5) is provided for each SLA rack. When a call is originated, the operation of the call indicator on the originating rack causes the operation of a correspondingly numbered group identification relay in the Group Identifier of the selected marker.

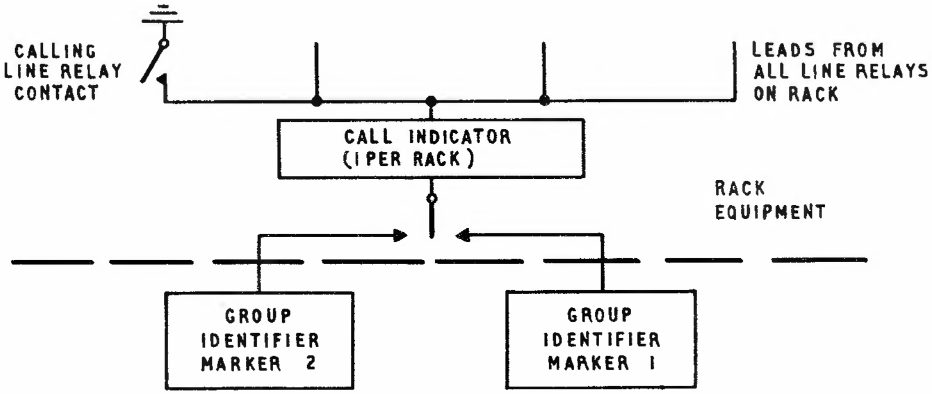


FIG. 5. GROUP IDENTIFICATION.

3.3 When two or more calls originate from different racks simultaneously, (Fig. 6), it could result in the operation of more than one group identifying relay in the same marker.

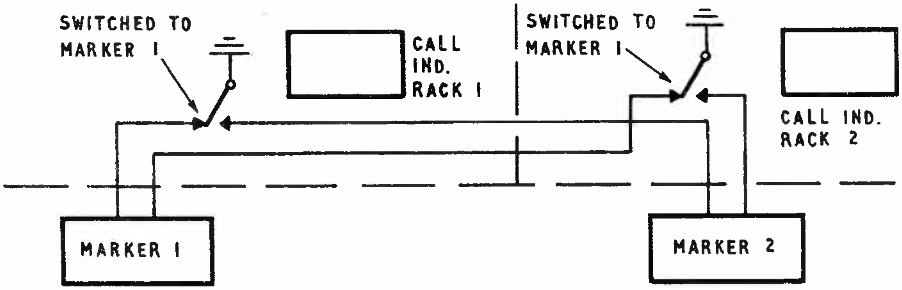


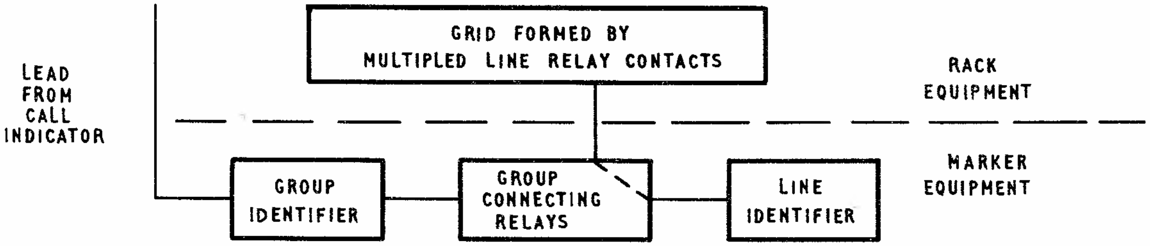
FIG. 6. SIMULTANEOUS CALLS.

When this condition occurs, the operated relays are wired in such a way that only one relay will maintain a holding circuit.

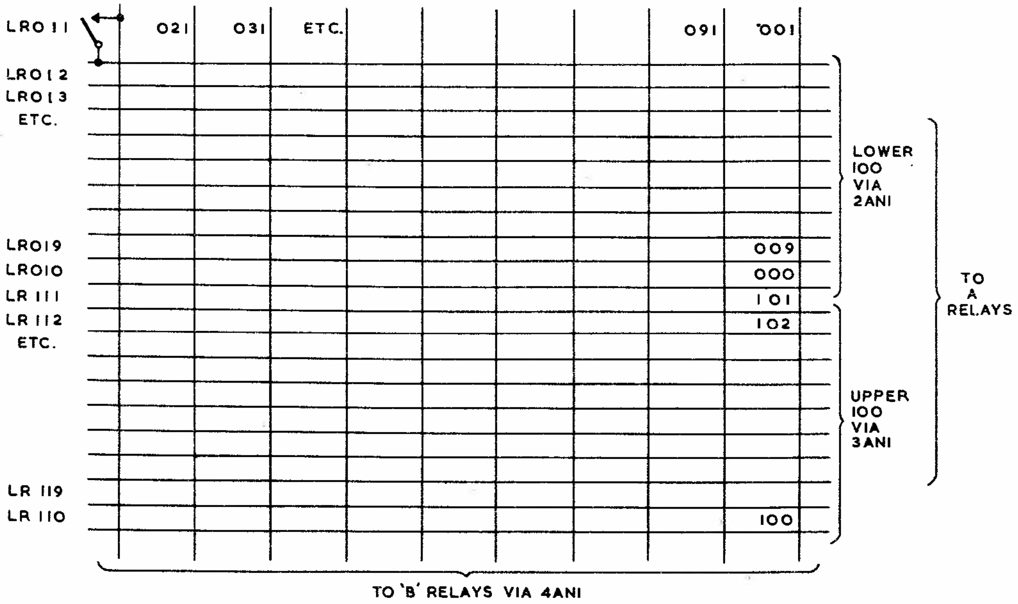
3.4 This method of connection is called an "identification chain". The particular relay to receive the holding circuit is determined by another arrangement of relays called a "call distributor".

3.5 The combined function of the relay selection chain and the call distributor is to provide a holding path when only one relay operates, but to select one relay when more than one operates.

3.6 Subscriber's Line Identification. When the originating rack has been decided by the holding of one group identification relay, associated connecting relays in the marker connect line identifying relays to a "co-ordinate" grid of line relay contacts on the selected rack (Fig. 7a). Fig. 7b shows the line relay contacts multipled in such a manner that the vertical row corresponds with the "tens" figure of the subscriber. The twenty horizontal rows are arranged so that rows 1 to 10 represent the "units" number of subscribers in the lower 100 group, and rows 11 to 20 represent "unit" number 1 to 0 of subscribers in the upper numbered 100 group.



(a) Connecting to Line Identifier.



(b) Identifying Grid.

FIG. 7. LINE IDENTIFICATION.

By this means it is possible to carry out identification with an extension of only 30 wires from the marker.

3.7 The line identification is carried out in two stages -

(i) Twenty relays are applied to the horizontals of this grid. The relay applied to the horizontal which is connected to the calling subscriber's line relay contacts operates, indicating the "units" number of the calling subscriber.

(ii) Ten other identifying relays are then applied to the verticals of the contact grid. One of these relays operates, indicating the "tens" figure of the calling subscriber.

3.8 Number Storage. The operation of the identifying relays determines the number of the calling subscriber. This information is stored by operating storage relays corresponding to -

(i) the rack number;
(ii) the "tens" number;
(iii) the "units" number;
(iv) the upper or lower 100 group.

The storage relays cause the operation of similarly numbered connecting relays on the originating rack.

3.9 Indication of Idle SLA verticals. The function of the rack connecting relays is to extend to the marker a testing circuit for each vertical on that rack which has access to the calling subscriber. On the upper half of the rack the required vertical in each switch is determined by the subscriber's "tens" number, while in the lower half of the rack the required vertical is determined by the "units" figure (Table 2).

Fig. 8 shows the path by which an indicating relay in the marker operates for every free, available vertical having access to the calling subscriber. The testing circuit is via a blocking key and contacts of a fuse associated with the switch magnets. If the fuse is operated the testing circuit will be open and the circuit will not be available for selection.

The contacts of the blocking key provide a means of busying an entire switch. If the key is operated the contacts open the testing circuits for all verticals on that switch.

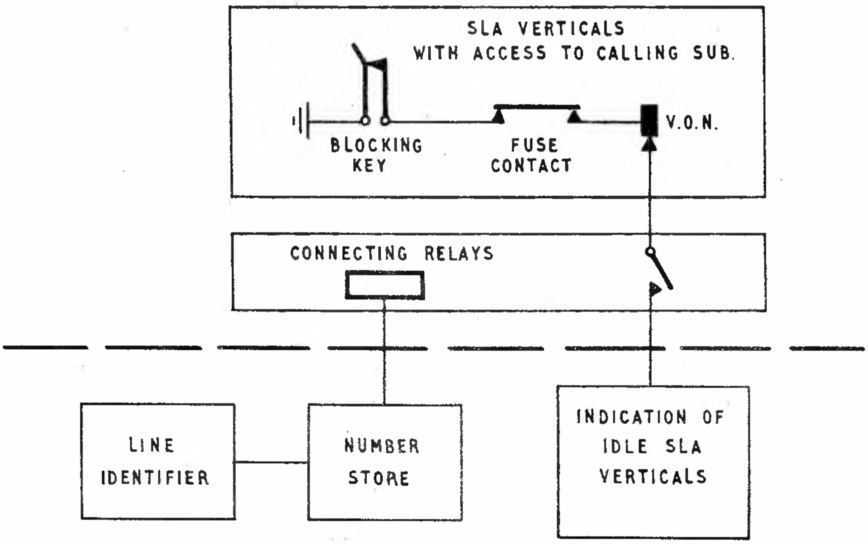


FIG. 8. INDICATION OF IDLE SLA VERTICAL.

3.10 Selection of Idle SLA vertical. After the idle verticals with access to the calling subscriber have been indicated, the next step is to select one of these verticals. This selection is dependent on the principle of conditional selection which states -

(i) that the vertical must have access to the calling subscriber;
(ii) that the selected vertical must have access via SLA and SLB stages, SR relay set and register finder to a free register.

When there are a number of possible paths which conform to these conditions, a selecting relay operates for each possible SLA vertical, and the final selection of the SLA vertical to be used on that call is made using a relay selection chain and call distributor.

3.11 Fig. 9 shows the path by which an SLA vertical is selected. By providing a testing path through contacts of the indicating relays, only available verticals can be tested. The testing path is via fuse contact springs and blocking key contacts at the SR relay set, vertical off-normal springs at the SLB and register-finder stages, and a contact of a relay (operated by a blocking key or an operated fuse) at the GVA stage. This ensures that the SLA vertical selected has access both to the calling subscriber and a free register.

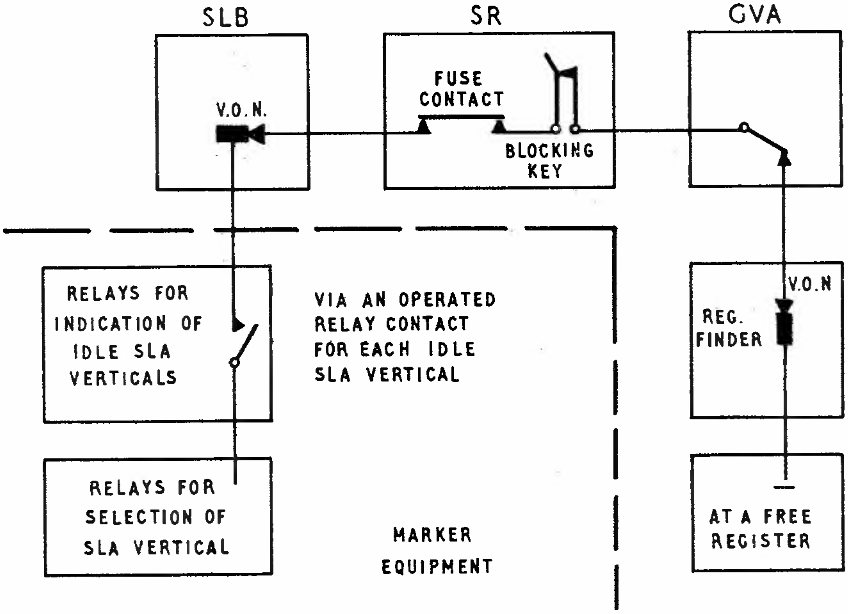


FIG. 9. SELECTION OF SLA VERTICAL.

The selection of an SLA vertical on a particular switch automatically determines the SLB switch to be used, as only one SLB switch has access to that vertical (Fig. 10).

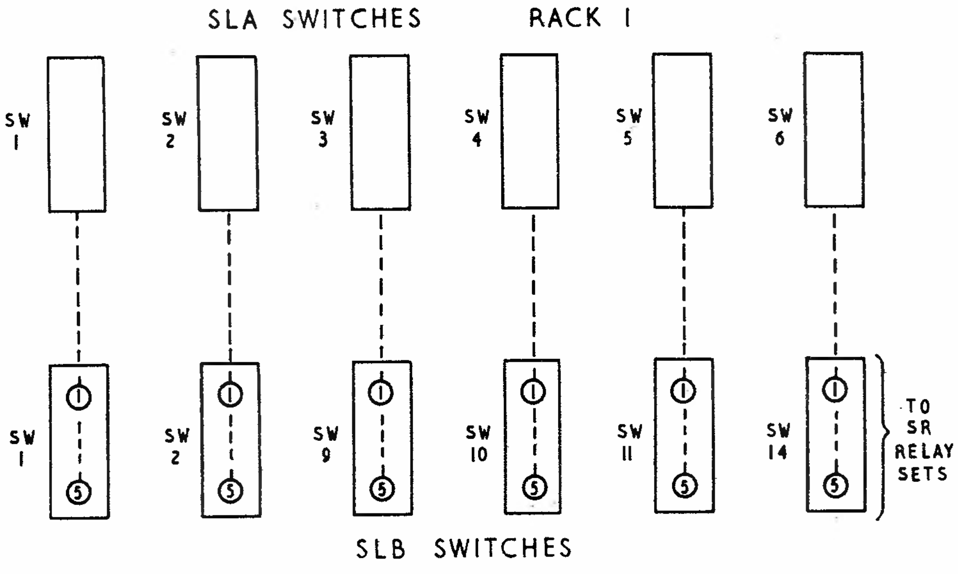


FIG. 10. SIMPLIFIED SLA/B GROUPING PLAN.

3.12 Selection of SLB Vertical. Of the ten verticals on the selected SLB switch, half are used for outgoing calls and half are reserved for incoming traffic. A test is made of the five outgoing verticals to determine which of these are free and have access to a free register. (Fig. 11.)

A relay operates for each free SLB vertical on the selected switch which has access to a free register. If more than one is available the vertical to be used is again decided by a relay selection chain and call distributor.

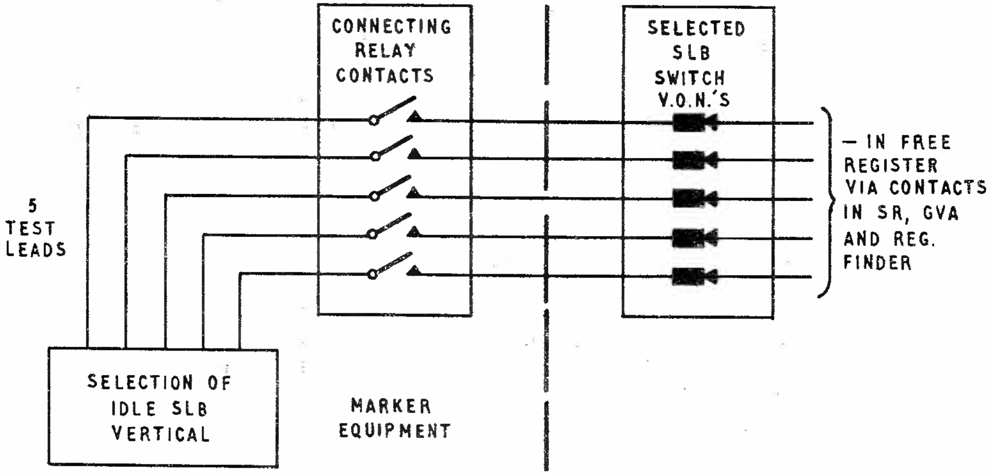


FIG. 11. SELECTION OF SLB VERTICAL.

3.13 Operation of Horizontal and Vertical Magnets. When the trunking of the call through the SLA and SLB partial stages is decided, the corresponding horizontal magnet for each switch is operated, followed by the magnet for each selected vertical (Fig. 12). The subscriber's line is switched through the stage and a signal is forwarded to the Register Finder Marker. The SL marker then releases.

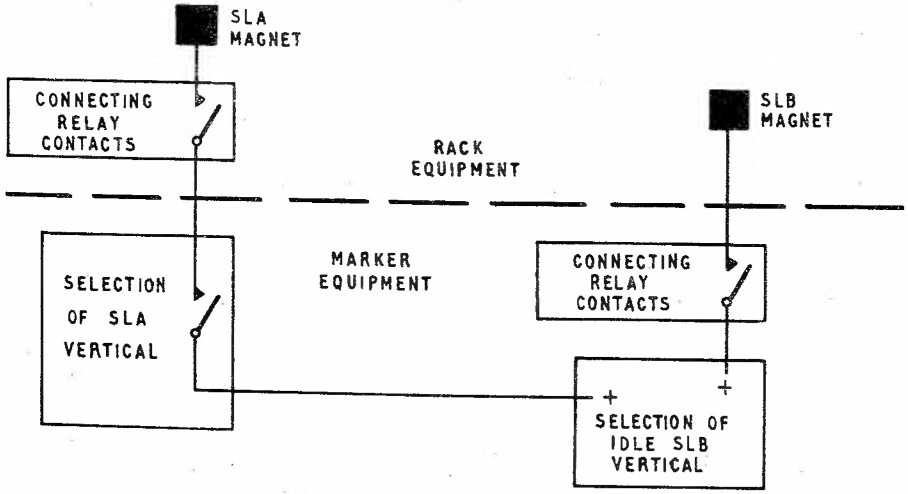


FIG. 12. OPERATION OF MAGNETS.

Both SLA and SLB vertical magnets are provided with an additional holding winding. During conversation both magnets are held operated from an earth or positive potential applied to the "d" wire of the selected circuit. This earth potential is applied originally from the register and when the register releases it is supplied from the SR relay set.

4. REGISTER FINDER STAGE.

4.1 Functions of the register finder (RS) stage. Register finders are used whenever a number of registers are made available to a group of calling circuits. When a local call is made, the register finder connects a calling SR relay to a register. In the case of incoming traffic the register finder completes the connection between an FIR relay set and a free register. A description of the register finder grouping plan and the method of commoning, is given in the paper "Grouping Plans for ARF Systems".

The functions of the register finder stage are -

(i) To identify the calling circuit.

(ii) To select a free register.

(iii) To connect the calling circuit to the selected register.

4.2 Fig. 13 shows the arrangement of apparatus on a typical SR/RS rack, and Fig. 14 shows a trunking diagram of the register finder stage used to connect a calling SR relay set to a free register.

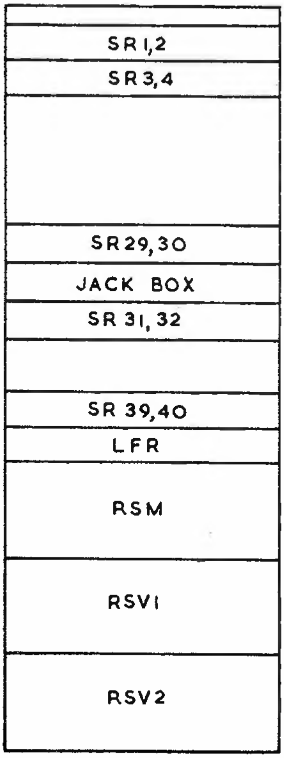


FIG. 13. SR/RS RACK.

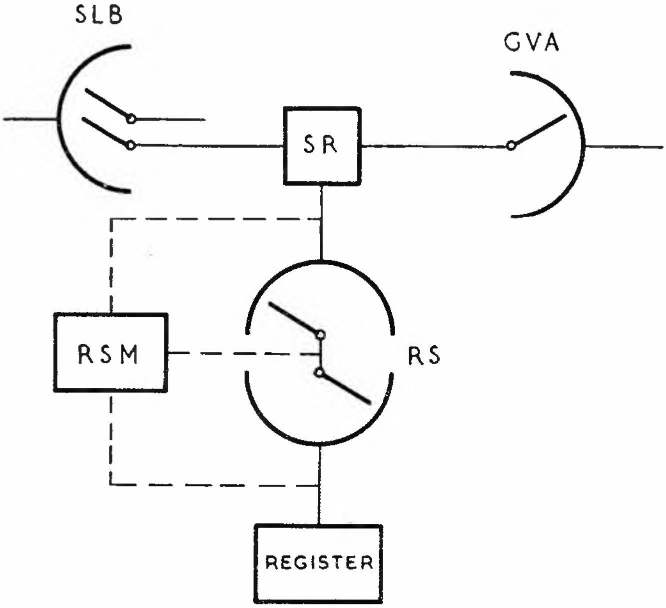


FIG. 14. REGISTER FINDER STAGE.

The register finder and its 40 associated SR relay sets are mounted on the same rack. The register finder consists of three relay sets connected by plug and jack. Two of the relay sets contain a crossbar switch; the third contains the register finder marker.

4.3 Identification of calling circuit. When the SLA and SLB switching has been decided, the SL marker extends a signal via the selected SR to the associated register finder marker. Fig. 15 shows in block form the sections of the register finder marker. The marker identifies the calling circuit in two stages using a 1 wire identification circuit.

The first stage divides the inlets from the 40 associated SR's into four groups of 10 and decides which of these groups contains the calling circuit.

The second stage identifies the calling circuit from the group of 10.

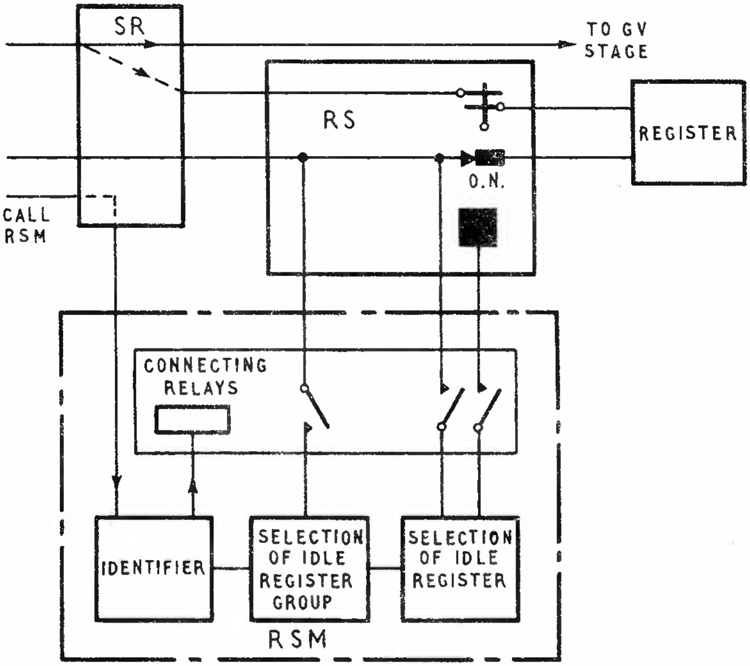


FIG. 15. BLOCK DIAGRAM OF REGISTER FINDER MARKER.

4.4 Selection of a free register. Associated with the register finder are 10 registers, which are arranged in two groups, each containing 5 registers.

Under the control of a call distributor, a relay operates selecting a group of five containing a free register, and another chain selects the register for that call from the group of five.

4.5 Switching of the register finder. When the selection of the calling circuit and free register has been completed, these selecting relays are used to control the operation of the correct horizontal and vertical magnets. The normal horizontal outlets are wired to the incoming SR circuits, and the HA and HB contacts are connected to registers. This arrangement enables each vertical to have access to 10 SR circuits and 2 registers.

4.6 After the switching has taken place, the register finder vertical magnet holds from a circuit provided by the register. A break relay now operates in the subscriber's line circuit, disconnecting the signalling circuit to the SLM. The SLM and the RSM now release and become available for further calls.

. GROUP SELECTOR (GV) STAGE.

5.1 The group selector stage, which consists of two partial stages GVA and GVB, connected together by 120 link circuits, is built up of units containing 80 inlets and 400 outlets. Each unit consists of two identical selector racks, with 4 GVA and 6 GVB crossbar switches mounted on each rack. Two such units are under the control of one GV marker. The marker equipment for the GV stage is divided into three sections, the basic functions of which are:-

(i) Identifier – Identification of the calling SR or FIR and connection of this circuit to the code receiver.

(ii) Code Receiver – This section receives the signals from the register, determines the route required, and where necessary, returns information to the register to control the sending of code signals, and in the case of the IGV stage to indicate number length and the destination of the call, whether crossbar or step-by-step.

(iii) GV Marker – The marker contains the equipment for testing and selecting an idle circuit on the desired route.

Fig. 16 shows the arrangement of switches on a group selector rack and Fig. 17 shows the equipment mounted on a GV marker rack. Fig. 18 shows the connections between the selector racks and marker equipment.

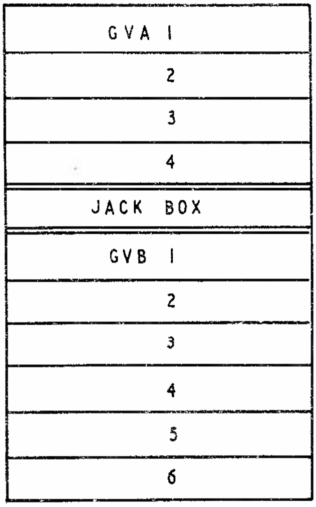


FIG. 16. GVA/B RACK.

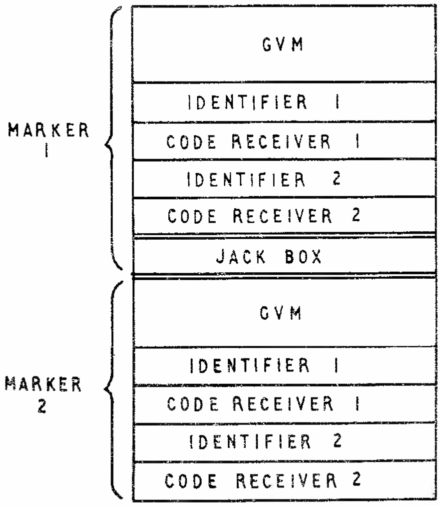


FIG. 17. GV MARKER RACK.

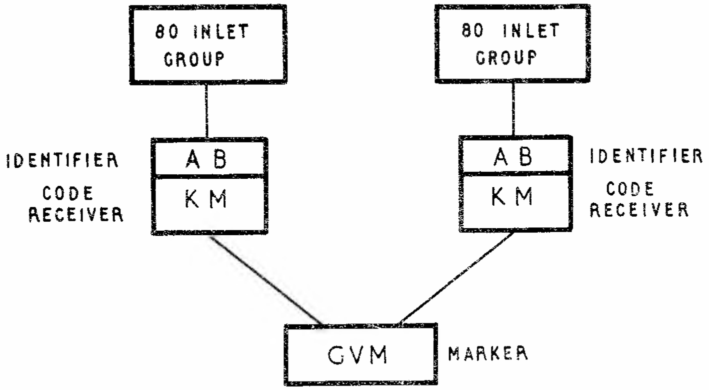


FIG. 18. CONNECTIONS BETWEEN GV STAGE EQUIPMENT.

5.2 When the group selector stage contains ten-line routes, the code receiver section is provided with an additional relay set, which enables the simultaneous testing of ten circuits in place of the normal twenty.

5.3 Two twenty-line groups may be combined into a forty-line route. On a call to such a route the marker tests one twenty-line group and when an idle line is not available a test is then made on the other group.

5.4 Each group selector unit may be provided with double code receiver equipments. When this is done an additional relay set KBR is added to distribute the calls between the two code receiver equipments. As the code receivers are used on alternate calls, this does not improve the traffic handling capacity, but it provides a more reliable operation in small exchanges with few group selectors.

5.5 Fig. 34 (attached) shows, in block diagram form, the interworking of the equipment associated with the GV marker and should be used in conjunction with the basic diagrams in this Section.

5.6 Identification. When the register has received and stored all the dialled digits, the SR calls the GV marker identifier. The calling SR is now identified by a two-stage 1-wire identifier circuit in a similar manner to that described for the RSM. The 80 inlet verticals are arranged in 6 groups and an identifying relay operates to indicate which group contains the calling circuit. A further relay operation then selects the calling SR from the group (Fig. 19).

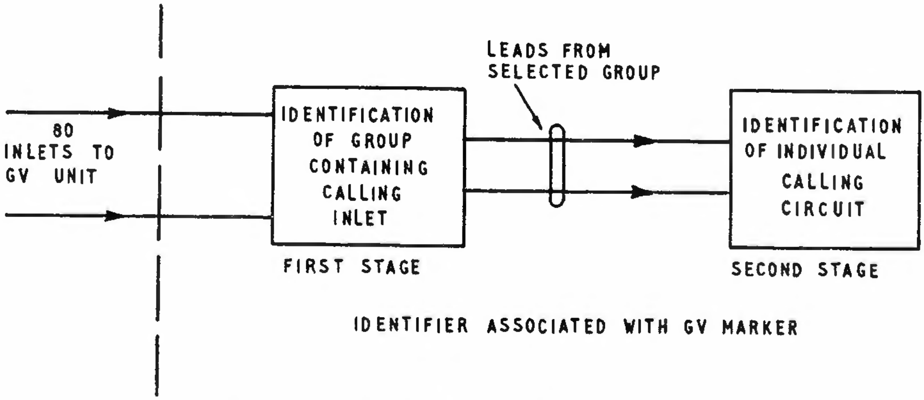


FIG. 19. IDENTIFICATION OF CALLING SR.

When the calling circuit has been identified, a connecting relay places the code receiver section across the line to receive signals from the register. (Fig. 20.) In early crossbar exchanges these signals consisted of a series of reversals, but later exchanges use a system of high speed voice frequency signalling.

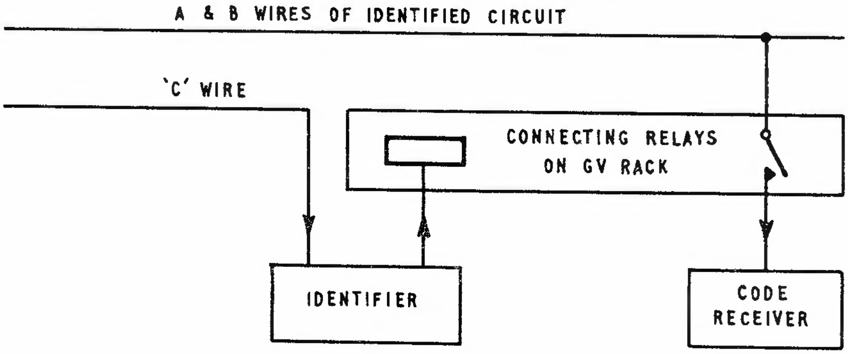


FIG. 20. CONNECTING CODE RECEIVER.

5.7 Code Reception and Digit Storing. When the code corresponding to the first digit is received from the register it is counted, stored in the code receiver store for digits and then examined to determine whether there is enough information to decide the route. If the information is insufficient (Fig. 21a), the code receiver sends a revertive signal to the register, causing the register to send the code information corresponding to the next digit. This is counted and stored in a similar manner and the combined information is now examined by extending a circuit via operated relay contacts to a route interconnecting block.

Fig. 21b shows that when sufficient information is received to determine the route, a corresponding "route" relay is operated on the selector racks of the unit concerned with that call. Contacts of this relay connect testing leads from the C wires for each circuit in the selected route to the GV marker (Fig. 21c).

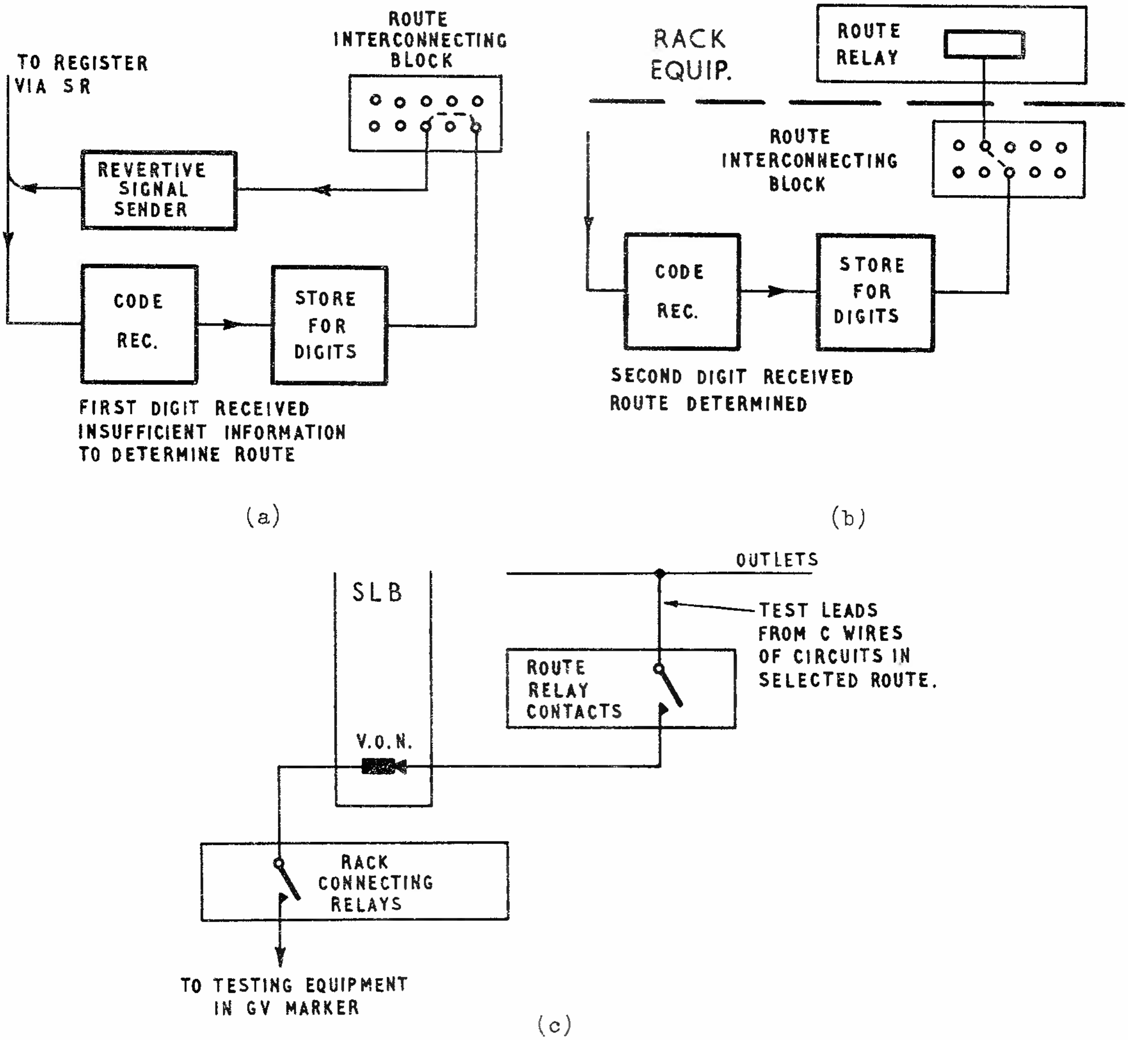


FIG. 21. CODE RECEPTION AND ROUTE SELECTION.

Although two digits are usually sufficient to decide the required route, it is possible to store up to four digits when more information is needed. In between each digit a revertive signal is sent from the code receiver to the register requesting an additional digit.

5.8 Outlet Testing. Outlets are normally tested in groups of twenty. The GV marker applies twenty cold cathode radio-active gas filled neon tubes simultaneously to the C wires of the circuits in the selected route. (Fig. 22.) One of the neon tubes connected to a free circuit will strike and operate an associated relay. The operating circuit is immediately disconnected from all other testing tubes.

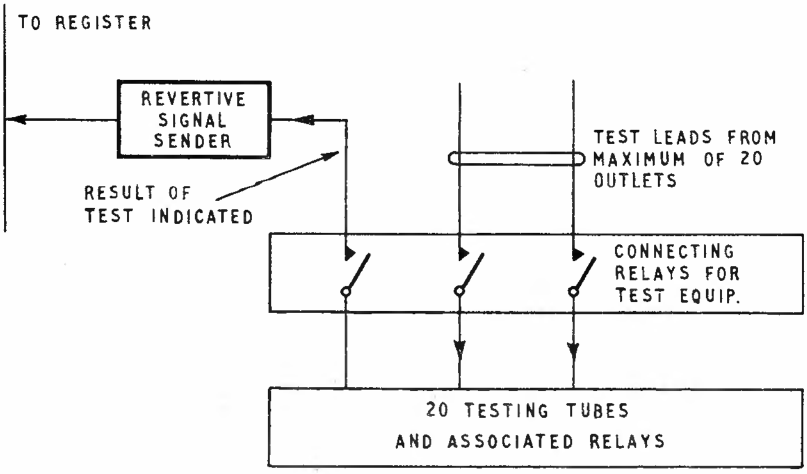


FIG. 22. OUTLET TESTING.

When several circuits are free, the radio-active gas usually causes one tube to strike before all others, providing random selection of a free outlet. However, if several tubes strike simultaneously, a selection chain ensures that only one of the associated relays will receive a holding circuit.

5.9 When a forty-line route is selected, the neon tubes are applied to the C wires of twenty circuits on this route. When there are no idle circuits in this group, the testing circuits are automatically transferred to the C wires of the other twenty circuits making up the route.

5.10 Test on an alternative route. When the GVM receives enough information from the register to determine the required route, the circuits on this route are tested in the manner described. If all circuits are busy and an alternative route is provided, the testing tubes are then applied to the circuits of the alternative route.

5.11 Free circuit. When the GVM has selected a free circuit, a revertive signal is sent to the register. If the circuit is on the desired route a signal is sent to the register to forward information about the next digit.

When the free circuit is on an alternative route, the signal to the register requests either the same or an earlier digit to be sent forward, depending on the route selected.

5.12 Congestion. When no free circuits are available a "congestion" signal is returned to the register. The switches are released by the register and the subscriber receives busy tone from his line circuit.

5.13 Switching. After a free circuit has been selected, the correct horizontal and vertical magnets in the GVA and GVB partial stages are operated, and the GV marker then releases.

When the inlet is connected through to the selected outlet, the GVA vertical magnet is held by earth applied to the C wire by the SR, while the GVB vertical magnet is held by earth applied to the C wire from a GVA contact.

6. SUBSCRIBER'S STAGE - INCOMING TRAFFIC.

6.1 Incoming traffic to the SL stage is connected to an SLD vertical and uses all four of the SL partial switching stages. Fig. 23 shows a trunking diagram of the incoming traffic section of an SL stage.

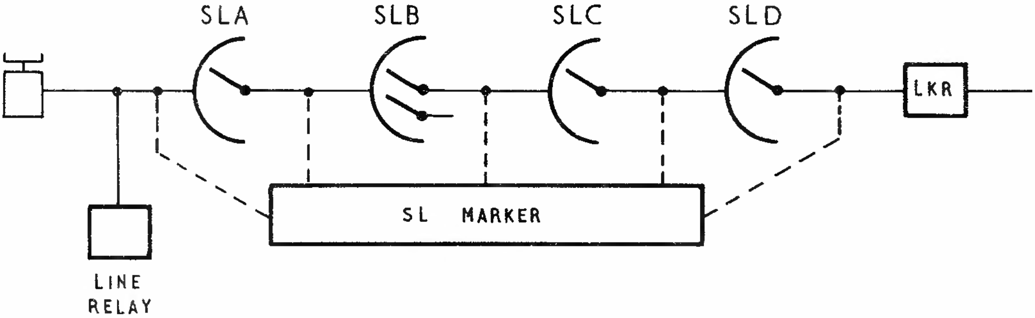


FIG. 23. TRUNKING - INCOMING SL TRAFFIC.

When a local call is switched through the GV stage, the code receiver associated with the SL marker is called from the GV stage on the holding wire via off-normal contacts on the SLD vertical. On local calls, the "B" subscriber receives ringing and current feed from the SR relay set, while on calls from other exchanges it is received from the FIR relay set.

6.2 As the SL stage is common to 1,000 subscribers, the SL marker receives from the register information concerning the last three digits of the subscriber's number. In earlier systems a revertive signal is returned to the register after the first of these digits but not after the second. This signal is introduced to make it possible for a 1,000 line group to be shared between two small exchanges. Later systems using compelled sequence multi-frequency signalling return a signal after each digit.

When the register has forwarded the information to the SL marker, it waits for a final revertive signal which is sent from the SL marker after it has tested the subscriber's line.

The signal indicates to the register that -

(i) the "B" subscriber is free
(ii) the "B" subscriber is busy
(iii) the "B" subscriber is intercepted, or
(iv) congestion has occurred in the SL stage.

When the called subscriber is busy or if congestion occurs, the register releases the switching train and the calling subscriber receives busy tone from his line circuit.

When the called subscriber is free, the register and the SLM are restored, and ringing current is connected to the "B" or called subscriber's line from the SR. The calling or "A" subscriber receives the first ring tone from the register before it is restored. All further ring tone is then received from the SR relay set. On incoming calls the same ring and feed functions are performed by the FIR relay set.

6.3 P.B.X. Facilities. Equipment is provided with each 1,000 group to facilitate calling subscribers with more than one line. One line only is listed in the directory, and when this line is called, the P.B.X. equipment automatically selects a free line from that subscriber's group. The directory line is only chosen if all other lines of that group are busy.

6.4 Number of lines per group. Normally, a subscriber can have a maximum of 20 lines in one P.B.X. group. When more lines are required, these are divided into groups, each containing a maximum of 20 lines. Lines other than the call number can be chosen at random from the 1,000 line group.

6.5 When a number in a P.B.X group other than the subscriber's directory number (call number) is dialled, the call is switched to the dialled number.

6.6 The C wires from all lines in the 1,000 line group are extended to a terminal strip at the top of the P.B.X. equipment rack. Below this strip, a relay set is mounted containing digit relays. This is followed by four empty relay sets intended for the P.B.X. relays. Provision is made for 80 P.B.X. relays which are inserted as they are needed.

If the subscriber's directory numbers or "call" numbers are chosen at random from the 1,000 line group, every P.B.X. subscriber needs one P.B.X. relay for the first three lines, and a further P.B.X. relay for each remaining group of four lines.

These P.B.X. relays are connected to three different places:-

(i) To one of the digit relays;

(ii) To the terminal strip containing the C wires;

(iii) To a special terminal strip mounted at the P.B.X. relay set.

Fig. 24 shows a typical P.B.X. chart on which details of P.B.X. groups are entered.

SUBSCRIBER	OTHER P.B.X. RELAYS	OTHER AUX. LINES	DIRECTORY NUMBER	DP RLY.	CONT.	UP RLY.	CONT.	P.B.X. RLY.	CONT.	OTHER P.B.X. RELAYS	TAG	AUX. LINES	'C' WIRE		TEST CIRCUIT		HUNDREDS AND TENS				UNITS				P.B.X. RLY.
													TERM. FIELD		P.B.X. CONT.	TAG IN TERM. STRIP	TAG IN TERM. STRIP	P.B.X. CONT.	P.B.X. CONT.	TAG IN TERM. STRIP	TAG IN TERM. STRIP	P.B.X. CONT.	P.B.X. CONT.	TAG IN TERM. STRIP	
NATIONAL BAKERY			41033			3	34	1	18			41496	X37g	11	12 14 16	101 102 103	121 122 123	21 23 25	22	49	141 142 143	31 33 35	32	166	1
HAPPY HARVESTERS			41088			8	34	5	18			41450 41749 41905	X36d Y50d Y66c	11 13 15	12 14 16	101 102 103	121 122 123	21 23 25	22 24 26	45 74 90	141 142 143	31 33 35	32 34 36	170 169 165	5
JOHN BROWNE LTD.			41044			4	34	6	18			41563 41726 41845	Y34c Y57b Y61d	11 13 15	12 14 16	101 102 103	121 122 123	21 23 25	22 24 26	56 72 84	141 142 143	31 33 35	32 34 36	163 166 165	6
PROPERTY SEEKERS			41077			7	34	4	18			41873 41745 41696	X74c Y46d X53g	11 13 15	12 14 16	101 102 103	121 122 123	21 23 25	22 24 26	87 74 69	141 142 143	31 33 35	32 34 36	163 165 166	4
PHELAN GOODE PTY. LTD.			41066			6	34	7	18			41234 41452 41163	X20c X37d Y4c	11 13 15	12 14 16	101 102 103	121 122 123	21 23 25	22 24 26	87 74 69	141 142 143	31 33 35	32 34 36	164 162 163	7

FIG. 24. SECTION OF P.B.X. CHART.

6.7 When the number of P.B.X. subscribers in a 1,000 line group is so great that one P.B.X. equipment unit cannot handle the traffic, additional units can be connected.

When two P.B.X. equipment units (commonly termed "equipments") are used, P.B.X.1 is called if the hundreds digits is 1-5, and P.B.X.2 if the hundreds digit is 6-0. The auxiliary lines in each group can still be chosen at random from within the 1,000 line group.

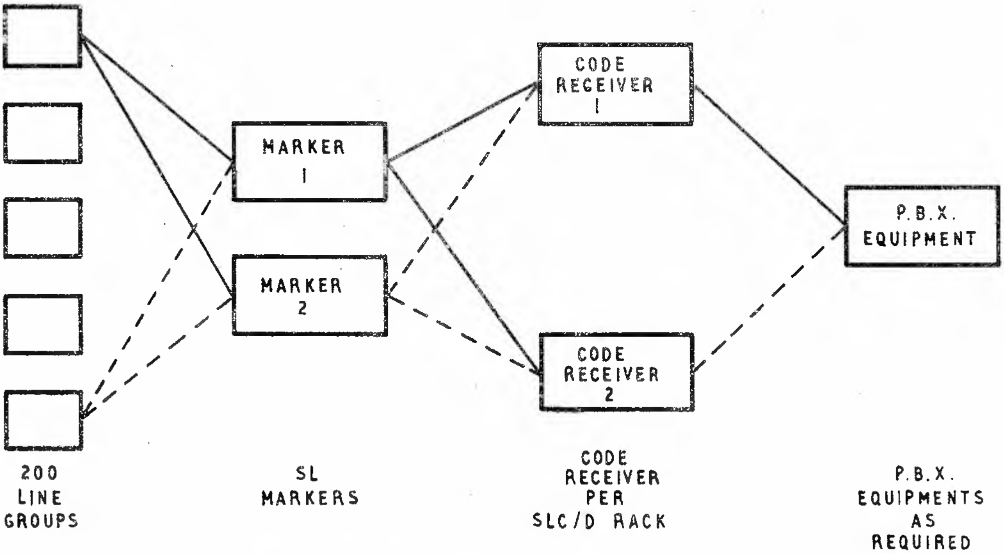
6.8 Code Receiver. Each SLC/D rack contains one code receiver. Each 1,000 line group is provided with a number of SLC/D racks determined by the traffic density. A maximum of five SLC/D racks can be provided. The associated code receivers each have access to -

(i) 40 calling inlets;

(ii) both SL markers;

(iii) P.B.X. equipments.

Fig. 25 shows the relationship between these items of equipment.



INTERCONNECTION OF INCOMING EQUIPMENT.

FIG. 25.

The code receiver consists of four sections -

(i) Identification section;

(ii) Connection;

(iii) Code Reception; and

(iv) Digit Storing

Fig. 35 (attached) shows in block form the function of the individual components used for incoming traffic in the SL stage.

6.9 Incoming Call. When the call is switched through the GV stage, a signal is sent to the code receiver dealing with calls to that particular group of 40 inlets.

6.10 Identification. The calling circuit is identified with a two stage, one wire identification circuit. The 40 incoming circuits are divided into 4 groups each containing 10 circuits, and the operation of one of 4 relays in the identifier indicates which group contains the calling circuit. The 10 circuits in this group are then connected to ten further relays, and the operation of one of these relays will indicate the calling circuit. When calls are received simultaneously on two inlets, one circuit is selected by a relay selection chain and the remaining circuit must wait until the code receiver is free.

6.11 Code Receiving. When the calling circuit has been identified, the circuit for receiving code is placed across the incoming pair and the codes corresponding to the last three dialled digits are received from the register (Fig. 26). As each digit is received the information is stored by operating relays in the digit storing section of the code receiver. A revertive signal calling for the next digit is sent to the register after the first of these three digits; the last two are sent without signals.

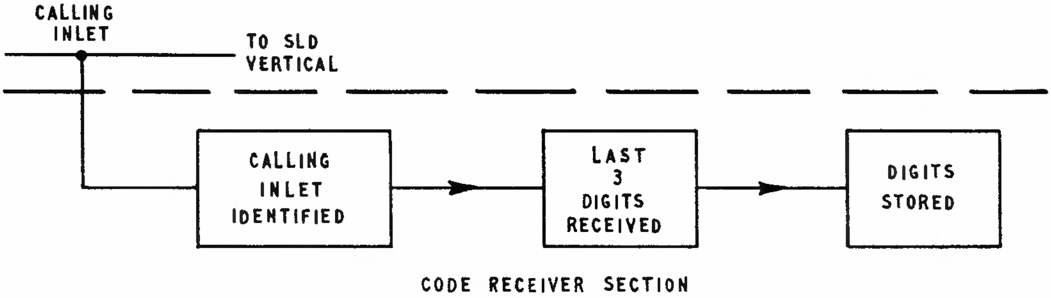


FIG. 26. RECEIVING LAST 3 DIGITS FROM REGISTER.

6.12 Call P.B.X. equipment. When all the information has been stored in the code receiver, a signal is forwarded to the P.B.X. equipment. When the called number is not a P.B.X. number, a signal is returned to the code receiver, the P.B.X. equipment is released and the call proceeds to the SL marker as described in paras. 6.15 to 6.19.

6.13 P.B.X. Call. Connecting relays connect the information from the digit store in the code receiver to the P.B.X. analyser. When the number dialled is a P.B.X. number, all the C wires of the P.B.X. group (except the directory number) are connected via contacts of P.B.X. relays to the test equipment to check for a free line in the group. When a number of lines in the group are free, the first free line is selected. If all auxiliary lines are busy, the call is switched to the directory number which will be tested for busy as an ordinary subscriber.

6.14 Transfer of new number. When an auxiliary line in a P.B.X. group is selected, the original number held in store is released, and a new number corresponding to the selected auxiliary line is now placed in the store in the code receiver. When the new number is stored, the P.B.X. equipment is released and a signal is forwarded to the SL marker. Fig. 27 shows the sequence of operations within the P.B.X. equipment.

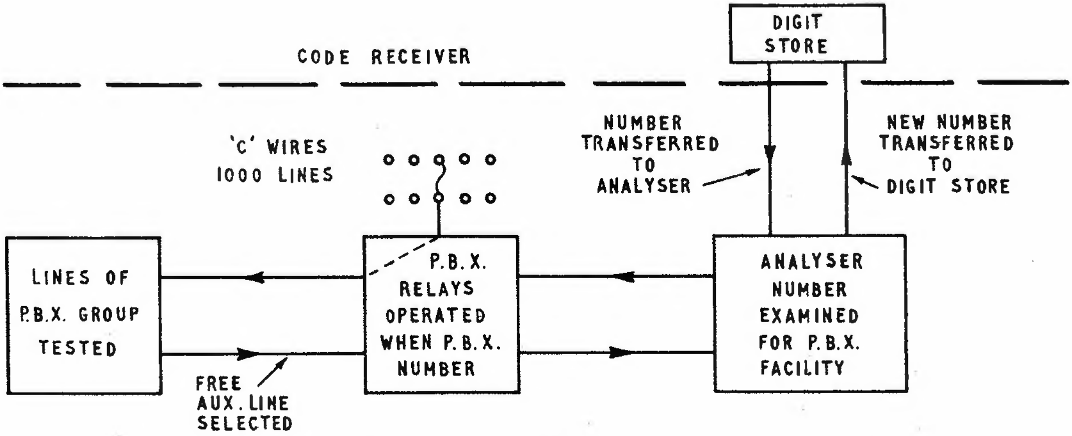


FIG. 27. SEQUENCE OF P.B.X. OPERATION.

6.15 Call SL marker. A centre-stable polarised relay is fitted on each SLC/D rack and the direction of operation of this relay decides the SL marker to be used on this incoming call. A similarly numbered relay operates in the selected SLM to indicate which code receiver is calling. Associated multicoil relays then connect the code receiver to the SLM (Fig. 28).

6.16 Transfer of number to marker. When the code receiver is connected to the SLM, the number finally stored in the code receiver is transferred to the number store in the SLM. If the 200 line group is already occupied by the other SL marker, this call must wait until the other marker releases the occupation of the 200 line group.

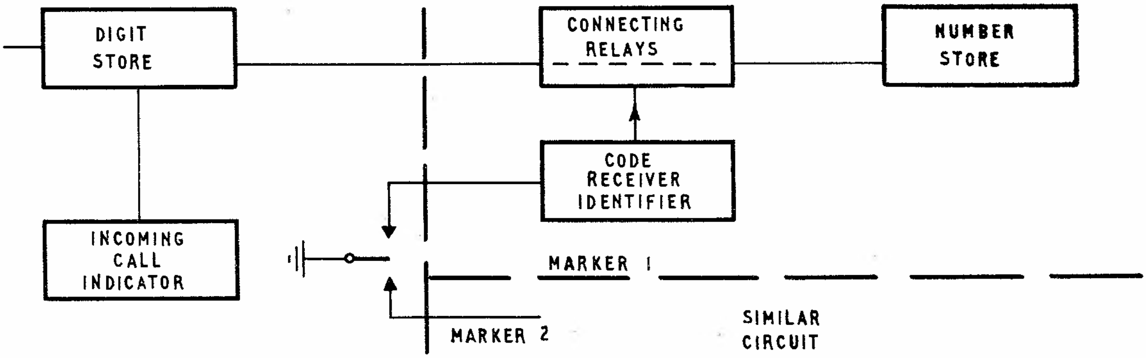


FIG. 28. CONNECTING TO SL MARKER.

6.17 Bypath testing. Operation of relays in the number store causes the operation of similarly numbered connecting relays on the SLA/B rack containing the required line. These rack connecting relays extend circuits which enable the SL marker to test for idle verticals with access to the required line. A testing relay operates for each free available SLA vertical with access to this line (Fig. 29a).

When the calling inlet was identified (para. 6.11), this also decided the SLD vertical to be used, as each inlet is permanently connected to one particular SLD vertical. Connecting relays on the SLC/D rack, where this vertical appears, extend testing circuits to enable free SLC verticals to be indicated (Fig. 29b). These verticals must be available to the calling SLD inlet.

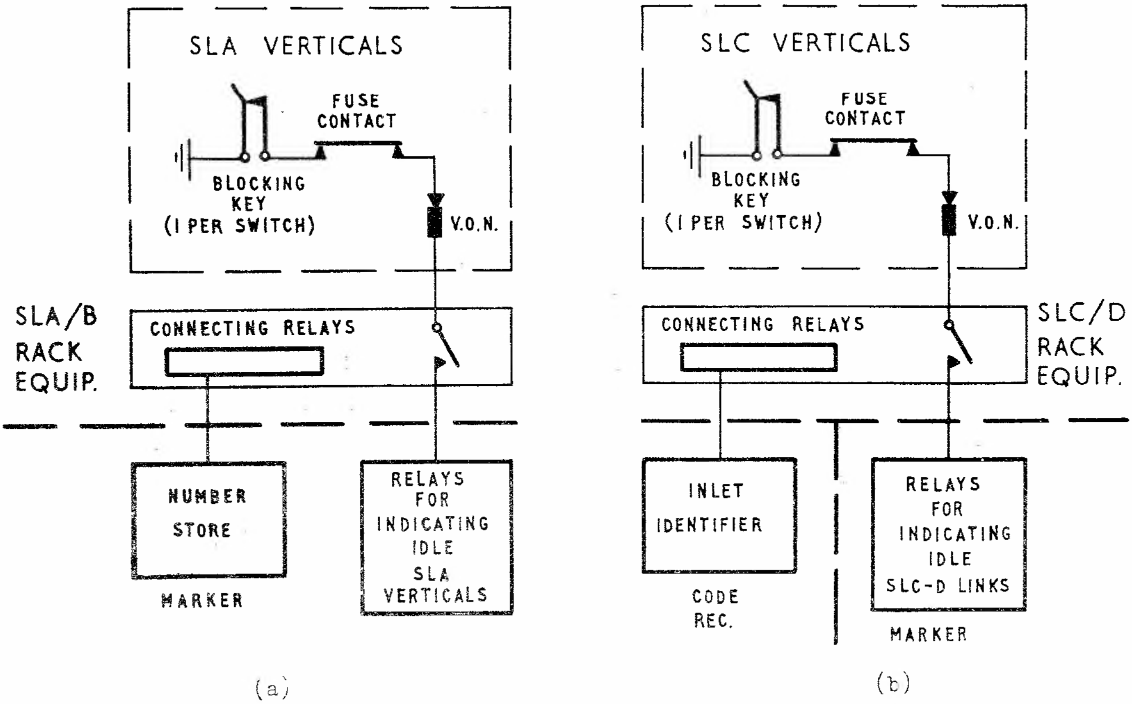


FIG. 29. INDICATION OF IDLE LINKS.

An idle SLA vertical is now selected. (Fig. 30.) The testing path ensures that the selected vertical has access to -

(i) the called subscriber's line;

(ii) a free SLB vertical with access to a free SLC vertical available to the calling SLD inlet.

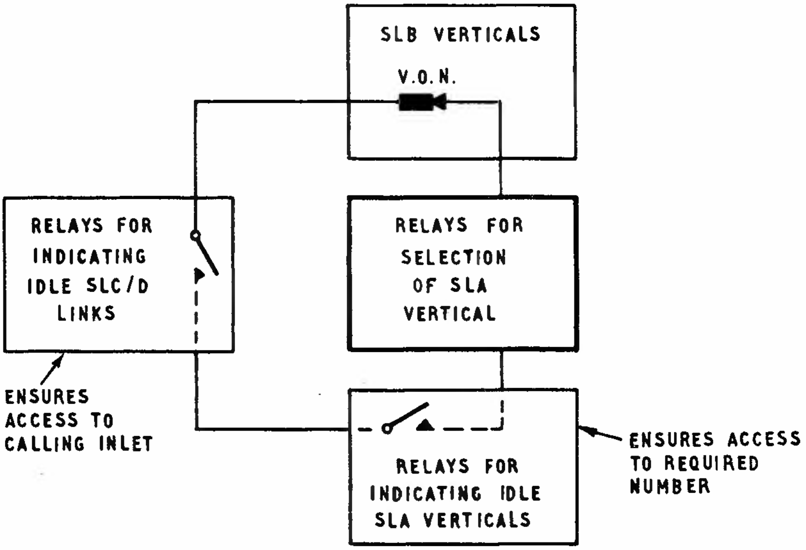


FIG. 30. SELECTION OF SLA VERTICAL.

The selection of an SLA vertical automatically decides the SLB switch, as only one SLB switch has access to that vertical. This association between SLA vertical and SLB switch is described in paras. 3.10 and 3.11.

Each SLB switch has five verticals reserved for incoming traffic. One of these verticals is selected, provided that it has access to a free SLC vertical which is available to the calling SLD inlet. Fig. 31 shows the testing path used to select an SLB vertical.

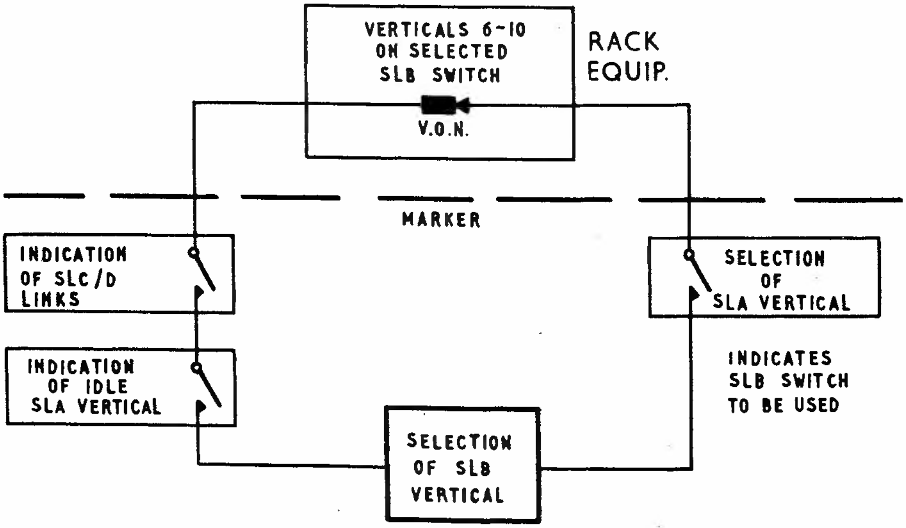


FIG. 31. SELECTION OF SLB VERTICAL.

Finally, a free SLC vertical is selected. This vertical must have access to the selected SLB vertical and must also be available to the SLD inlet. Fig. 32 shows the testing path used when selecting an SLC vertical.

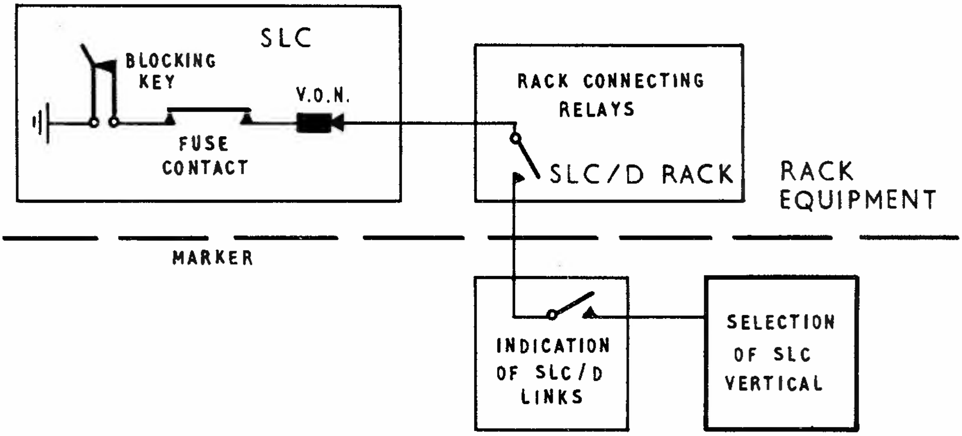


FIG. 32. SELECTION OF SLC VERTICAL.

At every partial stage, the path for the selection of a vertical is arranged through contacts of other indicating relays, ensuring that the vertical selected has access to both the calling inlet and the desired outlet.

This method of conditional selection, where a link is only chosen on the condition that a through path is available, is a feature of crossbar circuits and will be encountered continually.

It should be noted that the paths to indicate idle verticals are quite often via off normal springs of the vertical under test, contacts of a fuse, and normally making contacts of a blocking key. If the circuit is open at any of these points the indicating relay will not operate and that particular vertical cannot be selected.

The blocking keys, mounted in the jack box of each rack, are usually provided on the basis of one key for each switch, and serve as a means of busying an entire switch from use. Other blocking keys are provided, but their purpose is discussed in other papers of the course.

6.18 Subscriber testing. During the bypath testing, the subscriber's line is tested for idle or busy condition. As only small operating voltages may be available under some busy conditions, a polarised relay, being more sensitive than the standard relay, is used for this test.

6.19 Revertive Signals after testing. When both bypath testing and subscriber testing have been completed, signals are returned to the register by the revertive signal sender in the SL marker. These signals indicate -

(i) subscriber busy
(ii) subscriber intercepted
(iii) subscriber free
(iv) congestion or blocking in the SL stage

When the line tests busy, or when congestion occurs in the SL partial stages, the signal returned to the register causes the register to release the switching train, and the calling subscriber receives busy tone from his line relay.

When the line is free, the SL marker causes the operation of the correct horizontal and vertical magnets in each of the SL partial stages. The subscribers line is connected to a relay set which supplies ringing current. (Ring is supplied from the SR for a local call and from the FIR for an incoming call). The code receiver then releases, followed by the SL marker.

7. MISCELLANEOUS SUBSCRIBER FACILITIES.

7.1 Line lock-out. A calling subscriber in a crossbar exchange receives busy tone from the line relay circuit. During conversation both LR and BR relays are held in series from a potential on the C wire. If this potential is suddenly removed, both relays begin to release. The LR relay releases first and its contacts place the BR relay across the line to be held by the calling subscriber's loop. With only the BR relay operated the calling subscriber receives busy tone. This line lock-out operation may be caused by the following conditions :-

(i) After the subscriber receives dial tone, all dialling and register functions must be completed within 45 seconds. If dialling is not completed within this period, the register causes the release of the switching train and the subscriber receives busy tone from the line relay circuit.

(ii) When congestion occurs in any switching stage, a signal to the register from the marker at that stage causes a similar lock-out condition.

(iii) When the called subscriber tests busy, a signal from the SL marker to the register causes the lock-out condition to be applied.

(iv) When the called subscriber is free, but does not answer within 90 seconds, the call is released and the caller receives busy tone. This time limitation is removed on calls to step-by-step exchanges.

(v) When the called subscriber only replaces his receiver after a call (90 seconds delay).

7.2 Class of service. Facilities to provide up to fifteen classifications of subscriber have been arranged in the circuitry of the SL marker and associated relay sets. The originating registers are fitted with facilities to receive and recognise some of the signals indicating these classifications. Some of the proposed classifications are :-

(i) Normal line - unrestricted.

(ii) Unit-fee calls only.

(iii) Access barred to trunk codes (02-09 etc.) but access to unit-fee calls and trunk operator allowed.

(iv) Unrestricted but calls to 011 and 015 should be translated to 01N (S.T.D. Public Telephone).

(v) Access barred to trunk codes (02-09 etc.) but access to unit-fee calls and trunk operator allowed. Calls to 011 and 015 should be translated to 01N.

(vi) Special class marking for association with rectifier in the telephone loop so that the subscriber can choose with key control unrestricted service or restriction as in (v).

(vii) Special class marking for association with rectifier in the telephone loop so that the subscriber can choose with key control unrestricted service or service as in (v). (Multi-coin public telephones, leased services).

(viii) Line test - cancel release supervisory to give "A" party holding.

(ix) A rectifier in loop without associated marking to allow unit-fee calls only. When the rectifier is removed under key control the service is unrestricted.

(x) Full barring of all outward traffic. Used on such occasions as the subscriber failing to pay account.

7.3 Interception. Interception is provided in isolated ARF exchanges of up to 2000 lines by installing a local jack field and marking the number to be intercepted with a special marking plug. Incoming calls are routed to an operator who will answer the call and provide the assistance required. With this decentralised type of interception only one class of interception can be provided and the manual operator must establish the type of interception by enquiry.

For isolated ARF exchanges with more than 2000 numbers, or ARF networks of more than 2000 numbers, full centralised interception facilities are provided. A jack field is installed at the manual assistance centre and circuits are provided to this centre on the basis of one pair for each 1000 lines. Marking of the called number is performed on the jack field at the assistance centre, appropriate plugs being used to indicate the type of interception required.

Some of the types of interception proposed for ARF exchanges are :-

(i) Filtered Interception. This is used in cases of duplicated listing in the telephone directory so that callers can be challenged and switched through if calling the correct "B" party.

(ii) Changed Number. When a subscriber's number is changed for the convenience of the A.P.O. (re-allotting exchange boundaries), calls to the old number are re-directed until a new directory is issued.

(iii) Ceased and Unallotted Numbers. These include -

(a) spare 1000 groups;

(b) unequipped portions of 1000 groups;

(c) disconnected and unallotted numbers in fully equipped portions of the exchange.

Calls to (a) are analysed in the GVM equipment and re-routed to a recorded announcement. Calls to (b) are analysed in the SLM equipment and also re-routed to a recorded announcement.

Spare numbers (c) are marked with a plug in the interception jack field so that calls are re-routed to a recorded announcement.

(iv) Barred codes or Incorrect use of National codes. Some recognition of barred codes is performed by the local register and in other cases the analysis is performed by the trunk register. Calls by restricted subscribers to barred numbers, or incorrect use of the national code causes the caller to be routed to a recorded announcement at the centralised interception centre and extended through to an operator if the call is held.

(v) Malicious calls. Provision is made for malicious caller identification by strappings at the P.B.X. equipment and the associated SL marker. An incoming call to such a number causes a signal to be returned to the register, which converts the SR relay set to last party release. For the call to be traced, the "B" party's receiver must be left off and the complaints operator advised from another phone.

The use of interception equipment to intercept and hold such calls is under investigation.

8. GLOSSARY OF TERMS.

8.1 Many abbreviations used in crossbar working are contractions of Swedish words. The following list of Swedish words and standard abbreviations, together with their English equivalents, is given as an aid to better understanding of crossbar trunking and circuitry.

Swedish	English Equivalent
FIR	Incoming junction relay set.
FUR	Outgoing junction relay set.
Grupperingsplan	Grouping Plan.
Gruppvaljare GV	Group Selector.
I GV	First Group Selector Stage.
II GV	Second Group Selector Stage.
GVA, GVB	Partial group selector stages.
GVM	Group selector marker.
Inkommande	Incoming.
Jacklada	Jackbox (as in the centre of each rack).
Kopplingsplint	Terminal block.
Kopplingsfalt	Terminal field.
Kodmottagare KM	Code receiver.
LKR	Final selector relay set.
LR/BR	Line relays.
Mellankoppling	Interconnection.
MK	I.D.F.
KK	M.D.F.
RS	Register finder stage.
RSV	Register finder selector.
RSM	Register finder marker,
REG	Register.
Siffer-magasin SM	Store for digits or number store.
SL	Combined line finder final selector stage.
SLA, SLB	Partial line finder stages. Both used on every outgoing call.
SLA, SLB, SLC, SLD	Partial stages. All used as a final selector stage on every incoming call.
SR	Line finder relay set, sometimes referred to as a Cord circuit.

8. TEST QUESTIONS.

1. (a) List the partial stages in one SL stage associated with 1000 lines.

   (b) Which partial stages are used - (i) to switch an outgoing call; (ii) to connect an incoming call to a subscriber.

2. State the functions of the SL stage for - (i) outgoing traffic; (ii) incoming traffic.
3. Explain the meaning of the term "m = 8".
4. What limitations are placed on the simultaneous operation of two SL markers associated with the same 1000 line group.
5. What method is used to decide which of two SL markers will be used for a call.
6. State which 200 line groups are connected on each SLA rack.
7. List the points in a crossbar exchange at which a subscriber's line appears.
8. Show with a sketch the distribution of line relay sets on the rear of an SLA rack.
9. Sketch the arrangement of lines on a line terminal block associated with a line relay set.
10. Explain how a subscriber's line is located on an SLA switch - (i) above the jack box; (ii) below the jack box.
11. What is the function of a call indicator on an SLA rack.
12. Explain what happens when two calls originate simultaneously within the 1000 line group.
13. Describe briefly the two stage identification of a calling subscriber's line.
14. What is meant by the term "number storage" when associated with a calling subscriber's line.
15. How are idle SLA verticals indicated.
16. Upon what conditions does the selection of an SLA vertical depend.
17. Why does the selection of an SLA vertical automatically determine the SLB switch to be used.
18. List the functions of the register finder stage.
19. Sketch the trunking of the register finder stage.
20. Sketch the arrangement of apparatus on a typical SR/RS rack.
21. With how many SR relay sets is each RSM associated.
22. Describe briefly the identification of a calling circuit by the RSM.
23. How many registers are associated with each RS stage.
24. Each RS vertical has access to .... SR circuits and .... registers.
25. After switching has taken place in the RS stage, the register finder vertical magnet holds from a circuit provided by ....
26. A GV marker controls .... units, each containing .... inlets and .... outlets.
27. Sketch the arrangement of switches on a GVA/B rack.
28. List the functions of each section of the GV marker.
29. Show in block form the connections between the GV racks and marker equipment.
30. When is a relay set WTR used.
31. Describe the identification of a calling circuit by the GV identifier equipment.
32. Describe briefly how code is received and stored in a GV code receiver.
33. How many GV outlets may be tested simultaneously.
34. Sketch the trunking diagram of the incoming traffic section of an SL stage.
35. A crossbar subscriber can have a maximum of .... lines in one P.B.X. group.
36. When a number in a P.B.X. group other than the directory number is called, the call is switched to ....
37. Sketch a block diagram showing the interconnection of equipment used on incoming traffic.
38. Describe the progress of a call through the control equipment associated with incoming traffic.

END OF PAPER.

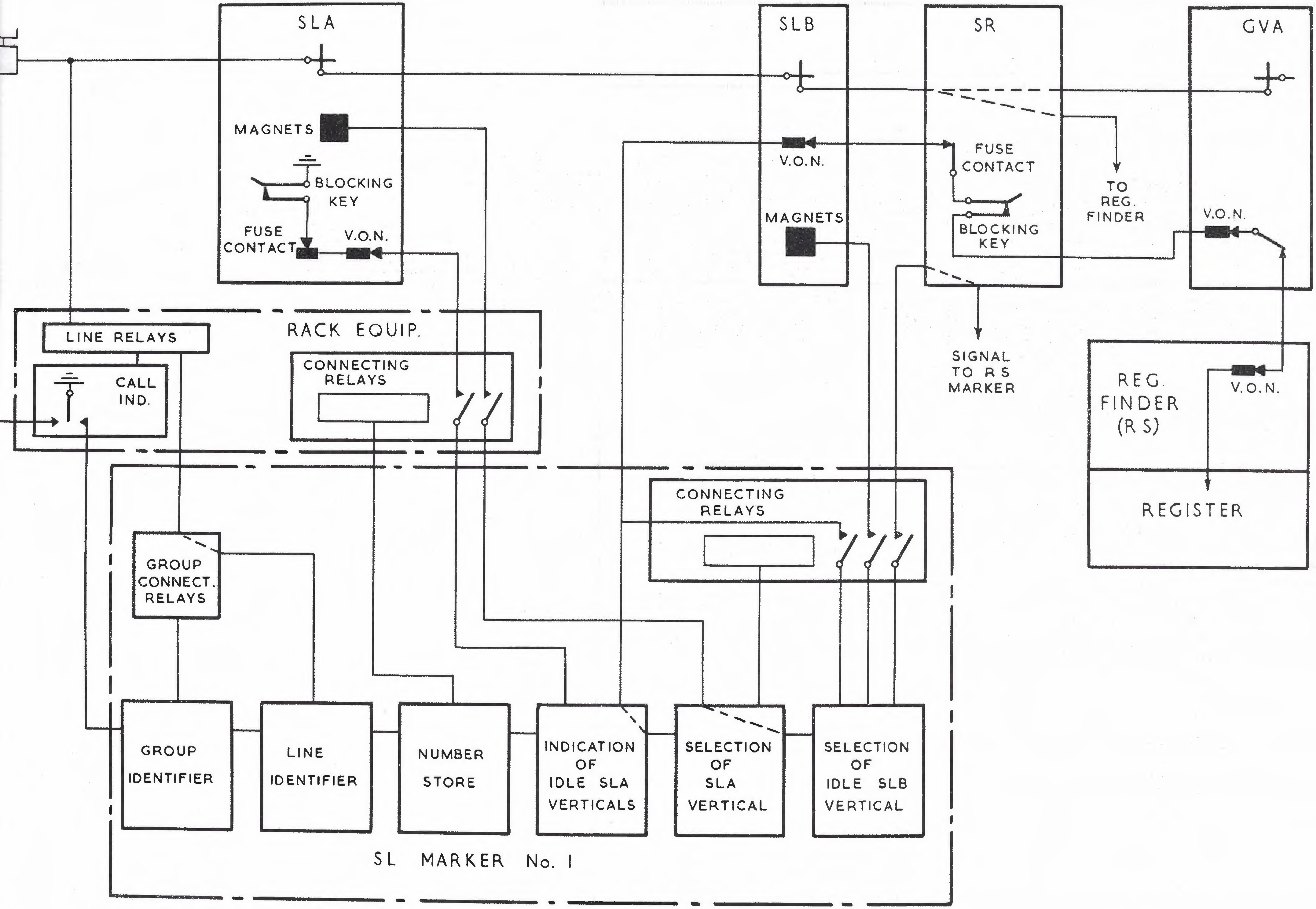


FIG. 33. SUBSCRIBERS STAGE. OUTGOING TRAFFIC.

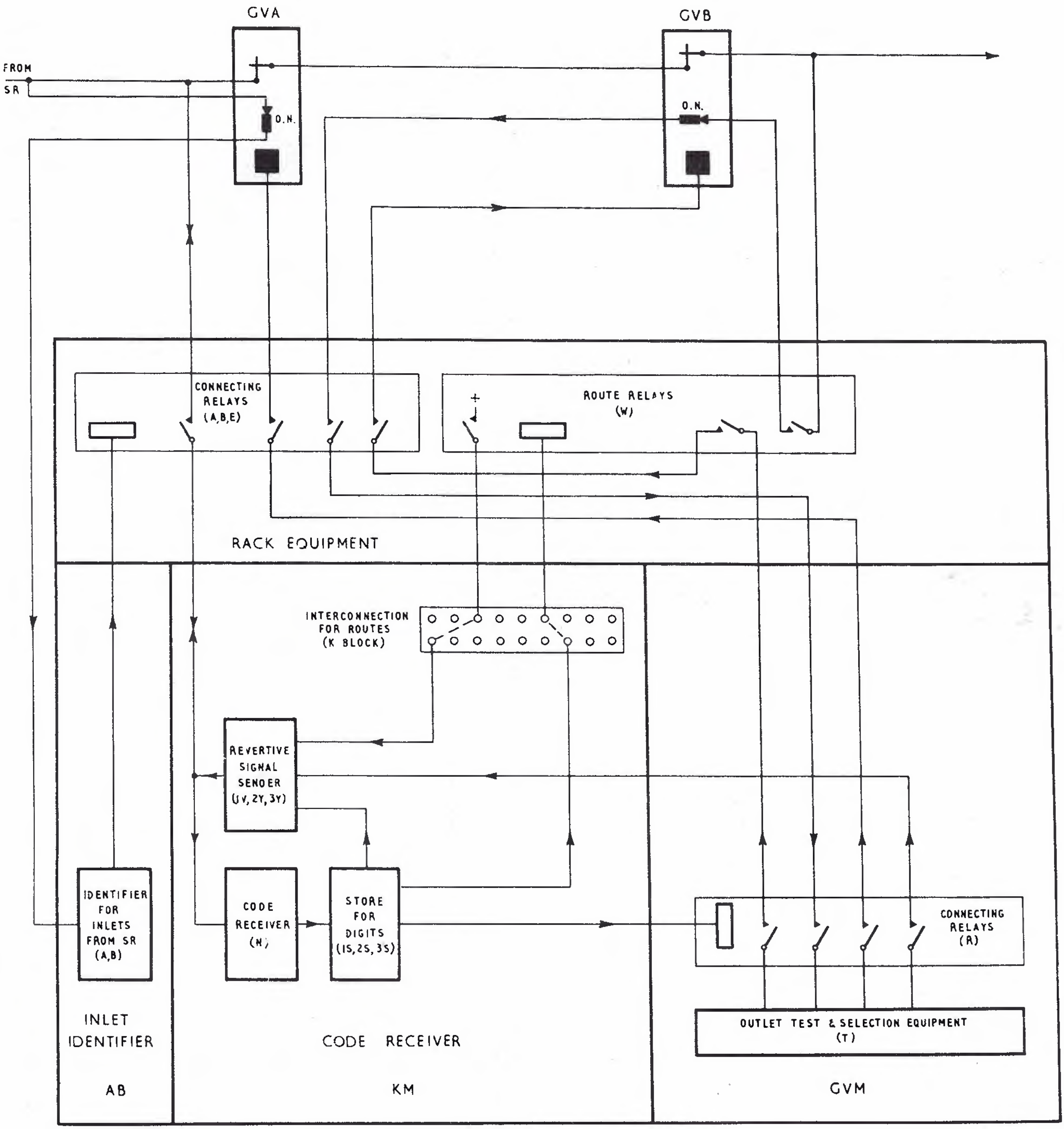


FIG. 34. GROUP SELECTOR STAGE.
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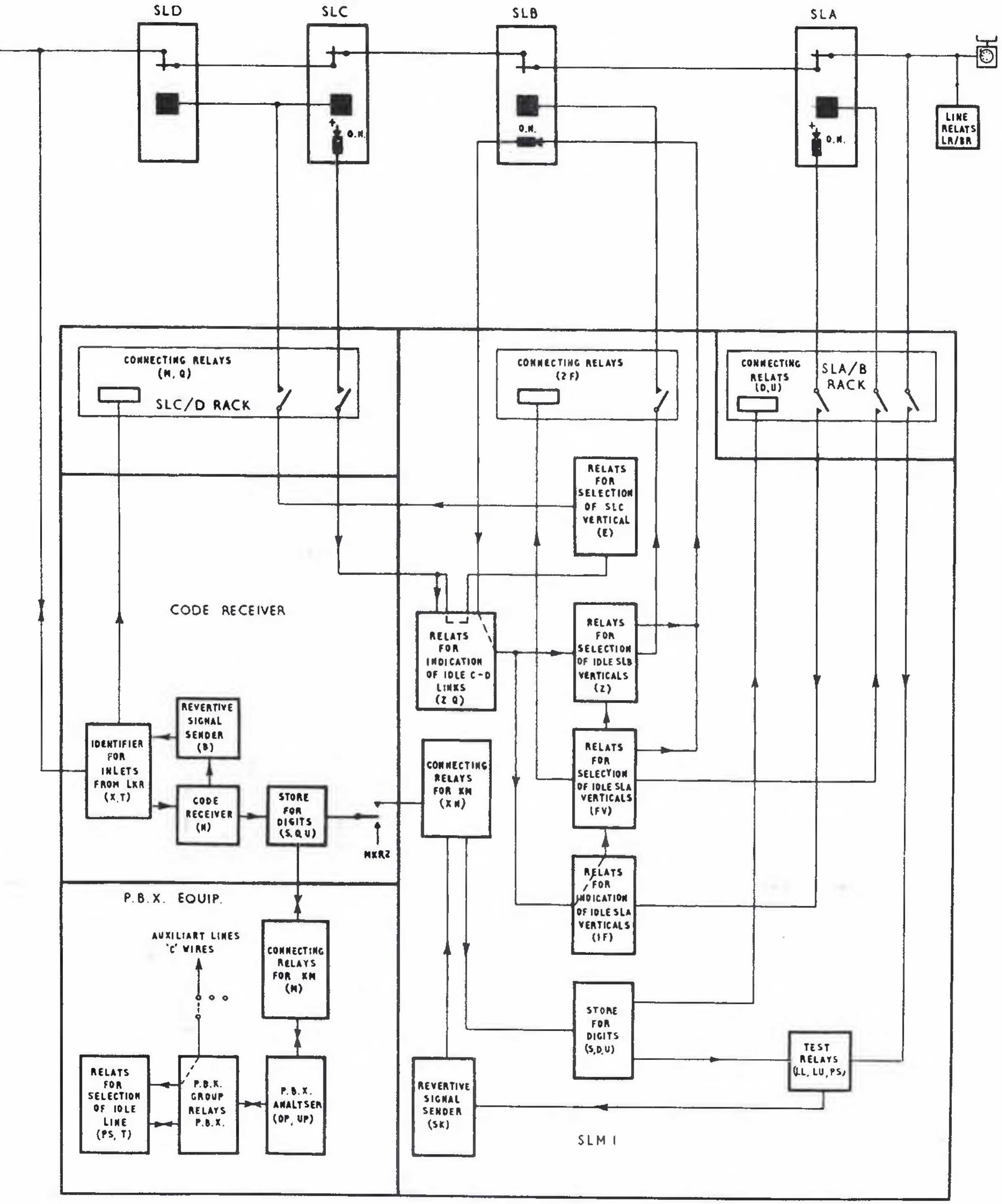


FIG. 35. SUBSCRIBERS STAGE. INCOMING TRAFFIC.

GROUPING PLANS FOR ARF EXCHANGES

1. INTRODUCTION.

1.1 The subject of grouping plans was introduced in the paper "Crossbar Trunking" and before any further study of grouping plans is made, this paper should be thoroughly revised, particularly in regard to the following points:-

(i) the vertical and outlet symbol;

(ii) the method of commoning outlets when two or more verticals have access to the same outlets;

(iii) the method of representing a number of verticals mounted on the same switch;

(iv) the method of multipling when verticals from different switches have access to the same outlets;

(v) the change in direction and the elimination of the outlet symbol when two partial stages are connected in tandem.

1.2 Each grouping plan represents the trunking between partial stages of a switching stage. A separate grouping plan is necessary for each switching stage.

1.3 This paper describes the grouping plans for each stage and the procedure to be followed when tracing calls in either direction through each switching stage.

1.4 Typical charts have been included, but these charts are only intended to illustrate a principle, as their form and layout may be changed as a result of further practical experience in their use.

2. SL STAGE - SLA/B SECTION OF GROUPING PLAN.

2.1 We saw in paragraph 2.3 of "Crossbar Switching Stages" in Crossbar Switching 1 that for outgoing traffic, partial stages SLA and SLB are used to connect the calling subscriber to a free SR relay set. Table 1 in the same paper showed how the "m" number decides the number of switches provided in each partial stage.

The "m" number also corresponds to the number of SLA switches over which each subscriber's line is multipled. For this reason, there is a slight variation in the grouping plan for different "m" values.

2.2 Fig. 1 shows the outgoing traffic section of a typical SL grouping plan when m = 8.

The outlets from each SLA switch are wired to the 200 lines connected to that rack, while the inlets to each SLA vertical are cabled from the outlets of an SLB vertical.

Each outgoing SLB vertical is connected to an SR relay set. As there are twenty SLB switches, each with five outgoing verticals, there is a maximum of 100 SR relay sets provided for 1000 lines.

In this size trunking pattern there are 8 SLA switches that have access to any particular subscriber. These are the 8 switches mounted on the same rack on which the subscriber's line terminates.

2.3 The SLA vertical and horizontal used on an outgoing call will depend on two factors:-

(i) the subscriber's number;

(ii) whether the SLA switch used is in the upper or lower half of the rack.

When the switch containing the chosen vertical is an odd numbered switch (in the upper half of the rack) the vertical corresponds to the subscriber's "tens" figure, and the horizontal corresponds to the "units" figure.

When the switch is an even numbered switch, or one in the lower half of the rack, the vertical is decided by the units figure and the horizontal by the tens figure. (Table 2 in Crossbar Switching Stages.)

2.4 Once the SL marker selects a free SLA vertical, there is only one SLB switch with verticals pointing towards the selected SLA vertical. One of the 5 outgoing verticals on this SLB switch is chosen to complete the switching to a free SR.

The number beside the chosen SLA vertical indicates the SLB outlet which is cabled to that vertical.

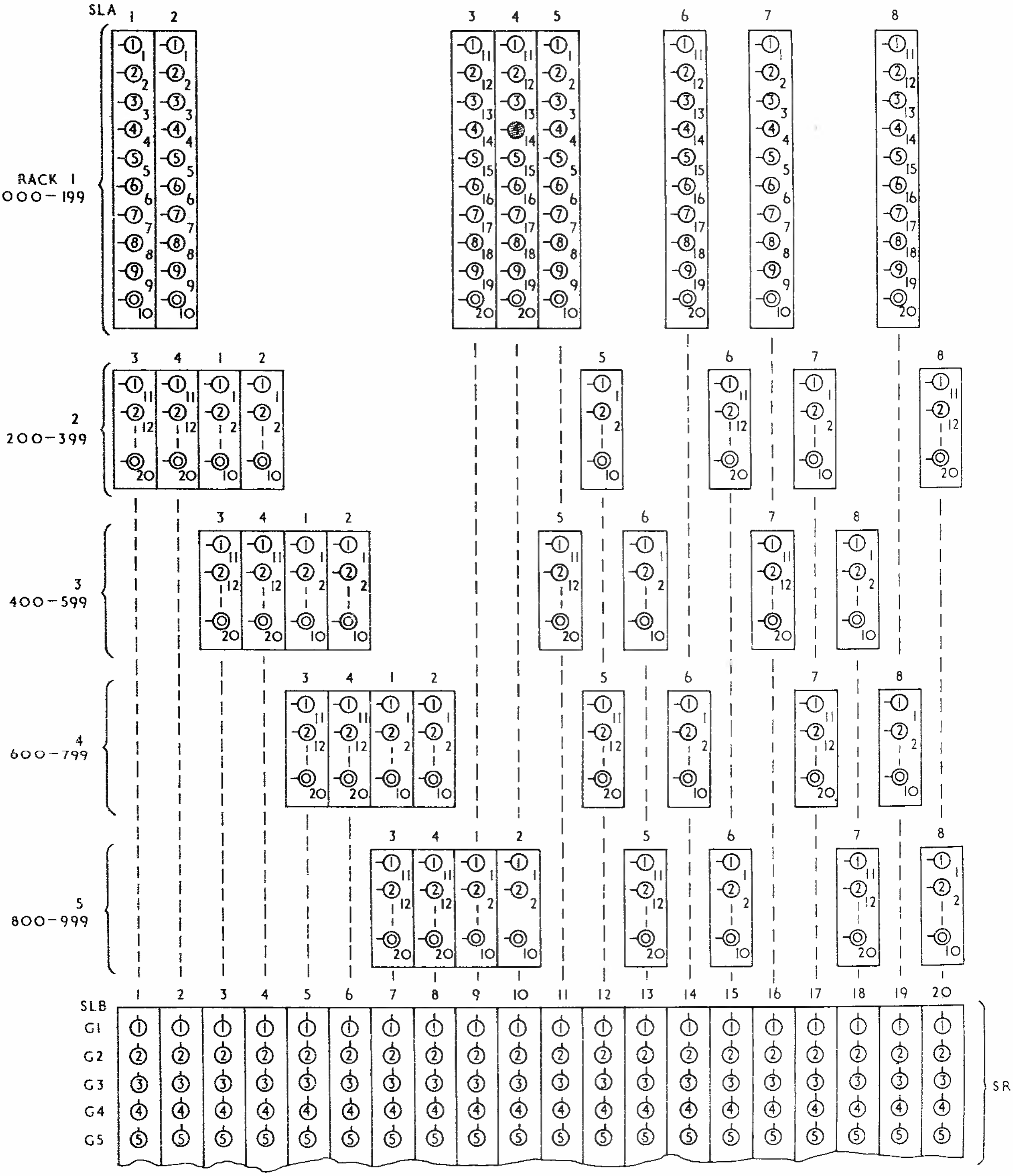
2.5 Call tracing. The procedure adopted when tracing a call through a stage will vary according to the information received. A subscriber may report no progress on an outward call. In this case, the subscriber's number is known and the procedure is as follows:-

(i) Locate the correct SLA rack. Assuming the calling number ended in 064, this number would be on the first SLA rack of that 1000 group.

(ii) Check the odd numbered switches for an operated 4th horizontal springset on a 6th vertical and the even numbered switches for an operated 6th horizontal springset on a 4th vertical.

(iii) When an operated vertical is found, verify that the HA springset is operated. (HA for lower or even 100, HB for upper or odd 100.)

It has been assumed that for this call the SLA vertical is vertical 4 on switch 4 on rack 1, as indicated by the shaded vertical on Fig. 1.



OUTGOING SECTION OF SL GROUPING PLAN.

FIG. 1.

(iv) Refer to grouping plan. The only switch with access to the selected SLA vertical is SLB10. The figure 14 beside the SLA vertical indicates that this vertical is trunked from the 14th outlet of a vertical on SLB10.

(v) Proceed to SLB10. Look for a vertical switched to the 14th outlet. In this case vertical 3 has been assumed. (Verticals 1-5 on all SLB switches are used for outgoing traffic.) Reference to a chart similar to Fig. 2 will indicate the SR relay set and GVA vertical associated with the selected SLB vertical.

SLB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
V1	SR. 1	41	6 6·15 1·1	46 7·16 1·1	11 6·16 1·1	51 7·17 1·1	16 6·17 1·1	56 7·18 1·1	21	61	26 6·19 1·1	66 8·16 1·1	31 7·13 1·1	71 8·17 1·1	36 7·14 1·1	76	81 6·16 4·1	86	91 7·17 4·1	96
V2	2	42	7	47	12 6·16 2·1	52 7·17 2·1	17 6·17 2·1	57 7·18 2·1	22	62	27	67	32 7·13 2·1	72 8·17 2·1	37 7·14 2·1	77 8·18 2·1	82 6·17 4·1	87 7·13 4·1	92 7·18 4·1	97 8·17 4·1
V3	3 6·14 1·1	43 7·15 1·1	8	48	13	53	18 6·17 3·1	58 7·18 3·1	23 6·18 1·1	63 8·15 1·1	28	68	33	73 8·17 3·1	38 7·14 3·1	78 8·18 3·1	83 6·18 4·1	88 7·14 4·1	93 8·15 4·1	98 8·18 4·1
V4	4 6·14 2·1	44 7·15 2·1	9 6·15 2·1	49 7·16 2·1	14	54	19	59	24 6·18 2·1	64 8·15 2·1	29 6·19 2·1	69 8·16 2·1	34	74 8·18 1·1	39	79 6·14 4·1	84 6·19 4·1	89 7·15 4·1	94 8·16 4·1	99 8·15 4·7
V5	5 6·14 3·1	45 7·15 3·1	10 6·15 3·1	50 7·16 3·1	15 6·16 3·1	55 7·17 3·1	20	60	25 6·18 3·1	65 8·15 3·1	30 6·19 3·1	70 8·16 3·1	35 7·13 3·1	75	40	80 6·15 4·1	85	90 7·16 4·1	95	100 8·16 4·7

6·14 SUITE 6 RACK 14
INDICATES GVA
3·1 SELECTOR 3 VERTICAL 1
(M = 8A)

FIG. 2. CONNECTING CHART SLB VERTICALS TO SR/GVA.

2.6 When the calling number is not known, and the call is being traced backwards from the GV stage, reference to a chart will indicate the SR relay set and SLB vertical associated with the GVA inlet. The procedure for tracing the call to the originating subscriber is as follows:-

(i) Proceed to the SLB switch and vertical indicated. Examine the switch and note the springsets operated on the particular vertical indicated on the chart.

(ii) Refer to the SL grouping plan. The verticals on the SLB switch have access to an SLA switch on two different racks. Assuming the same call traced forward previously, the chart indicates vertical 3 on SLB10. This vertical has access to switch 4 on rack 1 and switch 2 on rack 5. When the vertical is examined it will be noted that springsets HB and H4 are operated, indicating that the vertical is connected to outlet number 14.

Examination of the outlet numbers beside the verticals on the two SLA switches shows that outlet 14 is wired to vertical 4 in switch 4 on rack 1.

(iii) Proceed to rack 1 and examine the SLA vertical. Assuming the same call, springsets HA and H6 are operated.

As the SLA switch is an even numbered switch on the lower half of the rack, the combination of V4 and H6 indicates a subscriber's number ending in "64" (para. 2.3). Operation of HA springset indicates that the calling subscriber comes from the lower or even numbered hundred group.

As the 0/1 hundred groups are both connected to rack 1, the calling number is 064.

3. RS STAGE GROUPING PLAN.

3.1 When a call is originated, connection to an SLB vertical and its associated SR relay set is not made until the SLM determines, via by-path connections, that the SLB and SR have access to an idle register. The final selection of the SLB vertical and SR causes the SLM to act in conjunction with RSM, completing a connection from the calling subscriber through SLA, SLB, SR and RS to a free register. Fig. 3 shows a grouping plan of the RS switching stage.

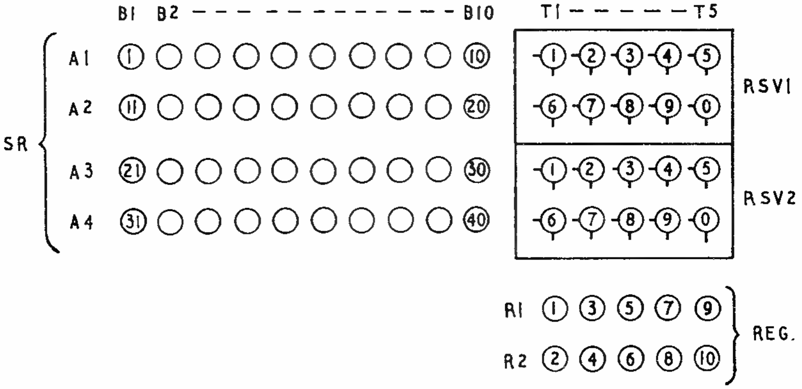
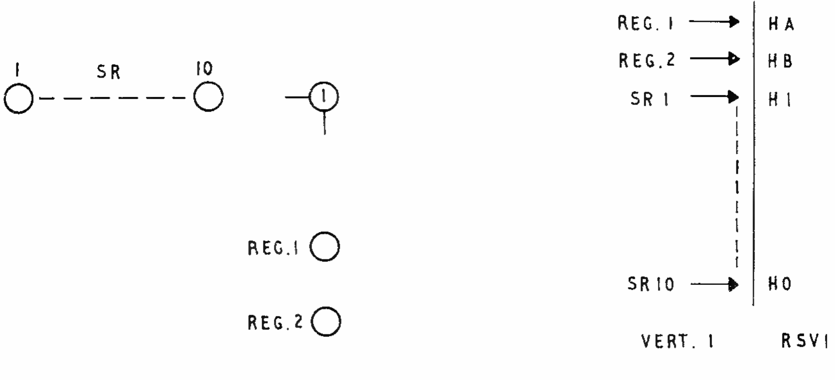


FIG. 3. SR/RS GROUPING PLAN.

3.2 Two crossbar switches, RSV1 and RSV2 are associated with 40 SR relay sets and 10 registers. A new chicken symbol with two "beaks" is introduced (Fig. 4). One of the beaks points in the direction of 10 SR relay sets which are connected to the normal horizontal springsets H1-HO, and the other beak points toward two registers which are connected to the HA and HB springsets. Fig. 4 shows the connections to the first vertical on RSV1.



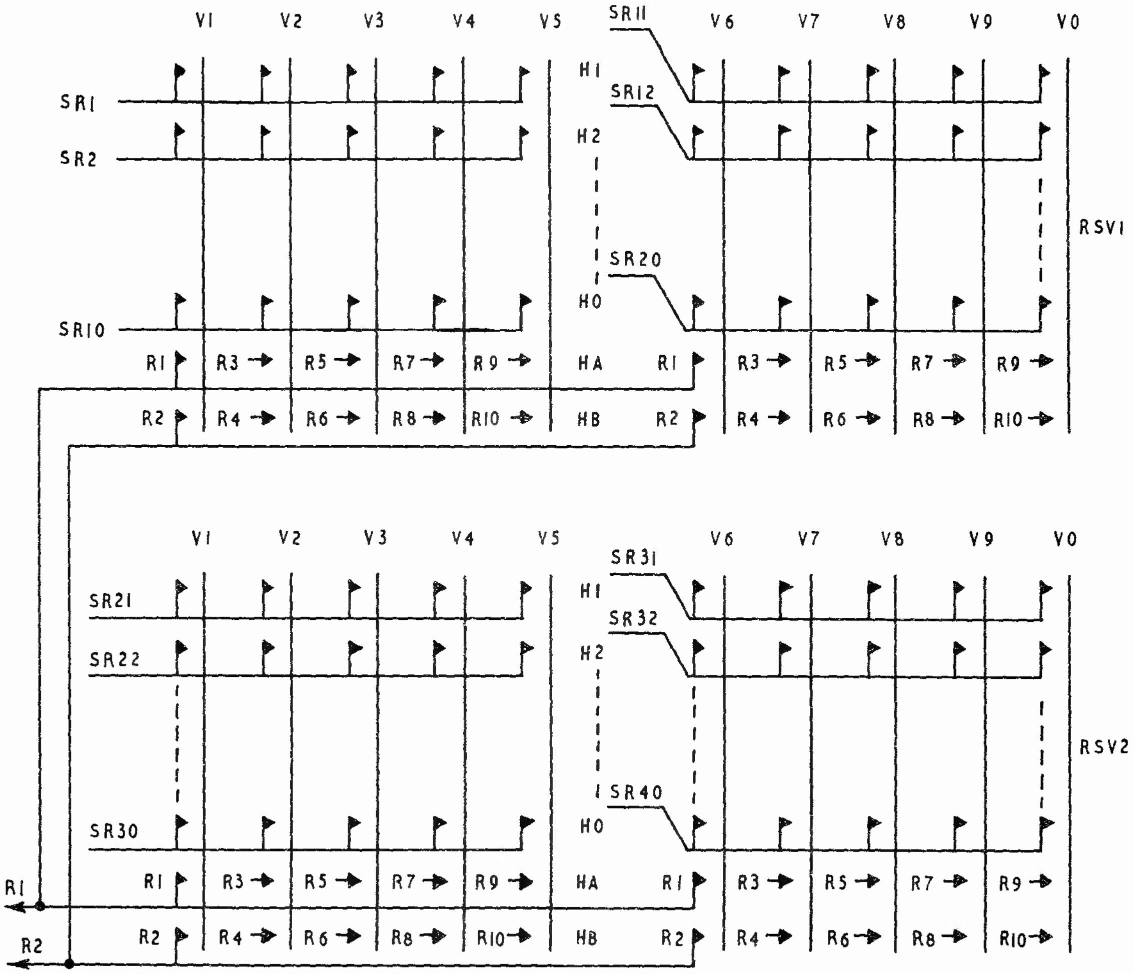
(a) (b)

FIG. 4. CONNECTIONS ON A REGISTER FINDER VERTICAL.

3.3 As SR relay sets 1-10 are available to RSV1 verticals 1-5, the normal horizontal springsets on these verticals are multipled. Similarly, wires from each other group of 10 relay sets are multipled over the horizontal springsets of five other verticals (Fig. 3).

3.4 Each group of two registers is available from four verticals. For example, Registers 1 and 2 in Fig. 3 may be reached from verticals 1 and 6 in RSV1 and verticals 1 and 6 in RSV2. This is done by multipling the HA and HB springsets of these four verticals. The wires from each other pair of registers are multipled over the HA and HB springsets of four other verticals.

This method of commoning allows any of the associated 40 SR circuits to be switched to any of the ten registers.



COMMONING ON REGISTER FINDER VERTICALS (RS/SR).

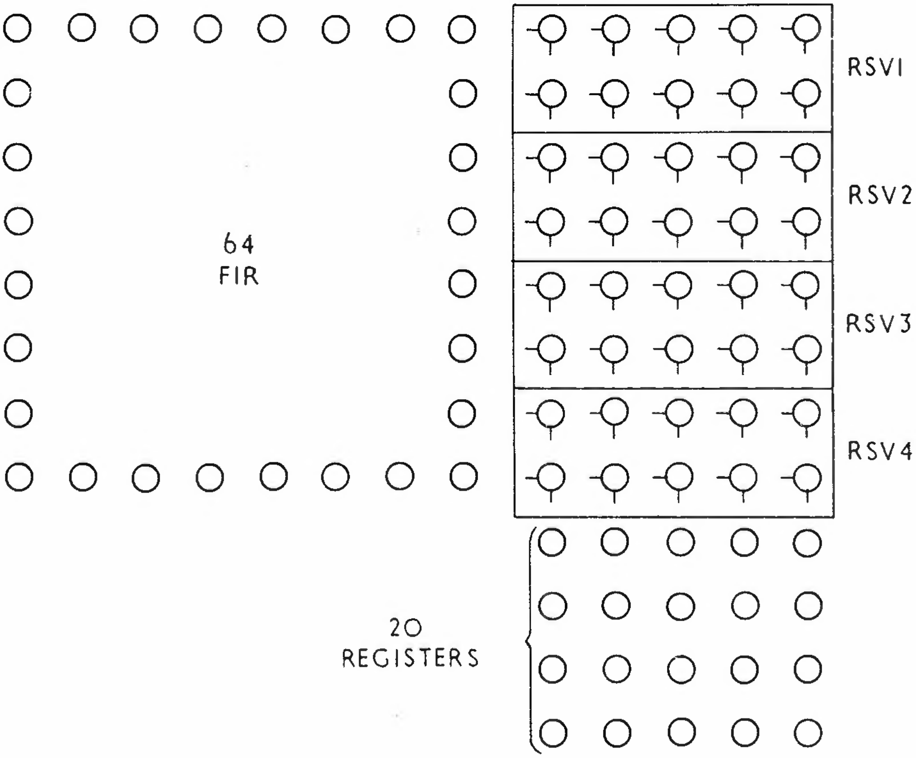
FIG. 5.

3.5 RS Stage - Incoming Junctions. Incoming junctions from step-by-step exchanges require a register to convert the pulses received at 10 impulses per second to high speed pulses suitable for signalling markers. As connection to a register must be completed within the time between two digits, a larger proportion of registers to incoming junctions is necessary compared to the provision for SR relay sets.

Each group of 64 FIR relay sets is associated with 4 register finder switches and 20 registers.

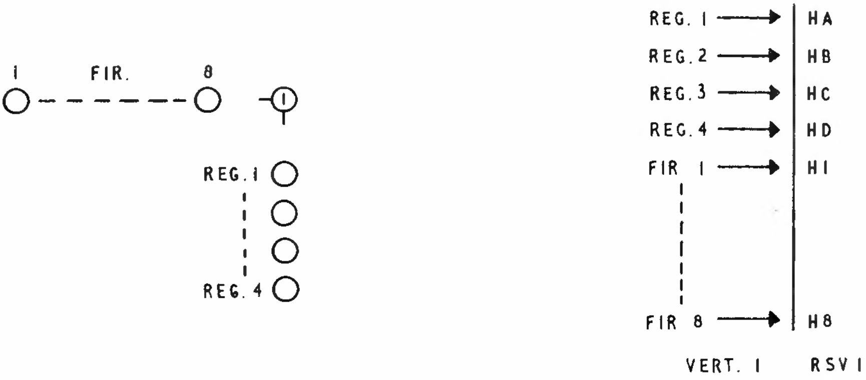
3.6 Each vertical on a crossbar switch can be fitted with a maximum of twelve separate spring piles. On a GV or SL switch these represent the ten horizontal springsets H1-HO and the HA and HB springsets.

The register finder switch associated with incoming circuits uses eight springsets on each vertical to connect to FIR relay sets. The other four springsets are called HA, HB, HC and HD and are used to switch to one of four registers.



(a)

3.7 Fig. 6a shows the grouping plan for an RS stage associated with incoming junctions and Figs. 6b and c show the connections on one vertical.



(b) (c)

FIG. 6. CONNECTIONS BETWEEN FIR AND RS.

As each group of four registers can be reached from eight verticals (Fig. 6), the HA, HB, HC and HD springsets are multipled over these verticals.

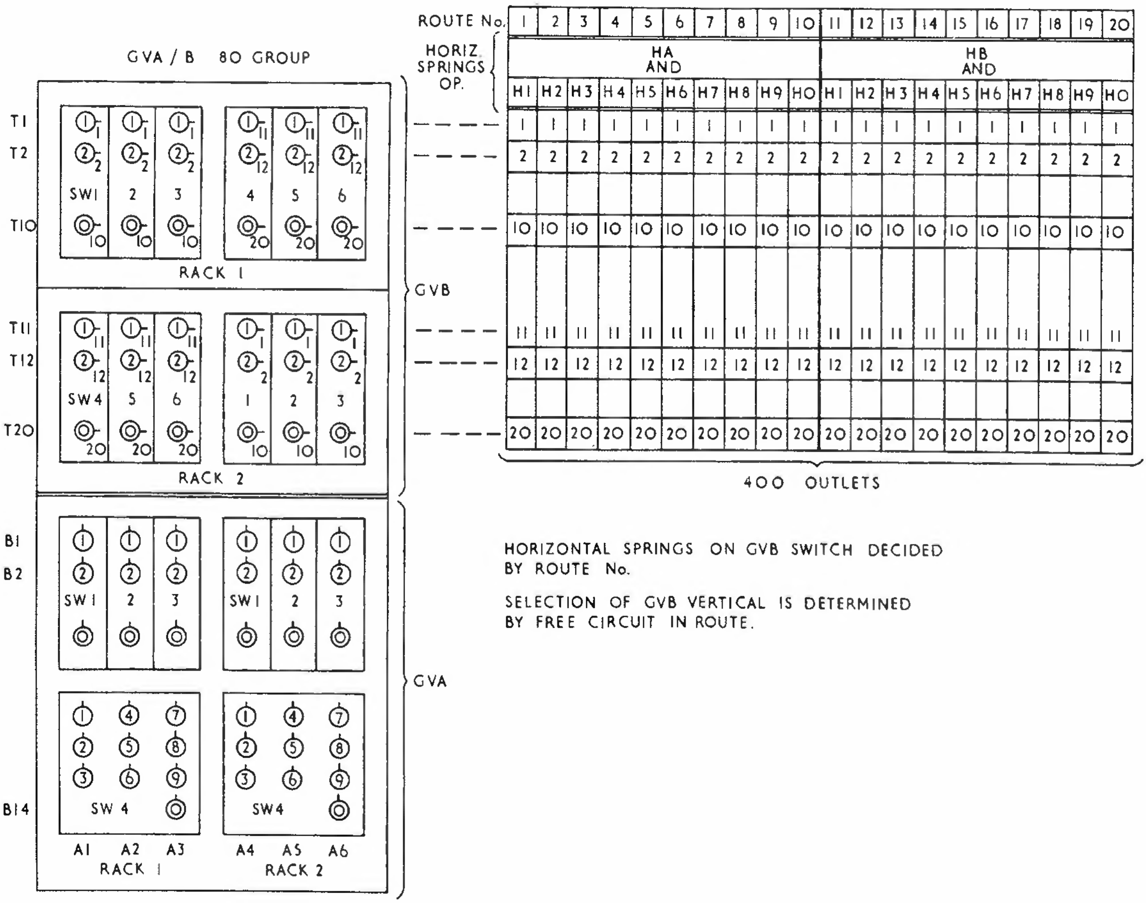
Each group of eight FIR relay sets is multipled over the horizontal springs H1-H8 on the five verticals to which they have access.

4. GV STAGE GROUPING PLAN.

4.1 Each group selector stage consists of two partial stages GVA and GVB, connected with one another according to the link principle.

It is built up of units, each unit consisting of two identical selector racks. Four GVA and six GVB switches are provided on each rack. As each switch is provided with ten verticals, there is a total of 80 verticals in the GVA stage, allowing 80 incoming circuits to be connected to each unit or pair of racks in the GV switching stage.

Fig. 7a shows a typical GV grouping plan, and Fig. 7b is a table showing the springsets operated when connecting a call through the GVB stage to a selected trunk. This table is not part of the grouping plan and is not provided in a crossbar exchange.



ROUTE No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
HORIZ SPRINGS OP.	HA AND										HB AND									
	H1	H2	H3	H4	H5	H6	H7	H8	H9	HO	H1	H2	H3	H4	H5	H6	H7	H8	H9	HO
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20

HORIZONTAL SPRINGS ON GVB SWITCH DECIDED BY ROUTE No.

SELECTION OF GVB VERTICAL IS DETERMINED BY FREE CIRCUIT IN ROUTE.

(a) (b)

FIG. 7. GV GROUPING PLAN.

4.2 Each GVA vertical has access to 20 GVB verticals. This is indicated by the numbers beside the GVB verticals extending from 1 to 20. The GVA switch No. 4 in each rack has springsets on verticals 1, 2 and 3 multipled to springsets on all ten verticals on switch 1. Similarly, springsets on verticals 4, 5 and 6 are multipled to the ten verticals on switch 2, and springsets on verticals 7, 8, 9 and 0 are multipled to springsets on all verticals on switch 3.

4.3 The GVB switches on rack 1 are multipled in such a manner that the same numbered verticals on each switch have access to the same trunks. To make this possible, the horizontal springs on vertical 1 on each switch are multipled. Verticals 2 to 10 on each switch are multipled in a similar manner. The GVB switches on rack 2 are multipled in a similar manner to those on rack 1.

4.4 The route to be taken is determined by the GVM after examining digits requested from the register, which has received them from the subscriber's dial. The GVM tests the circuits in the required route and also tests to ensure that there is a switching path available from the called inlet to the selected circuit. The marker then operates the appropriate magnets to complete the connection.

4.5 When switching takes place, the number of the selected route determines the horizontal sprintset to be operated, and the circuit or trunk number decides the number of the GVB vertical. The GVB switch to be used is decided by the position of the calling inlet.

As an example, assume that a calling circuit is connected to vertical 3 in GVA switch 4 on rack 1. It is desired to switch this call to circuit 1 in route 2. The only verticals with access to this circuit are the No. 1 verticals in each GVB switch on rack 1. Of these verticals, only the vertical in switch 1 has access to the calling inlet. Fig. 8 shows the connections from a section of the GV stage.

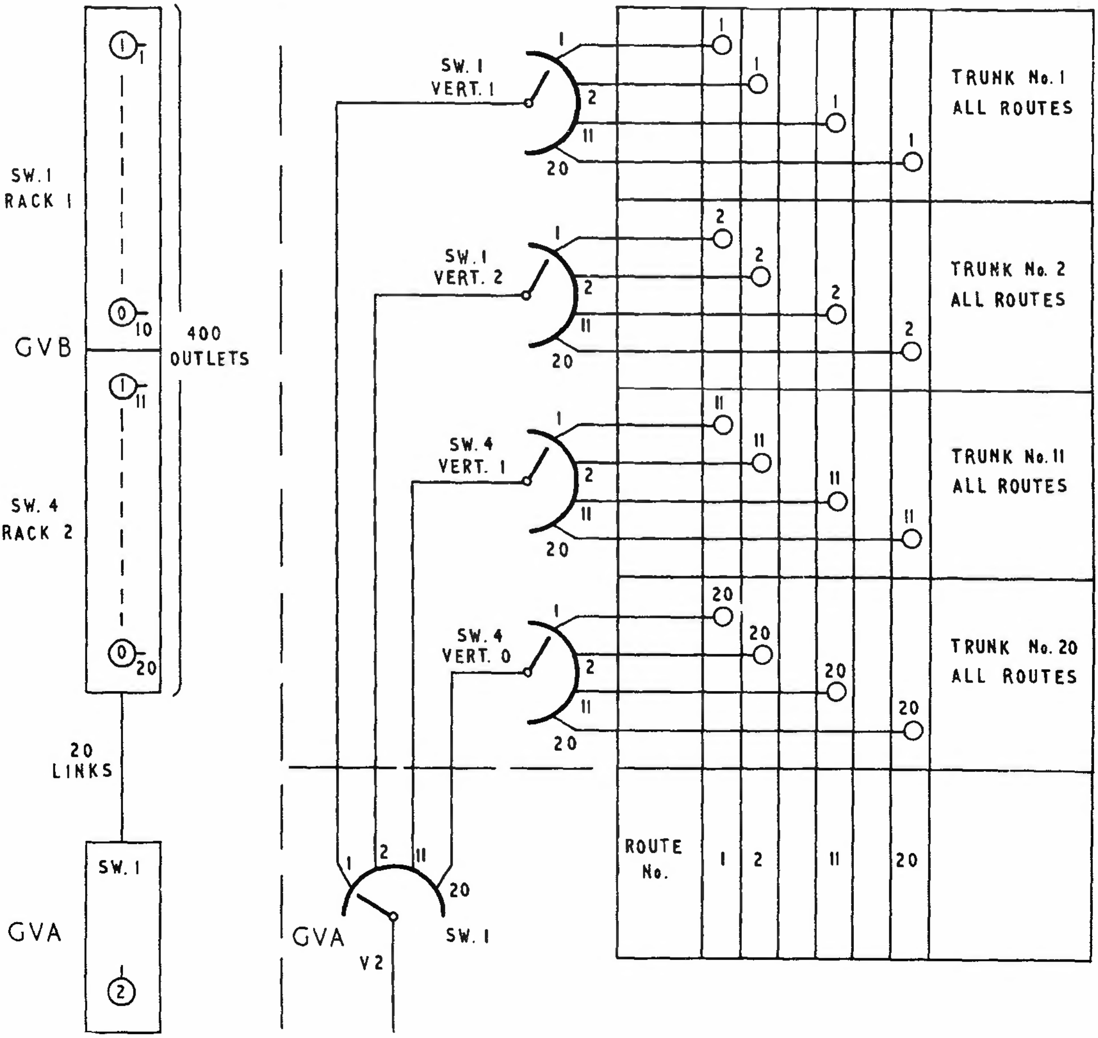


FIG. 8. SECTION OF GV STAGE TRUNKING.

4.6 Call tracing through GV stages. The following description uses the terms "routes" and "outlets" referring to the basic structure of these stages. Routes may be sub-divided or combined to meet the requirements of a particular exchange. For example, in Fig. 9, route 5 appears as a single route of 66 trunks with an availability of 20. However, the same route 5 could be sub-divided into four separate junction routes having availabilities of 5 or combined with others to give availabilities such as 30 or 40. In such cases the procedure is the same, but more information must be obtained from the final chart. When an outgoing call has been traced through the SL stage, reference to a chart (Fig. 2) indicated the GVA vertical associated with the outgoing SLB vertical. The procedure for continuing the tracing of this call is as follows:-

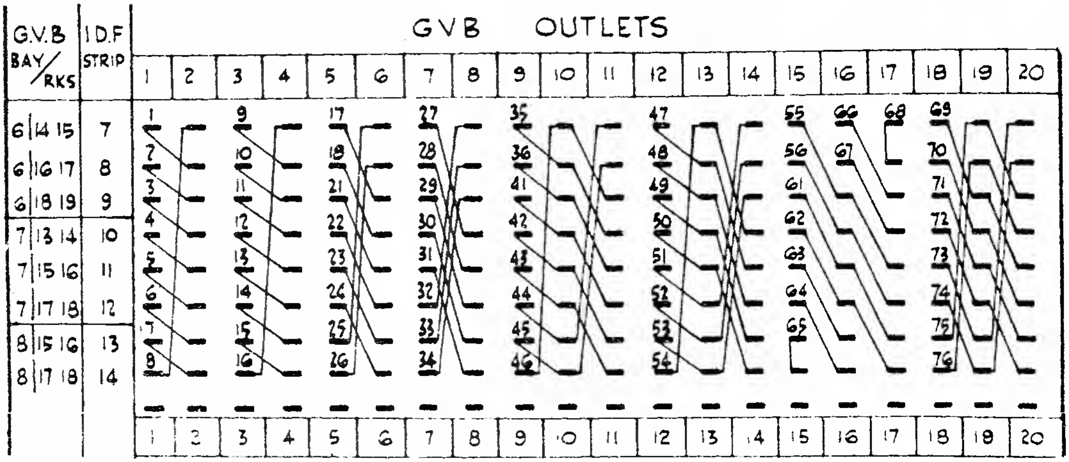
(i) Examine the GVA vertical indicated on the chart and note the springsets operated. In this case, assuming that the call is the same call previously traced through the SL stage, the GVA inlet is vertical 1 on switch 1 on the 15th rack in suite 8.

(ii) Examine the GV grouping plan. As the GV stage is formed from two rack units, the 15th rack will probably be rack 1 of a unit.

Assuming that the GVA vertical is switched to outlet 11, (H1 and HB operated) this outlet is connected to GVB switch 4, vertical 1 on rack 2. This is found by following the direction of the beak on the calling GVA inlet and searching for a GVB vertical with "11" beside the vertical symbol.

(iii) Examine the GVB vertical and note the springsets operated. The outlet number will correspond to the number of the selected route and the vertical number will correspond to the selected circuit in that route. (Fig. 7b.)

(iv) Refer to a chart similar to Fig. 9. This will show whether the selected route is trunked to a local LKR relay set or whether it is trunked via an FUR relay set to an outgoing junction. In ARF 102 exchanges LKR's are not used and the route is trunked direct to SLD verticals.



G.V.B BAY/RKS		I.D.F STRIP
6	14 15	7
6	16 17	8
6	18 19	9
7	13 14	10
7	15 16	11
7	17 18	12
8	15 16	13
8	17 18	14

ROUTE 5. TOTAL TRUNKS 66
OUTLETS GRADED ON I.D.F BAY 4 RACK 17
JUMPER TO LKR^S FOR 25^{000}- 25^{999} ON I.D.F BAY 4 RACK 16
LKR^S 1-20 I.D.F STRIP 54
LKR^S 21-40 " " 55
LKR^S 41-60 " " 56
LKR^S 61-80 I.D.F. STRIP 57

GVB OUTLETS. ROUTE 5
TO LKR^S 25^{000} - 25^{999}

FIG. 9. GRADING DIAGRAM - GVB TRUNKS.

The numbers in the left hand column of Fig. 9 correspond to the Bay (or suite) and rack number of the GV switch. The call to be traced came from Bay 8 rack 16.

The numbers along the top of the figure refer to the number of the circuit in the route. Numbers 1-10 are available from verticals 1-10 on any GVB switch on rack 1 of a unit. Numbers 11-20 are available from verticals 1-10 on rack 2 of a unit.

Fig. 7 shows that vertical 1 in switch 4 on rack 2 has access only to circuit No. 11 on the selected route. If a cross-reference is made on Fig. 9 from No. 11 at the top of the figure and Bay 8 Rack 16 in the left column, the intersecting point indicates the chosen circuit.

4.7 Back tracing through GV stage. When the SLD vertical (local call) or FUR (call to another exchange) is known, the procedure for back tracing the call through the GV stage is as follows:-

(i) Refer to a chart similar to Fig. 9. This will show that the chosen circuit is available from a number of racks. Assuming the same call that was traced forward, this circuit is available from vertical 1 on rack 16 in bay 8, vertical 0 on rack 15 in bay 7, and vertical 9 on rack 13 in bay 7.

(ii) Examine the switches on these racks for one of the correctly numbered verticals switched to outlet 5 (HA and H5 operated). The route number corresponds to the GV springset number.

(iii) As the same call has been assumed, the required GVB vertical will be vertical 1 in switch 4, rack 16 Bay 8.

Examine the grouping plan. The figure beside this vertical indicates which GVA outlet is connected to the GVB vertical. In this case the figure 11 indicates that it is cabled from outlet 11 on all GVA verticals in switch 1 rack 1, and verticals 1, 2 and 3 in switch 4 on rack 1.

(iv) Examine these GVA verticals to find a vertical switched to outlet 11 (H1 and HB).

(v) When the correct GVA vertical has been identified, reference to a chart similar to Fig. 10 will indicate the calling SR relay set.

GVA1	GVA2	GVA3		GVA1	GVA2	GVA3
1 1/3	1 1/4	1 1/5	SR	1 1/6	1 1/9	1 1/10
2 2/3	2 2/4	2 2/5		2 2/6	2 2/9	2 2/10
3 3/3	3 3/4	3 3/5		3 3/6	3 3/9	3 3/10
4 4/3	4 4/4	4 4/5		4 4/6	4 4/9	4 4/10
5 5/1	5 5/2	5 5/3		5 5/4	5 5/7	5 5/8
6 6/1	6 6/2	6 6/3		6 6/4	6 6/7	6 6/8
7 7/1	7 7/2	7		7 7/3	7 7/4	7
8 1	8 9	8 17	FIR.	8 25	8 33	8 41
9 49	9 57	9 65		9 73	9 81	9 89
10 ULR.1	10 ULR 17	10 ULR.33	ULR.	10 ULR. 9	10 ULR.25	10 ULR.41

RACK 14.

RACK 15.

1/3 INDICATES

1000 LINE GROUP 1

SR No. 3

FIG. 10. SECTION OF SR/GVA TRUNKING CHART.

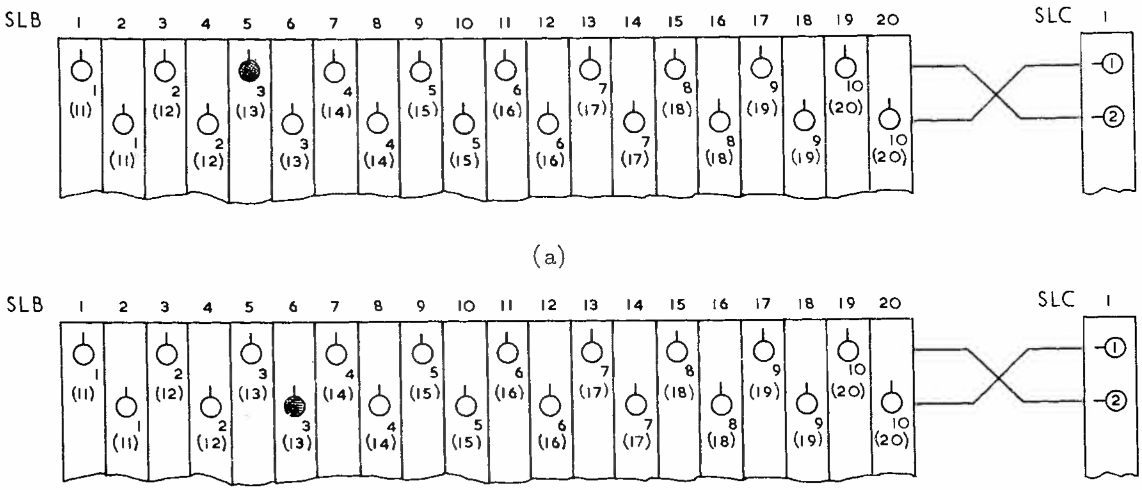
5. SL STAGE - INCOMING TRAFFIC.

5.1 Incoming traffic uses all four of the SL partial stages. When a call is switched through the GV stage a SLD vertical (local calls) or FUR (calls to another exchange) is seized. On local and incoming calls the SL marker selects a route through the SLD, SLC, SLB and SLA stages to the desired number. Fig. 12 shows the grouping plan for the complete SL stage when m = 8.

5.2 The outlets of each SLD vertical are connected to the inlets of the SLC stage. The SLC switches are bracketed together in pairs. The verticals on each pair of SLC switches may be reached from the twenty SLD verticals pointing towards them. As each group of twenty SLD verticals has access to the same links, the outlets from these verticals are multipled.

5.3 The outlets from SLC verticals are connected to SLB verticals. Only the last five verticals on each SLB switch are used for incoming traffic. As there are only 100 SLB verticals while there are 200 outlets from the SLC partial stage, each SLB vertical is available from two different SLC outlets.

Each of the SLB verticals has two outlet numbers beside it, and a "crossover" is shown between the SLB and SLC partial stages. When an outlet from 1-10 (HA switching) is used on an SLC vertical, the crossover is ignored and the SLC outlet is connected to an SLB vertical in a direct line. In Fig. 11a, the 3rd outlet from SLC vertical 1 in switch 1 would be connected to SLB switch 5 vertical 6.



(a)

(b)

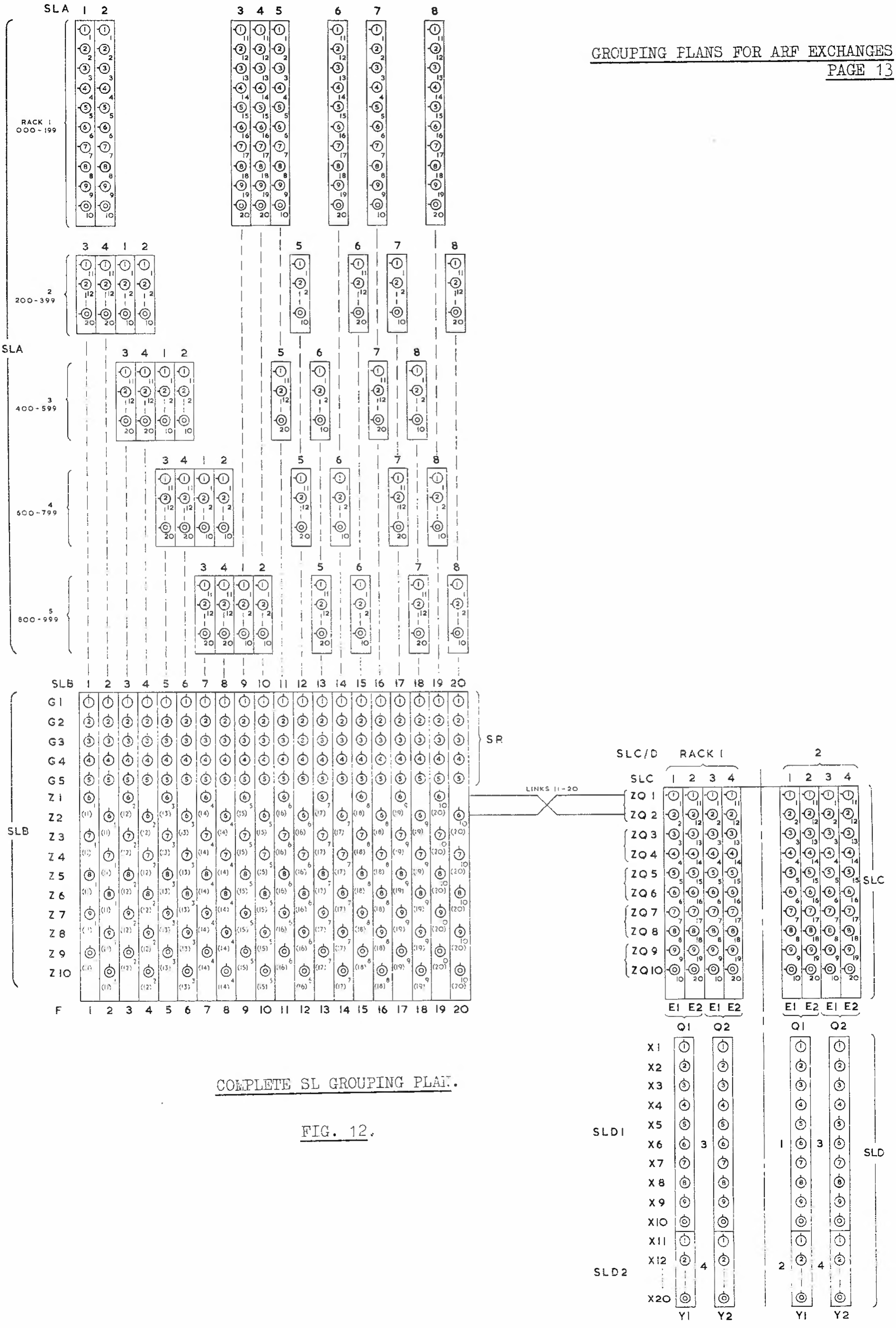
FIG. 11. SECTION OF GROUPING PLAN SLC/D.

5.4 When an outlet from 11-20 (HB switching) is used, the crossover is used and the outlet is connected to an SLB vertical in the alternate row. Fig. 11b shows that outlet 13 from the same SLC vertical is connected to vertical 6 on SLB switch 6.

Although the crossover is shown only between the top two rows of SLC and SLD verticals a similar crossover is understood between each other pair of rows.

The number without brackets beside each SLB vertical represents the SLC outlet number when using HA switching. The number enclosed within the bracket represents the SLC outlet number when using HB switching via the crossover.

The crossover is not used on grouping plans where more than 20 SLB switches are used.



COMPLETE SL GROUPING PLAN.

FIG. 12.

5.5 Call Tracing through the complete SL stage. When a subscriber has received a call requiring tracing - for example, a malicious call - the called subscriber's number is known and the SLA springset switched to this number is located in the manner described in para. 2.5. As it is known to be an incoming call to this subscriber, when tracing to the SLB stage it is only necessary to search the last five verticals of the SLB switch that has access to the correct SLA vertical. When the correct SLB vertical is found the procedure for tracing the call through the remaining stages is as follows:-

(i) Examine the grouping plan and note the two outlet numbers beside the SLB vertical. Assuming that the SLB vertical for this call is vertical 6 on SLB5, the two outlet numbers indicate that this vertical is trunked from outlet 3 on vertical 1 of each SLC switch, and outlet 13 on vertical 2 of each SLC switch.

(ii) Proceed to the SLC rack and examine each vertical 1 (HA, H3 operated) and vertical 2 (HB, H3 operated). Assuming that the call is switched from vertical 1, SLC1 on rack 1, the number beside this vertical on the grouping plan indicates that it is trunked from outlet 1 of the verticals on the SLD1 and SLD2.

(iii) Examine SLD switches 1 and 2 for a vertical switched to the 1st outlet (HA, H1).

5.6 When an incoming call is to be traced and the SLD vertical is known, the procedure for tracing the call through the SL stage is as follows:-

(i) Examine the SLD vertical and note the springsets operated.

(ii) Refer to the grouping plan and note the SLC vertical connected to this outlet. This is indicated by the number beside each SLC vertical.

(iii) Examine the SLC vertical and note the springsets operated.

(iv) Refer to the grouping plan. Note the SLB vertical connected to the SLC outlet. If the SLC outlet is from 11-20 the crossover is used and the number in brackets beside the SLB vertical is the number of the SLC outlet.

(v) Examine the SLB vertical and note the springsets operated.

(vi) Refer to the grouping plan and note the SLA vertical connected to this number. The number of the rack on which the SLA switch is mounted will indicate the 200 group of the called number.

(vii) Examine the SLA vertical and note the springsets operated. The HA or HB springset indicates the 100 group, and the vertical number and horizontal number indicate the called subscriber.

5.7 The following charts are included to provide practice in tracing calls through the grouping plans for each partial stage. The first line on each chart has been completed as an example of the information required.

Refer to the relevant grouping plans and fill in the details for all lines on each chart. Check with answers beneath test questions on page 16.

SUB. NO.	SLA					SLB				SR. NO.
	RACK	SWITCH	VERT.	HOR.	HA/HB.	SWITCH	VERT.	HOR.	HA/HB.	
016	1	1	1	H6	HA	1	3	H1	HA	3
192	1	3				9				24
562		2								52
	3			H7	HB			H1	HA	12
692	4		2			6	2			
876		3								17

SL STAGE OUTGOING CALL.

GVA					GVB					ROUTE NO.	CIRCUIT IN ROUTE.
RACK	SWITCH	VERT.	HOR.	HA/HB.	RACK	SW.	VERT.	HOR.	HA/HB.		
1	4	7	H1	HB	2	6	1	4	HB	14	11
2	1	2			1	4				5	2
1	2	0								2	12
1	4	6	H2	HA						4	
2	4	2			2	1	1			5	
		1			2	3	1	5	HA		

GV STAGE.

SUB. NO.	SLA					SLB				SLC					SLD				
	R	S	V	H	HA/HB	SW.	V	HOR.	HA/HB	R	S	V	H	HA/HB	R	S	V	H	HA/HB
012	1	1	1	2	HA	1	6	1	HA	1	1	1	1	HA	1	1	1	1	HA
732		3					7			1			3	HA	1	2	2	3	HA
			6	4	HB				HB				7	HB	1	2	4	6	HB
				3	HA			6	HB				5	HB	1	1	8	4	HA
				6	HB			4	HA				0	HA	2	1	6	7	HA
592		4					8			2	3	5				4	5		

SL STAGE INCOMING CALL.

6. TEST QUESTIONS

1. How is a subscriber's number located on an SLA switch (a) above the jack box.
   (b) below the jack box.
2. How many SLB verticals on each switch are available for outgoing traffic.
3. On a grouping plan, what is meant by (a) the number in the vertical symbol,
   (b) the number beside the vertical symbol.
4. To which partial stage are the outlets from SLB verticals connected.
5. Which SL partial stages are used for an outgoing call.
6. Describe the procedure of tracing an outgoing call through the SL partial stages.
7. Which springsets on an SLA vertical indicate the hundred group of the subscriber.
8. (a) Sketch and describe the symbol used to indicate a vertical on register finder switch.
   (b) How is the same vertical shown on a trunking diagram.
9. In an SR/RS grouping plan each vertical has access to .... SR relay sets and .... registers.
10. Describe the commoning on the springsets of the register finder verticals.
11. The FIR/RS stage consists of .... FIR relay sets associated with .... register finder switches and .... registers.
12. Each group selector stage consists of .... partial stages called ....
13. Each GV unit consists of .... selector racks, with .... GVA and .... GVB switches on each rack.
14. How many incoming circuits are connected to each GV unit.
15. State the GVB vertical and springsets used to switch each of the following calls:-
    (a) GVA rack 1, switch 4, vertical 2 to circuit 12 on route 11,
    (b) GVA rack 2, switch 1, vertical 8 to circuit 6 on route 15,
    (c) GVA rack 2, switch 4, vertical 3 to circuit 14 on route 6.
16. Describe the procedure of tracing a call in each direction through the GV stage.
17. Which SL partial stages are used for incoming traffic.
18. Explain the meaning of the two numbers beside each incoming SLB vertical.
19. What equipment is connected to (a) SLB inlets.
    (b) SLD inlets.
20. SLD outlets are connected to .... stage inlets.
21. Describe the procedure of tracing a local call in each direction through all switching stages.

SL Outgoing
016, R1, SW1, V1, H6, HA, SW1, V3, H1, HA, 3.
192, R1, SW3, V9, H2, HB, SW9, V4, H9, HB, 24.
562, R3, SW2, V2, H6, HB, SW6, V2, H2, HA, 52.
517, R3, SW1, V1, H7, HB, SW5, V2, H1, HA, 12.
692, R4, SW4, V2, H9, HA, SW6, V2, H2, HB, 52
876, R5, SW3, V7, H6, HA, SW7, V2, H7, HB, 17.

GV
R1, SW4, V7, H1, HB, R2, SW6, V1, H4, HB, 14, 1
R2, SW1, V2, H2, HB, R1, SW4, V2, H5, HA, 5,
R1, SW2, V0, H2, HB, R2, SW5, V2, H2, HA, 2, 1
R1, SW4, V6, H2, HA, R1, SW2, V2, H4, HA, 4,
R2, SW4, V2, H1, HA, R2, SW1, V1, H5, HA, 5, 1
R2, SW3, V1, H1, HA, R2, SW3, V1, H5, HA, 5, 1

SL Incoming
012, R1, S1, V1, H2, HA, S1, V6, H1, HA, R1, S1, V1, H1, HA, R1, S1, V1, H1, HA.
732, R4, S3, V3, H2, HB, S5, V7, H3, HB, R1, S1, V3, H3, HA, R1, S2, V2, H3, HA.
964, R5, S5, V6, H4, HB, S13, V8, H6, HB, R1, S2, V6, H7, HB, R1, S2, V4, H6, HB.
063, R1, S3, V6, H3, HA, S9, V7, H6, HB, R1, S1, V4, H5, HB, R1, S1, V8, H4, HA.
764, R4, S8, V4, H6, HB, S19, V9, H4, HA, R2, S1, V7, H0, HA, R2, S1, V6, H7, HA.
592, R3, S4, V2, H9, HB, S4, V8, H2, HB, R2, S3, V5, H2, HB, R2, S4, V5, H5, HA.

END OF PAPER

CROSSBAR SIGNALLING

---

1. INTRODUCTION.

1.1 At the commencement, and during the progress of a call associated with an automatic telephone exchange, certain information must be transmitted from the subscriber to the exchange and from the exchange to the subscriber. Also, if the call involves connections between two or more exchanges, there must be an interworking signalling scheme to enable the necessary information to be passed over the circuits between the exchanges.

1.2 Signalling is the term applied to this passing of information, enabling connections to be established, preventing other subscribers from intruding, charging for the call and finally disconnecting the parties after conversation has ended. The three main requirements for a signalling scheme in an automatic network are :-

(i) The transmission of number or digital information and revertive signals to control the routing of a call.

(ii) The supervision of the progress of a call.

(iii) The transmission of information relating to the charging of the call.

1.3 In a crossbar exchange, these three aspects of signalling can be broadly grouped into two classes :-

(i) Information signals passed from -

(a) subscriber to register,
(b) register to register,
(c) register to code receiver,
(d) code receiver to register.

(ii) Line or Supervisory signals, including metering. These are signals passed between the apparatus connected to each end of junction lines.

1.4 This paper describes the proposed programme of information and line signals to be used in the Australian crossbar network.

2. SIGNALLING REQUIREMENTS.

2.1 Signalling from subscribers to automatic exchanges. Three types of signal are necessary from the subscriber to the exchange -

(i) A signal is forwarded to the exchange indicating that a subscriber wishes to make a call. This signal, when received at the exchange, causes the subscriber's line to be connected to an information receiving device.

(ii) Information regarding the required number must be passed from the subscriber to the information receiving device, enabling the switching train to be selected.

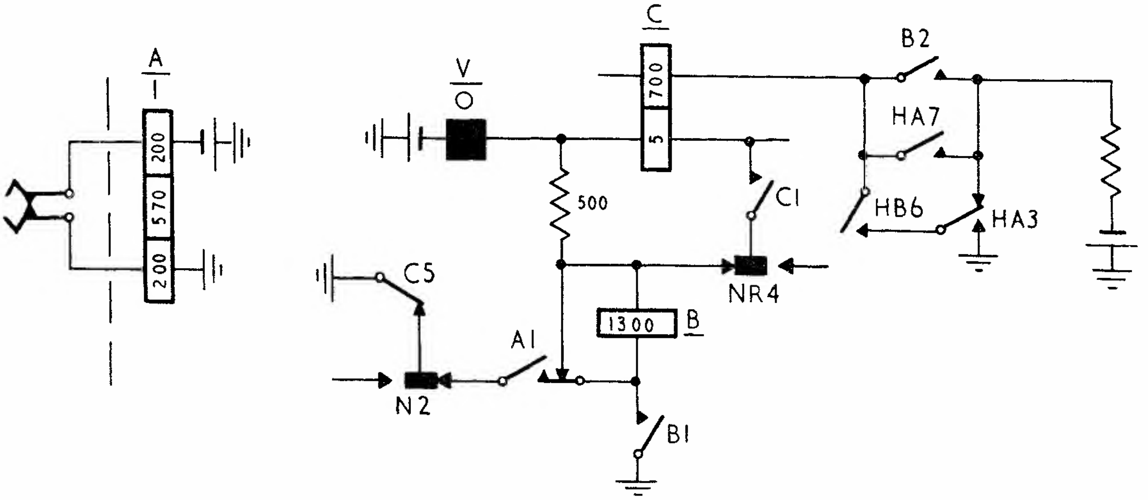
(iii) At the conclusion of the call, the calling subscriber indicates that all switching apparatus can now be restored to normal.

2.2 All C.B. manual and automatic telephones indicate signals (i) and (iii) by making or breaking a D.C. loop circuit to the exchange. In the case of C.B. manual exchanges, forming a loop causes a lamp to glow in the exchange. The telephonist connects the speaking circuit across the line and hears the information given verbally by the subscriber. At the conclusion of the call, breaking the loop circuit causes a supervisory lamp to glow, indicating to the telephonist that the connection can be released. Each subscriber connected to a step-by-step exchange operates a line relay, which causes the line to be connected to a bimotional switch. At the conclusion of the call the restoring of the receiver breaks the loop circuit causing the release of switches in the exchange.

Crossbar subscribers operate a similar line relay, causing the line to be switched to a register. At the conclusion of the call, the breaking of the loop circuit causes the release of the crossbar switches.

2.3 The information signals (ii) passed from the telephone to an automatic exchange consist of a series of D.C. pulse trains, delivered by the dial at a speed of about 10 pulses per second.

In step-by-step exchanges, each pulse·train (digit) is applied in turn to a bimotional group selector, the last two digits being applied to a final selector. Fig. 1 shows the pulsing circuit of a typical bimotional group selector.



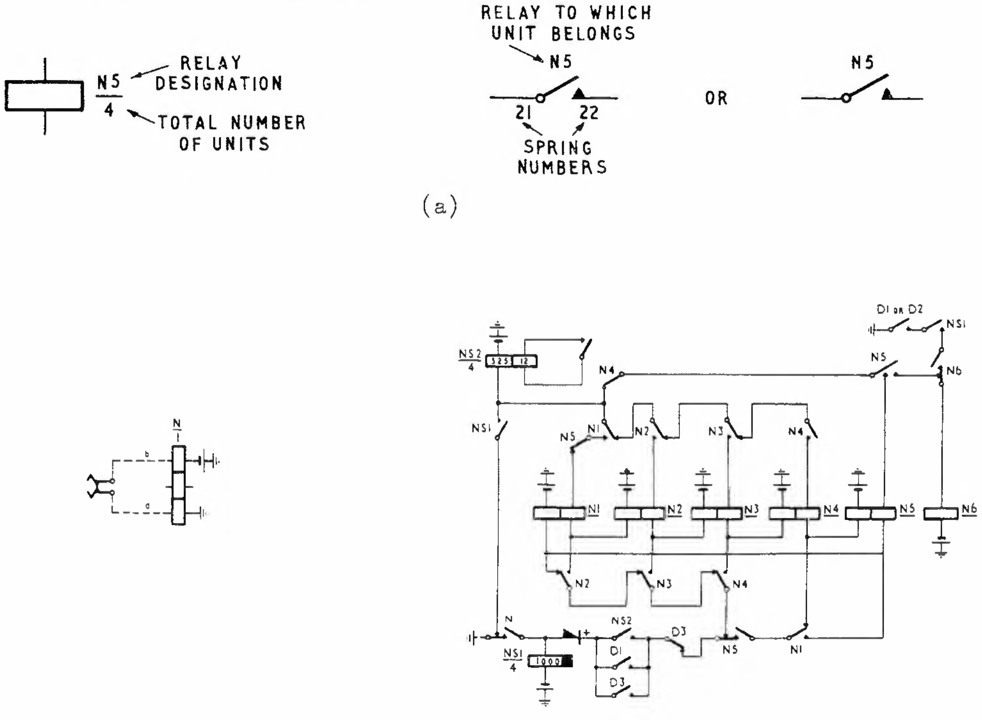
PULSING CIRCUIT 2000 TYPE GROUP SELECTOR.

FIG. 1.

2.4 Crossbar trunking is not under the same rigid control of the dial as that of step-by-step exchanges.

Digits received from the calling subscriber are counted and stored in a central register before the desired route is selected. This enables the most direct route to the desired destination to be selected, and when all circuits on this route are engaged, allows the selection of a circuit on an alternative route. Fig. 2 shows the circuit of the counting section in a central register.

As the designation of many relays in crossbar circuitry finish with a figure (for example N5) the designation of such relays and their contacts when arranged in a detached manner calls for a slightly different procedure. The method adopted for such circuits in this paper is shown in Fig. 2a.



(a)

(b)

FIG. 2. PULSE COUNTING IN CROSSBAR REGISTER.

2.5 The N relay in this circuit operates and releases under the control of the calling subscriber's dial. The operation of the counting relays is as follows:-

Loop applied - N operates.

N contact operates NS1 relay.

NS1 contact prepares a circuit for NS2.

(1st Break) - N releases.
(from Dial)

NS2 operates and prepares a circuit for relay N1.

1st Re-Make - NS2 holds (slow release due to a short-circuited winding).

Relay N1 operates via N operated, metal rectifier, NS2 operated, and normal contacts of relays D3, N5, N4, N3 and N2.

2nd Break - N releases.
- N1 relay holds on right hand winding.
- N2 relay operates on left hand winding.

2nd Re-Make - N operates.
- N1 releases.
- N2 holds on left hand winding.

Each further impulse from the dial causes the operation of an additional number relay in a similar manner to that described. When a number greater than "5" is dialled, the 6th impulse operates relays N6 and N1, the 7th impulse N6 and N2 etc. Table 1 shows the counting relays operated for each digit received.

Digit Dialled	Relays Operated	Digit Dialled	Relays Operated
1	N1	6	N6 + N1
2	N2	7	N6 + N2
3	N3	8	N6 + N3
4	N4	9	N6 + N4
5	N5	0	N6 + N5

TABLE 1.

2.6 After each digit is received from the subscriber and counted by the counting relays in the register, it is stored on a crossbar switch mounted in the register. One vertical is allotted for each digit, and the number of the horizontal magnet operated in each case corresponds to the number dialled by the subscriber.

Fig. 3 shows how the operation of the horizontal magnet is controlled by the counting relays.

When the dial in the telephone restores to normal, a steady loop applied to the line keeps N relay operated.

After a slow release period relay NS2 releases and completes the circuit to operate one of the horizontal magnets.

The operation of the horizontal magnet is followed by the operation of the vertical magnet (not shown), causing the operation of one set of springs on that vertical. The horizontal magnet is then released.

The counting relays are released, enabling the next digit dialled to be counted in a similar manner and stored on the next vertical.

The registers REG-L used in large city exchanges will have a 9 digit capacity and cyclic storage. At the present, the national numbering scheme does not call for a number with more than 9 digits, but the cyclic storage system provides for future expansion, with an ultimate scheme involving international dialling. Using a cyclic storage scheme, the numbers or digits stored on the early verticals are sent forward before the nine verticals are filled. Any further digits are then stored on the now vacant verticals, but the sending forward of the information continues on in the same order as dialled by the subscriber.

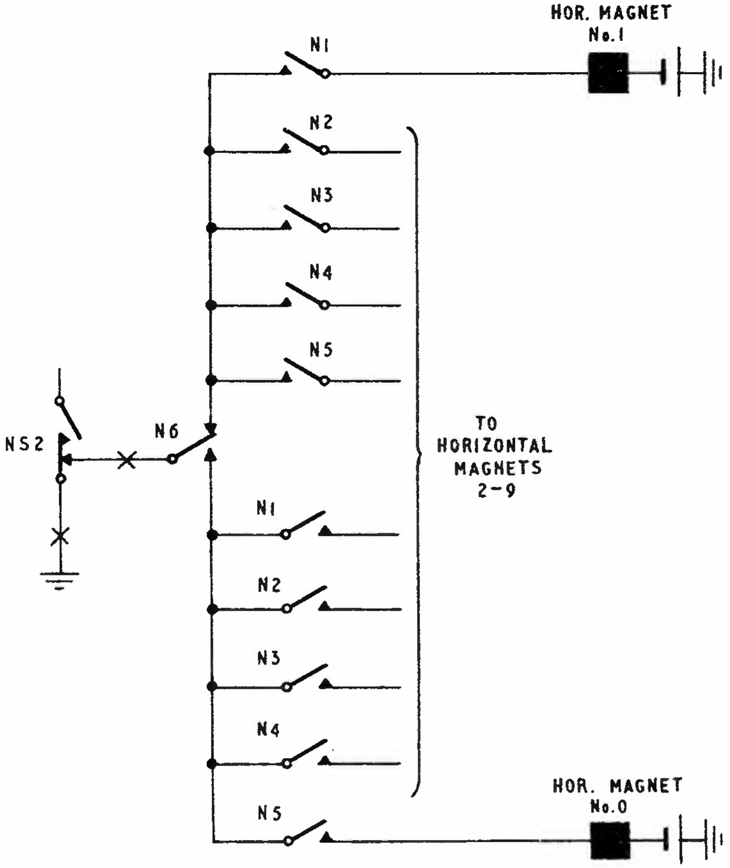


FIG. 3. DIGIT STORAGE.

2.7 Signalling from Exchange to Subscriber. Typical information from the exchange to the subscriber is -

(i) Dial tone - indicating that the exchange is ready to receive information about the wanted subscriber's number.

(ii) Ring tone - indicating that the wanted subscriber is free and that ringing conditions are being established.

(iii) N.U. tone - indicating that the dialled number is that of an unallotted number or group of numbers. (Where possible the caller is switched to a recorded announcement or to a manual operator.)

(iv) Busy tone - indicating that the wanted subscriber is engaged or on interception, or that switching conditions make it impossible to connect the caller to the wanted subscriber.

(v) Ringing current - sent from the exchange to the wanted subscriber with alternating current of standard frequency.

The tones provided enable a calling subscriber to supervise the progress of the call through the various switching stages.

2.8 Signalling between Stages and between Exchanges. Early crossbar exchanges use a system of D.C. polarity reversals to convey the necessary information between the register and the various switching stages. Later exchanges use a system of multi-frequency signalling employing a "compelled sequence" method of operation.

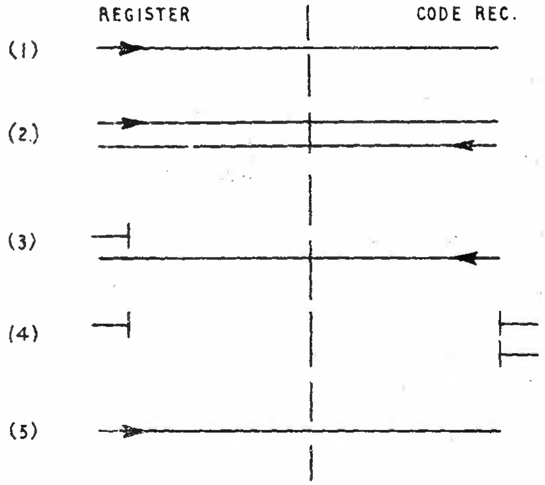
3. MULTI-FREQUENCY COMPELLED SEQUENCE SIGNALLING.

3.1 Six frequencies are provided for signalling from register to marker (digit information) and another six frequencies are available for backward or revertive signalling from marker to register but at present only five are in use. Each signal is accomplished by simultaneously sending two frequencies out of a possible six (or five).

Compelled Sequence signalling means that the duration of the signal is not determined by any timing arrangements, but is controlled by signals in the opposite direction; both the commencement and the termination of the signal are determined either by the arrival or by the disappearance of a signal sent by the other end of the connection.

Using the compelled sequence system the two frequencies constituting the first digit to be transmitted (continuous digit signal) are sent forward from the originating register. The transmission of this signal continues until the code receiver in the incoming register or marker recognises the signal and sends a backward signal (continuous controlling signal) to the originating register indicating that the first signal has been received. The backward signal operates a relay at the originating register, causing the forward signal to be disconnected, and the removal of this signal causes the disconnection of the backward signal. After this cycle the next forward signal is sent from the register.

Fig. 4 shows the principle of compelled sequence signalling.



A continuous digit signal is transmitted from REG.

When this signal is received in CR, the digit is identified and a continuous controlling signal is returned.

The controlling signal is received in the register, which interrupts the transmission of the digit signal.

When the digit signal disappears at CR, the transmission of the controlling signal is interrupted.

When the controlling signal disappears at the register, the new digit signal requested by the controlling signal is transmitted.

FIG. 4. COMPELLED SEQUENCE SIGNALLING.

The use of a multi-frequency compelled sequence method of signalling has been adopted for the following reasons -

(i) It is much faster than the earlier D.C. reversal signalling. The speed of sending is automatically locked to the speed of the receiver, resulting in an average signalling speed of 10 digits per second.

(ii) It is self-checking. Each signal consists of a combination of two frequencies, reducing the liability of false signals. If, owing to a fault, a non-existing combination of frequencies is transmitted, the switching process is immediately halted.

(iii) It is suitable for transmission over a wide variety of circuits including open wire, cable, carrier circuits, coaxial cables and radio links.

3.2 Allocation of frequencies. The code used for signalling must be within the speech band. The top limit of 1,980 c/s has been fixed to avoid interference with international line signalling systems which employ frequencies between 2,000 and 3,000 c/s. Table 2 shows the frequencies allotted in each direction.

The spacing between frequencies of any one series is 120 c/s, and the spacing between the two series of frequencies is 240 c/s. This facilitates the separation of the two groups by filtering.

Each frequency on the table has been given a code number, ranging from "0" for the first forward or backward frequency to "11" for the last frequency in each direction. This arrangement provides a means of checking the composition of each signal from No. 1 to No. 9.

For example, the signal for digit 1 is formed from frequencies 0 and 1, digit 6 from frequencies 2 and 4, etc.

Signals		Frequencies						
Numerical Value	Composition	Denomination	F0	F1	F2	F3	F4	F5
		Forward	1380	1500	1620	1740	1860	1980
		Backward	1140	1020	900	780	660	(540)
		Code Number	0	1	2	4	7	11
1	0 + 1		x	x				
2	0 + 2		x		x			
3	1 + 2			x	x			
4	0 + 4		x			x		
5	1 + 4			x		x		
6	2 + 4				x	x		
7	0 + 7		x				x	
8	1 + 7			x			x	
9	2 + 7				x		x	
10	4 + 7					x	x	
11	0 + 11		x					x
12	1 + 11			x				x
13	2 + 11				x			x
14	4 + 11					x		x
15	7 + 11						x	x

Note: The 540 c/s signal is not used at present.

TABLE 2.

3.3 Forward signalling. In the forward direction six frequencies are available providing a total of 15 signals, ten for digits and five for special purposes such as routing to a particular operator. The forward signals are called for by the backward or revertive signals.

3.4 Backward signalling. The backward controlling signals have three distinct functions to perform -

(i) They acknowledge receipt of a forward signal and indicate which signal is required next.

(ii) At the end of selection they indicate the condition of the called subscriber's line, whether free, busy, absent, non-metering etc.

(iii) To facilitate interworking with step-by-step network, and to signify to the register when it is to release, the register is informed by the distant code receiver as to -

(a) the length of the number being dialled.

(b) the nature of the terminal equipment (crossbar or step-by-step).

Table 3 shows the A.P.O. backward signalling scheme used with multi-frequency compelled sequence signalling. The switching network is complex and many backward signals are required to convey the necessary information to the originating register. However, by a scheme of multi-stage signalling, the same combination of frequencies can be used a number of times, the meaning varying with the position occupied by the signal in the signalling sequence. For example, signal A3 (end of selection) could be followed by No. 3 from the 1B series (interception).

In each case the number beside the signal represents the numerical value of the signal. Table 2 shows the combination of frequencies making up that particular signal.

'A' SIGNALS									
NEXT DIGIT	REPETITION	END OF SELECTION	CONGESTION	TERMINATING EXCHANGE MFC		TERMINATING EXCHANGE STEP-BY-STEP			
				6 DIGIT LENGTH	7 DIGIT LENGTH	5 DIGIT LENGTH	6 DIGIT LENGTH	7 DIGIT LENGTH	NUMBER LENGTH NOT KNOWN
1	2	3	4	5	6	7	8	9	10

FOLLOWED BY — FOLLOWED BY — FOLLOWED BY

1B	2B	3B
1. IDLE SUB.	1. NEXT DIGIT	1. NEXT DIGIT
2. MAN. EXCH. NO THROW OUT	2. REPETITION	2. REPETITION
3. INTERCEPTION	3. END OF SELECTION - 1B FOLLOWS	3. END OF SELECTION - 1B FOLLOWS
4. CONGESTION OR BUSY	4. CONGESTION	4. CONGESTION
5. IDLE-NON METERING	5. START DEC. 2ND DIGIT	5. START DEC. 1ST DIGIT
6. MALICIOUS CALL TRACING	6. " " 3RD "	6. " " 2ND "
	7. WAITING PLACE, NEXT DIGIT	7. " " 3RD "
	8. " " , REPETITION	8. " " 4TH "
	9. " " , SAME DIGIT	9. " " 5TH "
	10. " " , PREVIOUS "	10. SPARE

TABLE 3.

3.5 Typical examples of the use of these signals are -

(i) A local call. Referring to Fig. 5, the local subscriber's register (REG-L) receives the number as dialled by the subscriber. Although the register is not capable of a detailed analysis of the number, it is possible by suitable strappings to allow the register to recognise the local prefix. When such a recognition takes place, all digits are received and stored before a GV stage code receiver is seized.

After all digits have been received the register sends digits to the GV stage code receiver until enough information is received to determine the required route. A revertive signal A1 (next digit) is returned after each digit receive at the code receiver.

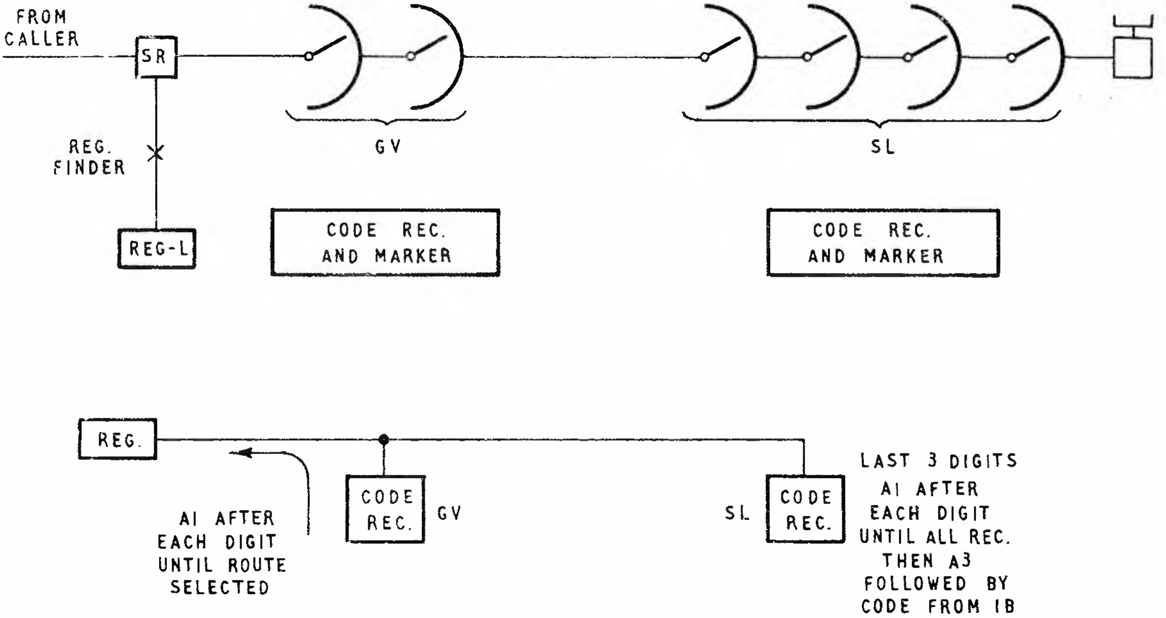


FIG. 5. LOCAL CALL.

When the GV stage is able to determine the route and select a free outlet to the required 1,000 group, further digits are then sent in a similar manner from the register to the code receiver in the SL marker. After all digits have been received in the SL marker (acknowledged each time by an A1 signal), the marker returns an "End of Selection" signal (A3). This prepares the register to receive further signals from the 1B series, indicating the class and condition of the called subscriber's line. If the called number is busy the complete connection is released and busy tone is sent from the calling subscriber's line relay. If the called subscriber is free a short period of ring tone is immediately returned to the caller to indicate that the connection is established. The register then completes its functions and releases, the ring and ring tone being supplied from the SR relay set.

(ii) A call to another crossbar exchange. When the call is for another crossbar exchange, the register will not recognise a local prefix and after the fourth digit has been received and stored, the register seizes a code receiver in the GV marker and the digits are transferred into the code receiver. The code receiver then determines whether the call is for a crossbar or step-by-step subscriber and the length of the number.

Assuming that the call is to a crossbar subscriber, a number length signal (A5 or A6) is returned to the Reg.L. This signal also prepares the register to receive a revertive signal from the 2B series (Table 3). When a direct route is seized, a "Waiting Place" signal (2B 7-10) is sent. This signal tells the register not to seize a distant code receiver until the complete number is received in the register. (The reason for this procedure is that if action is started on a purely crossbar call before all digits are received, the high speed of signalling and setting of switches results in the distant code receivers being held until the subscriber has finished dialling. This is undesirable as the code receivers are part of the common equipment which serves many circuits).

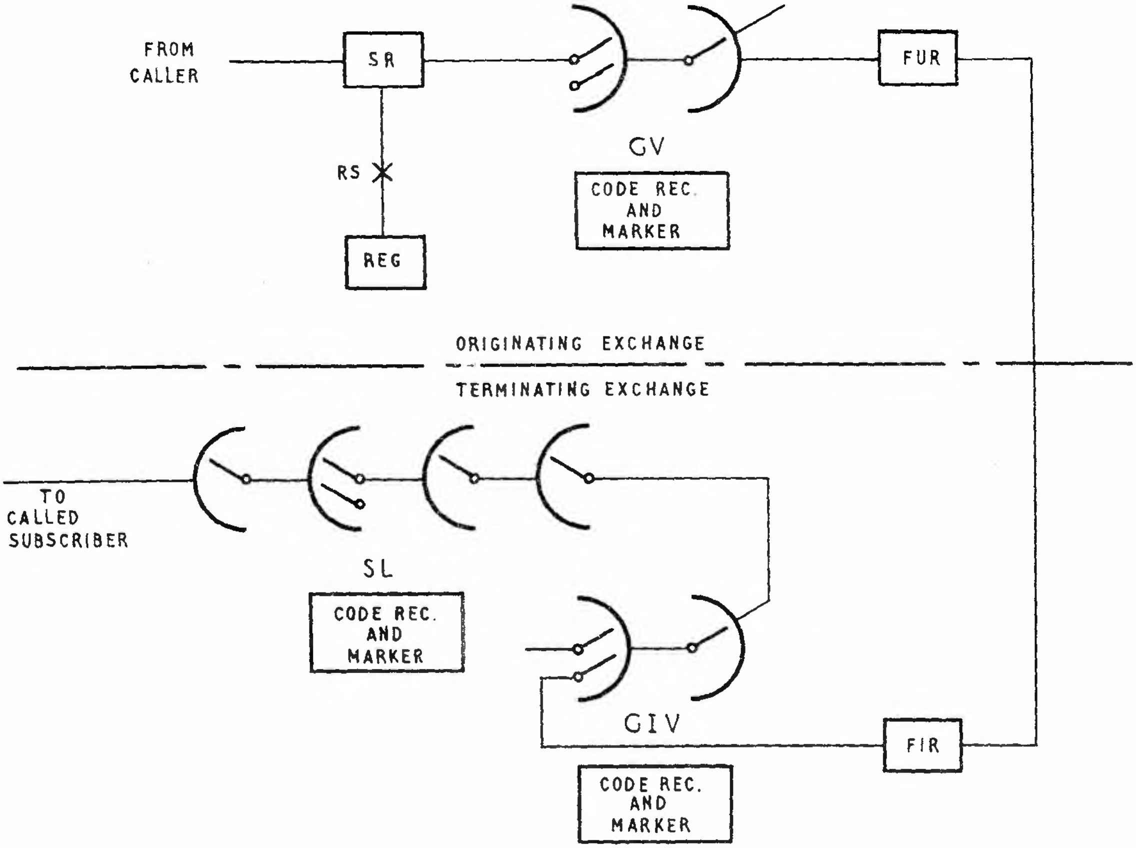


FIG. 6. CALL TO ANOTHER CROSSBAR SUBSCRIBER.

When all digits are received in the register, the code receiver in the next stage is seized and receives from the register the digit indicated by the second part of the waiting place signal (next, same, previous or restart, Table 3).

At this stage (Fig. 6), the code receiver stores each digit as it is received and at the same time calls for the following digit (2B-1). When it has sufficient information it sends no signal until the next route has been selected, and then tells the register which digit will be required by the next code receiver (2 B1). As a direct route between exchanges was assumed, this code receiver will be associated with the SL marker.

The SL code receiver receives the last three digits, returning a 2 B1 (next digit) signal after the first two of these digits. After the last digit is received the code receiver sends an "End of Selection" signal (2 B3), followed by a signal from the 1B series. The remainder of the call then follows a similar pattern to that followed in the local call.

When all circuits in the direct route are engaged, the GV stage marker in the originating exchange will search for a free circuit in an available alternate route. Assuming that this route is via another crossbar exchange, the number length signal (A5 or A6) is followed by a "Waiting place" signal from the 2B series. In this case the code receiver in the tandem exchange must know the original prefix to decide the route, so a 2B8 (Waiting place - repetition) is used.

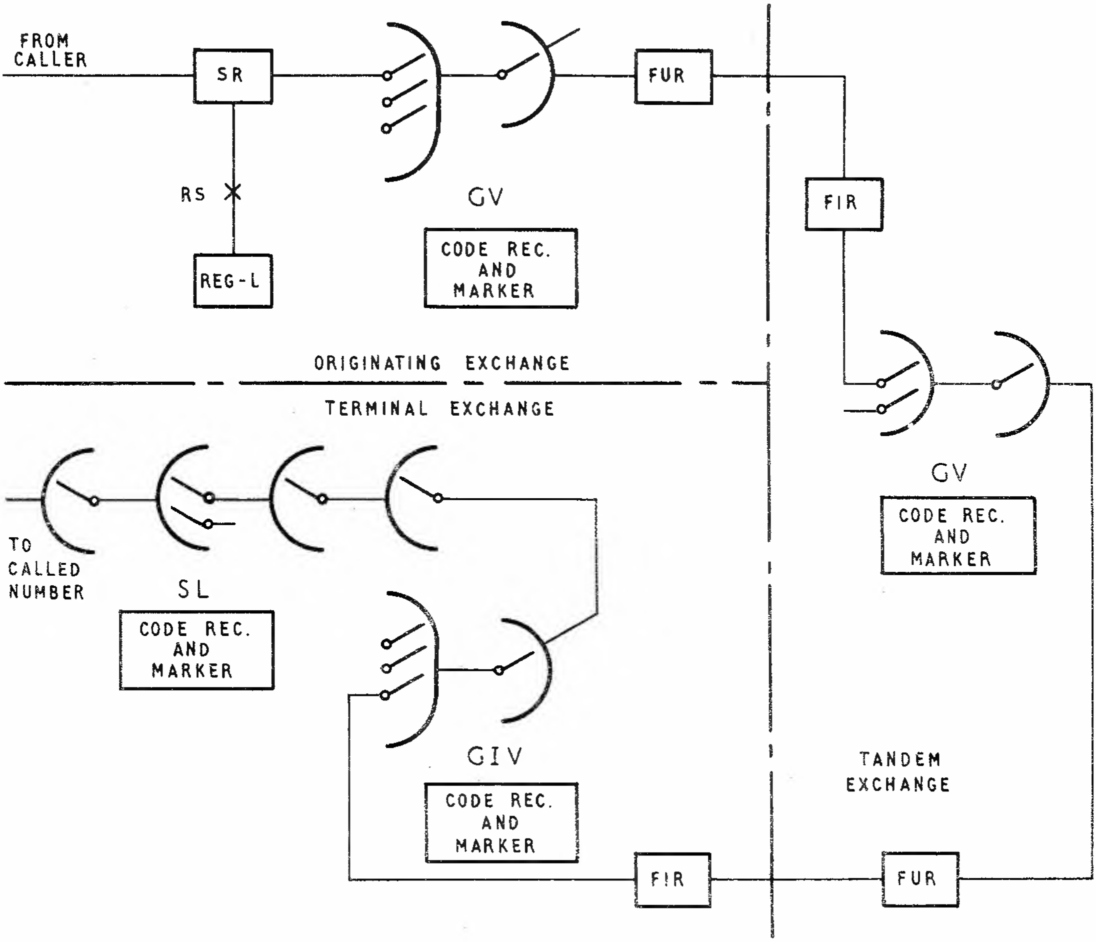


FIG. 7. CALL VIA TANDEM EXCHANGE.

After the register at the originating exchange has received all digits, it repeats the original digits in M.F.C. to the GV code receiver at the tandem exchange (Fig. 7). At this point each digit is stored and acknowledged by returning a signal 2B1 (next digit), until sufficient information has been received for the tandem GV stage to determine the required route.

When the circuit to the desired exchange has been selected, further digits are sent to the GV code receiver at that exchange and the remainder of the call functions in a similar manner to that described for the call via a direct route.

Where the call to a crossbar subscriber is routed via 1st, 2nd or 3rd selectors in a step-by-step exchange the register receives signal 2 B5 or 2 B6 and commences to send decadic pulses (pulses at 10 p.p.s.). At the point where the call again enters crossbar equipment an interworking register (Reg-I) receives the decadic pulses and converts the signalling to multi-frequency for the remainder of the call.

It is a feature of this type of signalling that once the method of signalling from the register is changed from M.F.C. to decadic, it cannot be changed back to M.F.C. again. Because of this, whenever the call passes through step-by-step stages to a crossbar terminal, it is necessary to insert an interworking register to convert the decadic pulses back to M.F.C. to enable the correct operation of the crossbar code receivers and marker equipment.

(iii) Call to step-by-step subscriber. The digits dialled by the subscriber are counted and stored in the register in the normal manner. After the fourth digit has been received, the register (Reg-L) seizes a code receiver and the digits are transferred into the code receiver, which then determines whether the call is intended for a step-by-step subscriber or a crossbar subscriber.

As this call is intended for a step-by-step subscriber the code receiver, after analysing the digits received, returns a signal from the series A7-10. Once the route into the step-by-step network is chosen, one of the signals 3B5-9 (Table 3) is sent, causing the register to send the remaining information at 10 p.p.s. The register releases after it has "cleared its store" of the full number; the length of which it knows from the "A" signal received.

If the code receiver is unable to determine the number length from the first four digits received, signal A10 is returned to the register, signifying "Number length unknown". The register then arranges to release itself approximately 4 seconds after passing on at 10 p.p.s. the remaining digits in its store.

No "immediate" ring tone can be given from the register to crossbar subscribers calling step-by-step exchanges, as this feature is controlled by an "idle subscriber" signal from the 1B series, and these signals cannot be returned from a step-by-step terminal exchange.

Fig. 8 shows the trunking and signals involved in a call from a crossbar subscriber to a step-by-step subscriber.

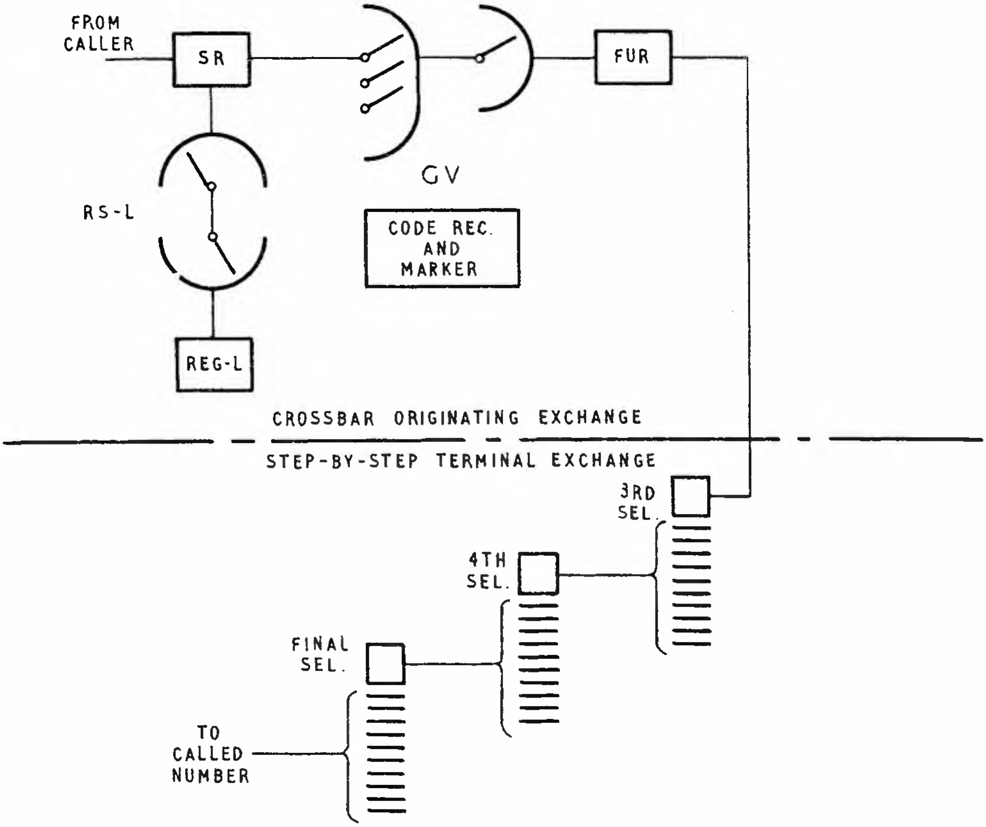
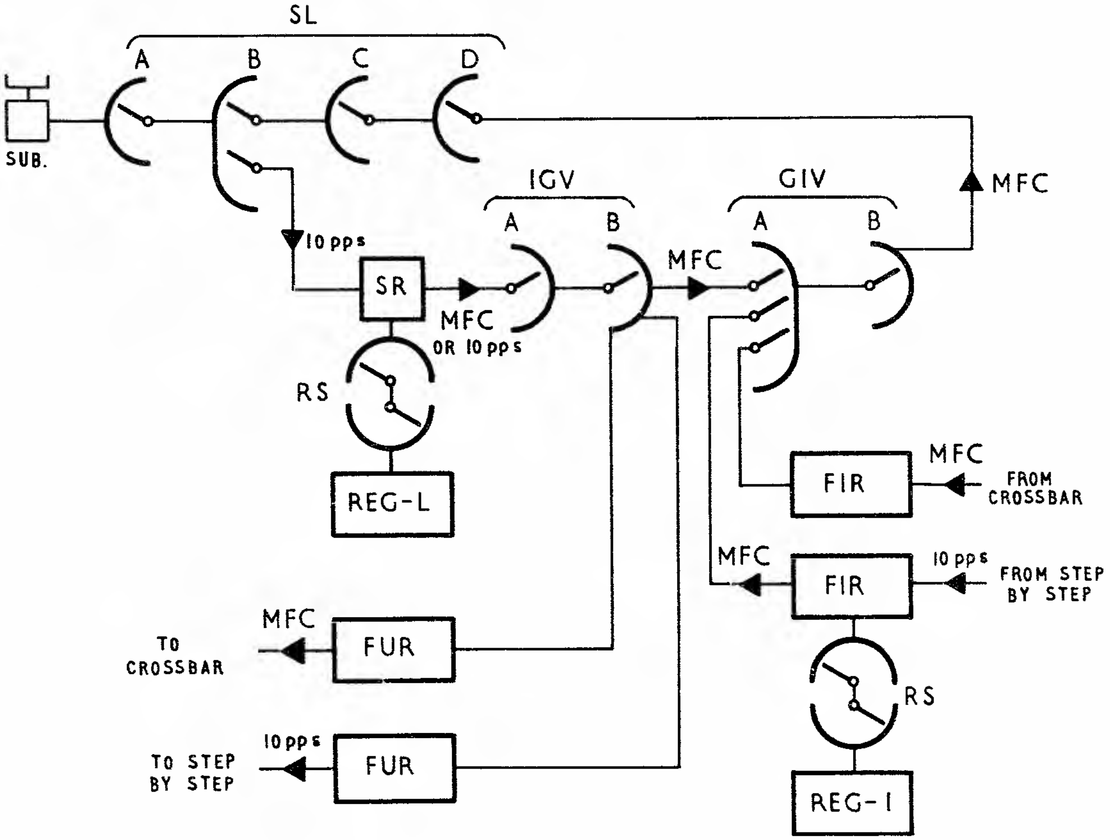


FIG. 8. CALL TO STEP-BY-STEP SUBSCRIBER.

3.6 Fig. 9 shows a typical trunking diagram indicating the sections of a crossbar exchange using multi-frequency signalling and the sections using decadic or 10 p.p.s. signalling.



SIGNALLING DISTRIBUTION IN A CROSSBAR EXCHANGE.

FIG. 9.

The digits are originally received into the register via SLB and SR at 10 p.p.s.

The method of signalling used by the register is determined by the type of call. On a local call MFC signalling is used between the register and the GV and SL markers. Where the call is via a direct route to another crossbar exchange, MFC signalling is again used at all stages. Fig. 9 shows both "MFC" and "10 p.p.s." between the SR relay set and the 1GV stage. This indicates that MFC is used for purely crossbar calls, but 10 p.p.s. is also used where step-by-step equipment is encountered. This is further indicated by the two outgoing junction routes, MFC being shown beside the crossbar route, and 10 p.p.s. beside the step-by-step route.

Similarly, on calls entering the crossbar exchange, 10 p.p.s. is shown beside junctions from step-by-step exchanges and MFC is shown beside the junctions from crossbar exchanges.

The MFC shown between the FIR associated with step-by-step junctions and the inlet to the GIV stage indicates that after the 10 p.p.s. signalling is received by the Reg-I it is then converted into MFC for the remainder of the call.

4. LINE OR SUPERVISORY SIGNALS.

4.1 The line or supervisory signalling system in a crossbar network is required to pass the following basic signals:-

- (i) Forward.
  - (a) Seizure.
  - (b) Clear Forward
- (ii) Reverse.
  - (a) Answer.
  - (b) Clear Back.
  - (c) Release Guard.
  - (d) Blocking.

4.2 Purpose of each signal. The following brief explanation indicates the purpose of each basic signal:-

(i) Seizure signal. The seizure signal consists of a short signal element sent from an outgoing junction relay set to the opposite end of the circuit, where it initiates operation of the apparatus.

(ii) Answer. The answer signal is a short signal element returned to the outgoing exchange to indicate that the called party has answered the call.

(iii) Clear back. A long signal returned to the outgoing exchange to indicate that the called party has cleared.

(iv) Clear forward. This signal consists of a long signal element sent from the outgoing junction relay set to release the connection after a call is completed.

(v) Release guard. A long signal returned in answer to the clear forward signal. It indicates that the release of the connection at the incoming end has been completed.

(vi) Blocking. The blocking signal is continuous and prevents the seizure of the circuit at the outgoing end.

4.3 Types of Line Signalling system. Line signalling systems can be classified into two main groups:-

- (i) Outband.
- (ii) Speech path.

Outband signalling systems are those in which the signals are passed over the link on a path other than the speech path. This separation can be either a frequency difference such as signalling on a carrier system using a frequency outside the speech band, or a physical separation where signalling and speech are carried out on two different circuits.

In speech path signalling both the speech and the signals are passed over the same circuit and within the same frequency band. The present 2VF systems are an example of speech path signalling.

At the time of writing the line signals have not been finalised but a typical signalling scheme that has been used is shown in Table 4.

SIGNAL	SIGNAL DIRECTION AND NOMINAL DURATION IN m/sec.	SENT FROM	SENT TO
SEIZURE	150 m/sec. →	FUR	FIR
ANSWER	← 150 m/sec.	FIR	FUR
CLEAR BACK	← 600 m/sec.	FIR	FUR
CLEAR FORWARD	600 m/sec. →	FUR	FIR
RELEASE GUARD	← 600 m/sec.	FIR	FUR
BLOCKING	← CONTINUOUS →	FIR	FUR

TABLE 4.

5. TEST QUESTIONS.

1. State the main requirements for a signalling system in an automatic network.

2. What exchange equipment is brought into use when a subscriber in a
   (i) C.B. Manual
   (ii) Step-by-Step
   (iii) Crossbar
   exchange indicates by lifting the receiver that an outgoing call is desired.

3. How is digital information conveyed from the subscriber to

   (i) a manual exchange;

   (ii) an automatic exchange.

4. Describe briefly how digital information from a subscriber is counted and stored in a crossbar exchange.

5. State the counting relays operated for each of the following digits:- 2, 5, 6, 0.

6. What type of information is conveyed by signals from an automatic exchange.

7. State the reasons for using the multi-frequency compelled sequence method of signalling.

8. Explain the principle of compelled sequence signalling.

9. State the range of frequencies employed for multi-frequency signalling.

10. How many frequencies are available for signalling in each direction.

11. List the functions of (i) the forward signals; (ii) the backward signals.

12. How is the number of backward signals increased without increasing the number of frequencies.

13. Explain the purpose of the "waiting place" signals.

14. How is the register procedure varied by receiving a "number length unknown" signal.

15. Sketch a trunking diagram of a crossbar exchange, indicating the method of signalling used (MFC or 10 p.p.s.) between the various stages of equipment.

16. What limitation is placed on the provision of immediate ring tone from the register to the calling subscriber when the called number tests free.

17. List the basic signals provided by the line signalling system.

18. Explain what is meant by
    (i) Outband
    (ii) Speech path
    line signalling systems.

END OF PAPER.