INTRODUCTION TO TELECOM. ENGINEERING — PART 7

CROSSBAR TELEPHONE EXCHANGES

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

THE AUSTRALIAN POST OFFICE

COURSE OF TECHNICAL INSTRUCTION

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PART 7

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FOREWORD

The Australian Post Office announced in April, 1959, that the future extension of the telephone system would employ crossbar switching equipment. This decision was taken after thorough investigation of all types of switching systems available, the particular design of crossbar equipment chosen being that manufactured by the L.M. Ericsson Telephone Company of Sweden. As the Australian automatic telephone network has in the past been developed with bi-motional switching equipment using the step-by-step principle, the change to crossbar introduces an entirely different telephone switching philosophy.

Crossbar, of course, is not new, in fact, the crossbar switch was one of the earliest developments in automatic telephony. However, the almost exclusive use of bi-motional step-by-step equipment in Australia has so influenced training and experience that instructional literature has made little more than passing reference to the variety of other systems in use in other countries of the world.

In 1962, the Telecommunication Division at Headquarters issued a book "Introduction to Crossbar for Traffic Officers", which described in simple language the principles, characteristics and main facilities of the crossbar switching systems being introduced into the Australian network.

Although this book was issued to give Traffic Officers a basic reference to this development in Australian telephone switching, staff in the Engineering, and other Divisions were able to make good use of the information it contained. A new issue of the book is required to cater for this expanded use and it has been reprinted with minor revisions as a Course of Technical Information Paper under the more general title of "Introduction to Crossbar Telephone Exchanges".

Whilst the scope of the papers cannot cover all the applications of crossbar, the information contained herein should provide the reader with sufficient basic information on any particular aspect to permit further study. Those who are interested in studying the subject in more detail, should refer to articles in the "Telecommunication Journal of Australia" and to the Departmental Course of Technical Instruction Books on Crossbar Switching".

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1. BASIC SWITCHING PRINCIPLES.

1.1 Introduction. The art of automatic telephone switching has developed in accordance with a variety of differing basic concepts and principles and, so that the crossbar form of switching may be studied against the background of general switching philosophy, this paper presents an outline of basic switching principles in current use throughout the world. Particular advantages of crossbar and the reasons for its choice as the future standard equipment for the Australian telephone system are summarised and the paper, as a whole, serves as an introduction to the succeeding papers which detail the particular features of the crossbar system as adopted by the Australian Post Office.

1.2 Principles of Switch Operation. The term "switch" may be used to describe the means whereby a path, track, line, circuit, etc., can be connected to other paths, tracks, lines and circuits, so that a movement or flow may take place. A switch therefore has inlets and outlets and the art of telephony lies in the means whereby switches of varying capabilities and complexities are utilised to permit the connection together of the speaking paths which constitute a telephone network.

The first practical automatic telephone switch, or selector, was developed by Strowger in 1891 and employed the bi-motional switching principle. At the time, this switch proved to be the most reliable and economical type and, consequently, with modifications and refinements, many of the early automatic telephone systems were developed with bi-motional switches. Other inventors developed other ideas of automatic switching and, although there is a wide variety of types of automatic telephone equipment in use throughout the world, they may be grouped into four broad categories which characterise the fundamental principle of operation of the switching equipment. These are:-

(i) The Bi-motional Switch. Connection of an inlet to an outlet is effected by two distinct movements of the switch inlet wiper contacts over the bank of outlets, usually vertically and horizontally, under the control of "stepping" magnets. There is usually only one inlet to each switch (some final selectors have two inlets) and outlets may number 100 or 200.

(ii) The Uniselector or Rotary Switch. Outlets are arranged in an arc and connection is established by the movement of the inlet wiper contacts around the arc. Switches may be stepped by interrupted electro-magnetic action or by a rotating electric motor. Each switch usually has one inlet and 25, 50 or 200 outlets.

(iii) The Crossbar Switch. A crossbar switch is composed entirely of relays with extended armatures in the form of bars arranged horizontally and vertically. Associated with each bar is a series of inlet and outlet contacts so arranged that the interaction of a horizontal and a vertical bar establishes a connection between the inlet and outlet contacts associated with the particular "crosspoint" of the two bars involved. The crossbar switch is a multiple switch in that it has several inlets, each one of which may be connected to any free outlet. The number of inlets and outlets per switch varies between different manufacturers, but the L.M. Ericsson crossbar switch adopted by the Australian Post Office is generally used with a 10/20 ratio, that is, 200 "crosspoints".

A detailed description of the construction, operation and application of the L.M. Ericsson crossbar switch is given in Section 2.

(There are other systems employing normal relays entirely, no switch mechanism being used, and whilst such systems cannot be truly classified as "crossbar", the trunking and control principles are somewhat similar to that adopted with crossbar - see para. 1.3.)

(iv) Electronic Exchanges. In recent years, telephone switching systems employing fully electronic techniques have been developed, but, as yet, only a few experimental installations have been placed in service. There is no single element of a fully electronic exchange which may be likened to the selector or switch in electro-mechanical exchanges and electro-magnetic relays are not employed. The connection of inlets to outlets is achieved by continuous scanning and space or time division techniques, extensive use being made of memory stores and logic circuits as in digital computers.

In space-division systems, each conversation requires its own physical path through the switching apparatus, sufficient paths being provided to handle the busy hour traffic load. In principle, this does not differ from existing electro-mechanical systems, but there are considerable differences in technique, particularly in control functions.

In time-division systems, many conversations are concentrated simultaneously on a single physical path. The switching network for a typical time-division exchange comprises several such multi-channel paths, known as "highways", suitably interconnected.

1.3 Principles of Trunking. The term "trunking" is used in the general sense to describe the interconnecting arrangements between the various switching stages, both within an automatic telephone exchange and between exchanges. The traffic carrying capacity of the various possible trunking schemes is limited by the number of switches and connecting circuits available, the designed grade of service, the method of connecting switches to the sources of traffic, the amount and character of the traffic offered and the physical characteristics of the switches used.

The number of circuits (and hence the number of switch inlets and outlets on which the circuits terminate) required to carry a given quantity of traffic from one particular group of switches to another may be determined in accordance with a particular "grade of service", or probability of congestion (lost call), based on Erlang's formula of probabilities.

The interconnecting circuits, or trunks as they are usually known, may be arranged in a variety of ways, but two basic methods are generally adopted. These are:-

(i) Direct Trunking. Direct trunking between any two switching stages applies when the outlets from one stage connect direct to the inlets of the following stage. This may be in two forms, known as:-

(a) Full Availability. When all the sources in one group have access to every trunk in another group, the condition of "full availability" applies. This condition is obtained only when the traffic between the switching stages is sufficiently small to be handled by a number of circuits equal to, or less than, the number of outlets from the preceding group of switches.

(b) Limited Availability. Where the volume of traffic requires a number of trunks greater than the number of outlets of the individual switches, the switches cannot gain access to the whole of the trunk group and such a condition is known as "limited availability". To provide better utilisation of the circuits in such a group, the outlets of the various switches are partly interconnected so that the trunks available from different groups of switches are partially common to one another. This may take the form known as "grading", whereby a group of switches is given access to individual trunks on early choices but, on later choices, access to trunks is shared with other groups of switches.

(ii) Link Trunking. Link trunking, as opposed to direct trunking, applies when the connection between the inlets and outlets of a particular switching stage is achieved through an intermediate switching medium. The switching stage is therefore divided into two (or more) partial stages in tandem, the interconnecting circuits between partial stages being known as links.

The links are so arranged that a given switch in one partial stage has access to all, or the majority of, switches in the following partial stage. In this way, the capacity of the switching stage, as a whole, may be increased independently of the capacity of the switches used. A complete switching stage may therefore be built up with any desired number of inlets and outlets. All inlets may have access to all outlets but, because of the intermediate switching, congestion in the links can occur. In order to reduce this internal congestion to a minimum, "conditional selection" is adopted, which means that a switch in a subsequent partial stage is seized only if it has access to a free outlet on the desired route. This requires that the link or links are seized at the same time as the chosen outlet, this being achieved by the use of "common control" equipment - (see para. 1.4.)

Link trunking may be defined as a tandem arrangement of switches which are set dependently of each other in such a way that an available free path is chosen. This form of trunking is a feature of crossbar exchanges and a fuller description is given in Section 3.

1.4 Principles of Control. As with all automatic machines and devices, there must be a means of control. The primary purpose of an automatic exchange is to permit subscribers to directly dial and talk one to another and the control of a call therefore basically lies with the subscriber. So far as the subscriber is concerned, the establishment of a connection is achieved merely by lifting the handset and dialling the number of the wanted subscriber; the looping of the line and the dialling pulses constituting the only information or instructions given to the equipment, plus, of course, the clearing condition. There are two basic methods by which this information may be used to control the automatic equipment, these being:-

(i) Step-by-step or Direct Control. In a system employing conventional step-by-step control, each switch involved in the establishment of a call is positioned in turn in accordance with the pulses received directly from the dial at the originating telephone. The positioning and holding control equipment is therefore directly associated with each switch and the routing of a call is determined entirely by the digits of the number dialled, that is, each digit represents a step in the setting-up of a call, hence the term "step-by-step".

(ii) Common Control. Common control, as the term implies, is the feature of a system where the equipment controlling the setting of the switch is separated from that required for holding the connection during conversation. Since the actual operating time of a switch is quite short compared with the time during which it is occupied by calls, the controlling equipment can serve a number of switches and is therefore referred to as common equipment. The holding of a switch, however, is required for the duration of the call and the holding equipment must therefore be provided at each switch as in the directly controlled system.

Where the common equipment controls all switches required for the establishment of a call in one or more stages simultaneously, and where the directing and control functions are effected by means of circuits entirely separated from the speech path, the system is referred to as employing the "by-path" method of common control.

The control equipment which actually sets the switches is termed a "marker" in that it marks the switches and links to be used and causes them to be connected together to form a through connection. In addition to the marker units, a further item of control equipment, known as a "register", serves as a storage device which receives the digital information furnished by the subscriber and, after analysis, passes on this information as required for the setting up of the call to the wanted telephone.

Common control is fundamental to the L.M. Ericsson crossbar system and the purpose and operation of marker and register equipment is given in more detail in Section 4.

1.5 Usage of Terms. In outlining the basic switching principles in the preceding paras. of this section, the terms used have been applied in the strict sense of their meaning. However, it is not entirely practicable to maintain the meaning of certain of the terminology within rigid definitions as many are complementary, thus giving a choice of terms, any one of which can serve to describe a particular switching philosophy or system.

This is exemplified in the case of the original Strowger bi-motional switch which was first employed on a direct trunking basis using step-by-step control methods. These principles were therefore inherent in the early automatic exchange systems and, as the term "step-by-step" characterises the switching philosophy, it was used in the collective sense to describe any telephone system where the connection is established more or less directly under the control of the dial at the originating telephone. The original Strowger concept has many variants employing rotary or crossbar switches, partial link trunking and part common control, but such systems have all been regarded as "step-by-step".

Common control systems, too, have been developed with a variety of types of switching equipment and, since the register is the essential feature of the thinking or concept involved, such systems have become known as "register" systems.

The first automatic exchanges in Australia were of the Strowger type and, although many modifications and refinements have been adopted and some use made of other than bi-motional switches, the original switching principles remained basically unchanged. It can therefore be said that the Australian telephone system developed initially as an exclusively step-by-step system.

The introduction of the crossbar switch as the standard for future development represented a significant change in the traditional characteristics of the Australian telephone system. As the crossbar switch is the most prominent feature of the new standard, "crossbar" has been used as the generic term. Likewise, the philosophy of common control and link trunking is identified with the adoption of "crossbar" and, consequently, the term "crossbar switching" is being used as a general term to describe these principles.

In subsequent papers, these terms will be used from time to time in the broader sense. It will be found also that similar usage has been applied in other literature, not only in that relevant solely to Australian practice, but also in publications of overseas administrations. It is as well, however, to keep in mind the more specific meanings of the terms used and to think of any particular system, not as a single principle, but rather as a combination of the three basic switching principles, namely; Switch operation, Trunking and Control.

1.6 Advantages of Crossbar. With the large increases in the number of telephones in service, particularly in the larger cities, some fundamental difficulties of the step-by-step system became apparent mainly from the viewpoints of numbering and trunking flexibility. This problem had been overcome in the United Kingdom in the early 1920's by the introduction of the "director" system which integrated a digit-storing and translating scheme into the step-by-step network, thus enabling any required connection to be established in the most direct and economical way without rigidly following the step-by-step routing and numbering requirements. The same problem in the United States of America had been solved by the use of the "panel system" which was essentially a common control system and was later discarded in favour of a crossbar system.

In view of the time which had elapsed since the development of the original director system, and also because of the need for a new approach to methods of operation, particularly of the trunk line system, and to methods of maintenance, the Australian Post Office made an exhaustive investigation of the automatic exchange switching systems available throughout the world. As a result of these studies, the decision was taken to adopt the crossbar switching principle as the future standard system for Australia, it being considered that the chosen L.M. Ericsson crossbar system would:-

(i) Meet the technical requirements for operation of Australia's telephone communication network at the highest possible standards, better than any other system.

(ii) Cater, better and more economically than any other available different system, for the expansion of the numbering capacity of the large metropolitan networks and the creation of rural linked numbering areas.

(iii) Be suitable for economic local manufacture.

(iv) Be more adaptable than any other available system to foreseeable future developments, such as full electronic control and push-button telephones, if these become commercially attractive.

(v) Be capable of complete integration with existing switching equipment.

(vi) Be more conducive than any other available system of a different type to reductions in the size and cost of automatic exchange buildings.

(vii) Permit a worthwhile reduction in the overall cost of automatic telephone exchange equipment.

(viii) Permit more readily than any other systems, the introduction of complete maintenance and service observation aids and a substantial reduction in the cost of maintenance of telephone exchange plant generally.

(ix) Provide for flexibility in traffic routing and more efficient usage of junction and trunk lines.

(x) Provide the most effective known available means of achieving greater value for a given expenditure on the network as a whole.

The increasing cost of operation of the trunk line system led initially to the adoption of the "one-operator-per-call" technique and later to subscriber trunk dialling (S.T.D.) with multi-metering. These two features accentuated other weaknesses of the step-by-step switching system, notably in the slow speed of setting the switches and in the introduction of switching noise at the various contact points.

As the development of S.T.D. necessitates the use of many switches in tandem, switching and "system" noises, which may be ignored in local networks, can have critical effects when the number of switching stages increases greatly.

The mechanical adjustment and other maintenance of rotating switches is a considerable cost item so far as technical staff is concerned and the use of a switch requiring less attention must naturally achieve further operating economies.

In this regard, the crossbar switch has particular merits which may be summarised as follows:-

(i) Mechanical movement and general wear are reduced to a minimum with resultant lower maintenance requirements.

(ii) High-speed operation is possible.

(iii) The switch contacts are of special alloy and of the relay type, thus minimizing switching noise and providing a high quality speech path.

1.7 <u>Summary</u>. <u>Fundamental concepts</u> in the development of automatic telephone systems:-

(i) <u>Switch operation</u>. Four main categories are:-

(a) <u>Bi-motional</u>.

(b) <u>Uniselector</u> or rotary.

(c) <u>Crossbar</u> and "all-relay".

(d) <u>Electronic</u>.

tion

(ii) Trunking. Two basic methods are:-

(a) Direct trunking in the forms of "full availability" and "limited availability".

(b) Link trunking.

Congestion minimized by "conditional selection".

(iii) Control. Two basic forms are:-

(a) Direct control or step-by-step.

(b) Common control - involving the use of "markers" and "registers".

Control function may be separated from speech circuit by "by-path" method.

(iv) Terminology has both precise and general application and, in Australia, the following terms are used in a general sense:-

(a) Step-by-step. Denotes the previous A.P.O. standard equipment which was essentially bi-motional employing direct trunking and step-by-step control methods.

(b) Register system. Systems employing common control methods - sometimes referred to as "register control".

(c) Crossbar. Indicates an exchange or network employing crossbar switches as the principal type of switching equipment.

(d) Crossbar switching. Trunking and control techniques usually associated with crossbar switches, i.e., link trunking and common control.

1.8 The advantages of crossbar are:-

(i) Minimum wear and tear with resultant lower maintenance.

(ii) High speed operation.

(iii) Good contact characteristics.

(iv) Flexibility of numbering.

(v) Flexibility of traffic routing and efficient usage of trunk and junction circuits.

(vi) Suitable for manufacture in Australia.

(vii) More adaptable to future developments.

(viii) Can be completely integrated with existing system.

(ix) Requires less cubic space.

(x) Lesser overall cost of exchange equipment.

(xi) Facilitates introduction of service indicator aids.

(xii) Best network investment.

2. THE CROSSBAR SWITCH.

2.1 Introduction. The crossbar switch had its beginnings in the very first days of telephony and, although new to the Australian telephone system, practical crossbar switches have been in operation for many years, notably in Sweden and the United States of America. This paper gives an outline of the history of the development of the crossbar switch and describes the essential electro-mechanical features of the particular switch manufactured by the L.M. Ericsson Telephone Company. The application of the crossbar switch and its association with common control equipment is dealt with briefly as a preliminary to more detailed consideration in the papers dealing with trunking and common control aspects of crossbar switching techniques.

2.2 Development of the Crossbar Switch.

(i) The Crossbar Concept. One of the earliest manual switchboards was designed on the crossbar principle and consisted of a series of vertical bars of metal, one for each subscriber, and a series of horizontal bars of metal arranged behind the verticals in such a manner that the two sets of bars did not touch each other. Perforations were provided at the crossings so that a connection between a vertical and horizontal bar could be established by passing a metal plug through the perforations at the intersection of the bars. Each subscriber was connected to a particular vertical bar and the horizontal bars functioned as the connecting circuits. Such a switch might also be made by substituting a series of contact points for the horizontal bars, as depicted diagrammatically in Fig. 1.

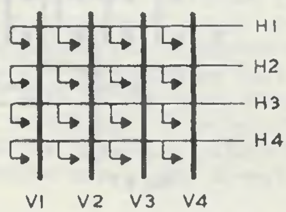


FIG. 1. ELEMENTARY CROSSBAR SWITCH.

From this it can be seen that if a contact point is made to close with a vertical bar, a connection may be established between a vertical and a horizontal circuit.

The simple arrangement illustrated permits the connection together of a single wire with another, but it will be obvious that, by providing a number of contact strips for each vertical bar (or unit) and increasing the number of horizontal contact points, the same principle can be applied for the simultaneous switching of 2, 3 or more wires, as is required in modern telephony. This is shown in Fig. 2, which represents a single vertical unit of a 3-wire crossbar switch, each "vertical" comprising three contact strips.

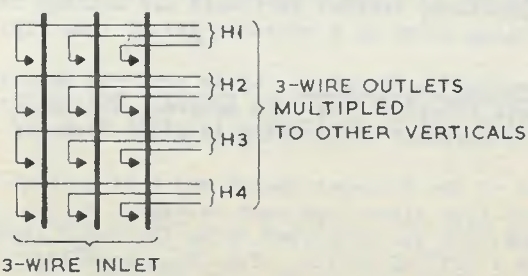


FIG. 2. ONE "VERTICAL" OF A THREE-WIRE CROSSBAR SWITCH WITH FOUR "HORIZONTALS".

It is interesting to note that the pyramid type magneto switchboard in common use at small country exchanges is, in effect, a manually-operated crossbar switch employing two-wire switching.

By providing a further set of contact strips and contact points, together with a means of switching the inlet to either set A or B as shown in Fig. 3, it will be seen that the number of outlets to a single vertical unit may be doubled.

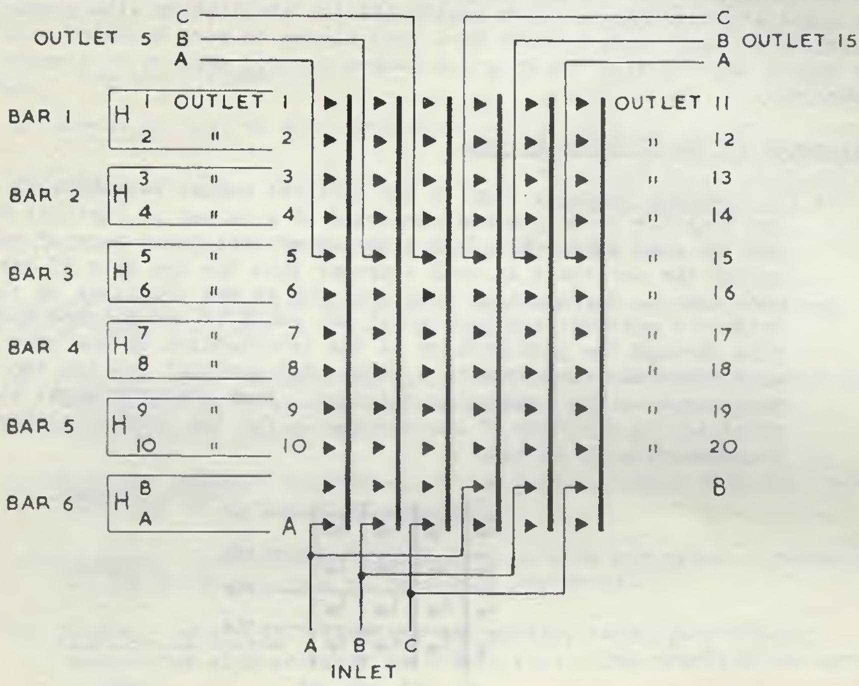


FIG. 3. ONE "VERTICAL" WITH 20 THREE-WIRE OUTLETS.

The contact multiple of a vertical as shown in Fig. 3 is representative of the arrangement adopted in the modern crossbar switch. The closing of a contact between a particular vertical unit and a horizontal outlet is achieved by means of horizontal and vertical bars which are actually extended armatures of horizontal and vertical magnets. Different manufacturers adopt differing means of establishing these "cross-point" connections, but all are essentially by the inter-action of vertical and horizontal bars, hence the original crossbar concept is retained although, of course, the bars themselves do not form any part of the actual speech circuits. The construction and operation of the L.M. Ericsson crossbar switch is covered in para. 2.3.

A single vertical unit therefore represents a switch with one inlet and a number of outlets. In practice, several verticals are mounted in a common frame, the resultant multi-switch being known as a crossbar switch (see Fig. 4).

(ii) Developments Leading to Crossbar. After numerous patents for automatic switching devices had been recorded from 1876 onwards, the patent of the first switch capable of practical development was granted to Almon Strowger of Kansas City in 1891.

The basic unit of the Strowger system was a bi-motional selector and the original scheme required five wires from each telephone to the exchange. Subsequently, a system of signalling was developed using the basic speaking pair, together with a rotary dial as a pulsing device. The Strowger switch had 100 outlets arranged in 10 vertical banks with 10 outlets in each and the switch was operated directly by pulses emanating from the dial.

The original Strowger switch was a mechanical device, and likewise all the systems subsequently developed from it. The bi-motional switch has the virtue of simplicity but, like all other mechanical contrivances, it is liable to excessive wear.

During 1,900, in Sweden, G.A. Betulander and N. Palmgren of the Swedish Telegraph Administration, during a series of pilot studies in automatic switching, devised the first practical crossbar switch. This early design, although not applied for a great many years, was the forerunner of the switch now employed in the American and Swedish crossbar systems.

In the United States of America in May, 1913, John N. Reynolds, Western Electric Co., filed a patent application for a selector with relay contacts actuated by a system of crossing bars which produced a direct and instantaneous connection between a co-ordinate series of multiple contacts.

The Reynolds switch did not meet with any great interest, no doubt due to the large capital investments required for its development and manufacture. The selector was rather complicated and probably too expensive to manufacture with the facilities available at the time.

Meanwhile, Betulander's crossbar principle was used to produce a relay switching system and the Relay Automatic Telephone Company acquired this system and installed several all-relay exchanges in the 1914-1920 period. A small unit of the all-relay type was installed in Sydney shortly after 1920. However, the crossbar switches and the relay system were at that time too expensive when compared with the simple Strowger bi-motional switch system. The main reason that crossbar switches proved too expensive was that common controls, on which a crossbar exchange relies, were not sufficiently fast in operation or reliable in service. Relay design and manufacture were in the early stages and single contacts were still used with little, if any, spark quenching. Wide operating tolerances, relatively slow speed of operation and the use of separate impulsing relays for each selector were the conditions which resulted in the extensive use of the bi-motional switch for early telephone exchanges.

Although there were several small trial installations earlier, it was not until 1926 that a large public crossbar telephone exchange (4,000 lines) was installed at Sundsvall in Sweden. This exchange operated on a step-by-step or direct-driven principle.

During the early 1930's, the Swedish Administration experimented with the application of crossbar to small rural exchanges, as well as to larger city exchanges. Towards the end of the decade, developments in relay design and manufacture, both in Sweden and the United States of America, had reached a stage where it was possible to take full advantage of the crossbar principle in telephone exchanges. In 1938, the first American crossbar No. 1 exchange, "Murray Hill 6", was cut into service. The equipment was manufactured and installed by the Western Electric Co., which, from that time on, became engaged in the manufacture of crossbar equipment on a major scale.

Since then, there has been an increasing tendency on the part of manufacturers and administrations throughout the world to take full advantage of the crossbar principle with modern high-speed controls.

In Australia, trial crossbar exchanges of the L.M. Ericsson type were installed in Sydney (Sefton) and in Melbourne (Templestowe) during 1957. These exchanges, although employing crossbar switches, function on a step-by-step basis using very simple registers associated with each switching stage. The first major crossbar exchange with common control (5,400 lines) was brought into service in September, 1960, at Toowoomba, Queensland.

2.3 The L.M. Ericsson Crossbar Switch. A crossbar switch of the Ericsson type (see Fig. 4) consists essentially of 10 vertical paths and 20 horizontal paths, together with a mechanism - operated by electromagnets - for cross-connecting any one of the 10 verticals to any one of the 20 horizontals. The selecting mechanism consists of six horizontal bars, each of which can be rotated a few degrees either side of normal by the operation of the bar actuating magnets. One of the five horizontal bars, in conjunction with the sixth, is used to "select" the required outlet, the connection to the outlet in any particular vertical being achieved and held by operation of the vertical bar in question. The contact strips and springsets, bars and actuating magnets are mounted in a single welded frame and enclosed by a glass-fronted cover.

It should be borne in mind that the crossbar switch itself does not select an outlet as does a bi-motional or rotary switch. The actual selection of a vertical, and an outlet from that vertical, is effected by common control equipment which causes the appropriate horizontal and vertical magnets to operate and so establish the connection between inlet and outlet. In general usage, however, the horizontal bar is often referred to as the "selecting bar" and the vertical bar as the "holding bar".

The principles of the switching mechanism are shown in Fig. 5, from which it will be seen that each horizontal bar is fitted with 10 flexible steel wire "selecting fingers", one for each vertical. These wire fingers extend into the switch assembly between the vertical holding bar and the vertical contact springsets. For each horizontal bar, there are two springsets in the vertical - an upper and a lower. The operation of a horizontal magnet tilts the bar positioning the selecting fingers opposite the upper or lower springset as the case may be and bridging a "U" shaped depression in the actuating spring of the springset assembly. The operation of a vertical magnet causes the holding bar to force the operated selecting finger against the actuating spring, thus causing the contacts to make. The horizontal bar then restores to normal, but the selecting finger, being flexible, is held in position by the pressure of the holding bar, thus maintaining the springset operated for as long as the vertical magnet remains actuated. Subsequent movement of the horizontal bar does not affect the already established contact and any horizontal bar may therefore be used for other connections, these, of course, being made in other verticals of the switch, the bar being free to move in the same or opposite direction to allow any of the remaining unoccupied fingers to initiate the closure of other vertical springsets in the switch.

When a horizontal bar is in the non-operated position, a vertical holding bar is free to move into the "U" shaped depression in the actuating spring, the selecting finger being merely moved sideways without operating a springset.

When the circuit of the holding magnet is opened, the holding bar releases, thereby permitting the finger to spring back to normal.

The operation of the sixth bar is identical and reference to Fig. 3 illustrates the function of this bar in selecting the left or right group of a vertical.

Summarised, the operating sequence in the crossbar switch is:-

(i) The required horizontal bars operate and move the selecting fingers in line with the springset assemblies.

(ii) The vertical magnet operates and the holding bar closes the contacts of the required springsets at the "cross-point".

(iii) The relevant selecting fingers are held in the operated position by the pressure of the holding bar.

(iv) The horizontal magnets release and the associated bars return to normal.

(v) The vertical magnet and holding bar remain operated for the duration of the connection.

1. Switch frame.
2. Vertical unit magnet.
3. Vertical armature.
4. Vertical unit springset.
5. Upper locking spring.
6. Contact strips.
7. Selecting bar.
8. Selecting finger.
9. Selecting bar magnet.
10. Soldering tabs.
11. Selecting bar springset.
12. Selecting bar armature.
13. Buffer.
14. Selecting bar armature pin.
15. Bearing screw with nut.
16. Lower locking spring.
17. Vertical unit base.
18. Stud for vertical unit springset.
19. Holding bar.
20. Multiple springset.
21. Operating comb.
22. Strip connections.
23. Vertical unit tongue.

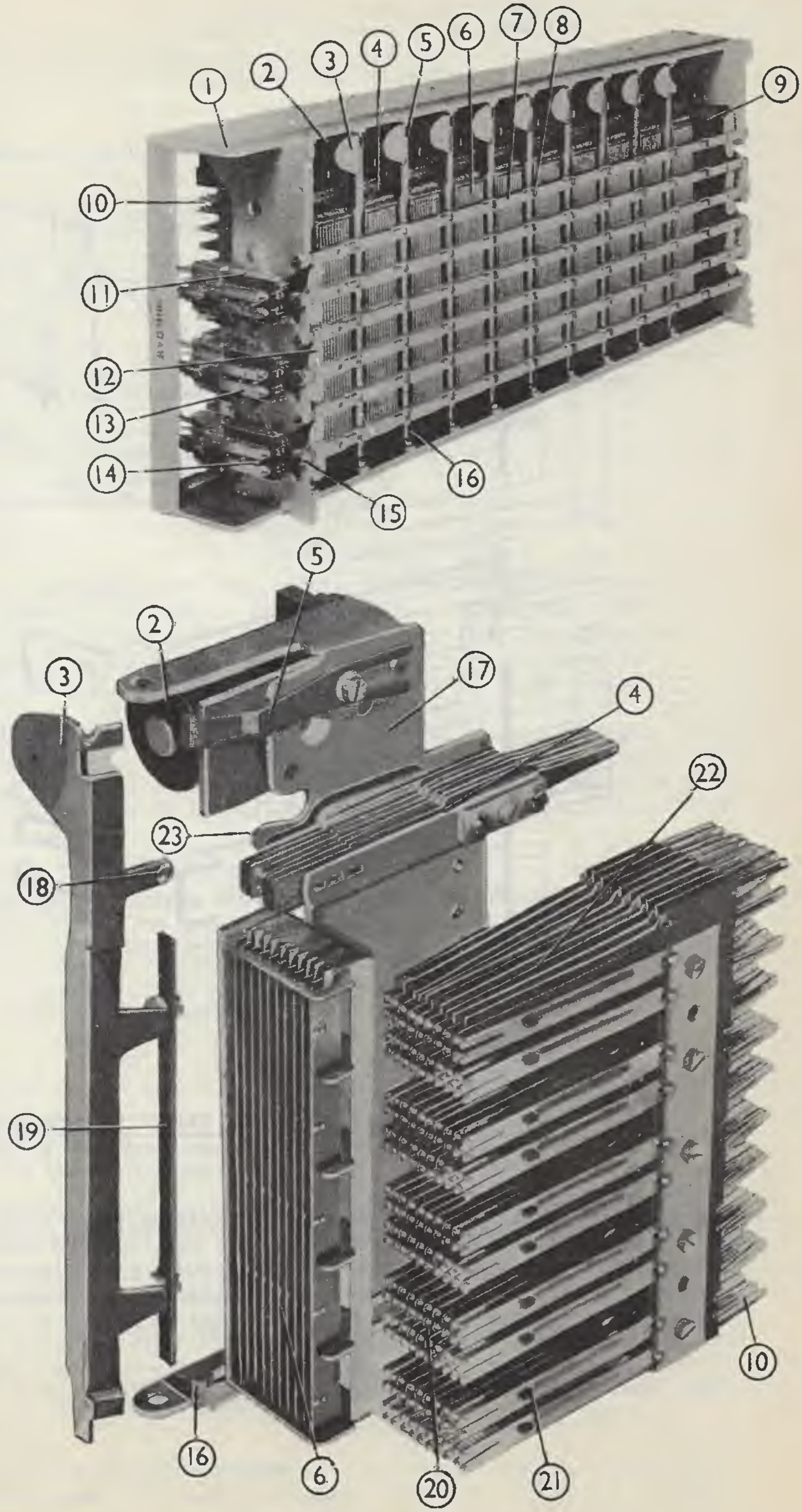


FIG. 4. CROSSBAR SWITCH. (L.M. ERICSSON TELEPHONE CO.).

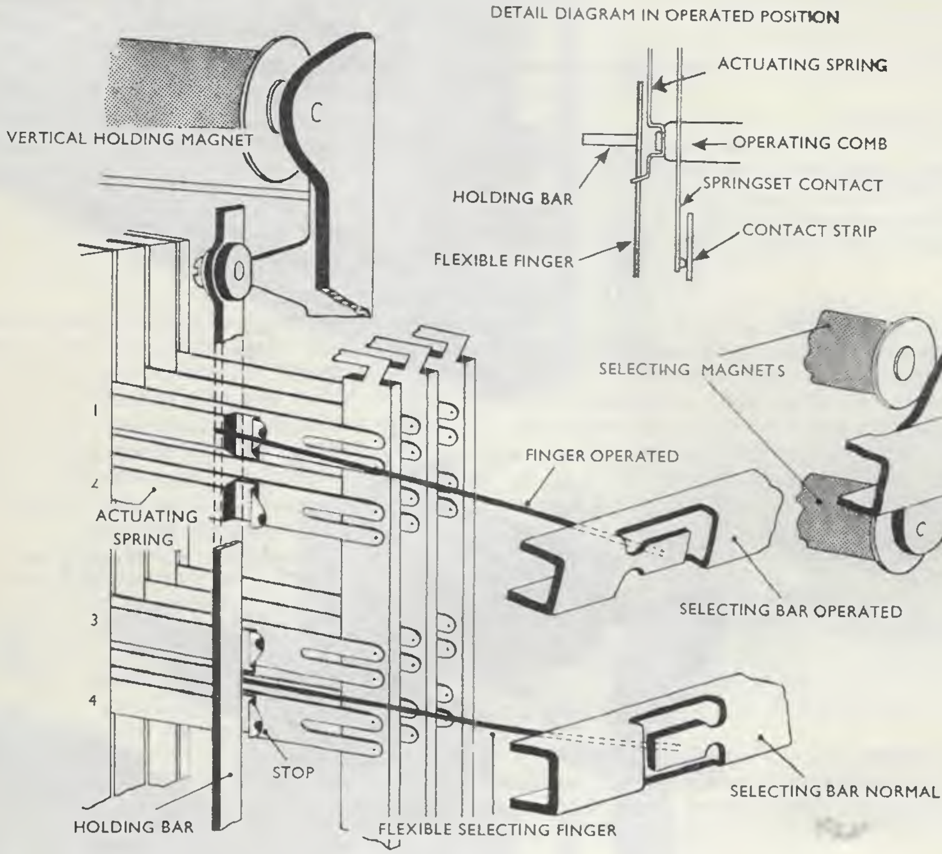


FIG. 5. PRINCIPLE OF SWITCHING MECHANISM.

2.4 Uses of the Crossbar Switch. In crossbar systems, the vertical unit of the crossbar switch is the basic switching device. The vertical can therefore be compared with the uniselector-type switch in that it represents a switching device with one inlet and a number of outlets. A "crossbar switch", however, comprises a number of verticals, the outlets of which may or may not be multipled to meet particular requirements. It is therefore possible in a crossbar switch for calls to be in progress through any number of verticals but, of course, only one connection within a switch can be set up at a time, that is, verticals cannot be operated simultaneously.

The crossbar switch is particularly versatile in its application and the same basic unit can be used for all switching functions. The range of its employment is briefly outlined here, the particular methods of interconnecting crossbar switches in an exchange being detailed in Sections 3 and 4.

(i) As a Line-Finder. In the large exchanges, subscribers' lines are connected in groups of 200 to the outlets of crossbar switches which function as line-finders under the control of common marker equipment. To ensure adequate trunking, the group of 200 lines is multipled over a number of switches, the verticals of which connect to the next switching stage.

(ii) As a Final Selector. The arrangement for a line-finder may be applied also as a final selector, again under the control of the marker equipment.

(iii) As a Combined Line-Finder/Final Selector. From the foregoing ((i) and (ii)), it will be obvious that the line-finder and final selector functions may be combined and both originating and terminating traffic handled in the same stage using a common subscriber's multiple. Such a stage may be termed the subscriber's line or SL-stage.

This arrangement is a particular characteristic of crossbar exchanges and is quite different from that of step-by-step exchanges in which the final selectors are distinct from the subscribers' line-finder or uniselector switches.

(iv) As a Group Selector. The SL-stage caters for a group of 1,000 subscribers' lines. Where greater capacity or special junction switching is required in an exchange, further switching stages are introduced to select the required 1,000-line or junction group, hence the term group selector. The basic crossbar switch, controlled by a special marker, is used to form a group selector stage which is known as the GV-stage (from the Swedish "gruppevaljare").

(v) As a Storing Device in Registers. The crossbar switch forms an important part of the register equipment. The switch is employed for the receipt and storage of digits. This is usually done by the horizontal selecting bars being set as the digits 1-0 are received, each digit being stored on successive verticals of the switch. Each vertical then corresponds to the position of the respective digit in the decimal system, that is, the first vertical stores the first digit, the second vertical the second digit, and so on. In the larger exchanges, the digit store crossbar switch is a 100-crosspoint device, that is, 10 verticals with 10 horizontals, whilst, for smaller exchanges, a 5 or 6-digit store is used. Both have provision for cyclic operation where the digits in a number exceed the capacity of the store.

(vi) As a Register Finder. Registers are common equipment and are connected only as required. The finding of a free register is effected by means of crossbar switches under the control of a special marker for this purpose.

(vii) Special Uses. The crossbar switch may also be employed for a number of special functions, for example, in traffic counting devices, subscribers' line concentrators, interception equipment, automatic trunk exchanges, etc..

2.5 Summary.

(i) The crossbar concept is not new and was adopted on early manual switchboards, e.g., the pyramid type.

(ii) The crossbar switch comprises a number of vertical units (usually 10), each of which has 10 or 20 horizontal springsets.

(iii) Interconnection between inlet and outlet is achieved by the interaction of horizontal selecting bars and vertical holding bars actuated by electromagnets.

(iv) The basic switch has 10 vertical bars and five horizontal bars - each horizontal being associated with two springsets per vertical.

(v) By the addition of a sixth bar, the number of "crosspoints" can be doubled.

(vi) Crossbar switches are controlled by common equipment.

(vii) The same basic unit may be used as a:-

(a) Line-Finder.
(b) Combined Line-Finder/Final Selector.
(c) Group Selector.
(d) Register Finder.
(e) Part of a Register.

3. TRUNKING ARRANGEMENTS.

3.1 Introduction. Early in the history of telephony, it became apparent that all subscribers did not require simultaneous use of switching equipment. From this concept was developed the branch of the art concerned with the provision and arrangement of such plant as is needed to carry telephone traffic with a specified probability of calls encountering congestion or, in other words, the specified "grade of service". This is known as "trunking" which, in automatic telephony, has a particular application and may be defined as the interconnecting arrangements between the various switching stages designed to handle the traffic load in the most efficient and economical manner.

In this Section, the particular form of trunking adopted in crossbar exchanges is outlined with the object of giving the reader an understanding of the makeup of a crossbar exchange and of the passage of calls through the various switching stages.

* 3.2 Symbols used in Trunking. So that the interconnecting arrangements for any particular exchange or switching scheme may be presented in simple diagrammatic form, use is made of certain symbols to represent the switching stages and their relationship to each other. Such drawings are known as trunking diagrams, or trunking schemes, and represent the basic elements of a telephone switching system. Trunking diagrams are therefore not to be confused with circuit drawings which indicate, in precise detail, the makeup of the various component parts.

(i) Step-by-Step. In step-by-step trunking, the symbols mainly used are those representing the uniselector and the bi-motional group selectors. These are shown in Fig. 6 and are largely self-explanatory in that they resemble the actual construction and principle of operation of the switches concerned.

FIG. 6. SWITCH SYMBOLS - STEP-BY-STEP.

(ii) Crossbar. The crossbar switch may be represented in a variety of ways and each has its particular application. In block circuit diagrams, the crossed bars symbol, representative of the vertical and horizontal bars, is used. This symbol is shown in Fig. 7a and can be made up of as many verticals and horizontals as necessary to explain the inlet and outlet connections.

A symbol representing a single vertical is depicted in Fig. 7b. This is popularly known as the "chick", the pointer (or beak) indicating the direction in which the device is multipled. Fig. 7c shows a "box" of verticals and represents a crossbar switch as viewed from above, the direction of the beaks indicating the multipling together of the outlets of the verticals in the same switch (horizontal multipling) or in different switches (vertical multipling).

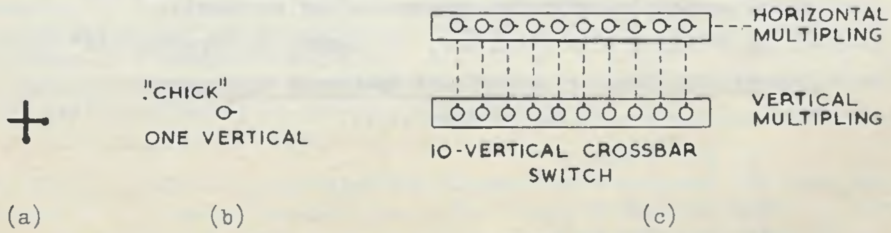


FIG. 7. CROSSBAR CIRCUIT AND GROUPING PLAN SYMBOLS.

The above symbols are used in the detailed consideration of crossbar circuitry and exchange cabling, etc., and are therefore outside the scope of this paper. Mention is made, however, so that the reader will recognise their meaning and purpose if encountered in general reading of crossbar literature.

A crossbar vertical is seldom used separately and a more convenient form of symbol is adopted to represent a crossbar switching stage. This is shown in Fig. 8 and is used only in trunking diagrams. It will be immediately seen that it is similar to the uniselector symbol used in step-by-step trunking, but the meaning of the symbol in crossbar usage should not be confused with the operation of the crossbar switch. The symbol represents the inlets and outlets of a switching device and it should be remembered at all times that a crossbar switch is set by common control equipment and cannot itself select or find an outlet as does a uniselector.

As mentioned previously, crossbar switches are set by common control equipment and in Fig. 8 this is shown by the dotted lines, in this case representing a marker. As will be seen later, a trunking diagram does not usually include the marker equipment, this being understood as integral to the switch operation.

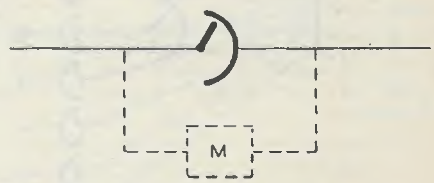


FIG. 8. CROSSBAR TRUNKING DIAGRAM SYMBOL.

* 3.3 Link Trunking. The link principle was employed in telephony long before the concept was defined. A typical example of link trunking is seen in the manual switchboard where, for a connection to be established between the calling and called parties, a connecting device (cord circuit) must be free and the operator must also be free. The success of a call is therefore dependent on two groups of connecting devices - one represented by the cord circuits, the other by the operator. In this case, the answering and calling cords may be considered as switching devices to find the calling subscriber and connect to the wanted subscriber, the movement or setting of the cords being controlled by the operator. This can be represented diagrammatically as in Fig. 9a or as in Fig. 9b using the trunking symbols described previously. The variation in Fig. 9c represents the case where both parties are connected to the same switchobard, i.e., in the same multiple.

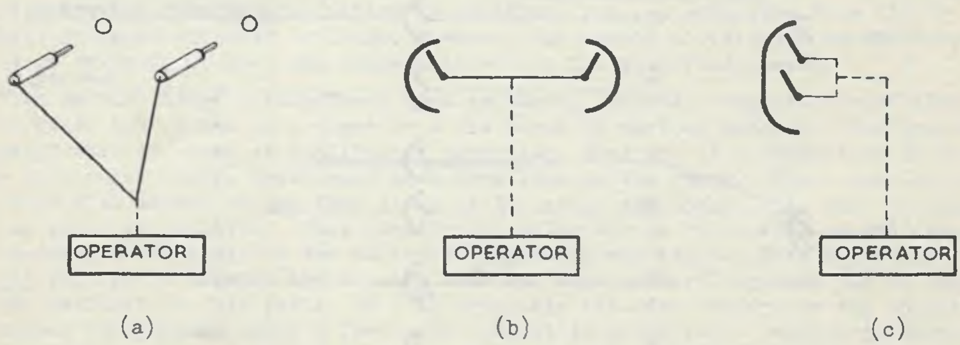


FIG. 9. MANUAL CORD CIRCUIT AS A LINK CONNECTION.

Consider now a switching device with one inlet having access to 10 outlets. In practice, 10-outlet switches do not provide economical working due to the necessity for grading of access to large routes, thus losing the advantages of full availability. By connecting 10-outlet switches in tandem, however, the number of outlets available to a particular inlet can be considerably increased. Furthermore, the availability, or number of outlets accessible, from a given switching stage becomes independent of the size of the switching device.

If, as in Fig. 10, each of the 10 outlets of switch A connects to another 10-outlet switch B, switch A can connect to 100 lines and a composite switching stage comprising switches A and B with a capacity of 100 lines has been produced. Fig. 10b depicts this arrangement in a simpler form.

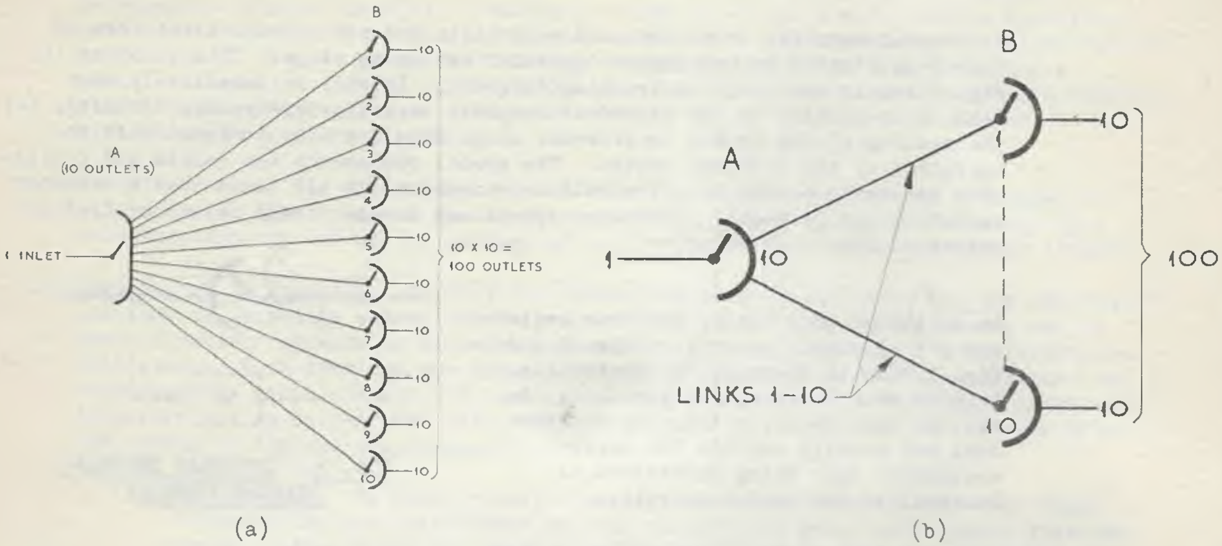
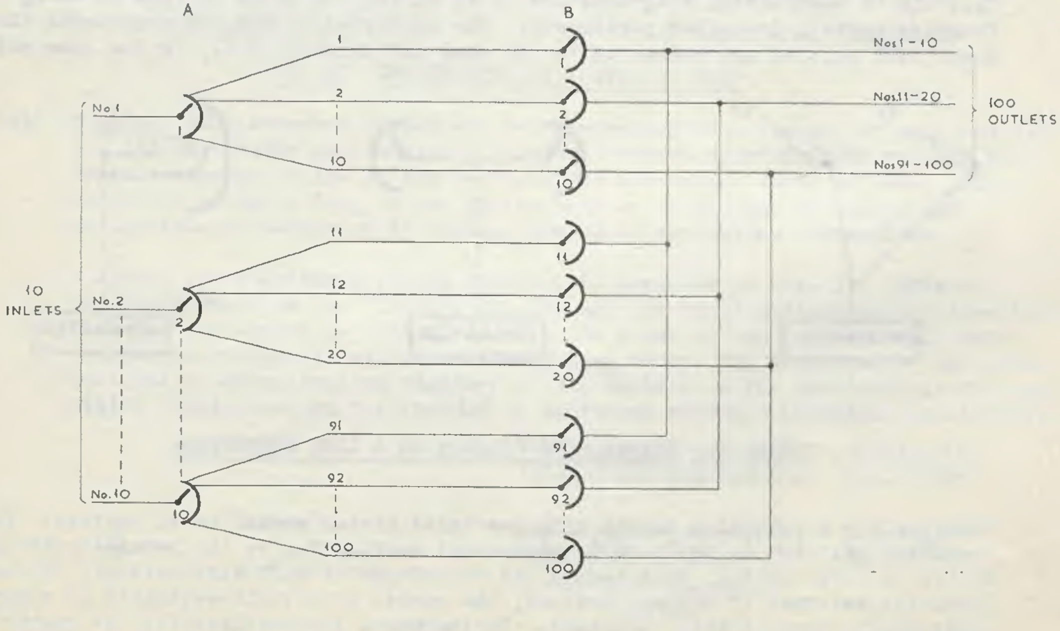


FIG. 10. COMPOSITE SWITCHING STAGE WITH 1 INLET AND 100 OUTLETS.

In short, this simple link system increases the capacity of two 10-outlet switches five-fold. This, of course, is the main reason for applying the link principle; it saves switches and it increases the capacity or availability of the switches.

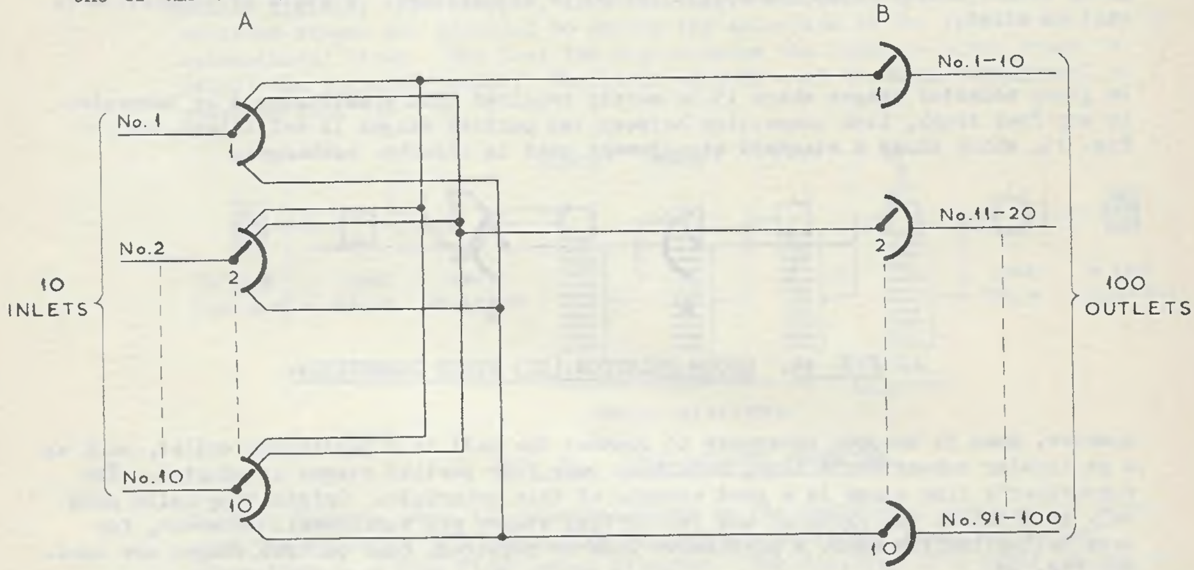
The same holds true for larger numbers of A switches and if, say, 10 switches are to be given access to the 100 outlets, this can be achieved by interconnecting as shown in Fig. 11.



(110 10-Line Switches.)

FIG. 11. SWITCHING STAGE WITH 10 INLETS AND 100 OUTLETS.

The number of 10-line switches required for this arrangement is 10 × 11 = 110 and it may be asked whether this number cannot be reduced. Examination will show that, for each connection through one A switch, only one of the 10 associated B switches is occupied and the other nine are idle. A significant reduction would therefore be possible if the B switches were accessible to more than one A switch. An arrangement of this nature is shown in Fig. 12. Here only 20 switches suffice to permit each A switch to reach any one of the 100 outlets.



(20 10-line switches.)

FIG. 12. SWITCHING STAGE WITH 10 INLETS AND 100 OUTLETS.

There is, however, one important difference between the two arrangements - in the second one it is not possible in all circumstances to reach all outlets. If, for example, A switch 1 is to be connected to outlet 1 (Fig. 12), the path must be through B switch 1. Since this switch provides the only connection path to outlets 1-10, it may be busy with a connection between any of the other nine A switches and any of the outlets 2-10. The whole arrangement is thus subject to internal congestion, which is the price to be paid for the considerable saving in switches, i.e., a reduction from 110 to 20. In a well-designed crossbar exchange, however, the number of switches in the various stages is so balanced to keep the congestion within the specified limits.

With partial stage arrangements such as these, internal congestion must always be kept in mind, but it can be brought to a low value by various methods. One possibility is to adopt what is known as conditional selection, that is, if a connection is required with a particular route, there must be a free line in the route. There must also be free links with access to the free lines in the route and these links must be accessible from the inlet in question. This conditional selection is controlled by the common equipment (marker) which controls the switches comprising the stage. This equipment first marks all free paths between the calling line and free outlets, chooses one of them and sets the switches to this path. This is precisely the same concept as the operator at a manual switchboard using a free cord circuit to establish a connection between two subscribers' lines.

The foregoing is necessarily a simplification of a complex subject, but suffices to indicate the principles involved. To summarise, link trunking may be defined as a method of connection satisfying the following conditions:-

(i) A split or partial stage arrangement between inlets and outlets.

(ii) An interconnecting arrangement whereby the link or links are seized at the same time as the chosen outlet.

(iii) Only those links which connect to the chosen outlet are seized. (Conditional selection.)

In this definition, condition (i) implies that the switches must be grouped into at least two partial stages in order to form a link system. Condition (ii) makes clear the difference between a link system and tandem-operated switching stages, whilst condition (iii) specifies the rules by which a connection may be established between an inlet and an outlet. If, however, a condition exists which does not satisfy the three link requirements, whether due to absence of a free link between the inlet and outlet, or of a free outlet, then connection cannot be established. A state of congestion is said to exist.

In group selector stages where it is merely required that a call should be connected to any free trunk, link connection between two partial stages is sufficient, as in Fig. 13, which shows a standard arrangement used in crossbar exchanges.

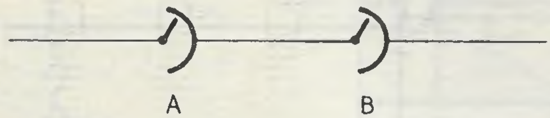


FIG. 13. GROUP SELECTOR (GV) STAGE CONNECTION.

However, when it becomes necessary to connect the call to a particular outlet, such as a particular subscriber's line, selection over four partial stages is adopted. The subscriber's line stage is a good example of this principle. Originating calls need only an inlet to the exchange and two partial stages are sufficient. However, for terminating traffic where a particular line is required, four partial stages are used. See Fig. 14.

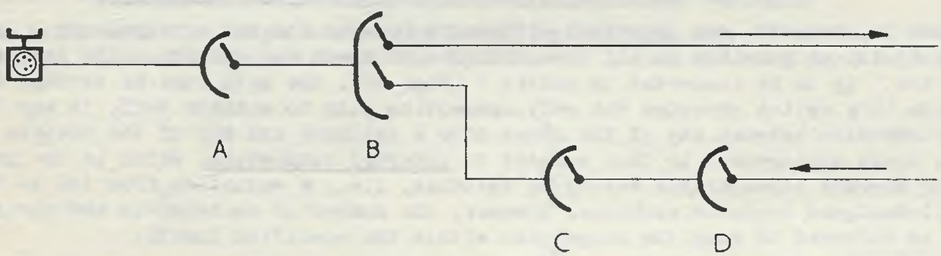


FIG. 14. SUBSCRIBER'S LINE (SL) STAGE CONNECTION.

The internal congestion for originating traffic can be kept low even though the connection consists only of the A and B stages, since there are paths to a large number of B switches through all the devices in the A stage over which the calling subscriber's line is multipled. If the terminating traffic is connected only through A and B, conditions are poor (from each B switch in Fig. 14 connection can only be made to a particular line through a single A switch). To limit the internal congestion, one or two secondary stages are usually incorporated (C and D in Fig. 14) in tandem for the incoming traffic. Consequently, all devices having access to the wanted subscriber's line can be reached by many different paths, and satisfactory conditions are obtained.

3.4 Basic Exchange Trunking. The prime function of a telephone exchange is to establish connection between two telephone lines - e.g., two subscribers' lines, two junctions or a subscriber's line and a junction - and an examination of the passage of a call from one subscriber to another connected to the same exchange will illustrate the basic trunking requirements of such an exchange.

(i) Comparison of Basic Control Methods.

(a) Step-by-Step. With step-by-step exchanges, the establishment of a call is directly controlled from the originating telephone; that is, each digit dialled progresses the call one switching stage "step-by-step". Thus the number of switching stages is directly related to the number of digits comprising the number dialled; for example, in a five-digit numbering system, three group selector stages are provided to narrow the selection to the final stage of 100 subscribers' lines. The last two digits cause the final selector stage to select the required number. The basic step-by-step trunking arrangement is shown in Fig. 15.

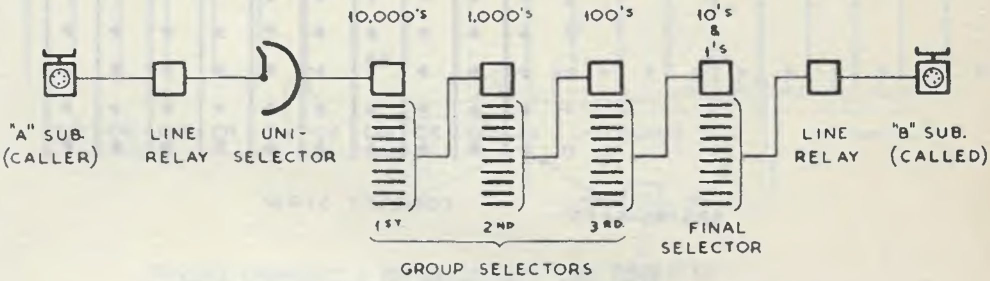


FIG. 15. STEP-BY-STEP TRUNKING.

In this diagram, each telephone connects to its individual uniselector which, upon the calling ("A") subscriber lifting his receiver, finds an outlet connecting to a free first group selector. The dialling of a digit causes the group selector to step vertically to the contact level dialled. The bi-motional switch then searches around the contact arc for a free outlet to the next group selector, which similarly responds to the next digit dialled, and so on for succeeding group selector stages. The final selector steps to the level corresponding to the "10's" digit dialled by the caller, final connection to the wanted or ("B") subscriber being obtained by the rotation of the switch wiper to the particular contact determined by the "units" digit.

(b) Common Control. In crossbar exchanges, a caller is first connected to a "register" which receives all of the digits dialled and, after examination of this information, determines the route required and initiates the switching action for completion of the call. In addition to the register, "marker" equipment is employed to set the various switching stages and perform other functions. The registers and markers provide the "common control" feature of crossbar and the function of these particular items of exchange equipment is described in Section 4. It will be noted, however, that the crossbar system employing common control provides a more flexible method of trunking than the rigid step-by-step method.

(ii) A Simple 100-Line Crossbar Exchange. Although a 100-line exchange is not standard, an understanding of such an exchange will illustrate the principles involved in small rural type crossbar exchanges and will assist in the understanding of the larger types. The particular features of the various types of crossbar exchanges are described in more detail in Section 6.

A crossbar switch comprising 10 verticals and five horizontal bars will contain 100 sets of contact springs. One hundred subscribers' lines may be connected to such a switch, as shown in Fig. 16 one line being connected to each set of individual springsets. To simplify the diagram, only one contact strip is shown for each vertical and each contact shown, therefore, represents a complete springset.

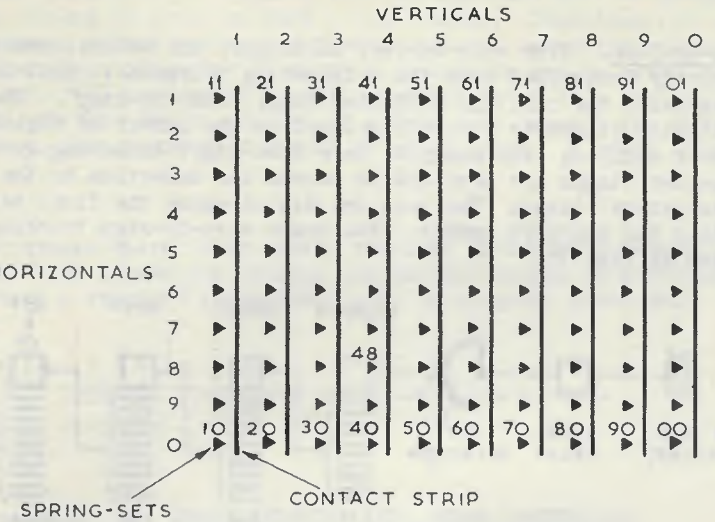


FIG. 16. 100 LINES ON A CROSSBAR SWITCH.

It will be seen that each vertical represents the "tens" digit of the subscriber's number, while the horizontals represent the "units" digit. For example, subscriber No.48 is connected to the eighth springset of the fourth vertical. Operation of the eighth horizontal and fourth vertical magnets would connect subscriber No.48 to the fourth vertical. Similarly, any other line could be connected to its particular vertical. The switching stage to which subscribers' lines are connected in this manner is termed the SL-A stage.

To enable two subscribers to be connected together, another switching stage, SL-B, is introduced. This consists of another crossbar switch in which the springsets in each horizontal row are multipled together, i.e., the contacts on SL-B vertical 1 connect to the corresponding contacts on each of the other verticals. This is known as horizontal multipling and is illustrated in Fig. 17.

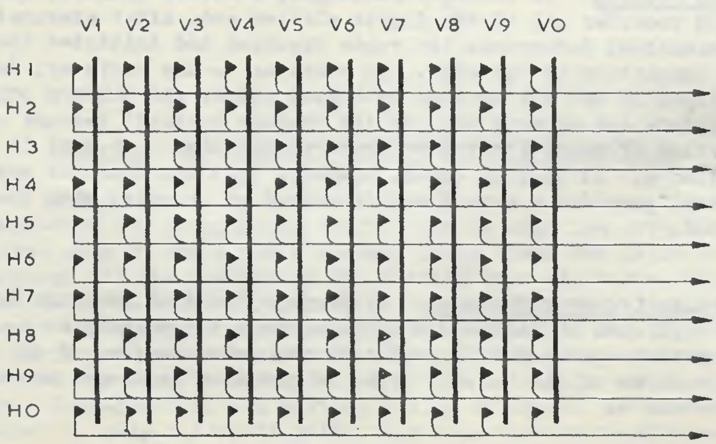


FIG. 17. MULTIPLE CONNECTIONS ON SL-B VERTICALS.

Each vertical contact strip in the SL-A switch is connected to a horizontal row in the SL-B switch, i.e., SL-A Vertical No.1 connects to SL-B Horizontal No.1; SL-A Vertical 2 to SL-B Horizontal 2, and so on as shown in Fig. 18.

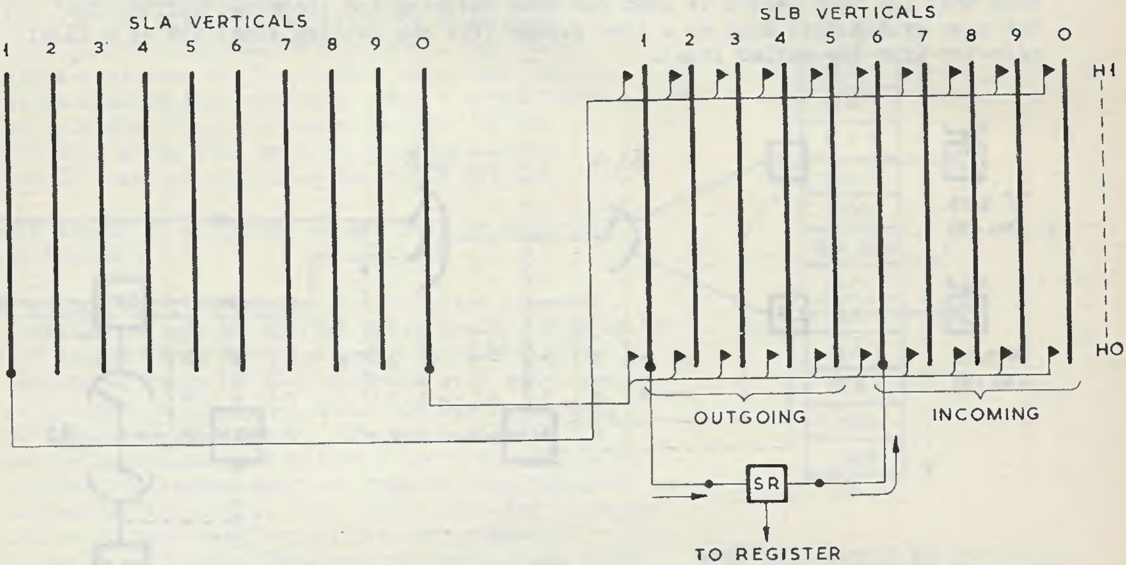


FIG. 18. CONNECTION BETWEEN SL-A AND SL-B.

Using the example of subscriber No.48, the operation of the springset would connect the line to the fourth SL-A vertical and, as this connects to the fourth SL-B horizontal, subscriber No.48 is now connected to the SL-B stage and can be reached from SL-B verticals. Similarly, another subscriber (say, No.14) could be connected via SL-A vertical 1 to SL-B horizontal 1 and could be reached from any SL-B vertical.

Assume that a call is to be made from No.14 to No.48.

When subscriber No.14 lifts his receiver, this causes the operation of the individual line relay (LR) from which a signal is sent to the SL stage marker (SLM). The marker identifies the calling line and, at the same time, finds a free "outgoing" switching path (a vertical) in the SL-B switch. It will be noted that the SL-B verticals are divided into "outgoing" and "incoming" and that one of each connects to an SR relay set. The SR relay set, in turn, is connected to a free register by means of register-finder switches (RS) which are controlled by a "register-finder marker" (RSM).

The SL marker then causes the necessary magnets to operate in the SL-A and SL-B crossbar switches to connect the caller to the selected relay set (SR) and register (Reg.). The SL marker is used only during the setting period and releases as soon as the connection is made and the "A" subscriber receives dial tone from the register. The caller (No.14) dials the wanted number (48) which is stored in the register.

The register now signals the SL marker and passes on the digital information by means of special high speed code (see Section 5 - Signalling). When the marker receives this information, it tests the line of the called subscriber and, if it is free, causes the operation of the necessary magnets in the SL-A and SL-B switches to connect the SR relay set, via its associated "incoming" SL-B vertical, to the called number. The marker and register release while the SR relay set sends ringing current to the "B" subscriber and ringing tone to the "A" subscriber. When the "B" subscriber answers, ring and ring-tone disconnect and the two subscribers are connected together via the SR relay set, which also provides for metering to take place.

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

Fig. 19 shows a trunking diagram for such a 100-line exchange from which it will be seen that the SL-A switch is used for both outgoing and incoming traffic, that is, the same switch acts both as a line finder (for the calling line) and as a final selector (for the called line).

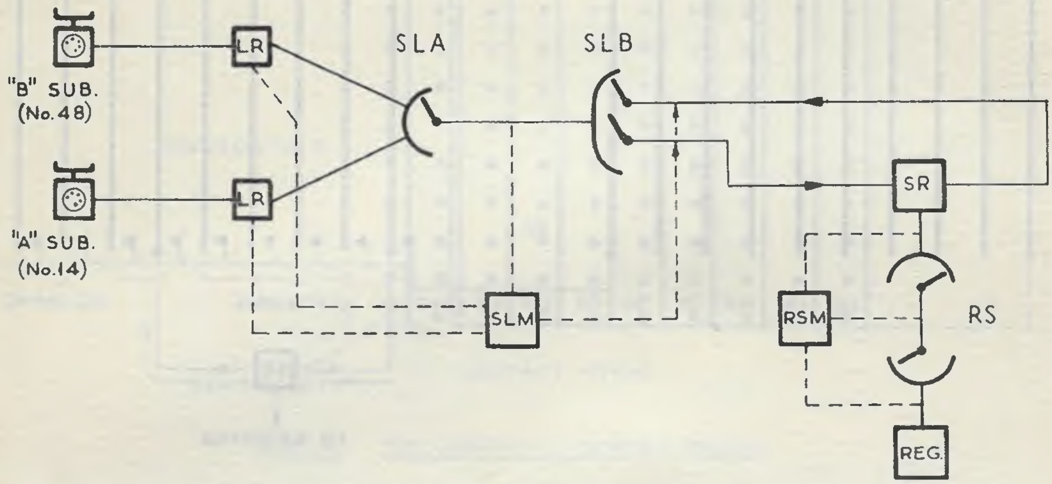


FIG. 19. TRUNKING DIAGRAM FOR 100-LINE EXCHANGE.

(iii) Multiple Connection of Subscribers' Lines. If only one SL-A switch was provided, only one subscriber out of the ten connected to each vertical could make or receive a call at any one time. To overcome this, several SL-A switches are provided (the number depending on the traffic to be carried) and the subscribers' lines multipled over identical springsets in each of these switches (vertical multipling).

(iv) Extension to 200 Lines. Reference to Section 2 (Fig. 3) shows that a crossbar switch may be increased in capacity to 200 lines by means of additional springsets and a sixth horizontal bar. The use of such a 200-line switch would therefore enable a 200-line exchange to be built up in the same manner. As before several 200-line crossbar switches are required in multiple to adequately cater for the traffic to and from 200 subscribers. If such a group of switches is mounted one above the other in an equipment rack, the multipling between the verticals of the switches is actually in the vertical direction.

In practice, equipment racks are built to accommodate a total of 10 crossbar switches, the most usual arrangement being six SL-A and three SL-B switches or eight SL-A and two SL-B. It is of interest to note here that the number of SL-A switches per 200 lines (or the number of verticals per 20 lines) is known as the "m" number - hence the traffic capacity of an exchange is often referred to as m = 6; m = 8 or even m = 10 for particularly busy exchanges.

The SL-A switches are designated 1-6 (or 1-8, etc.), the odd-numbered switches being located in the upper portion of the rack and the even numbers in the lower. It was mentioned in the description of the hypothetical 100-line exchange that the "tens" digit indicated the verticals of the switch while the "units" indicated the horizontal springset of that vertical, e.g., a subscriber's number ending in 48 would be connected to the eighth springset of the fourth vertical.

This method of terminating the line is adopted in the odd-numbered switches but, in the lower half of the rack, the multiple is transposed so that on all even-numbered switches, the "tens" digit indicates the horizontal while the "units" digit denotes the vertical. This transposition ensures that high calling rate lines in the 200-line group will be distributed much more evenly over the available switching devices.

The layout of a typical SL-A/B rack is depicted in Fig. 20.

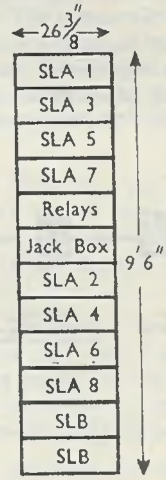


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FIG. 20. LAYOUT OF AN SL-A/B RACK (M = 8).

(v) Extension to 1,000 Lines. A 1,000-line crossbar exchange is made up of five basic groups, each of 200 lines. Each 200-line group is connected to individual racks of SL-A switches with which are associated the required number of SL-B switches, as described previously. The two partial switching stages SL-A and SL-B are not sufficient, however, to ensure adequate freedom from internal congestion (see Para. 3.3) in a 1,000-line exchange and it is necessary to add two more stages of crossbar switches. These are designated the SL-C and SL-D stages.

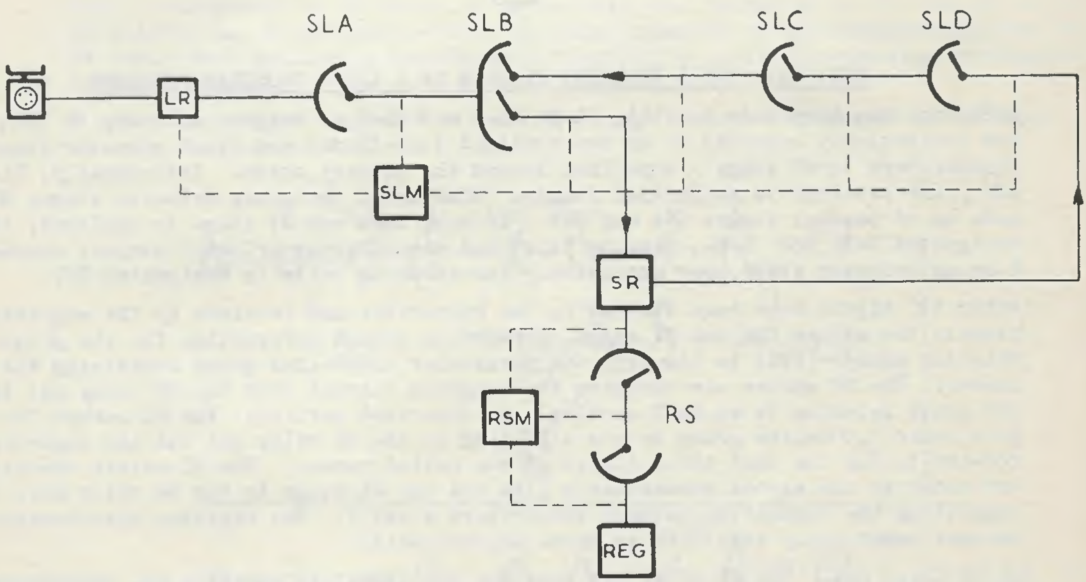


FIG. 21. TRUNKING DIAGRAM OF 1,000-LINE EXCHANGE.

It will be noted from Fig. 21 that the SL marker also serves the SL-C and SL-D stages and that the SL-C and SL-D stages are used only for incoming calls. A call through the exchange follows the same procedure as before, the SL marker this time, after connecting the caller to the register, releases and, upon receipt of the further signal from the register, causes the operation of the necessary magnets to complete a path from the selected SR relay set through stages SL-D, SL-C, SL-B and SL-A to the called number. The outgoing circuit from the SR relay set is, of course, permanently connected to a vertical of SL-D.

(vi) Extension beyond 1,000 Lines. If the exchange has more than 1,000 lines, or is part of a network with a capacity of more than 1,000 lines, it is necessary to add one or more group selector (GV) stages. However, it is not necessary to add a switching stage for every extra digit dialled as is the case with step-by-step systems. The reason for this is explained in Section 4 dealing with common control equipment. A typical basic trunking diagram is shown in Fig. 22, and it will be noted that a separate marker is provided for the group selector switches GVA and GVB.

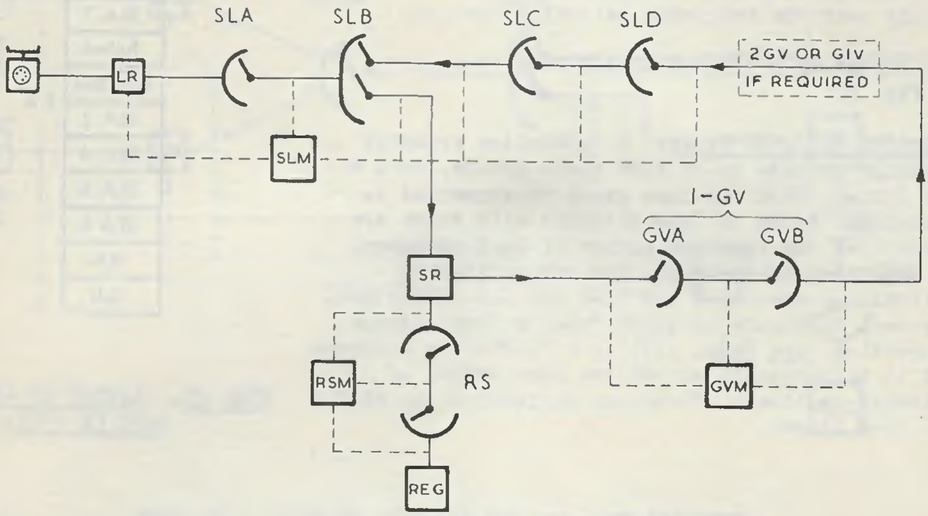


FIG. 22. BASIC TRUNKING DIAGRAM OF A LARGE CROSSBAR EXCHANGE.

Reference has been made to SL-A, SL-B, SL-C and SL-D as stages, whereas, in fact, they are collectively referred to as one combined line-finder and final selector stage, or the "subscribers line" stage - sometimes termed the primary stage. Individually, SL-A, SL-B, etc., are referred to as partial stages. Similarly, the group selector stages GV are made up of partial stages GVA and GVB. If more than one GV stage is employed, they are designated 1-GV and 2-GV, meaning first and second group selector stages, respectively. A group selector stage used exclusively for incoming calls is designated GIV.

After all digits have been dialled by the subscriber and received by the register, it signals the marker for the GV stage, forwarding enough information for the group selector marker (GVM) to identify the particular 1,000-line group containing the wanted number. The GV marker now connects the outgoing circuit from the SR relay set through the group selector to an SL-D vertical, as described earlier. The SL marker for the particular 1,000-line group is now signalled by the SR relay set and the register sends forward to SLM the last three digits of the called number. The SL marker identifies and connects the wanted subscriber's line via the SL stage to the SR relay set, thus completing the connection between subscribers A and B. The register disconnects and becomes immediately available to serve another call.

(vii) The SR Relay Set. The SR relay set provides the essential speaking and supervisory conditions between the conversing parties and, because of the similarity to manual working, is often referred to as a "cord circuit". The function of the relay set is to -

KNOW

(a) Supply transmission battery to both subscribers' lines.
(b) Operate the meter of the calling subscriber on an effective call.
(c) Provide a holding path for the switching magnets in the SL and GV stages.
(d) Apply ringing current to the called subscriber's line and ring-tone to the caller.
(e) Disconnect ring and ring-tone when the called subscriber answers.
(f) Effect time-supervision of calls.

The foregoing applies to calls within the same exchange. For calls between different exchanges, some of the functions are performed by other relay sets which are described later.

* 3.5 Basic Network Trunking. The telephone system is a complex of individual exchanges linked together by means of junction and trunk lines. Exchanges are grouped to form local call networks and connection between local call networks is achieved by means of the trunk switching system. The interconnecting arrangements between the exchanges and networks are influenced by several factors and the mixture of crossbar and step-by-step systems produces particular problems of interworking between the two systems. The trunking arrangements will therefore vary according to circumstances and, in Section 7, the general interworking aspects are outlined.

For the purpose of describing the basic trunking in a crossbar network, the passage of a local call from one exchange to another in the same network will serve to illustrate the principles involved in the larger exchanges. Somewhat different arrangements are adopted in the smaller rural exchanges and reference is made to these in Section 6 (Types of L.M. Ericsson Crossbar Exchanges).

(i) Calls between Crossbar Exchanges in the same Local Call Network. As described in Para. 3.4, the register of the calling exchange receives all the digits dialled, whereupon the marker equipment of the group selector is signalled and, depending on the numbering of the desired exchange, connects the call to a free outlet in the corresponding junction route. The GV marker is immediately released.

At this point of reading, it is of interest to examine briefly the outlet arrangements available from the GV stage. As indicated earlier, the GV stage comprises two partial stages GV-A and GV-B, utilising 20-outlet crossbar switches, thus giving a total of 20 × 20, or 400, outlets per GV stage. In the bi-motional group selector, in addition to there being only 100 outlets available (200 in later types), the number of routes available to any one stage is limited to 10, with a maximum of 10 (or 20) outlets each, (i.e., levels 1-0). In the crossbar group selector, however, the 400 outlets may be arranged in several ways. The basic arrangement is 20 routes of 20 outlets, but routes of 5, 10, 20, 40 or even 60 outlets may be arranged within the total capacity of 400 outlets from any one GV unit, thus permitting considerable flexibility in interconnecting arrangements between exchanges.

A basic trunking arrangement between two large crossbar exchanges in the same network is shown in Fig. 23.

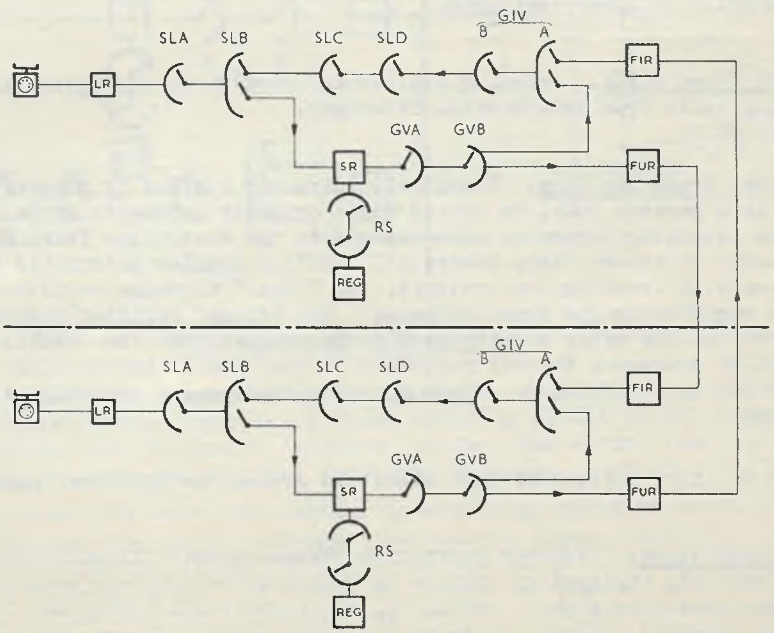


FIG. 23. BASIC TRUNKING FOR TWO CROSSBAR EXCHANGES.

Each outlet is connected to a junction via an outgoing relay set (FUR) in the originating exchange. At the terminating exchange, the junction is connected to an incoming relay set (FIR) and thence to a switch inlet. On connection of the junction, relay set FIR signals the marker equipment of the incoming group selector stage (GIV) in the called exchange and the register of the calling exchange sends to this equipment sufficient digital information to identify the desired 1,000 group. The marker connects the call through the incoming group selector stage, after which it releases. The connection in the called exchange progresses through the SL stage in the normal way but is guided all the time by the register at the originating exchange.

(ii) FIR and FUR Relay Sets. For a call entirely within the same exchange, as described in Para.3.4, the SR relay set provides the essential speaking and supervisory conditions. Where a call is made to another exchange, certain of these functions are performed by the FIR relay set at the incoming exchange, as follows:-

KNOW

(a) Applies transmission battery to the called subscriber's line.

(b) Applies ring current to the called subscriber's line and returns ring-tone to the calling exchange.

(c) Disconnects ring and ring-tone when the called subscriber answers.

(d) Provides a holding path for magnets in the incoming GV and SL stages.

The FUR (outgoing) relay set at the originating exchange provides the necessary repeater function on junction circuits and includes facilities for the guarding of the seizure and release of junctions.

(iii) Interworking with other Types of Exchanges. In general terms, crossbar exchanges can interwork with any other type of exchange equipment, both manual and automatic, by suitable modification of the registers and the SR and junction relay sets.

(iv) Calls to Special Services. Calls to special services' positions are routed in the same way as calls to other exchanges.

(v) Incoming Trunk Calls. Incoming dialled-in trunk calls are routed in the same way as incoming calls from interworking exchanges.

(vi) Subscriber Trunk Dialling. Trunk calls directly dialled by subscribers to other networks will, as a general rule, be routed via a crossbar automatic trunk exchange classified as a trunk switching centre in accordance with the Australian Trunk Switching Plan (reference "Community Telephone Plan, Australia, 1960"). Similar principles to those for intra-network trunking are employed, the "local" exchange register working in conjunction with a register in the trunk exchange. The "trunk" register determines the route required and the meter pulsing rate to be applied. As the establishment of the connection proceeds, further registers at the transit and terminal trunk exchanges are called in, as required, to effect specific routing and switching within the particular exchange.

A more detailed outline of this aspect is covered in the later papers.

(vii) Alternate Routing. Register controlled systems permit alternate routing techniques to be effectively employed to achieve increased efficiency and economies in exchange equipment and line plant. Basically, alternate routing provides for traffic to be offered first to a direct route to the destination exchange and for the overflow to be carried on other subsequent-choice routes via switching centres. Fundamentally, alternate routing takes advantage of the axiom that larger groups of circuits carry traffic more efficiently than small groups.

Single direct routes require a comparatively large number of circuits in order to cater for the random traffic peaks which occur. With alternate routing, however, the direct route may by purposely under-provided (thereby increasing its occupancy) and the traffic peaks, which represent a relatively small proportion of the traffic, allowed to pass via the second or later choice route. The sporadic traffic load peaks of several direct routes may be combined and carried on common overflow routes via traffic grouping centres, or switching points, generally referred to as "tandem" exchanges. The basic principle is to provide circuits on the direct route until a point is reached where it is cheaper to carry traffic via the overflow route. The final-choice route is actually the main or "backbone" route of a switching system and, as such routes carry traffic comprising a large number of small traffic peaks which, when combined, form a relatively constant traffic load, high efficiency of usage is achieved.

In Fig. 24, a simplified alternate routing pattern and its trunking diagram equivalent are shown. The direct route from Exchange A to Exchange B is designated 1 and the second-choice route via Exchange C is designated 2.

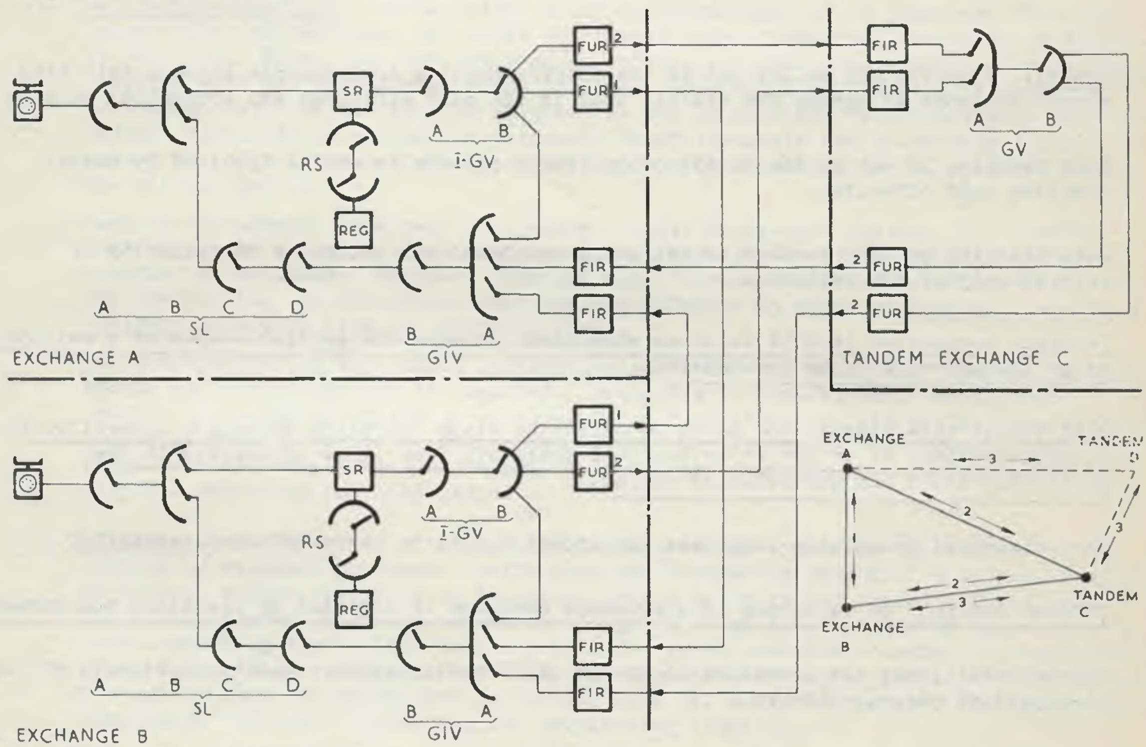


FIG. 24. ALTERNATE ROUTING.

In the crossbar equipment being adopted by the Australian Post Office, provision is made for a maximum of three choices, that is, a first-choice or direct route, a second-choice switched route and the final-choice or "backbone" route. The dotted line in Fig. 24 indicates the third or final-choice route via tandem Exchanges D and C.

From the diagram, it will be seen that savings in switching equipment result from the direct routes by-passing the tandem exchange. Savings are also achieved in line plant costs since the cables for the direct routes can be shorter and, in many cases, of lighter gauge than those carrying traffic via the tandem exchanges. Alternate routing in the trunk network follows the same principle and, whilst the advantages are similar, the emphasis is different. Whereas in a local network the major savings derive from economies in equipment rather than in line plant, in the trunk network the position is reversed, due primarily to the greater length and higher cost of trunk lines as compared to junctions.

In addition to the advantages of greater efficiency and economy, alternate routing provides additional security of communications. Where alternate routes are provided, breakdowns in the junction or trunk network do not necessarily mean isolation of exchanges or extreme congestion since the traffic is automatically routed another way. This feature is of particular importance in the trunk network because of its greater vulnerability.

Alternate routing involves additional switching and testing time and, consequently, the post-dialling delay (see Section 8) is increased. However, the high-speed operation of the crossbar system enables a considerable degree of alternate routing to be employed within the tolerable post-dialling delay limits.

The development of an effective alternate routing system demands careful design and planning of the system as a whole. Moreover, the traffic on the various routes must be watched carefully and action taken in sufficient time to ensure that excessive overflow from one route does not cause congestion on other routes.

3.6 Summary. Trunking may be defined as the interconnecting arrangements between switching stages designed to handle the traffic load in the most efficient and economical manner.

Link trunking is one of the oldest of telephony principles and is typified by manual position cord circuits.

Link trunking permits savings in switching equipment and increases the capacity or availability of the switches.

Internal congestion is said to occur when links between the partial stages of a switching stage are unavailable or inaccessible.

Conditional selection is the means of switching stage operation whereby a connection is established only if an outlet is free and there are free links accessible to the particular inlet and the selected outlet.

The seizure of connecting links and the chosen outlet is performed simultaneously.

"Common Control" of switching in a crossbar exchange is effected by registers and markers.

Subscribers' lines are connected in groups of 20 multipled over several verticals of the SL-A partial stage. ARF102

The number of verticals per 20 subscribers is known as the "m" number (e.g., m = 8, m = 6) and indicates the designed traffic capacity of an exchange.

Group selector stages (GV) may be arranged to cater for both large and small circuit groups.

Interworking with all other types of exchanges is practicable.

Provision is made for alternate routing over a maximum of three choices.

Alternate routing may be employed in both local and trunk networks.

High-speed operation of crossbar equipment permits considerable use of alternate routing principles.

4. COMMON CONTROL EQUIPMENT.

4.1 Introduction. In any automatic telephone system, several switches are required for the establishment of a speaking path between any two points. Once a switch is set, it remains so during the conversation, the devices for controlling the setting of the switches being relatively complex and used only during the setting up or clearing of a call. It has been found that the combination of the controlling devices into special units dissociated from the switches but with common access only when required, not only permits economies to be effected but also enables simplications of the switching equipment. This form of common control is fundamental to the crossbar system adopted by the Australian Post Office and this paper outlines the basic purpose and operation of the common control equipment.

The centralisation of the "intelligence" of the system is closely analagous to the operation of a manual system and readers will find it helpful to compare the common control equipment function with the mode of operation of the manual Telephonist.

4.2 The By-Path Principle. In automatic telephone exchanges, it is important that the large number of switches, and their associated control devices, should be as simple as possible. Since the time occupied in setting the individual switch is very short compared with the time during which it is occupied by calls, the most economical arrangement will be to free the switches as far as possible from individual setting devices which are in action for extremely brief intervals and to provide a small number of control devices which can be temporarily connected to the switches during the setting period.

Such an arrangement is known as a common control or by-path system. By "common control" it is meant that the setting of switches is controlled by units common to a number of switches. However, they are also "by-path" controlled in the sense that the controlling and directing functions are effected by means of by-path circuits entirely separated from the speaking path.

The holding time of the common control equipment is very short and thus only a small number of control devices is required. Being few in number, their design can incorporate extremely reliable elements and all desirable safety precautions without adding materially to the overall cost. Since the switches in the speech circuits are freed from all complicated mechanism, they can be of simple construction and with reliable operating characteristics.

4.3 The Marker. Fundamental to the L.M. Ericsson crossbar system is the control of the setting of switches by common control equipment known as markers. A marker consists of several relays operating in stages or groups to carry out specific functions. The actual number of relays per marker is quite large but, because of the extremely short operating time - less than one second - it is possible to serve a large number of switches from a single marker. In the large crossbar local exchanges, two markers per 1,000 lines are sufficient to set the SL-A, B, C and D stages of the subscribers' line stage for both originating and terminating traffic.

The marker is designed to operate on a delay basis, that is, if a particular marker is busy, an incoming call must wait until the marker is free. The waiting time is of very short duration, however, and causes little, if any, inconvenience to the subscriber. Because of the small number of markers installed, they can be designed for maximum reliability which, although increasing their cost, does not make them uneconomical. A number of guard circuits are incorporated to overcome the possibility of the marker being held by faulty equipment or a fault condition.

Types of Markers. Three types of marker are used in crossbar local (ARF) exchanges. These are:-

(i) The SLM or subscriber's line stage marker.

(ii) The GVM or group selector marker.

(iii) The RSM or register finder marker.

(Other types of markers are used in crossbar trunk exchanges and reference to these is made in Section 6.)

The functions of the SL and the GV markers are similar in that they are required to:-

- Identify the calling line.

- Receive information about the routing of a call.

- Determine the route or line desired.

- Test the called line or test and select an idle junction.

- Connect the calling line to the called line or to the selected idle junction.

The register finder marker (RSM) follows the same principles but has a much simpler task to perform in that it is required only to identify an SR relay set, select a free register and establish connection between the two.

Operation of Markers. A description of the marker operation for an outgoing call from a subscriber's line will illustrate the basic principles of the marker equipment in crossbar local exchanges and, for this purpose, a block schematic diagram for a typical SL marker and RS marker is shown in Fig. 25.

(i) Outgoing Call from Subscriber. When the calling subscriber lifts his handset, the line relay LR/BR operates and signals to the call indicator (AG) of the 200-line group in which the caller is located. The call indicator then calls in one of the two SLM's associated with the 1,000-line group involved.

The two identifiers are now brought into use, the first (1AN) to identify which 200-line group has seized the SLM, followed by the second (A, B) which identifies the particular subscriber in the 200-line group.

The information is now transferred to the digit store where there are three sets of relays (S, D, U) which record respectively the 200 group, the 10's digit and the units digit. The digit store relays control the operation of the connecting relays (also called D and U and located on the particular SLA/B rack) which connect testing leads from the SLA verticals to the test relays (1F) to indicate which are free. Once the idle SLA verticals have been indicated, one of them is now selected by relay FV on condition that it has a free path through to a free register. Connecting relays FG operate, the SLB verticals are tested and one selected by relay G, thus choosing the SR relay set. The register finder marker (RSM) is called by relay G and the RSM (relays A, B) identifies the SR relay set. A group of five registers, which contains a free one, is chosen by relay R and the T relays select a particular register in the group. The register finder (RS) now connects the chosen register to the SR relay set.

The RSM and SLM restore and the calling telephone is now connected to the register which returns dial tone to the caller and is ready to receive digital information.

The entire operation takes about half a second, that is from the moment of lifting the handset and the receipt of dial tone. There are some 500 relays in the SL marker and a large number of circuits is extended to the various components of an exchange, for example, 30 are required for line identification.

Although seemingly complicated, the analogy with manual operation is quite obvious, that is call indicated, line identified, cord circuit selected and plugged into line jack, thus connecting the Telephonist ready to receive information from the subscriber. In such an analogy, "number please" is equivalent to dial tone.

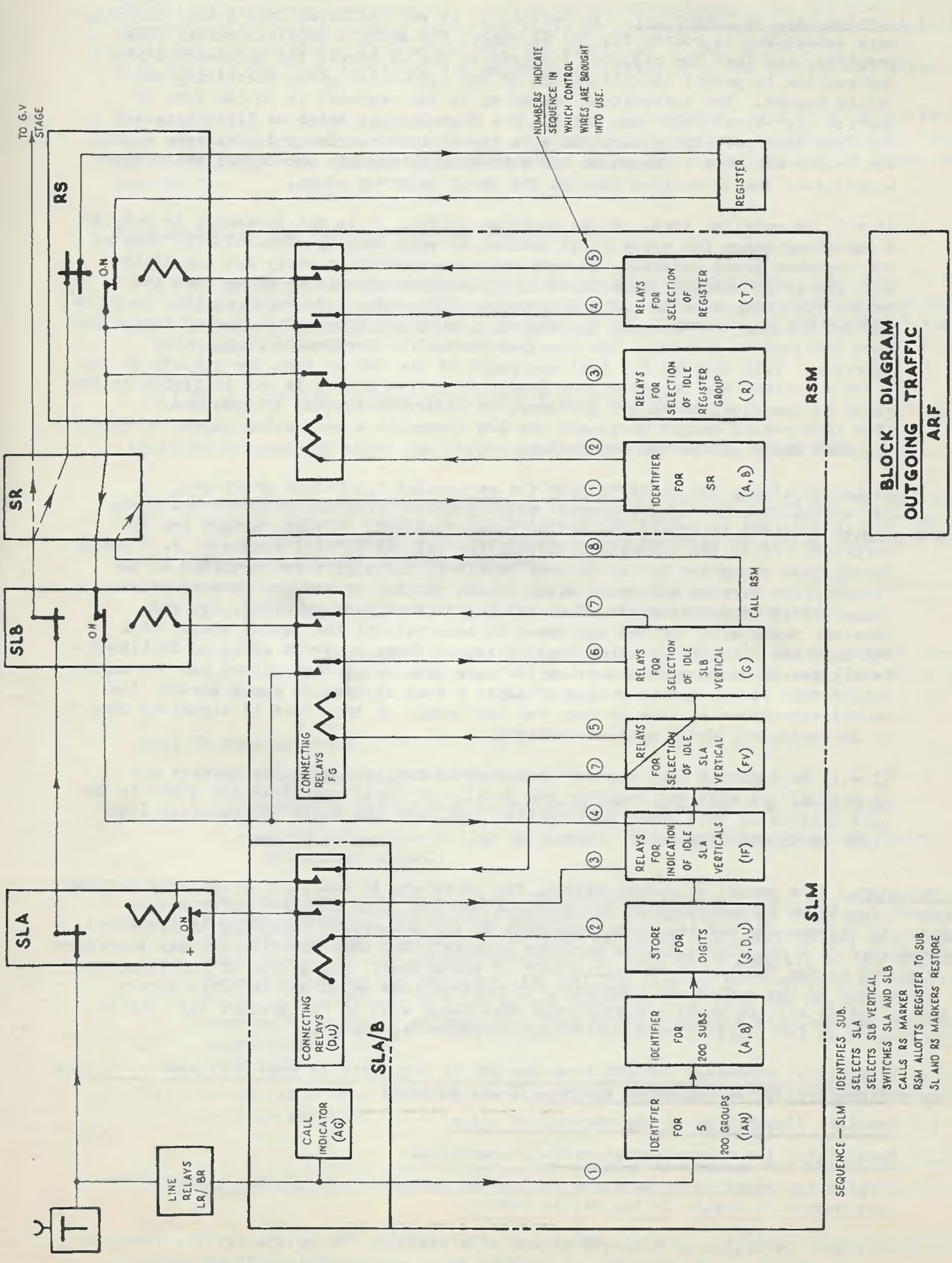

BLOCK DIAGRAM
OUTGOING TRAFFIC
ARF
TO G.V STAGE
NUMBERS INDICATE SEQUENCE IN WHICH CONTROL WIRES ARE BROUGHT INTO USE.
RS
SR
SLB
SLA
ON
REGISTER
LINE RELAYS LR/BR
CALL INDICATOR (AG)
CONNECTING RELAYS (D,U)
CONNECTING RELAYS FG
SLA/B
RSM
SLM
IDENTIFIER FOR SR (A,B)
RELAYS FOR SELECTION OF IDLE REGISTER GROUP (R)
RELAYS FOR SELECTION OF REGISTER (T)
IDENTIFIER FOR 5 200 GROUPS (IAN)
IDENTIFIER FOR 200 SUBS. (A,B)
STORE FOR DIGITS (S,D,U)
RELAYS FOR INDICATION OF IDLE SLA VERTICALS (IF)
RELAYS FOR SELECTION OF IDLE SLA VERTICAL (FV)
RELAYS FOR SELECTION OF IDLE SLB VERTICAL (G)
CALL RSM
SEQUENCE — SLM IDENTIFIES SUB.
SELECTS SLA
SELECTS SLB VERTICAL
SWITCHES SLA AND SLB
CALLS RS MARKER
RSM ALLOTTS REGISTER TO SUB
SL AND RS MARKERS RESTORE

FIG. 25.

(ii) Incoming Call to Subscriber. In Section 3, it was indicated that a call incoming to a subscriber is routed via the GV stage, for which a separate marker (GVM) is provided, and that the register forwards to the GV marker the necessary digital information to permit identification of the 1,000-line group containing the called number. The information passed on by the register is in the form of special high-speed code (see Section 5 - Signalling), which is first received in the Code Receiver (KM) associated with the GV marker. The code receiver stores and interprets this information and subsequently engages the marker which then establishes the connection through the group selector stage.

It will be recalled that, in the crossbar system, it is not necessary to provide a switching stage for every digit dialled as with step-by-step. In the case of the crossbar group selector, on each call the identifier relay set associated with the group selector rack identifies the particular inlet being used and causes its connection to the code receiver (KM). The code receiver then receives digital information from the register and, when a sufficient number of digits has been received to determine the required route, the particular route relay operates. This enables the test equipment of the GVM to test the outlets of the route concerned and select a free line. If a free outlet is not available in the route in question, tests are performed on alternate routes, if provided. If a free outlet cannot be found, the GVM transmits a congestion signal to the register which clears the connection.

In the SL stage, the SL marker for the particular 1,000-line group has associated code receiver equipment which receives from the register the three digits required to locate the called subscriber and, in turn, causes the SL marker to effect the connection through the four SL partial stages A, B, C and D. During code reception by the SL code receiver, the digits are repeated to the interception service equipment which checks whether or not the subscriber is connected to "interception". When all digits have been received, the code receiver tests with the PBX equipment to ascertain if the called number is a PBX service. (A more detailed description of these tests is given in Section 8 - Facilities.) An SL marker serving the code receiver is now called and the digits transferred to the number relays of SLM. A test is made to check whether the wanted subscriber is idle or busy and the result of this test is signalled back to the register, which acts accordingly.

It will be apparent that the code receivers associated with the markers are closely allied with the register and details of their operation are given in the next section of this paper dealing with registers and their interworking with other switching stages.

4.4 The Register. In a manual telephone system, the operator, in addition to carrying out the "marker" functions as described in the previous section, also receives information, interprets its meaning and then acts according to the prescribed operating instructions. The register in a crossbar exchange performs precisely the same function and may therefore be regarded as the "brain" or "intelligence" of the system. The degree of intelligence is determined by the number and complexity of instructions which may be built into a register and it will be readily appreciated that these will be far greater than can be incorporated in the simple direct-controlled step-by-step system.

The most important advantage derived from the use of registers is that they enable routing to be independent of the numbering scheme. This, in turn:-

(i) Provides flexibility in the routing of calls.

(ii) Facilitates the allocation of exchange numbering.

(iii) Permits equipment to be provided on traffic considerations alone, irrespective of the number of digits in the called number.

More intelligent switching is achieved by use of a register due to its ability to store the digital information received until it has examined enough of the called number to determine the best route to use and initiate switching processes accordingly.

Functions of the Register. In different switching systems using registers, the functions of the register vary considerably. In L.M. Ericsson equipment, the register functions are comparatively limited as many so-called register operations are performed by the code receivers and markers. This means that the operation of the register is closely linked with that of the code receivers and markers associated with the various switching stages.

The signalling between the registers and the various crossbar switching stages with which they must work (including the transfer of digital information) is performed by means of a multi-frequency code system which is referred to as MFC signalling and is described in Section 5.

Fundamentally, the functions of the register are:-

(i) To recognise the classification of the calling subscriber's line, e.g., P.T.; barred access to subscriber trunk dialling circuits; temporarily disconnected, etc.. (For complete details concerning classification of subscribers' lines, refer to Section 8 - Facilities.)

(ii) To provide the calling subscriber with dial tone.

(iii) To receive and store the digits dialled by the calling subscriber.

(iv) To inter-work with the appropriate code receivers/markers to switch the call through various stages to the called subscriber. In the case of certain types of calls, inter-working with registers in intermediate switching exchanges and the distant exchange is also required.

(v) To release when the call is connected to the wanted subscriber.

(On the "B" subscriber's line being found to be free by the SL marker, the appropriate "end-of-selection" signal is sent back to the register which then releases - see Section 5 - Signalling.)

(vi) To release when:-

- congestion signal is received.
- excessive set-up time is encountered, including P.G. conditions.
- wanted subscriber's line is engaged (this is indicated by an "end-of-selection" signal).

(Before release in these cases, the register arranges for the release of all equipment back to the calling subscriber's line circuit. "Try again" tone is applied from the line circuit so that switching equipment is not held under these conditions. If the congestion signal is received before all of the digits have been received by the register, the calling line is not immediately connected to "line lock-out" (see Section 8) but receives tone from the register. In this way, continued impulsing is prevented from seizing another register and causing a wrong connection.)

(vii) On receipt of the interception signal, to re-route the call to the interception service position.

(viii) In a mixed crossbar and step-by-step system, to arrange for the correct form of signalling (i.e., MFC or 10 i.p.s.) to be sent to line.

(ix) To determine the correct time of its own release on calls to step-by-step exchanges where no "end-of-selection" signal is given as in (v) above.

Speedy release of the register after it has performed its functions is necessary, as any increase in register holding time will increase the number of registers required. The determination of when the register should release may be one or a combination of the following methods:-

- Receipt of an "end-of-selection" signal which, in general, is only provided from crossbar exchanges.
- On the receipt of an answer supervisory signal. In a step-by-step exchange this would be the reversal.
- By means of "time-out", i.e., if the register does not receive a full number within 45 seconds or, in certain cases, a further digit within 4 seconds.
- By code analysis and digit count. The initial digits are examined to determine the number length and the number of digits is counted.

Operation of the Register. The register is composed of a series of relays, including a crossbar switch which functions as the digit store, each received digit being stored on successive verticals. Reference was made to this use of the crossbar switch in Section 2. In the smaller exchanges, the digit store has only five verticals, that is, only five digits can be stored at any one time. To cater for numbers containing more than five digits, the cyclic storage principle is used whereby digits may be released at a rate sufficient to enable further digits to take their place in the store. The larger exchanges have 10-digit registers, provision being made for cyclic operation if required.

The basic components of a register are shown in the block schematic drawing in Fig. 26, which illustrates the inter-working arrangement between a register and the GV stage code receiver and marker. The numbers indicate the various operating sequences as follows:-

1. The classification of the calling subscriber ("A" Sub.) is received from the SL marker, e.g., P.T., barred access to subscriber trunk dialling circuits, temporarily disconnected, etc.. (See also Section 8.)
2. Dialled impulses received in the impulse receiver from the "A" subscriber.
3. Digits transferred to digit store as received.
4. When the register has enough digits to ensure that initial routing of the calls may proceed, it signals to the GV stage for connection to a code receiver. (Compare with Para. 4.3(ii) - Incoming Call to Subscriber.)
5. Identifier in code receiver (KM) identifies GVA inlet to which register is connected and operates appropriate connecting relays.
6. Code receiver advises register (by MFC) to send digits.
7. First digit of dialled number signalled to code receiver (by MFC).
8. Code receiver transfers digit to digit store.
9. Digit offered to route discriminator which attempts to determine route on which call is to be switched.
10. If information insufficient, route discriminator sends a progress signal to call for a further digit.
11. Operations 8-10 are continued until route discriminator has sufficient information to determine first-choice route. Appropriate route relay is operated.
12. Code receiver (KM) engages the marker (GVM) when it is spare. (Each marker serves two code receivers.)
13. All spare lines on the chosen route which are accessible from the identified GVA inlet are offered to the marker and the marker chooses one for connection.

14. The marker operates the appropriate GVA and GVB magnets to connect the identified GVA inlet via the chosen link to the chosen junction.

15. Should no spare circuit be offered to the marker, the marker informs the route discriminator so that the alternate route, if any, may be tested.

16. If there is an alternate route, operations 11-15 are repeated as necessary.

17. When the marker can switch the call (as in 14), it sends a proceed signal to the revertive signal sender.

18. If the alternate route has been chosen to switch the call, a signal is sent from the route relays to the revertive signal sender where the "proceed" signal from the marker is amended to a "re-start" signal. The appropriate signal is sent to the register from the revertive signal sender as in (6). In addition, depending on the route chosen to switch the call, a signal is sent to the register advising the form of signalling (M.F.C. or 10 i.p.s.) required to operate the next switching stage.

19. Should the marker find it impossible to make a connection, a congestion signal is sent from the marker to the register via revertive signal sender (as for 17).

20. As soon as the marker has signalled either "proceed" or "congestion", the code receiver and marker are released to be available to handle the set-up of other calls.

21. The whole process 4-20 above is repeated at each switching stage with the local register at the "A" subscriber exchange inter-working with each code receiver/marker in turn until connection is made to the "B" subscriber.

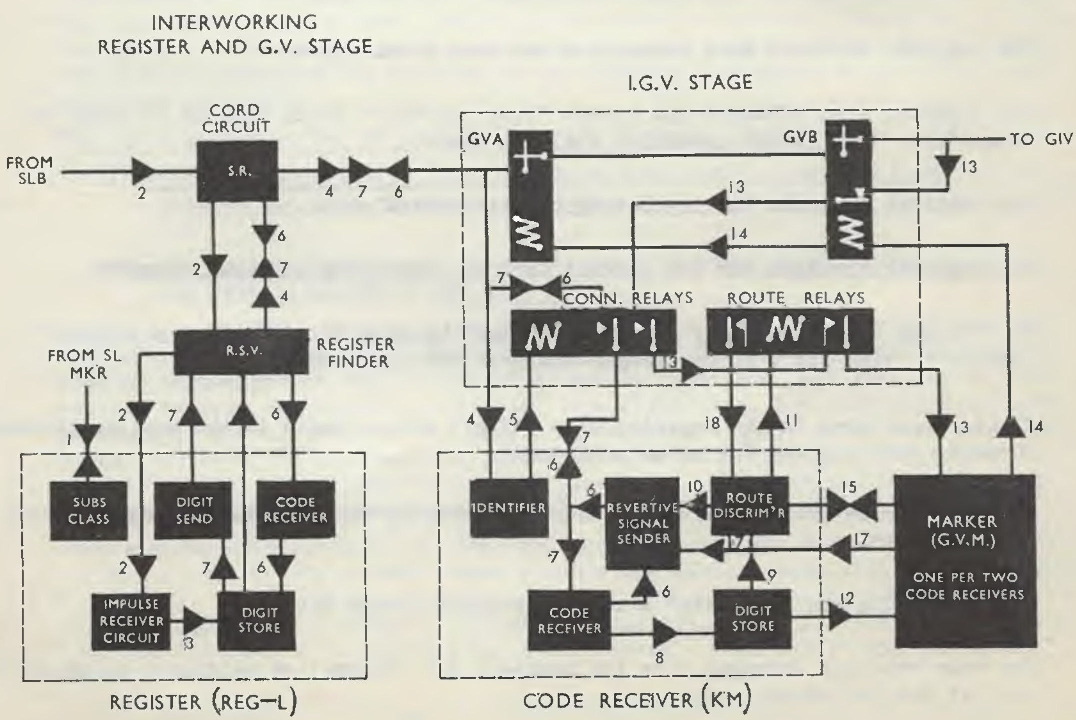


FIG. 26.

4.5 Summary. Common control systems utilise common equipment for the setting of switching stages, thus permitting simplification of the switching equipment.

The controlling and directing functions of this common equipment may be applied by means of a by-path separate from the speaking path.

Common control equipment comprises markers, registers and code receivers.

Markers are designed for maximum reliability.

The holding time of a marker is very short and two markers only are required for 1,000 subscribers' lines.

The marker operates on a delay basis, i.e., a call encountering the no-marker-available condition is held and is not lost.

Markers are provided for each switching stage.

The functions of the marker are to identify the source of a call, determine the routing and establish and through connection.

The register contains the "intelligence" of the system.

Register control enables routing to be independent of numbering.

The register receives and interprets the digital information received and passes on appropriate signals to the code receivers associated with the markers.

The register releases when connection has been established.

The register also releases and causes "line lock-out" to be applied in cases of congestion, WBY, PG and excessive dialling time.

The register controls the re-routing of intercepted calls.

The register arranges for the correct form of signalling in mixed networks.

The release of the register may be determined by receipt of "end-of-selection" signals - "time-out", number length analysis and digit count.

Digits are stored in the register on a 5-digit cyclic basis in the smaller exchanges - 10-digit cyclic store for larger exchanges.

The register inter-works with the code receivers by means of multi-frequency code (MFC) signals.

Code receivers are associated with the switching stage markers.

The code receiver receives from the register the information necessary to switch the call at the particular stage.

5. SIGNALLING.

5.1 Introduction. Signalling in a telephone system is the communication of instructions or information and the application of controls necessary for the establishment, maintenance and clearance of a connection between the two parties to a telephone conversation. The setting up of a call through an automatic telephone system requires an interchange of signals between the subscriber and the exchange and from point to point within the exchange. Similarly, connections between exchanges require an interworking signal system over the trunk and junction circuits between the exchanges. Certain signals convey instructions to the telephone switching medium whilst others perform supervisory or control functions, these being known respectively as "information" and "line" signals.

In this Section, the basic signalling requirements are outlined with particular reference to the multi-frequency code (MFC) system adopted for crossbar working. Methods of line signalling are surveyed briefly so that the reader may gain an appreciation of the subject as a whole.

5.2 Basic Requirements of a Signalling System. The broad requirements of a signalling system are to convey the instructions of the caller to the switching equipment so that the required connection may be established; to prevent other subscribers from intruding; to effect the charging for the call; and, finally, to disconnect the parties when required.

In the case of the magneto manual exchange system, these functions are achieved by the use of a ringing generator to call the attention of the operator, who ascertains the details of the wanted number, establishes the connection and, in turn, similarly calls the attention of the wanted party by ringing generator. Supervision by the operator guards against intrusion by other subscribers and the ring-off by the conversing parties signals the operator to effect disconnection and debit the charge for the call.

In an automatic system, the signals between a subscriber and the exchange comprise the "receiver-off" and "receiver-on" conditions, together with the digital information in the form of dialling pulses. These signals must be conveyed from point to point in the system, both within and between exchanges, and provision must therefore be made for the seizure, guarding and clearing of the various interconnecting circuits and junctions involved.

The various signals may be divided into two classes, namely:-

(i) Line (or Supervisory) Signals, which have controlling functions and are passed between the line relay set, switches, etc., connected to the speech circuit; and

(ii) Information Signals, which are passed from point to point as required to effect the establishment of the connection.

Separation of Line and Information Signalling. In the manual system, separate line and information signalling methods are employed. The operation of the generator to drop an indicator (or the looping of a line to light the call lamp in the case of central battery operation) constitutes line signalling, the signalling equipment being permanently associated with the line. Information signalling is represented by the verbal requests and instructions passed between subscriber and operator and between operators; the signalling "equipment" (i.e., the operator) not being directly associated with the speech path but making use of it only as required.

In a step-by-step automatic system, the necessity for the distribution of information throughout the system renders impracticable the dissociation of line and information signalling. With crossbar working, however, the use of the common control marker and register equipment is closely analogous to the principle of the manual system and so line and information signalling may be separated. This separation has several advantages:-

(i) The information equipment is only required for a short time on each call and can therefore be provided on a common basis, with resulting economies in provision.

(ii) The digital information is stored in the registers and these are connected only whilst the call is being routed. Therefore, the information signalling equipment can be associated with the registers.

(iii) Using common information signalling equipment, high speed code signalling can be employed over the normal speech path and independent of the type of circuit involved.

(iv) A line signalling relay set can be associated with each speech circuit, thus enabling a variety of types of trunk or junction links to be used between switching centres. These relay sets can be relatively simple since, ultimately, there will be no requirement for forward pulsing at 10 i.p.s..

(v). Finally, the use of information signalling equipment, separate from the line signalling relay sets, eliminates the necessity for voice immunity guards in the information signalling receivers, since speech cannot intrude when these are in use. This simplification removes one of the major difficulties encountered in the design of V.F. speech path signalling receivers and considerably reduces their costs.

Types of Signal Required. As with the manual system, line and information signals must be passed in both directions over a circuit; for example, the call or seize forward to a distant exchange and the receipt of an answer signal sent backwards from the distant end. Likewise, the passage of information signals back and forth between the registers, markers and code receivers in the crossbar automatic system corresponds to the similar interchange of operating phrases between Telephonists.

Line Signals used are:-

LIFT OFF
HANG UP

FORWARD	BACKWARD
Seizure	Answer
Clear Forward	Clear Back
	Release Guard
	Blocking

Information Signals vary according to the form of control used in an automatic system. For a system employing common control, the essential requirements are:-

FORWARD	BACKWARD
Digit Transfer	Sending Control
	End-of-Selection and Congestion

The purpose of the individual line and information signals is covered more fully in the succeeding sections of this paper, as also are the various methods which may be employed for their transmission.

5.3 Line Signalling. As indicated earlier in this paper, line signals are required in the forward direction for seizure and clear forward conditions, whilst in the reverse direction, answer, clear back, release guard and blocking signals are employed.

Purpose of Each Signal. The purpose of each of these basic signals is as follows:-

(i) Seizure Signal. The seizure signal is sent forward to the opposite end of the circuit, where it initiates operation of the apparatus.

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

(iii) Clear Back. This signal is returned to the outgoing exchange to indicate that the called party has cleared.

(iv) Clear Forward. At the completion of a call, when the calling party clears, the clear forward signal is sent from the outgoing end of the circuit to release the connection.

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

(vi) Blocking. The blocking signal, applied at any point in a circuit, prevents seizure at either end.

In addition to the above signals, provision must be made in some cases for the line signalling relay set to transmit S.T.D. meter pulses to a terminal exchange. These periodic pulses are transmitted from the S.T.D. charging equipment at the trunk exchange during the course of the conversation. Similarly, the provision of subscribers' private meters would also require facilities for the transmission of meter pulses from the exchange.

Types of Line Signalling Systems. Several different types of line signalling systems are currently in use throughout the Australian network. All of these are combined line and information systems but, in view of the special high-speed information signalling requirements for crossbar working (see Para. 5.5), the information signalling component of existing equipment will have little, if any, application under crossbar conditions. The crossbar information signals are within the normal voice-frequency band and may be passed over any circuit suitable for speech transmission, thus it may be practicable to utilise existing signalling equipment to fulfil the line signalling requirements of crossbar working.

Line signalling systems can be classified into two main groups, namely - "Outband" and "Speech Path (Inband)".

(i) 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 by:-

(a) Frequency difference, such as with DC loop signalling, and signalling on a carrier channel using a frequency outside the speech band; or

(b) By physical separation, where signalling and speech transmission are effected on two different circuits.

(ii) Speech Path Systems are those in which both the speech and the signals are passed over the same circuit and within the same frequency band. These have found their main application for operator trunk dialling over carrier channels, for example, the present 2VF system. Speech path systems are essential on carrier channels which do not have outband signalling facilities.

Line Signalling Methods. The method of line signalling used may vary according to the circuit over which the signals are passed and can be either DC, AC (low frequency) or VF. The principle characteristics and application of the various types of equipment in use in Australia are given in the following:-

(i) DC or Loop Signalling (Outband). With this method, the signals are passed by means of breaks in the flow of current in a loop circuit. This method is employed in the existing step-by-step system, as follows:-

Forward	Seizure	Loop
	Clear Forward	Break
Backward	Answer	Polarity reversal
	Clear Back	Break in loop
	Release Guard	Busy condition on private wire
	Blocking	
	Metering	Polarity reversal

DC signalling can be used on short-distance open-wire or cable circuits not fitted with voice-frequency amplifiers. It can also be used on cailho and composite circuits.

(ii) Low Frequency AC (Outband). AC signalling employs signal elements of low-frequency currents of 50-200 cycles. AC signalling can be employed on unamplified metallic circuits where conditions prohibit the use of DC, i.e., longer lines may be used.

(iii) Voice Frequency (VF) Inbuilt (Outband). For traffic on amplified and carrier circuits, signalling must usually be at voice frequencies. If the signals are sent within the range available for speech, there is a risk of false signals being generated by the speech currents and so signal frequencies are restricted to those outside the normal speech bands, but within the bandwidth of the carrier channel itself, hence the term "inbuilt".

Signalling equipment of the outband VF type can be classified, according to the signalling code used, namely, "continuous tone" and "pulse code".

With the continuous tone method, tone is normally sent from both ends of the line, the necessary signal being indicated by interruptions to the tone from either end.

With pulse code signalling, the various signals are transmitted as pulses of definite duration in either direction. A typical scheme of this type is shown in Table 1.

SIGNAL	SIGNAL DIRECTION AND NOMINAL DURATION IN MILLI-SECONDS
Seizure	150 m/sec →
Answer	← 150 m/sec
Clear back	← 600 m/sec
Clear forward	600 m/sec →
Release guard	← 600 m/sec
Blocking	← Continuous →

TABLE 1. SINGLE FREQUENCY LINE SIGNALS.

(iv) Separate Path (Outband). This signalling method makes use of a circuit completely separate to the speech path. The S.T.C. 12-channel VF system is typical of this type in which one voice-frequency channel is used as a bearer for a telegraph type carrier system, the channels of which provide the necessary separate signalling paths for each of the telephone channels.

Separate path systems can be used to provide the advantages of outband signalling for carrier systems not having this facility built in.

(v) Speech Path (Inband). Signalling in the normal speech path using voice frequencies and a pulse code was common practice in the early days of carrier systems before it became practicable to adopt outband techniques. Several difficulties were encountered with voice immunity and receiver sensitivity - two conflicting requirements - and, as a result, the separate path method was developed. However, speech path signalling found a very wide application for operator trunk dialling and the Australian 2VF system was one of the earliest examples.

Speech path signalling systems may employ single or multi-tone signals and may be used on any type of trunk circuit, irrespective of physical make-up. However, pulse type signalling codes are necessary, thus calling for more elaborate relay sets than are required for continuous tone systems.

5.4 Information Signalling. Information signalling equipment is required to send information forward from the originating register to each register (or code receiver as the case may be) which is involved in the setting up of a call. Similarly, equipment is also required for the transmission of the backward signals and information signalling is therefore sometimes termed inter-register signalling. The digital information is stored in the register at the originating local exchange and the digits required at each switching point are sent forward as requested by means of the backward signals from the equipment at the switching points. The control of the call is retained by the originating register until final connection is established with the wanted party; the transit control equipment and registers being associated with the connection only whilst the call is being routed through the exchange in question.

This method of register control is therefore similar to the manual operating practice whereby an "A" Telephonist controls a connection completed via a "B" Telephonist.

In order to minimise post-dialling delay; to take full advantage of alternate routing and to minimise unpaid holding time of trunk and junction lines and switching equipment, the transfer of information must be effected at a much higher speed than the decadic (10 impulse-per-second) signalling employed in step-by-step working. This is achieved by means of special coded voice-frequency signals, the particular method adopted in crossbar working being the multi-frequency "2 out of 6" code (MFC) which operates at a speed of some 10 digits per second. This technique has been widely adopted in Europe and U.S.A. and more detail is given in para. 5.5 of this paper.

Forward Signals. The forward signals, in the main, comprise those for each of the 10 decimal digits - often termed numerical signals. In addition, auxiliary signals are used for special purposes such as routing to a particular operator, e.g., interception. The forward signals are called for by the backward signals.

Backward Signals. The backward signals may be grouped into four classes, as follows:-

IMPORTANT.

(i) Control.- to acknowledge receipt of a forward signal and to indicate which signal is required next, e.g., next digit, repeat.

(ii) End-of-Selection - to indicate the condition of the called subscriber's line - whether free, engaged, intercepted, non-metering, "B"-party release, etc..

(iii) Congestion - to indicate when switching congestion is encountered and to instruct the register to cease sending. This signal is not to be confused with the 'subscriber engaged' condition, as in (ii).

(iv) Terminating Exchange - to indicate the type of terminal exchange and to determine the form of signalling required, i.e., MFC for crossbar or decadic for step-by-step.

Subscriber Signals. The forward and backward MFC signals are transmitted before conversation takes place and arrangements are made to ensure that the calling subscriber does not hear the voice frequency tones comprising the various signals. The subscriber, however, must be informed of various stages of progress of a call and this is achieved by the use of the normal service tones - "dial tone" as soon as the calling telephone is connected to the register; "try-again tone" if the 'subscriber busy' or 'congestion' condition is encountered; "check number tone" for non-working lines and "ring tone" if the called line is free.

5.5 Multi-Frequency Code (MFC) System. Information signalling between registers and markers is effected by means of a compelled sequence multi-frequency code.

Compelled Sequence. 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 dissappearance 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 is received 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. 27 shows the principle of compelled sequence signalling.

A continuous digit signal is transmitted from the register.

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

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

When the digit signal disappears at Code Receiver, 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.

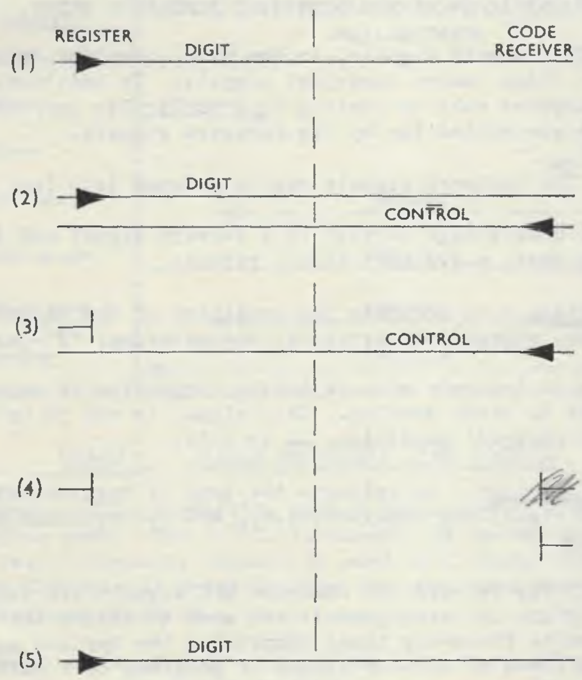


FIG. 27. COMPELLED SEQUENCE SIGNALLING.

Signal Frequencies. Since the normal speaking path is used for the transmission of the various signals, the frequencies must lie within the limits of the normal speaking or voice frequency range. An upper limit of 1980 cycles per second has been fixed to avoid interference with international line signalling systems which employ frequencies between 2,000 and 3,000c/s. To enable simultaneous signalling in both directions, different frequencies are used in the forward and in the backward directions. Six frequencies are provided for forward signals and another six are available for the backward signals although, initially, only five will be used. Each signal is composed of two frequencies out of the six (or five) available and, in this way, 15 frequency combinations may be obtained, as shown in Table 2.

The frequencies are spaced at intervals of 120c/s, the forward signals using the higher frequencies whilst the lower frequencies are used for backward signals. The separation between the highest backward and the lowest forward signal is 240c/s to facilitate the separation of the two groups by filtering.

The frequencies in each of the backward and forward series have been given a code number, ranging from "0" for the first frequency to "11" for the last frequency.

The 15 signal combinations for each direction have been allotted the numbers 1-15 (or numerical values) and, with 3 exceptions, the summation of the code numbers is equivalent to the numerical value of the signal. This feature provides a ready means of checking the composition of each signal.

SIGNALS		FREQUENCIES						
NUMERICAL VALUE	CODE NO. COMPOSITION	DENOMINATION	F0	F1	F2	F3	F4	F5
		FORWARD	1380	1500	1620	1740	1860	1980
		BACKWARD	1140	1020	900	780	660	(540)
		CODE NO.	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

<u>NOTE</u>: The 540c/s signal will not be used initially.

TABLE 2. MULTI-FREQUENCY CODES.

Equipment for sending and receiving signals is associated only with registers and code receivers and, since each signal always consists of two frequencies, the system is self-checking in that the absence of one of the elements, or the presence of a third, indicates malfunction.

(i) Forward Signals. Of the 15 forward signals, ten (Nos. 1-10) are used for the 10 decimal digits and the remaining five are used for the auxiliary codes referred to in Para. 5.4.

(ii) Backward Signals. The complexities of the switching network require many backward signals to convey the necessary information to the originating register. However, by a scheme of multi-stage signalling, the same frequency combination can be used for a variety of signals, the meaning being dependent upon the position which the signal occupies in the signalling sequence. Table 3 shows the A.P.O. backward signalling scheme for metropolitan networks and, in each case, the number beside the signal represents its numerical value (see Table 2).

Purpose of Each Signal. The functions of the forward information signals have been adequately described earlier in this paper. The backward signals, however, are more complex and an appreciation of their purpose may be gained from illustrations of typical calls. Certain signal functions are mentioned in Section 4 and the description therein of register, code receiver and marker operation may be read in conjunction with the following:-

'A' SIGNALS									
NEXT DIGIT	RESTART	END OF SELECTION	TERMINATING EXCHANGE M.F.C.			TERMINATING EXCHANGE STEP-BY-STEP			
			5 DIGIT LENGTH	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 1B	FOLLOWED BY 2A			FOLLOWED BY 3A			

1B SIGNALS	2A SIGNALS	3A SIGNALS
1. IDLE SUB	1. NEXT DIGIT	1. NEXT DIGIT
2. BUSY SUB	2. RESTART	2. RESTART
3. NO THROWOUT	3. END OF SELECTION - 1B FOLLOWS	3. END OF SELECTION - 1B FOLLOWS
4. CONGESTION	4. START DEC. 1st DIGIT	4. START DEC. 1st DIGIT
5. IDLE - NON METERING	5. " " 2nd, "	5. " " 2nd. "
6. INTERCEPTION, MALICIOUS CALL	6. " " 3rd, "	6. " " 3rd. "
	7. WAITING PLACE, NEXT DIGIT	7. " " 4th. "
	8. " " , 1 RESTART	8. " " 5th. "
	9. " " , SAME DIGIT	9. " " 6th. "
	10. " " , PREVIOUS DIGIT	10. SEND PREVIOUS DIGIT

CONGESTION IS ALWAYS GIVEN AS A3 (OR 2A3, 3A3) + 1B4
WAITING PLACE SIGNAL IS GIVEN ONLY ONCE IN A CALL

SIGNALS RECEIVED AFTER 2A7 - 10 ARE INTERPRETED AS 3A SIGNALS

CROSSBAR: M.F.C. CONTROL SIGNALS

TABLE 3. MFC BACKWARD SIGNALS (METROPOLITAN).

(NOTE: A lesser number of signals will be used in the trunk network. In general, trunk signalling will employ only six backward signal combinations and hence only four frequencies are required.)

(i) Call Within a Crossbar Exchange. As the calling subscriber dials, the digits are received in the register. The register is able to recognise the numbering of its own exchange and all digits are received and stored in the register before a GV stage code receiver is seized.

The register then sends digits to the GV stage code receiver until enough information is received to determine the required route. A backward "next digit" signal (A1) is returned after each digit received at the code receiver.

When connection is established through the GV stage to the code receiver in the SL stage marker, further digits are sent in a similar manner, acknowledged each time by an A1 signal. After all digits have been received in the SL marker, an "end-of-selection" signal (A3) is returned to the register. This prepares the register for the receipt of further signals of the 1B series, indicating the condition of the called subscriber's line. If the called number is busy (1B.2), the complete connection is released and tone sent from calling subscriber's line relay (line lock-out condition). If the caller subscriber is free (1B.1), a short burst of ring tone is immediately sent from the register to indicate that the connection is established and the register then releases. The purposes of the other 1B signals are obvious from the titles and the switching sequences for calls in these categories are described elsewhere under the appropriate headings.

(ii) Call to Another Crossbar Exchange. When the call is for another crossbar exchange, the register, after receipt of the fourth digit, seizes a code receiver in the GV marker and transfers the digits thereto. From the composition of these digits, the code receiver determines the length of the number being dialled (i.e., 5, 6 or 7-digit) and also whether the destination is a crossbar or step-by-step exchange.

The number length signal (A4, A5 or A6) is returned and prepares the register for a further backward signal of the 2A series. If a direct route to the distant exchange has been seized, a waiting place signal (2A 7-10) is sent to instruct the register not to signal to a distant code receiver until the complete number has been received in the register. (This is necessary to prevent the idle holding of the distant code receiver whilst the subscriber completes dialling.) When all digits are received, the distant code receiver is seized and receives from the register the digit indicated by the second part of the waiting place signal (i.e., next, re-start, same, previous). This code receiver stores each digit as it is received and, at the same time, calls for the following digit (2A.1). When it has sufficient information to determine the further routing of the call, further backward signals are not sent to the register until the route has been selected, whereupon the register is instructed as to which digit (2A.1 or 2A.2) will be required by the next code receiver, e.g., that associated with the SL marker. The SL code receiver receives the last three digits of the called number (returning a 2A.1 signal after the first two) and, upon receipt of the final digit, returns an "end-of-selection" signal (2A.3) followed by a signal from the 1B series (i.e., free, busy, etc.), whereupon the register completes its function and releases as described previously.

(iii) Call to a Step-by-step Exchange. A call to a step-by-step exchange proceeds in the normal manner up to the point at which the number length and type of destination signals (A7-A10) are sent from the GV code receiver at the originating exchange. Once the route into the step-by-step network is chosen, one of the signals 3A4-9 (Table 3) is sent, causing the register to send the remaining information as decadic pulses. An end-of-selection signal is not returned from step-by-step equipment and 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 cannot determine the number length from the first four digits, the A10 signal is returned to the register, signifying "Number length not known". The register then arranges to release itself approximately four seconds after clearing the remaining digits in its store, i.e., if a further digit is not forthcoming within four seconds, then the digits sent must comprise the complete number.

Immediate ring tone cannot be given to crossbar subscribers calling step-by-step exchanges as this feature is controlled by the "idle subscriber" signal from the 1B series which cannot be returned from a step-by-step terminal exchange.

(iv) Call to Crossbar via Step-by-Step. If the call to a crossbar subscriber is routed via a step-by-step exchange, the register receives signal 2A.4, 2A.5 or 2A.6 and commences to send decadic pulses. At the point where the call again enters crossbar equipment, an interworking register (Reg. I) receives the decadic pulses and converts the signalling to MFC for the remainder of the call. The form of sending from the register, however, remains decadic for, having once changed, it is not possible to change back to MFC.

Inter-system Signalling. The preceding sections of this paper give an introduction to the signalling system adopted in crossbar exchanges. Some reference has been made to certain aspects of the introduction of crossbar exchanges into the existing step-by-step network and a more detailed consideration of the subject of interworking with existing exchanges is contained in Section 7.

For quite a considerable period, it will be necessary for a majority of calls to be completed by step-by-step equipment using decadic pulsing and the register is therefore designed to provide for both high speed intra- and inter-crossbar exchange working and for decadic interworking with step-by-step exchanges.

It is important, however, to appreciate that although the slow acting dial will be retained for many years, it is essential that high speed signalling should be used between stages of the crossbar system. This is necessary, not only to enable fast transmission and rapid appreciation of routing information and switching via alternate routes, etc., but also to reduce the holding time of common equipment in the exchange and to minimise the post-dialling delay which is inherent in register working.

5.6 Summary. Signals are of two classes.

- "Line" for control and supervisory purposes.
- "Information" for establishment of connection.

Advantages gained from separation of "Line" and "Information" signals.

- Short holding time permits use of information equipment on common basis.
- Information signalling can be associated with register.
- High-speed code signalling possible over normal speech path.
- Line signalling equipment may be suited to varying types of trunk and junction links.
- Eliminates necessity for voice immunity guards.

Signals are passed in both directions.

- Forward line signals are required for seizure and clear forward condition.
- Backward line signals provide for answer, clear back, release guard and blocking.
- Forward information signals convey digital information from register to register.
- Backward information signals control forward sending of information and indicate conditions of called subscriber's line; congestion conditions and type of terminating exchange.

Line signalling systems are either.

- Outband using other than the speech path, either in the same or separate channel.
- Speech Path using same circuit and frequency band as for speech transmission.

Line signalling methods in general use are:-

- DC or loop.
- Low frequency AC.
- Voice frequency (VF) using either continuous tone or pulse code.

High-speed information signalling at 10 digits per second achieved by use of multi-frequency code (MFC) system.

High-speed signalling minimises post-dialling delay, facilitates alternate routing and reduces ineffective holding time.

MFC system is self-checking and uses compelled sequence operation.

6. TYPES OF L.M. ERICSSON CROSSBAR EXCHANGES.

6.1 Introduction. The L.M. Ericsson Telephone Company of Sweden is one of the major telephone equipment manufacturers of the world, producing a wide variety of exchange systems, including other than crossbar types. The Australian Post Office has adopted the L.M. Ericsson crossbar exchange system as the standard for the future development of the network and, although some crossbar equipment is being imported from Sweden, arrangements have been made for its manufacture in Australia also. Crossbar design and manufacture will thus be developed locally to suit Australian conditions.

Variations and improvements will naturally result as experience is gained in the use of crossbar and, in time, crossbar in Australia will assume particular A.P.O. characteristics. Initially, however, three basic types will be utilised to meet local and trunk switching requirements in accordance with the Community Telephone Plan. In this section, the purpose and application of these exchange systems are outlined.

6.2 ARF Exchanges. L.M. Ericsson's crossbar system for exchanges used in metropolitan and the larger country networks is called the ARF system, the particular type being known as ARF.10. These exchanges are intended for installations ranging from a few hundred to 10,000 or more lines and will thus form the bulk of the crossbar network. The ARF.10 exchange is register-controlled and composed of subscriber stages (SL stages) and group selector stages (GV stages).

In the previous sections, the ARF system has been used as the basis for the description of crossbar principles and in this paragraph, therefore, reference is made only to the general features applicable to ARF exchanges.

SL Stage. The SL stage functions as both line-finder and final selector for complete 1,000-line groups. Each 1,000-line group is divided into sub-groups of 200 lines and thus exchange capacities can be increased in units of 200 subscribers' lines.

The SL stage is designed for up to seven different traffic capacities; namely:-

from "m = 6" - 48 Erlang outgoing; 42 Erlang incoming

to "m = 10" - 106 Erlang outgoing; 122 Erlang incoming.

(See Section 3 for explanation of "m" symbol.)

GV Stage. The group selector stages (GV) switches traffic to SL stages, to outgoing junction routes or to other GV stages, and are made up in units of 80 inlets and 400 outlets. The outlets can be grouped into routes of different sizes, the general practice being to employ 40 or 20 outlets on each route. Thus, it is possible to have 10 routes with 40 outlets each, or 20 routes with 20 outlets. Likewise, 40-outlet and 20-outlet routes, or even up to 80-outlet routes, can be combined in the same group selector stage.

Markers. One or two markers, SLM, may be connected to each 1,000 line SL group. A.P.O. policy is to provide two markers for the first 1,000 line group and a second marker for other 1,000 line groups only if the traffic requires it.

Where two markers are provided, each can deal with one call at a time and together they can usually set up two simultaneous calls. In case of failure of one marker, the other can handle the entire traffic in the SL stage but, in such circumstances, increased delay in receipt of dial tone may be encountered.

Two group selector stages, of 80 inlets each, together form a unit served by one or two markers as is the case in the SL stage.

Registers. Although registers are common equipment which can be made available to the exchange as a whole, they are usually considered to be part of the SL stage as they are directly connected to the SR relay sets through a register-finder as required. Each register-finder serves 40 SR relay sets and 10 registers and, in a typical "m = 6" exchange, each 1,000-line group has access to 80 SR relay sets, i.e., two register-finders. However, the registers may be graded to appear on a number of register-finders, hence the total number of registers is usually less than 10 times the number of register-finders; that is, something less than 20 registers per 1,000 subscribers.

General Technical Features.

(i) Switching Times.

SL stage - originating call; connects to register in about .5 second.

- terminating call; connection to wanted subscriber in about 1 second.

GV stage - .5 to .6 second to record digits and set switch.

(ii) Subscribers' Line Limits. Normal line loop resistance of 1,800 ohms, including telephone instrument.

(iii) Dial Speed. May vary between 8 and 14 impulses per second - may be increased to 22 i.p.s. under certain conditions.

Application. ARF exchanges will generally be installed where capacities of upwards of 1,000 lines are required. Normally they will function as terminal or tandem exchanges in local networks and in association with automatic trunk exchanges (type ARM). The group selectors, however, are designed so that an ARF exchange can also function as a small transit centre with limited subscriber trunk dialling.

Exchanges of the ARF type will be employed as:-

(i) Complete crossbar installations in new buildings.

(ii) Crossbar group selector stages in step-by-step exchanges replacing one or more ranks of bi-motional switches, e.g., taking the place of DSR stages. Exchanges now trombone trunked may have first-stage crossbar switching installed.

(iii) Extensions to step-by-step exchanges; this may comprise SL stage extensions trunking from step-by-step group selectors or the extension may utilise both GV and SL stages.

6.3 ARK Exchanges. Exchanges of the ARK type are designed for use in country areas where installations ranging up to 2,000 lines are required, the particular L.M. Ericsson system adopted by the A.P.O. being ARK.50. The main characteristics of the ARK.50 series are:-

(i) The exchanges can be built up in small units.

(ii) The exchanges are designed without registers and operate under the control of a parent automatic trunk switching exchange.

Two main types are available, namely, ARK.511, with an ultimate capacity of 90 lines, and ARK.521, with a capacity of up to 2,000 lines. Both types are used as terminal exchanges operating in conjunction with the parent ARM type crossbar trunk exchange at the appropriate trunk switching centre. The ARM trunk switching equipment is described in para. 6.4 of this section.

Another exchange in the ARK.50 series is the ARK.523, which has been developed from the ARK.521 and is a terminal exchange with limited transit switching facilities.

Special arrangements are made regarding registers and signalling when ARK exchanges work into step-by-step or manual parent exchanges.

Type of Crossbar Switch used in ARK. The crossbar switch used in ARK exchanges differs from the more familiar type used in ARF and ARM exchanges in that it has a capacity of 300 outlets. The switch has 10 vertical and 6 horizontal bars and 10 contacts per springset pile. The 10 vertical and 5 horizontal bars operate in the same manner as described in earlier sections, but the sixth horizontal bar can take up any one of three positions. Each position causes the connection of a different set of three contact strips in the vertical and thus 30 three-wire outlets per vertical are obtained.

ARK.511. Type ARK.511 is extensible in 30-line units and thus can be equipped for 30, 60 and 90 lines. They therefore serve a similar purpose to the existing A.P.O. type R.A.X. and, like the smaller R.A.X., are designed to meet the requirements for telephone service in the smaller townships and rural areas.

The exchange comprises a single subscriber line stage (SL), the basic trunking arrangement being as shown in Fig. 28.

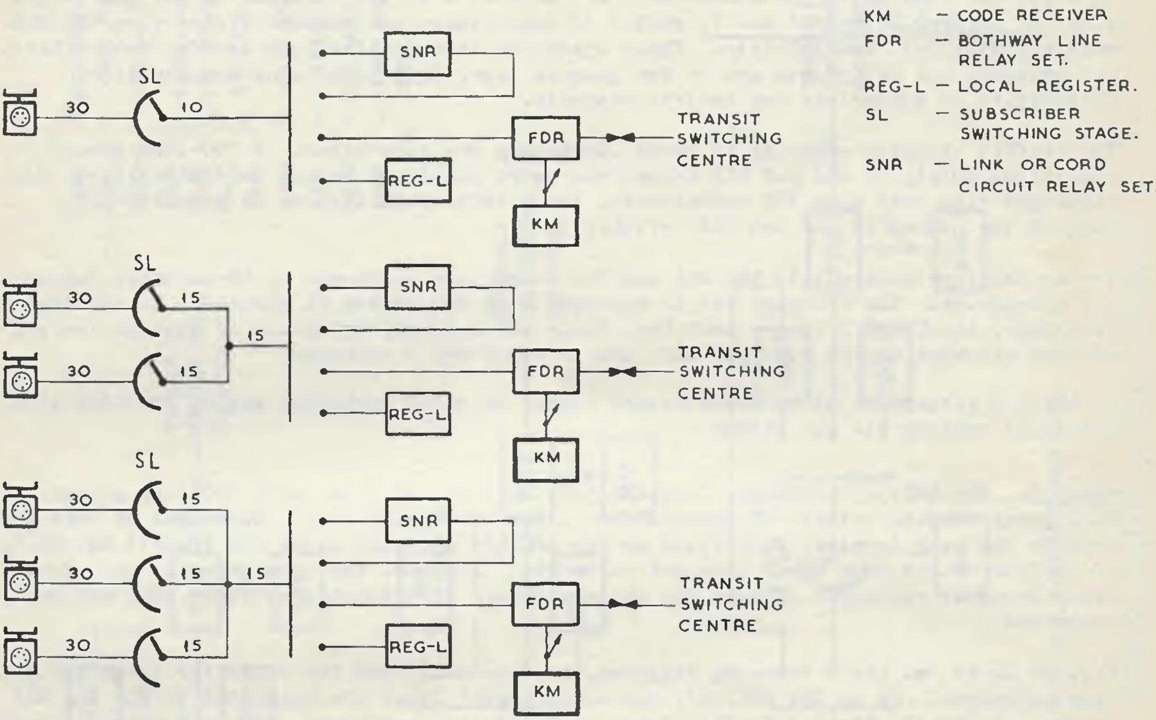


FIG. 28. TERMINAL EXCHANGE ARK.511 (30, 60 AND 90 LINES).

SAME AS SR

In the diagram, SNR denotes the "cord circuit" (c.f. SR in ARF exchanges). FDR is the relay set for the both-way junctions or trunk lines to the parent exchange and KM is the code receiver which, in association with the marker (not shown), receives the digital information from the register at the parent exchange and sets the SL stage accordingly.

The line relay sets and registers each require one vertical whilst each "cord circuit" occupies two verticals. The number of FDR's, REG's and SNR's that may be accommodated is therefore limited by the number of verticals available, i.e., 10 for 30-line units and 15 for 60 and 90-line units. However, the number of both-way trunks or junctions cannot exceed seven.

No direct switching is possible with these exchanges. All calls other than those within the exchange itself must be switched via the parent trunk centre.

ARK.521. This type has an initial capacity of 100 subscribers' lines and is extensible up to 2,000 lines in 100-line units. If necessary, extensions may be made in smaller units as all of the crossbar switches and relay sets are connected to the racks on a "plug-in" basis.

The trunking arrangement for a 100-line exchange employs two partial switching stages SLA and SLB, as shown in Fig. 29a.

For exchanges larger than 100-200 lines, a C-stage is introduced (Fig. 29b) and exchanges larger than 300-400 lines are normally provided with a D-stage as well (Fig. 29c). The number of C and D switches is determined by the number of junctions or trunk lines connected, the number of cord circuit links and the volume of traffic to be carried.

In every 100-line group, 90 subscribers are connected to the multiple of the SLA stage, with "m" varying between 6 and 7, whilst 10 subscribers are reached direct from the SLB multiple with full availability. These lines are intended for high-traffic subscribers. All switches and relay sets are of the plug-in type, thus permitting considerable flexibility in subscriber and traffic capacity.

The traffic handling capacity is about .08 Erlang per subscriber. A 100-line group consisting solely of SLA and SLB stages can carry about .06 Erlang per subscriber. For exchanges with more than 100 subscribers, the traffic capacity can be regulated by varying the number of SLC and SLD switches.

The switch functions within the SLA and SLB stages are performed by AB-markers, common to all 100-groups. The exchange can be equipped with one or two AB markers. In the larger exchanges, the C and D stages each have their own markers, which are of similar design, and the exchange may be equipped with one or two C and D markers.

At ARK.521 exchanges, up to three direct routes to other exchanges may be provided with alternate routing via the parent.

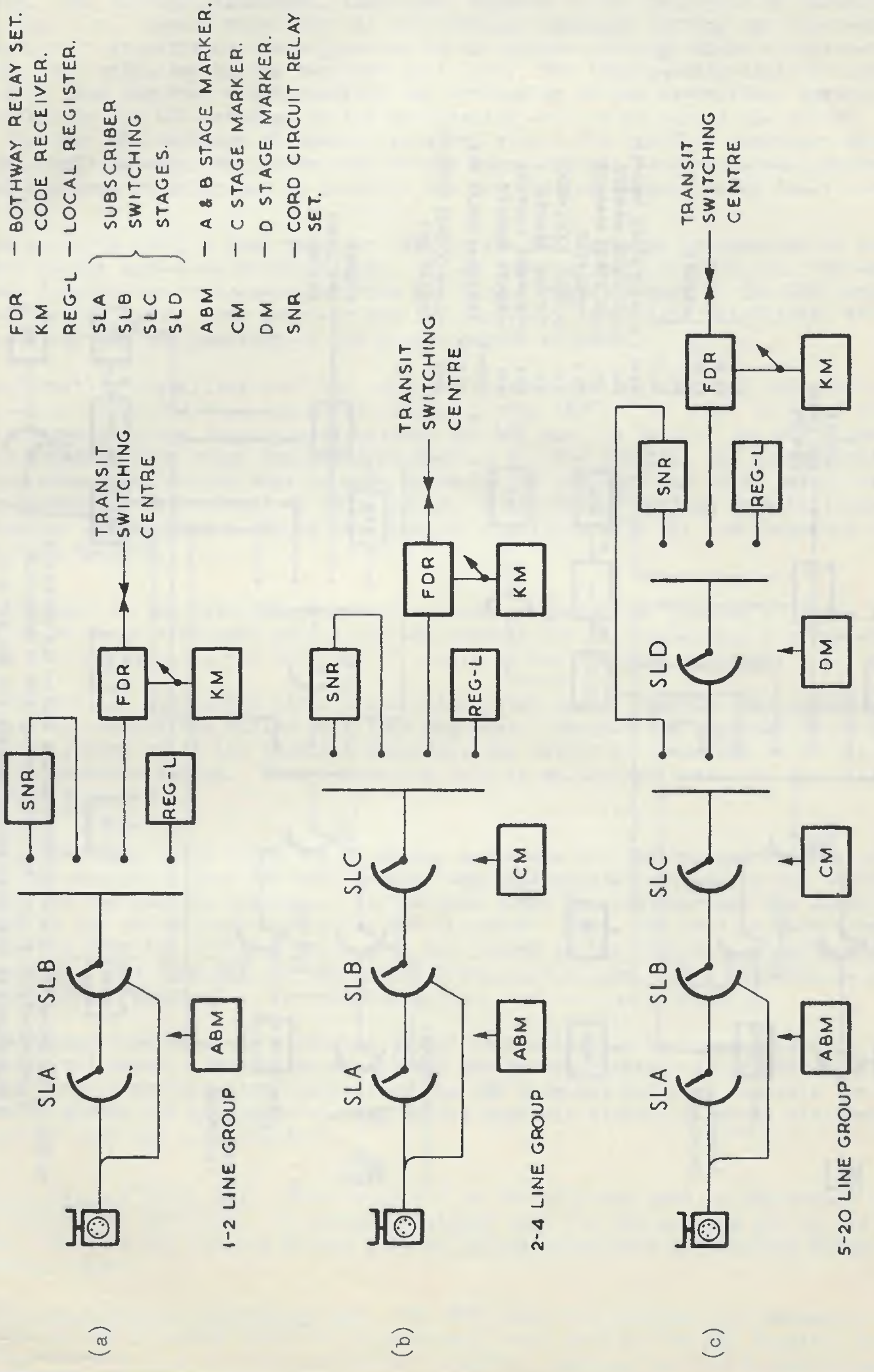
ARK.523. The ARK.523 exchange, like ARK.521, is built up from basic 100-line groups, each group serving either 100 subscribers' lines or 20 junctions. Exchanges of this type provide the same terminal facilities as the ARK.521 and also cater for transit switching of traffic routed from other terminal exchanges. However, the connection of junctions from other terminal exchanges reduces the maximum number of subscribers' lines that can be connected.

Fig. 30 shows two basic trunking diagrams, one for small and the other for large ARK.523 type exchanges. As in the ARK.521, the subscribers' lines are connected to SLA and SLB stages. To handle transit traffic from other terminal exchanges, only a B stage (SLB-NE) is provided. Thus, a basic line group for local traffic incorporates an SLA and an SLB stage and can serve up to 100 subscribers' lines. A basic line group for handling transit traffic has only one stage, SLB-NE, and can handle up to 20 junctions. Any number of either type of basic group can be provided in an ARK.523 exchange, as required, but the total number of line groups cannot exceed 20. The grouping in a 100-line basic unit for local traffic is the same as for ARK.521.

In this diagram, the route marker (VM) determines the route and charging rate from the digital information received from the register or code receiver. The code sender (KS) is connnected to the register as required by the sender coupler (KSS) and provides the various information signals necessary to the setting up of a connection. The registers provided for the ARK.523 exchanges are more versatile than the auxiliary local registers (REG-L) normally supplied with the ARK.521 terminal exchanges, since they must be able to handle transit as well as local calls.

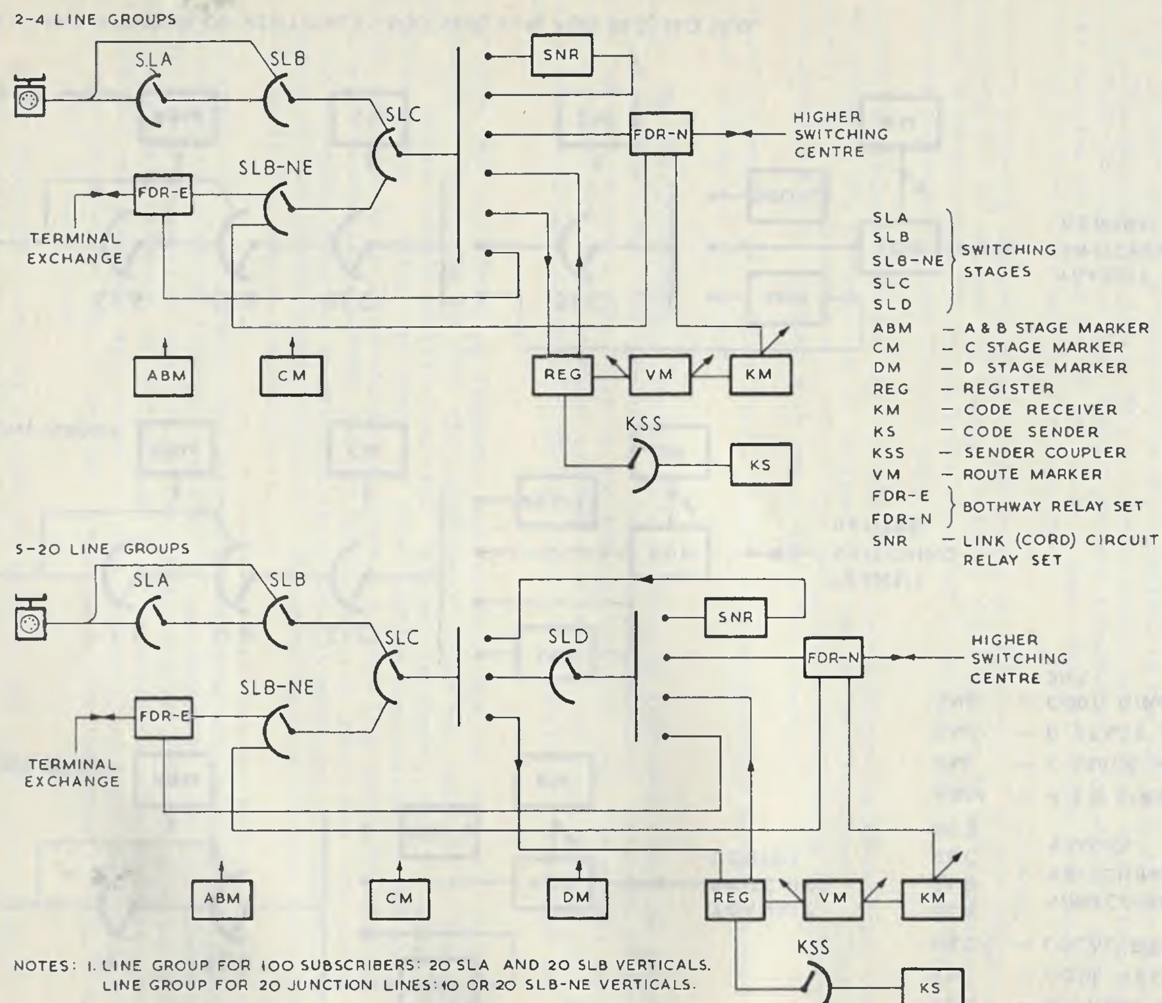
The ARK.523 is therefore a combination terminal exchange and transit switching centre. As it performs functions essentially the same as those of an ARM trunk exchange, including subscriber trunk dialling, it can operate independently of ARM equipment and thus may be used to establish the smaller minor centres in the automatic trunk switching network.

Principles of ARK Operation. The essential points necessary to an understanding of the principles of operation of ARK type exchanges will be apparent from an outline of its function as part of a wholly crossbar network. ARK exchanges can, with suitable modification, interwork with step-by-step and manual exchanges and reference is made later to the specific interworking requirements to meet these cases.



NOTE:- MAX. NUMBER OF VERTICALS: 400 SLA, SLB, 200 SLC, 160 SLD.

FIG. 29. TRUNKING DIAGRAMS OF ARK.521 EXCHANGES.



NOTES: 1. LINE GROUP FOR 100 SUBSCRIBERS: 20 SLA AND 20 SLB VERTICALS.
LINE GROUP FOR 20 JUNCTION LINES: 10 OR 20 SLB-NE VERTICALS.
2. MAX. NUMBER OF VERTICALS: 400 SLA AND SLB, 200 SLC, 240 SLD.

FIG. 30. TRUNKING DIAGRAMS OF ARK.523 EXCHANGES.

The main feature of ARK.511 and ARK.521 operation is the centralisation of the register function at the parent automatic trunk switching exchange, which must be either ARM or ARK.523. ARK terminal exchanges, therefore, operate on the principle of advanced occupancy, i.e., upon a subscriber at the terminal exchange lifting the receiver, connection is established via a junction to the parent exchange where a register is seized, from which the caller receives dial tone. The subsequently dialled digits are stored in this register which controls the setting up of the connection, whether it is for a call within the ARK exchange or for an outgoing call to or beyond the parent. However, each terminal ARK exchange is usually provided with a few overflow registers which can handle a call between two subscribers of the same terminal exchange should access to the parent exchange register not be possible due to junction congestion or fault condition.

For an outgoing call, a code receiver (KM) in the ARK exchange is employed to receive and respond to the end-of-selection signal. If an internal call is involved, the necessary digital information is transmitted from the parent register back to the ARK exchange where it is received by the code receiver and the necessary connection established within the ARK exchange and the junction to the parent centre released.

All information signalling over the junction between the register and code receiver is effected in compelled sequence multi-frequency code (MFC). In order to cater for the particular signalling requirements between the ARK and its parent, the MFC signals used differ somewhat from those described in Section 5. For example, the classification of the calling subscriber's line must be made known to the register and other particular signals are required for the control of local switching and direct routing possibilities. For line signalling, ARK exchanges can be equipped for operation with DC, low-frequency AC and VF signalling systems.

All exchanges of the type ARK.50 employ a technique known as "jumping". Since it is peculiar to these exchanges and is not employed in the ARF exchanges, a brief explanation of the process is given for the case of a call within the same exchange.

When the calling subscriber lifts his receiver, the marker operates the necessary switching elements to connect the caller to a free register. Whether the register is in the transit switching centre or at the terminal exchange, the caller is connected to it via a vertical of an SL crossbar switch. This connecting path is maintained until all the dialled digits have been received.

The register then again calls the SL marker and sends all the routing information to it. The marker selects a free SNR and operates the appropriate horizontals and verticals to connect the two parties together. At the same time, the register and the connection between it and the calling subscriber are released. Thus, the calling subscriber is transferred from the vertical which gave him access to the register to another one which connects him to a free SNR and the called subscriber's line. This transfer is usually referred to as "jumping". IE. RECONNECTING TO CHOSEN SNR.

The switching time taken to arrange a "jump" is too long to be accommodated in the inter-digital pause. This means that, when the parent exchange is of step-by-step type and the local discriminating register at the ARK terminal exchange controls the routing of the call, direct and alternate routing is not possible without a second dial tone (after the access code has been dialled).

SNR Cord Circuit Relay Set. This relay set is the only one used in the speech paths of calls within the exchange. It provides battery feed for the calling and called subscribers' lines; the test and ringing relays for the called subscriber and holding relays for the switching stages.

FDR Both-way Junction Line Relay Set. The FDR relay set provides the necessary repeater function on the both-way junction circuits and, when used at the ARK terminal exchange, provides battery feed for the subscriber connected (calling or called, depending on the call being outgoing or incoming), holding relays for the switching stages and the test and ringing relays for the called subscriber.

Metering. Local call charging is effected at the ARK terminal exchange when the called subscriber answers. Under S.T.D. conditions, the charging equipment at the parent switching centre is brought into use, the necessary meter pulses being passed back to the ARK exchange over the junction circuit.

Interworking. ARK exchanges are designed for direct interworking with other ARK exchanges and with automatic as well as manual parent exchanges. A detailed description of these arrangements is given in Section 7 but, as the ARK exchange is dependent upon its parent switching centre, it is appropriate at this point to outline the principles employed.

(i) Manual Parent Trunk Exchange. One or several ARK exchanges can be connected to the same manual parent trunk exchange. An ARK exchange, when employed as a local exchange interworking with a manual trunk exchange, is equipped with sufficient registers to handle all of the traffic within the exchange and from the operators at the manual parent.

If open code access is employed for calls between terminal exchanges, automatic switching of these calls may be provided. No code receivers or MFC signalling equipment will be required in this case.

(ii) Automatic Parent Trunk Exchange. All terminal exchanges within a certain area are connected to a trunk transit exchange (e.g., ARM). All calls between the terminal exchanges are established by the central registers available at the switching centre. Direct routes between the terminal exchanges with alternative routing via the parent may be introduced. All exchanges may be included in a closed numbering area. MFC signalling and code receivers will be used in this case.

Where the parent exchange is step-by-step, special registers are required for interworking purposes, these being normally located at each ARK exchange.

6.4 ARM Exchanges. ARM is the common designation for L.M. Ericsson register-controlled crossbar systems designed specifically for trunk switching purposes. Such exchanges provide the necessary means for the interconnection of calls within the national trunk network.

The particular types adopted by the A.P.O. are the ARM.20, for large capacities, and the ARM.50, for small and medium capacities up to 2,000 trunk and junction lines. ARM exchanges can be used in conjunction with normal manual trunk switchboards and cater for operator as well as subscriber trunk dialling.

Trunk Switching Network. In considering the purpose and operation of trunk exchanges, it is necessary to keep in mind the general principles of the national trunk network plan and the concept of nation-wide subscriber dialling. This envisages the linking together of all exchanges in a basic national network, such that traffic is concentrated and routed over trunk circuits between the various switching centres. These switching centres are classified in increasing order of importance, as follows:-

(i) Terminal Exchange - an exchange which performs no through switching of inter-exchange calls.

(ii) Minor Switching Centre - serves a number of terminal exchanges.

(iii) Secondary Switching Centre - serves a number of minor switching centres and also, if received, terminal exchanges.

(iv) Primary Switching Centre - switches traffic from secondary switching centres and also, if required, minor centres and terminal exchanges.

(v) Main Switching Centre - serves a number of primary switching centres (principally on a State basis) and also, if required, secondary and minor centres and terminal exchanges.

In the national exchange network then, subscribers' lines are connected to terminal (or local) exchanges, each of which is trunked to at least one switching centre. A call between two subscribers connected to the same terminal exchange is served by that exchange, but trunk traffic is routed via switching centres of increasingly higher order. For reasons of plant economy, minor and secondary centres are connected by a star-shaped network of trunk circuits whereas the main and, to some extent, primary centres are usually interconnected by direct circuits to form a mesh superimposed upon the lower-order stars - see Fig. 31.

The basic switching plan implies, as previously stated, that a call from one terminal exchange to another is routed via at least one switching centre. However, in some cases the traffic load between terminal exchanges, or between minor centres may justify direct trunking between the exchanges. In such cases, the bulk of the traffic passes over the direct early-choice "high usage" links but, when these are congested, the overflow traffic is channelled over the final (or "backbone") route via a switching centre. Alternate routing in the trunk network is therefore similar in principle to that in the local networks (as described in Section 3) and, of course, applies throughout the trunk network wherever economically justified. The routing pattern for the trunk network, showing examples of early-choice routes, is depicted in Fig. 32.

It will be seen then that ARM type exchanges installed at the various switching centres, and interworking one with another by means of the MFC signalling system, will comprise the future Australian trunk switching network. Each ARM exchange will serve as the parent for the various types of terminal exchanges in the particular switching area, whether these exchanges be crossbar, step-by-step or manual.

The routing of calls in any automatic switching system is dependent upon the information dialled into it by the user. In the case of an operator-controlled trunk switching system, routing is the only requirement but, with the introduction of subscriber trunk dialling, provision must be made for automatic call charging and this, too, must be determined from the information dialled by the subscriber. The method of numbering is therefore important from both the switching (or routing) and charging viewpoints and the "linked closed numbering" scheme has been adopted for the Australian national automatic telephone system.

This provides for the establishment of closed numbering schemes within defined numbering plan areas (usually a secondary switching area) so that for calls within an area, subscribers dial only the number shown in the directory. Each numbering plan area is assigned a national area code and, for calls from one area to another, the wanted subscriber's directory number is prefixed by the area code. The use of two dialling procedures in this manner necessitates the use of a special access code to indicate that the call is going beyond the numbering plan area and the "0" digit has been chosen for this purpose.

For ease of reference, the particular digits in the national number are shown as the A, B, C, D, etc., digits. For example, a typical national number could be of the form OABC-D Exxx where 0 is the trunk prefix; ABC designates the destination numbering area and D Exxx the called subscriber's directory number, the particular exchange in this case being designated by DE.

To meet charging and routing requirements, the Australian numbering plan, in general, provides for determination of the numbering or secondary switching area by not more than the ABC digits. For calls within an area, the minor switching centres will generally be identified by the D digit and the particular terminal exchange by the E digit, due provision being made for the particular zoning arrangements within the area in question.

General Principles of ARM Exchanges. Systems ARM.20 and ARM.50 consist of group selector stages for two or four-wire through-connection, with crossbar switches for setting up connections through a single or two-group selector stage. The systems operate on the by-path principle, the switches being operated under the control of markers.

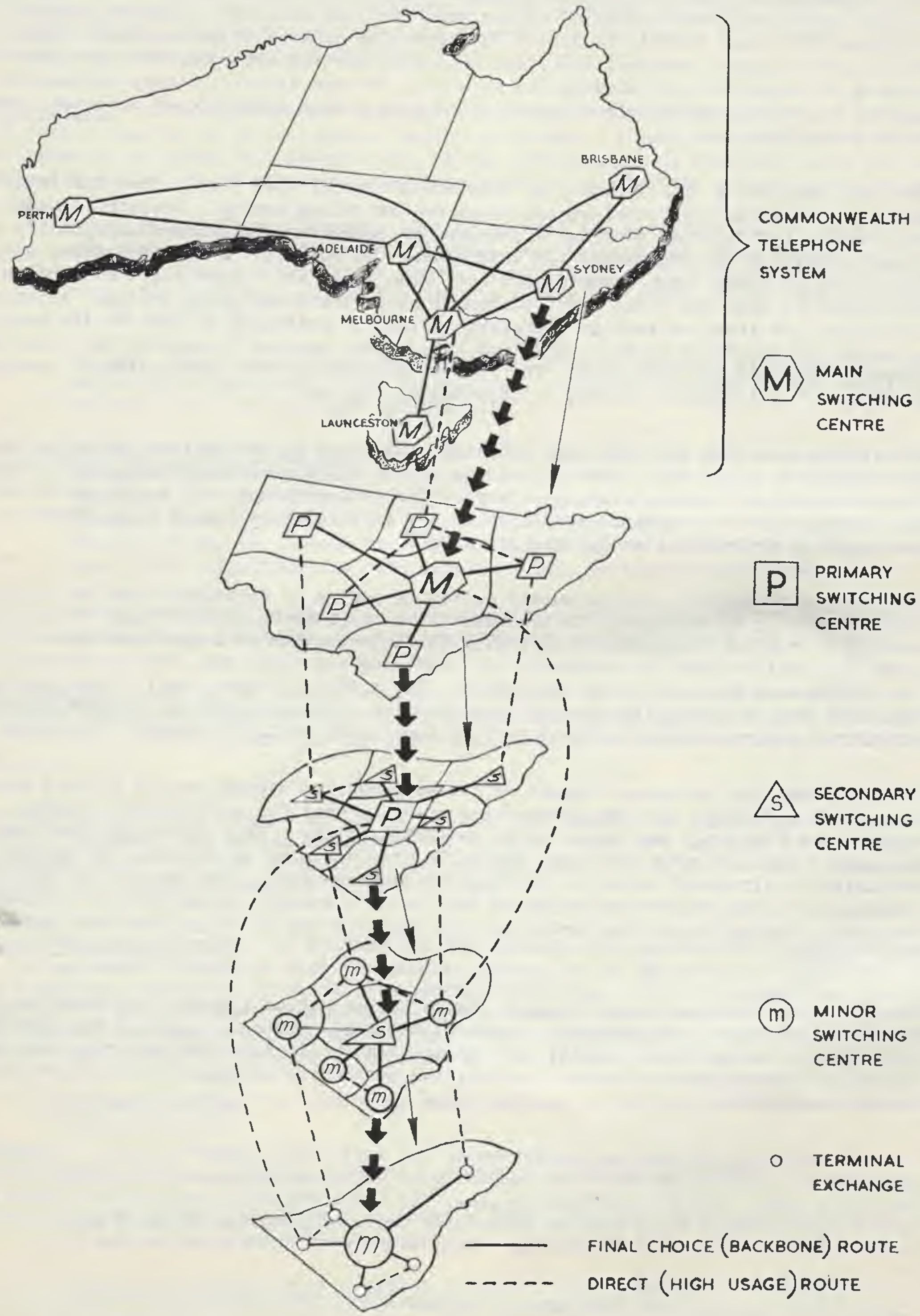


FIG. 31. DIVISIONS OF THE TRUNK NETWORK.

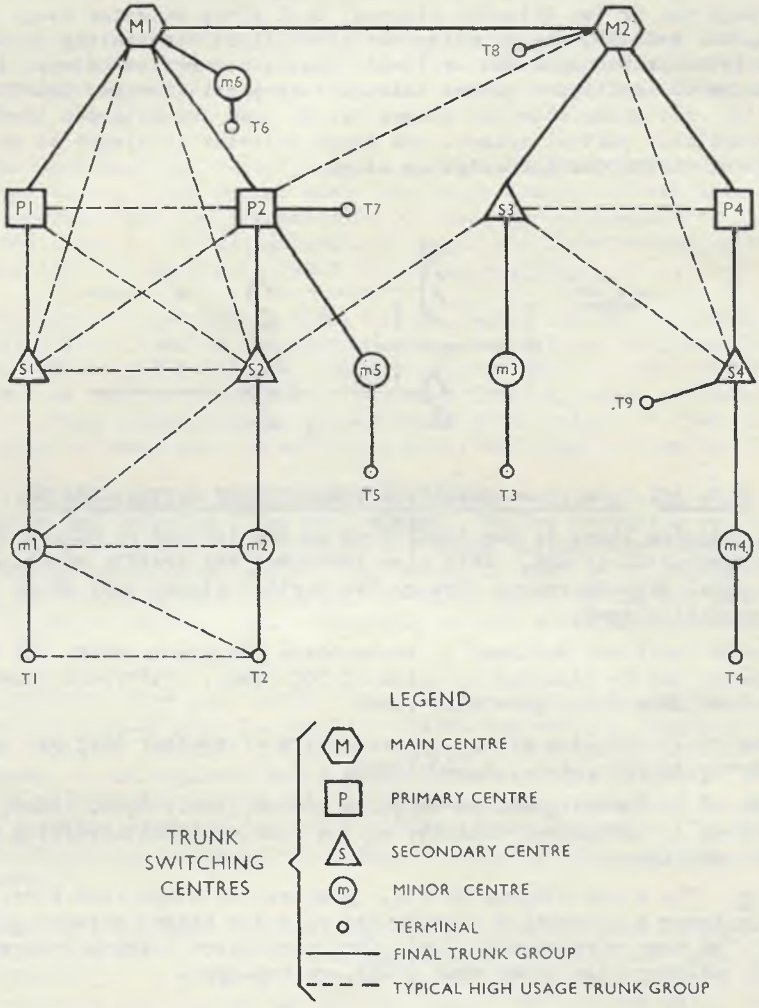


FIG. 32. TRUNK NETWORK ROUTING PATTERN.

The line relay sets with associated registers can be supplied for different signalling systems. Interworking with existing local or transit exchanges can therefore be arranged by adaptation of the line relay sets and registers.

For metering purposes, incoming relay sets from local and terminal exchanges usually incorporate tariff relays controlled from the marker equipment. During conversation, metering impulses from the tariff relay contacts are transmitted via the line relay set to the local or terminal exchange.

Of the two systems, ARM.20 covers the range between 100 and 8,000 circuits, while ARM.50 is intended for exchanges with a capacity not exceeding 2,000 circuits (1,000 incoming and 1,000 outgoing).

ARM.20. System ARM.20 is designed for handling manual, semi-automatic and subscriber-dialled trunk traffic. It is a group selector system built up of crossbar switches for the register-controlled setting-up of telephone connections by conditional selection (see Section 3) through one or two selector stages. Each group selector stage consists of two partial stages, GDA and GDB, the junction and trunk lines terminating on the GDA multiple. The GDB verticals are interconnected by links, thus a connection between two lines terminating on the GDA multiples passes through four partial stages GDA-GDB-GDB-GDA, as shown in Fig. 33. All group selector stages can be used for both-way traffic but, for a connection through four partial stages, one group selector is always to be regarded as the incoming stage and another as the outgoing stage.

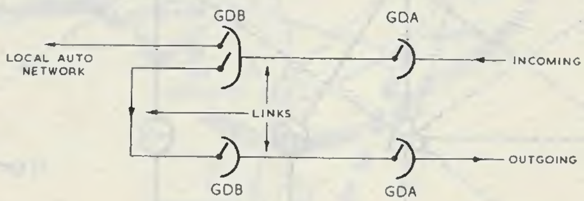


FIG. 33. ARM.20 - CONNECTION THROUGH FOUR PARTIAL STAGES.

By terminating outgoing lines to the local area on GDB instead of GDA, a larger number of lines can be accommodated in GDA. This also increases the traffic handling capacity since traffic to the local network passes through two partial stages only while other traffic requires four partial stages.

The group selector units are designed to accommodate 200 lines in the GDA multiple and, hence, the exchange can be expanded in units of 200 lines. Different sizes of ARM.20 exchanges have been developed, providing for:-

(i) A maximum of 20 200-line groups, irrespective of whether they are used for one-way or both-way traffic, i.e., 4,000 lines.

(ii) A maximum of 20 incoming and 20 outgoing groups, i.e., 8,000 lines, or of 20 both-way groups and, if necessary, capacity may be doubled by interworking between two similar exchanges.

ARM.20 Operation. The block diagram in Fig. 34 shows, in simplified form, the equipment employed in setting-up a connection through the selector stages between an incoming and outgoing line. The same arrangements apply for connections between both-way lines except, of course, that both-way line relay sets (FDR) are employed.

KNOW.

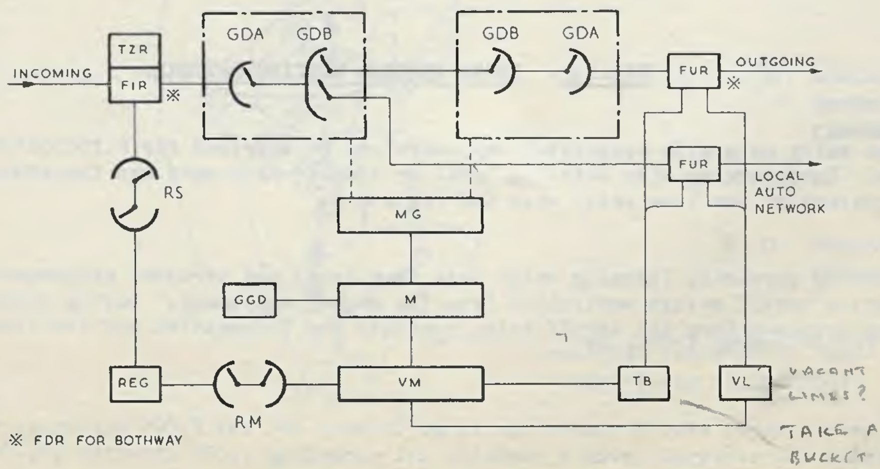


FIG. 34. ARM.20 - BASIC TRUNKING.

On an incoming call, the line relay set FIR is connected to a free register REG via a register-finder RS, the identity of the calling line being signalled from FIR to REG and stored there.

The register receives and stores the digital information which may come from another register, from an operator's keyset or from a subscriber's dial. Upon receiving sufficient information to determine the route required, the register calls and seizes a free route marker VM via the connecting multi-coil relay device RM.

The digits and other information identifying the particular group selector serving the incoming line are transmitted to the route marker where the route and tariff are determined. The route marker also provides for the transmission of charging information to the incoming line relay set (described later), for time supervision facilities, for recording traffic statistics and for the transmission of signals to fault recording equipment, etc..

VM tests with the route-free indicating relay set VL, which indicates in which of the test blocks TB there exist free lines on the wanted route, the various outgoing lines being distributed over a number of test blocks. VM now selects one of these test blocks, to which it becomes connected as soon as the block is released from any other connection that may be in progress. The routing information is passed to TB which selects a free line and VM is informed of the group selector unit to which the selected outgoing line is connected.

VM thereupon calls an idle marker M and passes to it information of the group selector units in which the incoming and outgoing lines are located. Before switching can be effected through the group selector stages, the marker must check whether any other marker is engaged in either of the two group selector units. This check is made by an equipment GGD. After establishing that no switching is in progress in either unit, the marker obtains access to the units via MG, an equipment which connects test and control wires between the marker and selector units.

The marker M now selects a free path between the incoming line FIR and the outgoing line FUR, sets up the connection through the four partial stages and sends a clearing signal to the register REG. The register releases the marker equipment and the connection is then held under the supervision of the register which sends forward to the outgoing line the requisite digits and other signals necessary for the completion of the connection to the wanted subscriber in the terminal exchange, or via a further trunk exchange. The register is released when the connection is completed or when control is taken over by another register in a subsequent exchange.

ARM.50. System ARM.50 is designed for small and medium sized transit centres for which ARM.20 would be uneconomical and can be used in conjunction with normal cord-type trunk operating positions. Like ARM.20, it is a group selector system but using one group selector stage only. The group selector consists of two partial stages GVA and GVB which are interconnected by means of links - see Fig. 35. The stage is one-way (from GVA to GVB), the incoming lines terminating on GVA and the outgoing on GVB. Both-way lines must therefore be terminated on both partial stages.

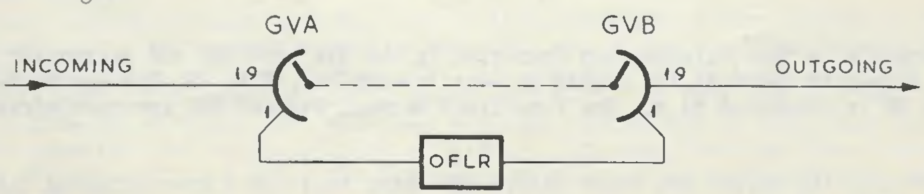


FIG. 35. ARM.50 - BASIC GROUP SELECTOR UNIT.

The basic unit shown in Fig. 35 has 20 inlets and 20 outlets, two such basic units being accommodated in a single rack, the capacity of which is thus 40 inlets and 40 outlets. The initial capacity of system ARM.50 is therefore 40 incoming lines and 40 outgoing lines and extensions are made in steps of 40+40 inlets and outlets. However, one inlet and one outlet in each basic unit is used to provide overflow links OFLR which, in the event of internal congestion, permit a connection to be established via a free overflow link. Therefore, the effective capacity is 38 incoming and 38 outgoing lines for each group selector rack.

With this arrangement of two partial stages A and B, this type of exchange can be extended to a maximum of 240 inlets and 240 outlets. For a higher capacity, a third partial stage, GVC, is added to which the lines of all minor trunk groups are connected. The size of the C stage is not directly dependent on the size of the A and B stages, but is determined by the number of lines and traffic loading on the trunk groups concerned. By the use of the C stage, it is possible to attain a maximum capacity of up to 1,000 inlets and 1,000 outlets.

ARM.50 Operation. The equipment employed in setting up a connection through an ARM.50 exchange is shown in the simplified block diagram in Fig. 36.

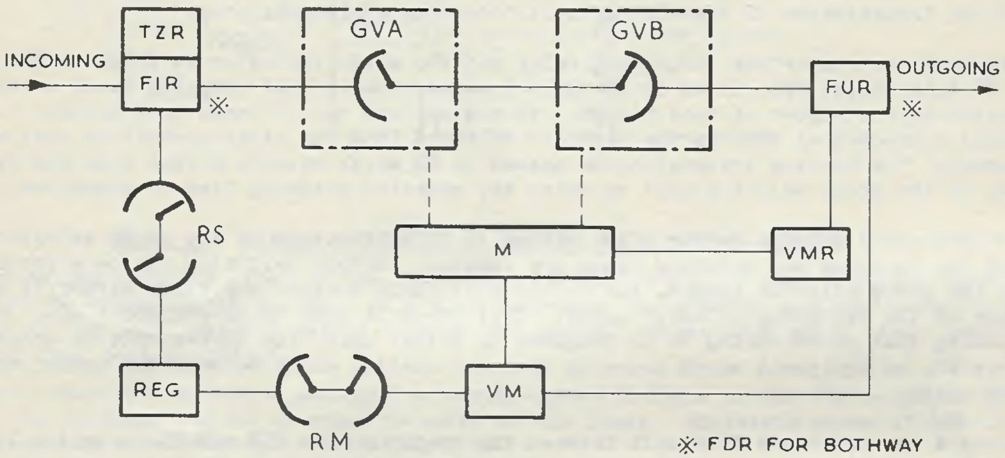


FIG. 36. ARM.50 - BASIC TRUNKING.

On an incoming call, the line equipment FIR is connected to a free register REG via a register-finder RS. The digits are received by the register and, when sufficient information for identification of the route has been received, a free route marker VM is called and connected to REG via connection relays RM. An indication of the origin of the line goes from FIR to REG and is stored there.

Transmission to VM of digits and other special instructions follows the same principle as in ARM.20. Route and tariff determination take place thereafter in VM.

A free marker M is then selected and connected to the GVA unit for the particular incoming line. A signal to identify the marker is sent through GVA, FIR, RS, REG and RM to VM, whereupon VM is connected to M. The free links between GVA and GVB are then marked.

Associated with the marker are route relays VMR which test for a free outgoing line relay set (FUR). A free FUR, to which there is access on a free link between GVA and GVB, is now selected and testing and busying of the GVB unit on which the selected line terminates take place from M, after which the connection is established between FIR and FUR via the previously marked free links.

A signal is now sent to REG for release of VM and M, which are then free to handle other calls. If the register is to control the subsequent switching, it remains in circuit, otherwise it releases.

Overflow Relay Sets (OFLR) in ARM.50. It will be seen that normal link trunking principles are applied in ARM.50 systems but, in addition, special overflow links are employed to improve further the trunking efficiency. As mentioned previously, one overflow link (with relay set OFLR) is provided in each basic group selector unit. Two such basic units are shown in Fig. 37.

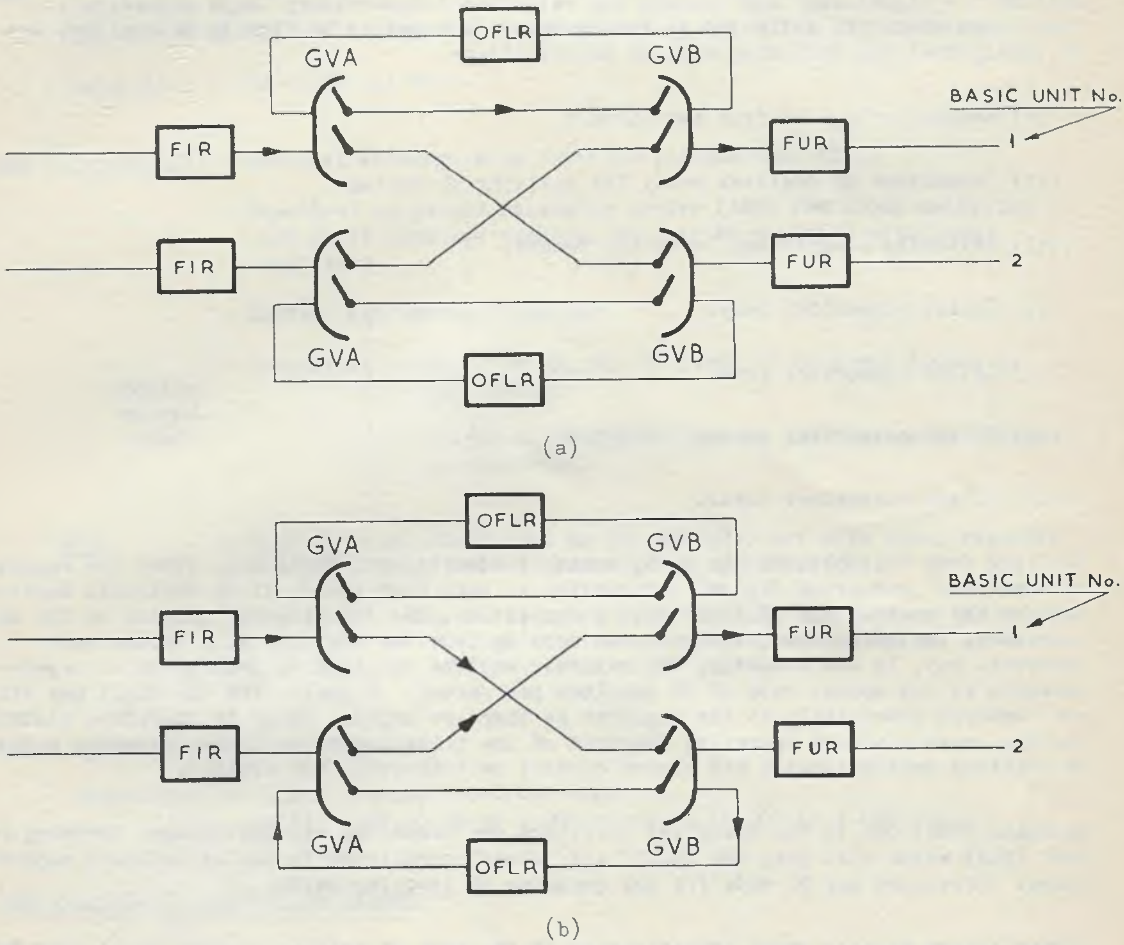


FIG. 37. ARM.50 - OVERFLOW LINKS.

If a call arrives at basic unit No.1 and is to be routed to a line located in GVB in the same basic unit, the connection can be made over one of the ten links between GVA and GVB of basic unit No.1, as shown in Fig. 37a. If, however, all of these links are occupied, a test is made on an overflow link of basic unit No.2. If this link is free, connection is made from GVA in basic unit No.1 over a normal link to GVB in basic unit No.2, thence via the overflow link to GVA of basic unit No.2. If, now, there are free links from this GVA to GVB of basic unit No.1, the through connection can be established as indicated in Fig. 37b.

Manual Operating Positions Associated with ARM Exchanges. Any type of manual operating position may be associated with ARM type exchanges, the special junctions to and from the switchboards being terminated in the automatic trunk multiple in much the same way as the ordinary trunk and junction lines to the network as a whole. The switchboard junctions, however, are terminated on special relay sets which, in addition to performing the functions of the normal trunk relay sets (FIR, FUR and FDR), provide for the supervisory signals and other operating facilities required for the manual handling of calls.

The "outgoing" junctions from the switchboard provide operators with access to special registers in the ARM exchange, connection to all trunk and junction groups being on an automatic selection basis via the register. So that the operator will be aware of the conditions encountered during the establishment of a call, provision is made for the switchboard outgoing relay set (ULR) to interpret the various line control signals (see Section 5 - Signalling) and operate the switchboard supervisory lamps accordingly. Conditions which are indicated to the operator have yet to be finally determined, but it is likely that the following will be practicable:-

(i) Seizure of outlet from switchboard.

(ii) Connection of register ready for dialling or keying.

(iii) Switching congestion, local and remote.

(iv) Called subscriber busy.

(v) Called subscriber free.

(vi) Called subscriber answer (or interception).

(vii) Called subscriber clear.

(Items (iv) to (vii): Includes Service Codes)

Dialling from switchboards may be by means of conventional dials but, since the register is capable of receiving digital information at very high speed, it is obviously desirable to make the maximum use of digit keying facilities. As the crossbar content of the network increases, the advantages of high-speed sending from the register will become more apparent, but, in the meantime, the register will be required to impulse into step-by-step networks at the normal rate of 10 impulses per second. Signals from the digit key strip are conveyed immediately to the register as they are keyed. Delay is therefore minimised and the unsatisfactory operating features of the present-type sending equipment, as used in existing semi-automatic and sleeve control switchboards, are avoided.

Incoming junctions to the operating positions are connected via switchboard incoming relay sets (BLR) which also pass the "call" and "clear" conditions to the switchboard supervisory lamps. Provision may be made for the queueing of incoming calls.

(Other design aspects under investigation at the time of writing include facilities for preferential access to trunk lines, timing of calls and traffic control aids.)

Call Charging Equipment. In both ARM.20 and ARM.50 systems, one of the functions of the route marker VM is to determine the charge applicable to the call being connected. This is achieved by examination of the digits received from the register, the charging information being stored in the "memory" of the charge determining equipment in such a way that the appropriate charging rate can be interpreted from any combination of digits. This may be compared to the use of the "Call Charge Table" in manual practice whereby cross-reference between the listings for the calling and called exchanges produces the rate applicable between the two.

Having determined the charge rate, the marker then causes an appropriate marking to be made in the tariff relay set TZR (associated with the appropriate incoming relay set) and to which is connected the meter pulse generating equipment.

Upon the receipt of the answer signal, which is returned when the called subscriber answers, TZR causes the meter pulses to be sent backwards over the junction circuit to the originating exchange to operate the meter associated with the calling subscriber's line.

6.5 Summary. Three types of L.M. Ericsson crossbar exchange have been adopted as standard, namely - ARF, ARK and ARM.

ARF - Complete terminal exchange with full facilities.

- Has provision for small amount of trunk switching and S.T.D., if necessary.

- Capacity - 1,000 lines and over.

ARK (511 and 521) - Terminal exchange with fewer facilities than ARF.

- Dependent on parent switching centre (ARM) for trunk switching and inter-exchange working, but may be equipped with local registers.

- Simpler and cheaper than ARF.

- Capacities - ARK.511 - 30, 60, 90 lines (7 both-way trunks or junctions).

ARK.521 - 100-2,000 lines in 100-line units (trunks as required).

(523) - Same terminal facilities as for ARK.521, but with local register and providing limited trunk switching facilities.

Capacity - May be equipped with 100-line subscribers' units and 20-line terminal exchange junction units, up to a combined total of 20 units.

ARM - Automatic trunk exchange.

- Capacities - large - ARM.20 100-8,000 circuits.
small - ARM.50 up to 2,000 circuits (1,000 in 1,000 out).

Application of Crossbar Exchanges.

ARF - New installations in city and large country centres.

- Extensions or replacement of existing step-by-step exchanges.

- First stage switching in step-by-step networks.

ARK - New installations in country centres where not more than 800-1,000 lines in 20 years.

ARK.523 may be used at minor trunk switching centres.

ARM - Switching centres of national trunk network.

- Provides for S.T.D. and operator-controlled trunk traffic.

Existing types of manual operating position may be associated with L.M. Ericsson exchanges.

7. INTERWORKING.

7.1 Introduction. In a telephone system employing exchanges entirely different in switching principle, there are naturally problems in achieving satisfactory interworking between dissimilar elements. The introduction of common control exchanges into the Australian predominantly step-by-step system therefore has special interworking features and one of the important advantages of the L.M. Ericsson register-controlled crossbar system is its proven ability for interworking with step-by-step exchanges.

In this section, an outline is given of the main aspects of the integration of crossbar with exchanges already in service, reference being made also to requirements for interworking with the existing trunk line network.

7.2 Interworking between Crossbar Exchanges. From the descriptions given in the preceding sections, it will be clear that interworking between crossbar exchanges is essentially a question of the form of signalling from one to the other, that is, between the line relay sets on which the interconnecting junction and trunk lines are terminated, and between the controlling registers in the exchanges concerned. These aspects are covered in Section 5 (Signalling) and further reference is not required here. However, an appreciation of the general interconnecting arrangements between crossbar exchanges in a regional network may be obtained from the model trunking scheme embracing systems ARF, ARK and ARM, as shown in Fig. 39. This, of course, is capable of considerable variation but, if examined in conjunction with the descriptions already given of the signalling methods and the operation of the individual types of crossbar exchange, will serve to illustrate the make-up of a wholly crossbar telephone network.

7.3 Interworking with Step-by-Step Exchanges. The operation of the step-by-step system is achieved by signalling the dialled information in the form of loop-disconnect impulses which act directly on the selecting equipment to set the switches according to the digits received. In register-controlled crossbar equipment, the transfer of the dialled information is by means of multi-frequency code and the crossbar switches are set indirectly by common control equipment after examination of the dialled information.

Because of these differences in signalling and switch setting, the two systems are completely incompatible when considered in their own right. In effect, they do not speak the same language so that, whenever information must be passed from one to the other, some form of interpretation or signal conversion is required.

ARF Crossbar to Step-by-Step. 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 - see Fig. 38.

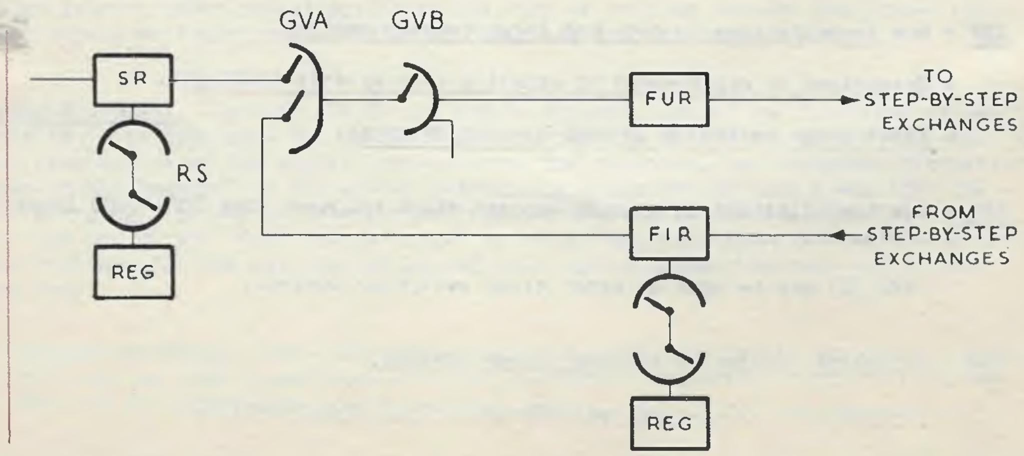


FIG. 38. TRUNKING BETWEEN CROSSBAR AND STEP-BY-STEP EXCHANGES.

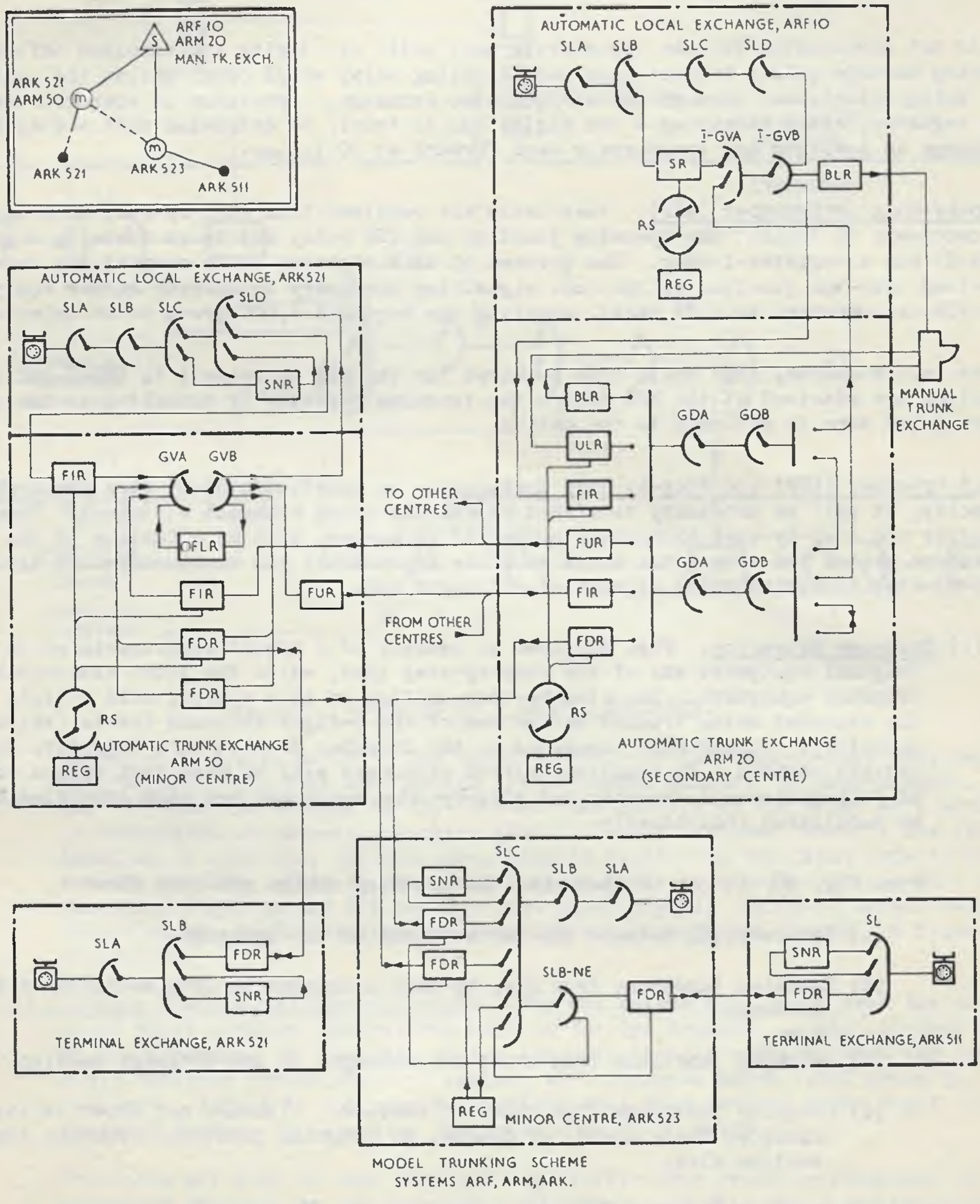


FIG. 39. MODEL TRUNKING SCHEME.

The remaining digits are sent at normal speed (10 i.p.s.) to the step-by-step equipment, after which the register releases.

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

It is not practicable for the register to wait until all digits are received before sending decadic pulses because long post-dialling delay would occur whilst the connection was being established through the step-by-step exchange. Provision is therefore made for the register, after receiving a few digits (up to four), to determine that a step-by-step exchange is involved and immediately send forward at 10 i.p.s..

Step-by-Step to Crossbar (ARF). 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.

There is, of course, some small time required for the FIR to connect to REG-I and if any impulses are received at the FIR before the incoming register is connected to the circuit, "try again" tone is returned to the caller.

Mixed Crossbar (ARF) and Step-by-Step Exchanges. As existing step-by-step exchanges reach capacity, it will be necessary to effect extensions using crossbar equipment. These mixed crossbar and step-by-step exchanges, or hybrid exchanges, will be a feature of the telephone system for many years as it would be impractical and uneconomical to discard step-by-step equipment still capable of efficient use.

(i) Exchange Extension. Fig. 40 shows an example of a hybrid exchange in which the original equipment was of the step-by-step type, while the later extensions are of crossbar equipment. The step-by-step section in this example used 6-digit working, the crossbar being trunked out on one of the 6-digit thousand levels (third selector). Subscribers connected to the crossbar section will therefore have 7-digit numbers. In practice, hybrid exchanges will be developed with a variety of combinations of crossbar and step-by-step equipment and each installation must be considered individually.

From Fig. 40, it can be seen that the trunking scheme provides for:-

(a) Interworking between the two sections of the exchange.

(b) Incoming junctions from step-by-step exchanges to both sections of the exchange.

(c) Incoming junctions from crossbar exchanges to the crossbar section.

(d) Outgoing junctions from crossbar section. Although not shown in this example, there could, of course, be outgoing junctions from the step-by-step section also.

(e) Incoming Traffic of Step-by-Step Origin. This 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. 7.3

A call to a subscriber in the step-by-step section is trunked from the GIV stage to the bi-motional fourth selectors. For this call, the register must provide decadic pulses to operate the step-by-step equipment.

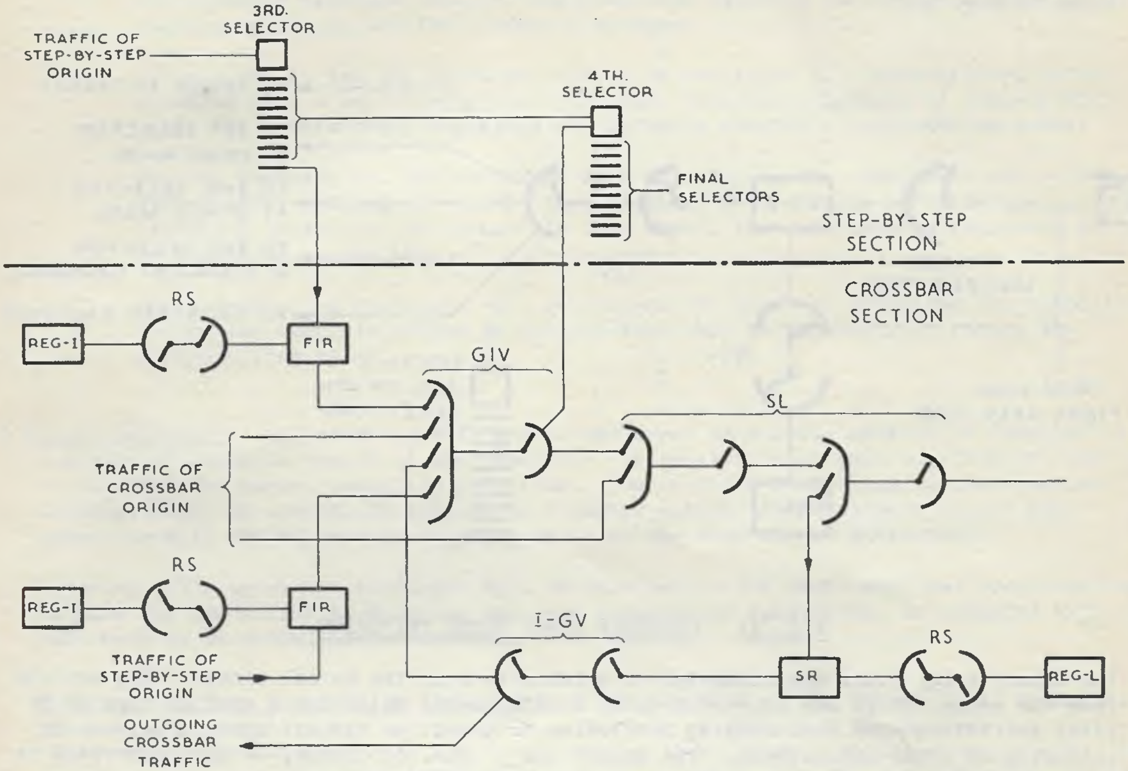


FIG. 40. TRUNKING OF A HYBRID EXCHANGE.

Incoming 10 i.p.s. calls to the third selector of the step-by-step section of the exchange will step this switch in the normal manner. In this example, the "1" level is trunked to the crossbar section via an FIR relay set, with which is associated an incoming register (REG-I). This 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 of crossbar origin will send the third digit to the GVM as the first coded signal. Calls to levels other than "1" on the third selector are switched via bi-motional fourth and final selectors.

(f) 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 (third digit of number) will indicate which 1,000 group is required. A call to the crossbar section will need another coded digit (fourth digit of number) to determine the individual 1,000 group.

Provision may also be made for incoming traffic from crossbar exchanges 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.

(ii) First Stage Crossbar (ARF) Switching in Step-by-Step Exchanges. Crossbar switching stages may be used in step-by-step exchanges to replace one or more ranks of bi-motional switches. In this way, the general advantages of crossbar may be realised, in particular those of direct and alternate routing, and this application of crossbar will be seen in cases where new D.S.R. stages would normally be provided at step-by-step exchanges. For example, exchanges now trombone trunked will have first stage crossbar switching equipment installed.

Typical trunking for such a crossbar first stage in a step-by-step branch exchange is shown in Fig. 41.

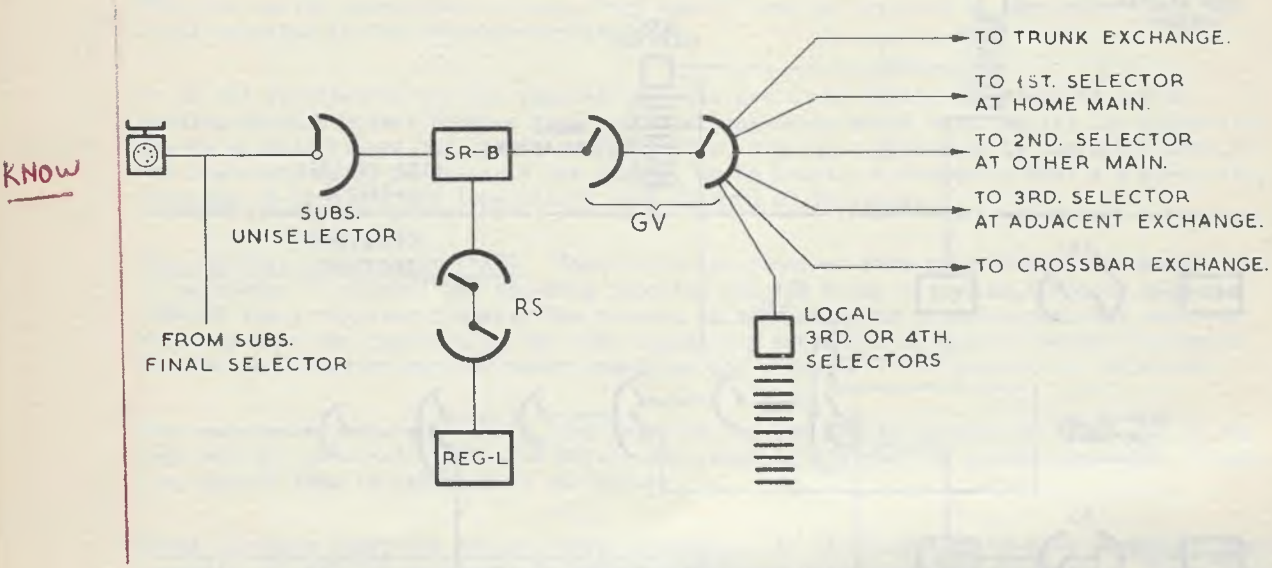


FIG. 41. CROSSBAR FIRST STAGE SWITCHING.

The subscribers' lines are connected to uniselectors in the normal manner. The outlets from the uniselectors are connected to SR-B relay sets, which are a special type of SR relay set fitted with back-busying facilities to guard the circuit against seizure or intrusion by other subscribers. The subscriber's line, of course, is also connected to a bi-motional final selector as in a normal step-by-step exchange.

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

When a subscriber originates a call, the calling line is switched by the uniselector to a free SR-B 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 high-speed code.

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

(a) Local third and fourth selectors.
(b) Second and third selectors at other step-by-step exchanges.
(c) Group selector stage of crossbar exchanges.
(d) The trunk exchange.

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

Calls to step-by-step switching stages cause the register to send pulses at the normal speed of 10 i.p.s.. On calls to crossbar exchanges, the necessary information is forwarded from the register in the form of high-speed code.

The arrangement described caters for outgoing traffic to other exchanges. It is also possible, of course, for incoming calls from other exchanges to be switched by crossbar first stage group selectors in a similar manner as for the hybrid exchange trunking scheme shown in Fig. 40.

ARK Interworking with Step-by-Step. When ARK exchanges are to interwork with a step-by-step exchange, special registers are required for the conversion of the signals needed in the two differing systems.

If only one or two ARK exchanges are to be connected to a step-by-step parent, which is also a switching centre for other terminal exchanges of step-by-step type, the interworking registers are normally located at each ARK exchange.

Should, instead, the ARK exchanges be a majority in the area, with only a few step-by-step exchanges, an ARM trunk exchange will usually serve as the switching centre for the area. In this event, the interworking registers will be available at the ARM.

The interworking registers will be designed to start to establish the connection before the complete number is dialled when this is necessary to reduce the post-dialling delay.

7.4 Manual Exchanges. Interworking with manual exchanges in a local network is essentially a matter of suitable design of the junction line relay sets to pass supervisory signals to and from the manual operating positions. The circuits connecting to the crossbar exchange will, in effect, be similar to crossbar automatic subscribers' lines and operators will therefore make outgoing calls in the same way as subscribers.

Incoming calls to manual exchanges will be received in the usual way, but provision must be made for the differing metering and time supervision conditions, as compared with a call made to an automatic subscriber.

Metering and Time Supervision Arrangements. In the case of the manual local exchange, the metering condition may be applied in a variety of ways, but the Telephonist must first answer the incoming call - metering taking place later. In the normal course, the answer signal is passed back to the originating exchange when the automatic subscriber answers and this cancels the time supervision feature, at the same time setting up the metering condition. However, a call to a manual exchange may be ineffective due to DA or WBY conditions, or the called subscriber may be slow in answering and, as the call must be metered subsequent to the initial answer by the Telephonist, provision must be made for the time supervision feature to be inoperative on calls to manual exchanges.

The manual exchange concerned will have been reached via either crossbar or step-by-step equipment and the appropriate type of destination signals returned to the originating register. Reference to Section 5 - Signalling, will indicate how this is achieved and it will be noted from Table 3 of that section that specific provision is made for the cancellation of the time supervision feature, i.e., backward signal 1B.3 - "no throwout".

When the metering condition is applied by the answering Telephonist, or upon answer by the manual subscriber where this is provided for, the normal line signal indicating the "B-party answer" condition is passed back over the circuit, thus causing metering to take place at the originating exchange in the normal way.

Non-metering Services. It will be noted from the table of signals previously referred to that special provision is made for calls to non-metering lines. This will apply on wholly-crossbar calls to manual operators obtained via the special services codes (i.e., "011", etc.) and, in these cases, the normal time supervision conditions apply since it is possible to return the "answer" signal when the operator answers but without causing metering to be effected.

It should be noted, however, that non-metering services obtained via step-by-step exchanges will not provide the normal reversal and, since this is the only form of answer signal provided by step-by-step equipment, provision must be made for cancellation of the time supervision feature on all calls to step-by-step exchanges.

Further reference to this aspect of interworking is made in Section 8 - Facilities.

Trunk Operating Positions. Ultimately, when subscribers are able to dial the bulk of their trunk calls, the need for operating positions designed specifically for trunk call working will largely disappear and, in their place, general purpose "assistance" positions will be used.

In the meantime, it will be necessary to continue the use of the presently termed "trunk positions" primarily for the connection of originating operator-controlled trunk calls and incoming or transit traffic where automatic switching is not available.

Crossbar local exchanges (ARF and ARK) are readily adaptable for interworking with various types of manual operating positions and it is therefore possible to use the existing standard sleeve-control switchboards as a manual trunk suite in direct association with the local exchange. The ARM trunk exchange equipment is designed primarily for automatic trunk switching and is similarly capable of interworking with various types of modern cord and cordless operating positions. The particular type of switchboard which will be adopted as the standard manual assistance position for crossbar trunk exchanges has yet to be determined.

7.5 Existing Trunk Network. In general terms, interworking with the existing DC, AC and 1VF line signalling systems in the junction and trunk network will be relatively simple since the various types of line relay sets already provide for signal conversion between the systems themselves and are thus readily adaptable to the requirements of crossbar line signalling. Inter-register signalling over all of these circuits does not present any problem since it is quite independent of the type of line signalling used and requires only the normal speech path for the transmission of the multi-frequency code signals, thus conversion to any other form is not necessary.

However, some interworking problems arise where extensive use has been made of 2VF signalling. It is proposed to avoid signalling conversion in this case, wherever possible, because the 2VF system is not suitable for subscriber trunk dialling conditions as it was designed fundamentally for operator-controlled dialling. The necessary modifications to provide for S.T.D. are unattractive and it is proposed to keep the 2VF and MFC networks separate, i.e.:-

(i) 2VF for operator-controlled calls.

(ii) MFC for S.T.D. calls via crossbar equipment.

The proposed method of handling trunk traffic from Trunk Area A to Trunk Area B is shown in Fig. 42. For simplicity, only the A to B direction has been shown. As indicated by the full lines, the trunk traffic is at present handled at a manual trunk exchange where the operator dials direct to the called subscriber in Trunk Area B via the trunk switching network, 2VF signalling being used between the two switching centres. With the introduction of S.T.D., the objective is to route the S.T.D. calls via crossbar equipment and the proposed trunking is shown by the dotted lines. The digital signalling between the exchange networks and the Crossbar Trunk Switching Centre will be either 10 i.p.s. or MFC, depending on whether the terminal exchange is step-by-step or crossbar, respectively, the signalling between the crossbar trunk centres, of course, being MFC.

This method of handling trunk traffic keeps the 2VF and MFC signalling systems separate from each other but, as the trunk system will be extended with crossbar equipment in the future, it is possible that some overflow will be required from the manually operated system into a crossbar trunk centre. As shown in Fig. 42, this would be achieved by using a 2VF-MFC signalling conversion register which would have similar functions to the REG-I in a network crossbar exchange.

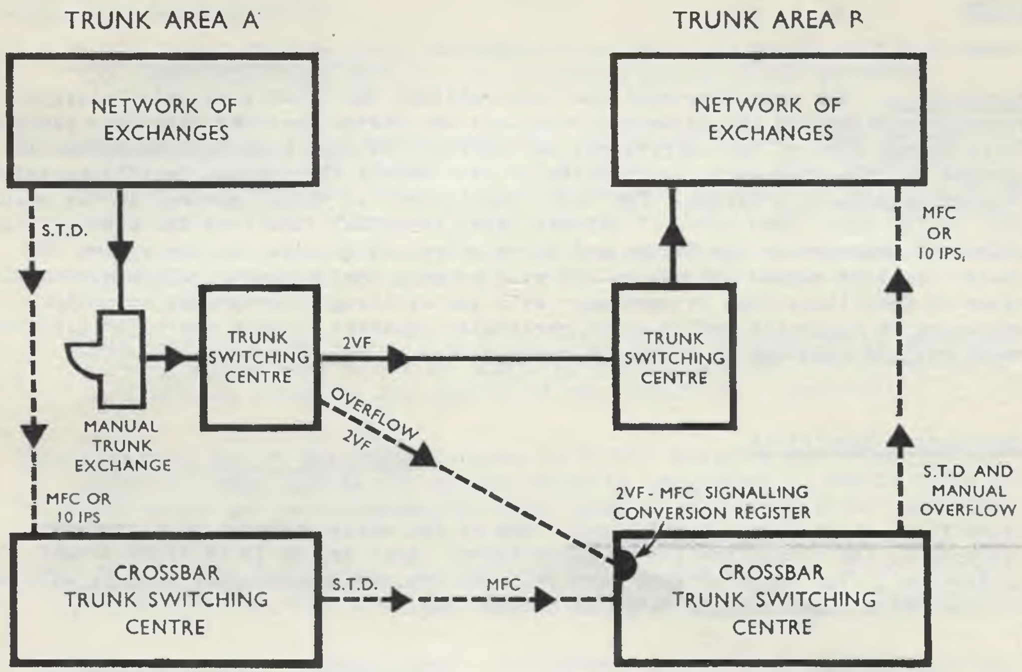


FIG. 42. INTERWORKING WITH THE 2VF TRUNK NETWORK.

7.6 Summary. The basic interworking requirements may be summarised as follows:-

(i) Difference in Signalling.

Crossbar to SxS. SxS exchanges require 10 i.p.s. dialling; therefore, crossbar register must start sending before all digits received from subscriber - otherwise long post-dialling delays occur.

SxS exchange recognised by analysis of up to four digits of called number.

SxS to Crossbar. 10 i.p.s. from SxS has to be converted to MFC for crossbar. Incoming register required in crossbar exchange.

Trunk Network. 2VF not suitable for S.T.D. as it is deisgned essentially for operator use.

Generally, 2VF and MFC will be kept separate. Overflow from manual trunk system requires 2VF-MFC conversion similar to SxS to Crossbar in local networks.

(ii) Time Supervision. Time supervision is controlled by "answer" signal, i.e., reversal in SxS exchanges.

Absence of reversal on calls to non-metering SxS services requires cancellation of time supervision on all calls to SxS.

Manual Exchanges. Telephonist must answer before reversal applied; therefore, necessary to cancel time supervision on calls to manual exchanges.

8. FACILITIES.

8.1 Introduction. The preceding sections have outlined the principles and philosophy of crossbar working and the essential technical and design features have been described. In so doing, some of the operational and service features have been mentioned and the purpose of this section is to describe in more detail the various facilities which crossbar equipment provides. The term "facilities" is rather general in its meaning but, in the sense used here, it denotes those technical functions and possibilities which are inherent in the design and which represent to users of the system the characteristics of its operation. It will be seen that crossbar offers a much wider range of facilities than is customary with the existing step-by-step automatic exchanges in Australia and it is of particular interest to note the major differences which will be apparent to telephone users.

8.2 Subscribers' Facilities.

Classification of Subscribers' Lines. One of the major features of a crossbar exchange is the classification of subscribers' lines or, as it is often termed, "class of service". The usage of this term requires explanation in order that it will not be confused with other similar terms in current use.

Subscribers' services are "classified" in many ways - there are "business" and "residence" services; "exclusive", "duplex", "P.B.X.", "public telephone", etc., and in some quarters the class of service might be known as "handset", "leased coin - attachment", "extension telephone" and so on. Many of these interpretations are applicable in crossbar working, but it is important to note the particular significance of the term when used to denote a crossbar facility.

In a crossbar exchange, the subscriber's line stage marker (SLM) is designed to perform a variety of functions (see Section 4), one of which is to identify the calling line. Arrangements are made in the circuitry of the marker equipment and associated relay sets so that each subscriber's line is permanently "marked" according to its particular classification and, upon connection to a register, the particular "class marking" is conveyed to the register where it is recognised and further access permitted or denied accordingly. The important point here is the word "access" and it will be seen that "class-of-service" can be interpreted to mean not only the type of sub-station equipment, but also the degree of access available from a particular service. It is preferable, therefore, to think in terms of classification of subscribers' lines and it will be readily seen that this is analogous to the manual exchange practice of utilising special lamp cap and jack markings which, in addition to indicating the type of sub-station equipment, for example, a public telephone, also remind the Telephonist to carry out particular operating instructions.

In ARF type exchanges provision is made for 17 line classifications. Some have been reserved to classify junctions from terminal exchanges which are parented to the ARF and the remainder have been provisionally allocated for subscriber classifications. The subscriber classifications may be conveniently sub-divided into:-

(i) Originating classifications those which in some way modify or restrict a subscriber's capacity to originate a call, and

(ii) Terminating classifications those which pass back special information to the calling end when a subscriber is to receive a call. The following originating and terminating classifications are proposed:-

Originating Classifications.

(a) Normal Line - Unrestricted. Telephones in this class would have full access to the local call area, to S.T.D. in Australia and to trunk operators.

(b) Local Call Only. This would completely bar access to the trunk network either subscriber dialled or through the trunk operator. It would serve local-call-only public telephones and leased coin attachments. In addition it could be used on subscribers' lines with key control for conversion to unrestricted access.

This category is suitable for high calling rate lines terminated directly on a 1GV inlet as well as for lines connected via the SL stage.

(c) Trunk Operators and Local Calls Only. This classification would be suitable for barring subscribers to S.T.D. Again such a service could be converted to unrestricted access by key control at the subscriber's premises.

(d) Multi-Coin Public Telephone. Access to S.T.D. would be prevented, and certain operator codes such as 011 and 015 would be translated to enable calls from multi-coin public telephones to these operator positions to be identified.

(e) S.T.D. Public Telephones. Access to S.T.D. routes would be permitted, and operator codes would be translated for identification purposes as for category (d).

(f) Temporarily Disconnected Lines. Provision may be made for services to be temporarily deprived of outgoing access by this means, rather than by the current practice of sleeving line relay contacts.

(g) Test Lines. These lines are given unrestricted access. However, time supervision in the register is suspended and arrangements are made to retain the register connection on calls to busy lines or when the congestion signal has been received. Further, the SR is set for last party release.

Terminating Classifications.

(a) No Throw-out. A subscribers line marked for this class of service will, on being tested and found free, return an end of selection signal, B3. The register at the calling end then suspends time-out before answer in the originating SR. This category may be used for manual exchanges connected to the SL stage, or for any subscriber for which ringing for longer than 90 seconds is required. Further details are given in para. 8.4(iii), SR relay set time-out.

(b) Idle Non-Metering. In this case signal B5 is returned if the called subscriber is free. The metering circuit in the originating SR is disconnected by the register.

(c) Interception-Malicious Call. A line with this category marking will return signal B6 on being tested idle. Where ARF type centralised interception is provided, the originating register diverts the call as described in para. 8.3 interception arrangements. Where Ericsson centralised interception has not been provided, the register sets the calling SR for last party release. This arrangement may be used for malicious call tracing as described in para. 8.2 "Nuisance Calls".

(d) Unallotted Group. This category has been designed to handle calls to unallotted 100 line groups within the exchange. At the terminating end the call is diverted to a special number within the called 1,000 line SL group, to which "check number tone" is connected. The limitations on the capacity of the classification circuitry in the subscribers line stage equipment make it impractical to class mark every spare number in the exchange; however this classification could be utilized for handling changed number calls.

The need is also foreseen for such facilities as:-

(i) International Access. Exchange lines in this class would provide for subscriber dialling to overseas countries and would also have full national access.

(ii) Data Transmission. Provision may be necessary for the telephone system to cater for data transmission in the future. A special line classification for this facility would permit the controlling registers to take special action, if necessary, and would cater for observation and testing services under these conditions.

(iii) P.M.B.X. and P.A.B.X. Services. Whilst the classification appropriate to ordinary telephones will cater for individual P.M.B.X. and P.A.B.X. services, the possibility of catering for all telephone facilities in large buildings by the provision of common exchange equipment within the building itself may demand one or several classification identifications. This action would avoid the necessity to install individual P.A.B.X. services throughout the building and provide for ordinary straight-line services, as well as the P.A.B.X. requirement.

Subscribers' lines will normally be connected as "unrestricted" and although provision could be made for all subscribers' lines in a 1,000-line group to be marked with one or other of the restricted classifications, this is a costly and largely unnecessary requirement for the whole of an exchange. The normal ARF design provides for simultaneous classification markings to be provided for up to 23% of the lines in any 1,000-line group.

At the ARK type exchanges, which are of simpler design than the ARF type, up to six subscribers' line classifications are possible in the marker equipment. As ARK exchanges probably will not extend much beyond 1,000 lines, the fewer subscriber classifications should meet all normal requirements. As with ARF equipment, simultaneous marking is limited to some 20% of the subscribers' lines although, by the addition of special relays, this may be increased to 100%.

P.B.X. Group. The term "P.B.X. Group" is commonly referred to as "rotary group", deriving obviously from the rotary movement of the bi-motional selector. The rotary searching characteristic of the bi-motional switch also necessitates that groups of exchange lines be allotted in sequential order. With crossbar, there is no such conception of movement, rotary or otherwise, nor of sequential searching, hence "rotary group" has no place in crossbar terminology and, instead, the use of the term "P.B.X. group", or "group search", is more appropriate, irrespective of the type of exchange equipment involved.

In ARF exchanges, only specific 1,000-line sections are equipped for P.B.X. working, special relay sets being associated with the SL marker equipment. On all calls incoming to the subscriber's line stage, a test is made at the P.B.X. equipment to ascertain if the called number is a P.B.X. service. If the number is a P.B.X. service, the P.B.X. equipment selects a free auxiliary line in the particular P.B.X. group and the connection is established to the selected line. The term "auxiliary line" is used to denote lines in a P.B.X. group other than the principal line, which is the one listed in the directory. Since the P.B.X. equipment selects a free auxiliary line as a first choice, it will be obvious that the dialled directory number is chosen only when all auxiliary lines are busy and thus it becomes the last choice in the group.

As a general rule, the directory numbers for P.B.X. groups are confined to those which have the last two digits the same (e.g., 2 5711, 2 5433), there being 100 such numbers in each 1,000-line section of an exchange. Provision is made, however, for other numbers to be used as P.B.X. group numbers, if required. The lines of a P.B.X. group need not be numbered in sequence but may be anywhere within the particular 1,000-line section and it is unnecessary therefore to reserve spare numbers for each P.B.X. subscriber. If the exchange P.B.X. search equipment is faulty, the connection is made to the dialled number. Similarly, as with bi-motional exchanges, if a number in the P.B.X. group other than the principal advertised line is dialled, the connection is established to that number only. The size of a P.B.X. group in an ARF exchange is usually limited to a 20-line maximum and, if more are required, separate groups of 20 are provided.

Normally, the line first tested by the P.B.X. equipment would be advertised for night switching, with the result that after-hours calls to the principal or listed number would be switched to the night switched line, unless, of course, it was busy. The P.B.X. search facility may also be applied over individual numbers of the after-hours lines. At ARK exchanges, similar provision can be made for P.B.X. groups, but the size and number of groups is much smaller. In general, three 5-line groups may be provided with ARK.511, whilst with ARK.521, up to 13 6-line groups may be catered for. Larger groups up to 11 lines may be provided if the total number of P.B.X. lines in the exchange does not exceed 80.

P.A.B.X. In-dialling. Provision is made in the exchange equipment to allow direct in-dialling access to P.A.B.X. extensions. The national numbering plan makes provision for P.A.B.X. extension numbers to be included in the local network numbering, consequently, it will be possible to dial directly to an extension of a P.A.B.X. by dialling a number no greater in length than for ordinary subscribers' services.

As a general rule, in-dialling services will be centralised into selected 1,000-number groups for easy discrimination and it is likely that sub-division into 100-number groups and smaller will also be practicable.

Party Lines. ARF equipment provides for two-party services without inter-party communication and will operate with the standard A.P.O. duplex sub-station equipment.

At ARK exchanges, provision is made for normal two-party service with selective ringing and metering and inter-party communication, with or without secrecy. Provision may also be made for three-party and four/six-party services with non-secret intercommunication, selective metering and code ringing by dialling the directory number.

Public Telephones (and Leased Coin Attachments). Existing types of public telephones and leased coin attachments will operate satisfactorily with crossbar exchanges.

Multi-coin instruments connected to ARF exchanges may be marked with a classification which causes calls to 011 and 015 to be specially identified to operators, either as a special calling lamp signal or by diversion to a special answering point. Alternatively, tone may be inserted at the trunk exchange and calls combined with the normal queue, thus rendering unnecessary the provision of tone relay sets individual to public telephone lines. Public telephones connected to step-by-step exchanges cannot use the translation facility, hence the continued use of tone relay set equipment will be necessary in mixed crossbar and step-by-step networks.

Local call public telephones are grouped with lines classified "local calls only".

A new type of coin-telephone instrument capable of being used for S.T.D. calls is being developed. Provision is made for such lines, including leased services, to be marked with a distinctive classification which, whilst permitting access to the trunk dialling network, will cause calls to the standard trunk service codes to be specially identified to operators.

Access to Remote Assistance Centres. As a general rule, subscribers will be required to obtain all assistance and information from one centre within their particular area. Subscriber access to service codes in other areas will normally be barred, with the possible exception of "directory information". A call for out-of-area directory information would be obtained by dialling the appropriate national area code followed by the service code 013, for example, 0 ABC-013, and the crossbar register will be "instructed" to accept such calls. Calls to other distant area service codes will be barred or diverted to the local assistance centre.

Metering. The design of ARF equipment provides for the metering of local calls to take place at the end of the call, that is, when the calling party clears. However, on high calling rate-lines connected directly to the 1GV stage metering on answer is employed. With ARK exchanges, metering takes place when the called subscriber answers.

The original design of ARK equipment provided for meter-on-answer conditions for calls connected via the parent switching exchange (ARM) whilst, for calls within an ARK exchange, end-of-call metering applied. In order to achieve uniform metering conditions for all calls originating in ARK exchanges, the design has been modified for metering-on-answer. With ARF equipment, it was not considered worthwhile to modify the existing methods of manufacture.

On subscriber trunk dialled calls, uniform metering conditions apply at all types of exchanges, that is, the meter operates immediately the "B" party answers. The first of the regular timed pulses arrives at random within the space of one chargeable period but, to avoid the possibility of overcharge, this pulse is suppressed. Subsequent metering occurs at the regular fixed intervals determined by the particular tariff rate. The period between the operation of the meter-on-answer and its next movement therefore cannot be less than one nor greater than two chargeable periods.

This form of metering is known as modified periodic (or modified Karlsson) metering and ensures that there is one registration on all chargeable calls, no matter how short the duration.

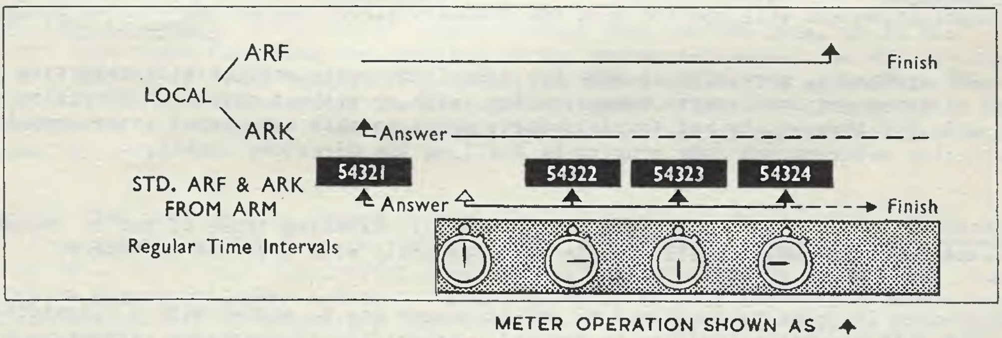


FIG. 43. METERING CONDITIONS.

Meters in crossbar exchanges are of the standard A.P.O. five-wheel type mounted on specially designed plates and racks and, in keeping with the requirement that movement within crossbar exchanges be reduced to a minimum, the meter racks are placed to permit reading without entering the equipment room proper. The racks will be of L.M. Ericsson design and the meters may be mounted 10 × 10 instead of 5 × 20 as is the practice in step-by-step exchanges.

Both ARF and ARK exchanges provide for the operation of private meters at subscribers' premises by pulses of alternating current inaudible to the subscriber.

Nuisance Calls. The main difficulty with the nuisance call is the tracing of its origin. With the existing step-by-step exchanges, this can only be done whilst the connection is held intact from the calling telephone, which usually means maintaining conversation with the offending party. This method is unsatisfactory since it is quite often unsuccessful because of the time taken to effect the tracing of a call which may have originated anywhere within a network. The length of time involved is such that an annoying call will probably be terminated long before it is possible to identify its source.

With ARF crossbar exchanges, it is possible to arrange a special connection in the marker equipment of the called party so that the clearing of a connection is controlled by the called subscriber. The called subscriber, by leaving the handset off the rest, can then hold any connection back to the originating exchange primary equipment, thus permitting the calling line to be identified. Even though this connection is held, the caller is not prevented from making or receiving further calls and would therefore be unaware that the call could be traced.

The main disadvantage of this facility is the need to leave the handset off until such time as the attention of the exchange Technician or assistance operator can be obtained from another telephone. The provision of a more elaborate facility would involve considerable additional manufacturing cost and it has therefore been decided to adopt this simple method of tracing nuisance calls as standard for A.P.O. crossbar exchanges. In the case of the persistent annoying caller, special arrangements involving the use of either the interception or observation facilities will be available.

It must be borne in mind that the "B" party hold feature will be fully effective only in a wholly crossbar area. Where other types of automatic exchange are involved, it will be practicable to hold the connection only as far as the step-by-step junction incoming to the crossbar network.

At ARK exchanges, tracing facilities are not provided, but connection to "interception" should be sufficient to meet requirements in areas served by ARK equipment.

Trunk Access Barring. There will be a requirement in certain cases for access to the trunk line network to be barred from a particular subscriber's service, for example, a leased coin attachment. Provision has therefore been made for comprehensive access barring facilities in crossbar exchanges by means of the line classification feature. (See para. 8.2.)

8.3 Operational Facilities.

Interception Arrangements. In step-by-step exchanges, the interception circuit is mainly used to enable incoming calls to certain subscribers to be filtered by an operator and "switched through" or re-directed, as the case may be. A simplified version of the interception circuit is used to provide "changed number" and "diversion" services, either with operators or recorded announcements.

"Interception" may therefore be used to describe all such conditions and it is in this general sense that the word is applied in crossbar terminology.

(i) ARF Interception. In ARF type crossbar exchanges, on every incoming call, the subscriber stage marker (SLM) makes a test via a special circuit to a central interception point to check whether or not the called subscriber is "on interception".

The interception centre, which may serve a complete closed numbering area, is equipped with a special jackfield in addition to manual and recorded answering facilities. The jackfield contains one jack for each subscriber in the area served and is made up of 1,000-line units, each measuring 8" × 20". By inserting a special plug in a jack, the particular line is marked for interception. Three different coloured plugs may be used to divide intercepted subscribers into categories such as:-

(a) filtered by operator;

(b) changed numbers; and

(c) vacant lines in fully equipped portions of the exchange.

On the initial test made by the SL marker, coded signals equivalent to the last three digits of the called number are forwarded over the special test circuit to set special crossbar switches associated with the interception jackfield to "find" and test the jack for the number called. If any one of the three plugs is in the particular jack, the interception signal (see Section 5) is immediately fed back to the originating register (or the controlling incoming register in the case of calls from other networks or areas) and the interception test circuit and SL marker at the called exchange are released.

This operation is very rapid, the holding time being merely a few milliseconds, and one test circuit per 1,000 subscribers' lines is usually sufficient. When the controlling register receives the interception signal, it obeys the "instruction" for interception, translating the original digital information and setting up a fresh connection direct to the interception centre, either over a direct circuit or via the normal junction network. Relay equipment at the interception centre, on receipt of this call, tests the particular jack at the jackfield to determine the interception category (as indicated by whichever plug is in the jack) and finally establishes the connection to the appropriate answering point, which could be an operator, a recorded announcement or a tone. Provision is made for the number called to be displayed to the operator, thus permitting the interception records to be consulted before speaking to the calling party. If an operator is not immediately free to accept a call, the call is queued and ring-tone fed to the caller.

(NOTE: The foregoing describes the interception equipment currently supplied by L.M. Ericsson Ltd. (see Fig. 44). A new method of marking lines for interception has recently been developed which utilises a compact strapping field and wire loops rather than the jackfield and plugs. The method of operation is the same but provision is made for a greater number of interception categories.)

Intercepted calls which are connected to a recorded announcement may, if the caller remains in circuit for a given time - say, two or three complete announcements - be automatically extended to an operator.

Interception of calls to spare 1,000 groups and unequipped portions of 1,000 groups, or in the case of cutover number changes, may be arranged within the exchange independently of the normal interception service and would, in most cases, be served by a recorded announcer within the particular exchange. With this type of interception, it is not possible to cancel the time supervision feature (see para. 8.4) and it is therefore not practicable to extend such calls to a manual operator.

(ii) ARK Interception. At ARK type exchanges, a much simplified form of interception facility is provided. The line is put on "line lock-out" (see para. 8.4) and all calls to the particular number are directed by the register to the interception operator. A single class of interception only is therefore available with ARK exchanges and the number called is not displayed at the interception answering position. Calls to lines placed on "line lock-out" due to permanent loop or other fault conditions are also intercepted, thus permitting faulty lines to be recognised.

With both types of crossbar exchanges, a caller encountering the busy subscriber condition is connected to "line lock-out" and the exchange equipment released. In ARK exchanges, however, the use of the line lock-out form of interception requires, on normal "subscriber busy" calls, that the connection to line lock-out be delayed for a short period to avoid being placed on interception whilst the caller listens to the "try again" tone.

Initial ARK installations will be equipped for the line lock-out interception facility, but the possibility of integrating ARK and ARF interception on a fully centralised basis is being examined.

(iii) Location of Interception Centres. The use of the jackfield method of marking intercepted lines permits a large degree of centralisation of the interception service and whilst firm principles have not yet been formulated, it is likely that interception answering positions will be associated with the assistance centre for a particular area. Several centres possibly will be required for the larger metropolitan networks but, in country areas, one centre for each secondary area will probably be sufficient.

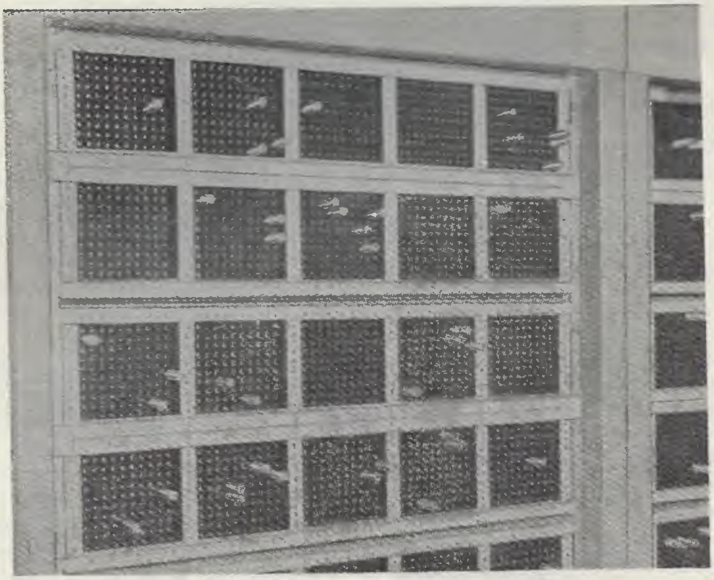


FIG. 44. INTERCEPTION JACKFIELD.

Calls to Barred Codes. Calls attempted from restricted services to barred codes will be directed by the local register (or the trunk register) either to a recorded announcement or to an operator. Use of the line lock-out condition is not satisfactory as it is identical with the "busy" condition and could therefore cause repeated attempts to be made to establish the call.

The recorded announcer may be located at the interception centre and, if the call is held for a given period - say, two or three announcements - it would then be extended to an operator. If the extension-to-operator feature is not required, the recorded announcing equipment may be located at the local exchange.

Incorrect Use of the National Code. Each closed numbering area of the national numbering plan is assigned a distinctive area code. Calls within an area do not require the use of the area code and, to avoid the unnecessary occupation of trunk switching equipment, subscribers calling their own national area code will be routed either to a recorded announcement or to an operator so that they may be suitably informed of correct dialling procedures.

Trunk Offering. Trunk offering will continue to be provided by Telephonists at special assistance ("Service Difficulties and Faults") positions. Testing facilities at these positions will enable the operator to make a quick check on a line, particularly to test for DNA or continuously busy conditions, up to five testing circuits per 10,000 lines being provided. These testing circuits will be used to provide the trunk offering facility.

Trunk Caller Hold. This facility enables an operator to hold the connection to the calling subscriber on a demand trunk call and have the call traced for caller verification or other purposes. It is therefore similar in function to the "B" party hold feature utilised for nuisance calls (see para. 8.2).

Performance Indicators. Crossbar exchanges are equipped with a number of maintenance and observation aids from which statistics may be readily obtained for the evaluation of the exchange or network performance.

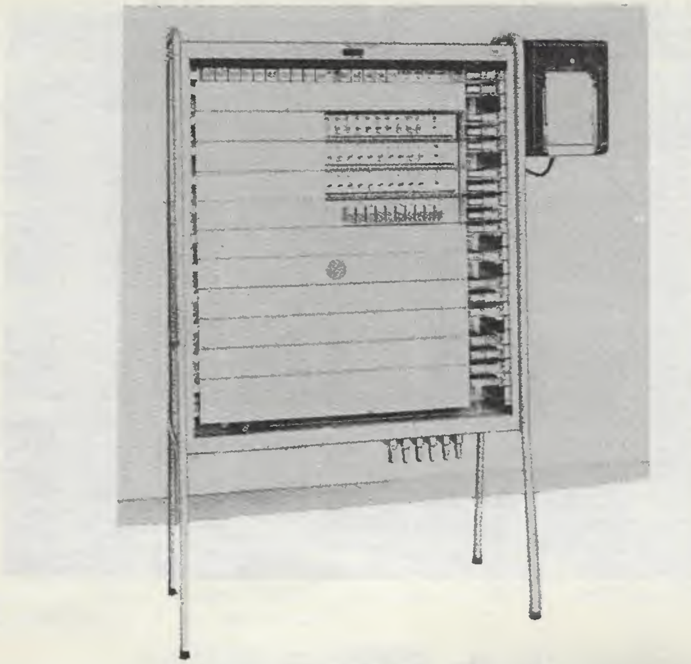
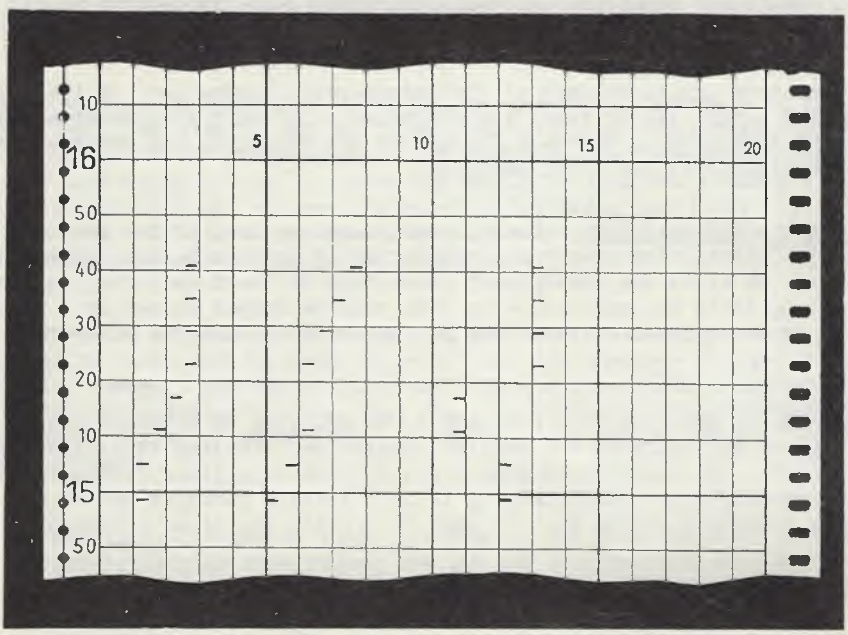


FIG. 45. TRAFFIC ROUTE TESTER WITH CONNECTED CENTRALOGRAPH.



Every horizontal row contains space for fault indications on one connection.

Every column contains space for indications by two hammers. The indications from hammers 15 and 16, for example, will appear in column 8.

FIG. 46. EXAMPLE OF CENTRALOGRAPH RECORDINGS.

Manufacturers claim that the fault incidence in crossbar systems is considerably lower than in bi-motional equipment. Unattended exchanges have operated for considerable periods without a single fault occurring, but it is nevertheless necessary to be able to detect such faults as do occur before serious trouble is caused.

(i) Occupation Indicator. A fundamental principle of crossbar exchange operation is that, upon selection of a connecting path during the process of setting up a call, a test is made to check if the circuit is satisfactory before completing the connection. The verticals represent the main part of the traffic paths through an exchange and, by the use of what is known as an Occupation Indicator, a check may be maintained on the use of vital verticals in an exchange. If a particular link has not been used for some time, there is reason to suspect a fault in the associated switches or control unit.

(ii) Traffic Route Tester. The Traffic Route Tester (T.R.T.) (Fig. 45) is a testing device which establishes artificial calls through an exchange or network and records the conditions encountered. When working continuously, the T.R.T. automatically makes calls from each of ten selected test numbers to each of ten other numbers in the exchange or network at a rate of about 200 calls per hour. The tester checks to see that the connection has been made to the correct called number, that speech transmission is acceptable and that no disconnection or wrong metering has occurred. If the attempted connection has failed or has been delayed, the faulty connection and the nature of the trouble is recorded in a printing device which is known by the trade name of "Centralograph" (Fig. 46.)

Faulty calls may be held by the T.R.T. or, alternatively, recorded only, and the data used as a basis for statistical analysis of the service being encountered.

(iii) Fault Recording Register. Each exchange may be equipped with Fault Recording Registers on the basis of one for every 5,000 lines of equipment. In addition to operation as a normal register, the Fault Recording Register follows up and checks each connection it establishes. It checks the progress of the call and, when a failure occurs due to a fault in the switching equipment, the register can be made to hold the connection. In addition, it also tests the metering wires through the switches and link circuits used.

The register can be used as a sampling device to print out on a "Centralograph" or to record on counting meters certain conditions or faults encountered.

(iv) Service Observation. The fault recording register also provides a tapping point for manual observation of the quality of service being experienced by subscribers. Since the register is the initial recipient of the digits dialled by the subscriber, this form of tapping is akin to the first-selector tapping technique used in step-by-step exchanges. All connections made through the fault recording register may be observed at the observation positions in the same way as for step-by-step exchanges. The observation supervisor holds the register for as long as necessary for the progress of the call to be observed aurally, the various stages of the call and conditions encountered being indicated visually by means of number displays, lamps, meters, etc.

Observation facilities suitable for both crossbar and step-by-step exchanges are being developed on the basis of a single observation centre within an area or network with provision for simple portable units at the more remote exchanges which do not warrant permanent connection to the observation centre.

(v) Subscriber (or Special) Observation. Facilities similar to those now in use will be available, that is, both inward and outward calls may be observed. On outgoing calls, the dialled digits will be displayed.

The use of automatic paper tape printing equipment to record the essential features of calls, more particularly the meter operation, is under consideration.

(vi) Alarm Equipment. Failures in the switching or associated equipment are indicated by a system of alarms and meters. Both visual and acoustic signals are used to call the attention of the maintenance staff, lamps of different colours being used to indicate the location of the faulty equipment. Every faulty connection or disturbance in the normal function of the equipment is recorded on Trouble Occurrence Meters.

In ARK exchanges, provision is made for urgent and non-urgent fault alarms to be extended to the parent exchange.

8.4 General Service Facilities.

Time Supervision. Since the operation of a crossbar exchange is dependent upon the use of common control equipment, it is necessary to ensure that such equipment is not held out of service by mal-operation or fault conditions elsewhere in the system. To achieve this, a system of time supervision (or time-out) is employed whereby, if a given condition is encountered for a given period, the equipment is released and the calling line placed on "line lock-out" (Page 85). Since the exchange equipment is caused to release by the time supervision feature, similar protection is afforded against unnecessary holding time on junction and trunk lines.

(i) Marker Time-out. If, on any one connecting operation, a marker is unable to find a free outlet within a second or so, the marker is disconnected and the "busy" condition indicated to the caller. If a call occurs when the markers are busy, it waits until one becomes free, but the delay is a fraction of a second only and, in fact, is very difficult for a subscriber to detect.

(ii) Register Time-out. The holding time of a register is limited to 45 seconds from the time of receipt of "dial tone" by the caller. During this period, all dialling and subsequent equipment switching operations must be completed, otherwise the line lock-out condition is applied. It is also necessary for the register to be informed of the number of digits comprising the called number and, where this cannot be achieved by analysis of the first three or four digits, such as in seven-digit city networks, provision is made for an inter-digital time-out period of four seconds on subsequent digits. In other words, after four seconds without receiving a digit, the register assumes that the full number has been received and releases after sending forward the received digits. Should a number be only partially dialled, release of the equipment takes place at 45 seconds. If a subscriber's line is looped but dialling does not take place, for example, on a "PG", the register releases at the 45-second time-out period and is available for other calls.

(iii) SR Relay Set Time-out. A further throw-out feature is incorporated in the SR relay set through which the final connection is established between the subscriber's line stage and the following group selector stage. This is timed to operate at 90 seconds from the time the switching is complete and the initial ring signal is fed to line. This means that the called subscriber must answer within 90 seconds. Also, if the called subscriber has cleared but the caller has not, release takes place if the called subscriber has not re-lifted his handset within 1½ minutes.

The operation of the time supervision feature in the SR relay set is dependent upon the return of an "answer" signal from the distant end. With calls to step-by-step and manual exchanges, the only answer condition fed back is that of line reversal on effective calls to metering services and, since it is not practicable to discriminate between working services and intercepted or other non-metering lines at such exchanges, it is necessary to cancel the pre-answer time-out feature on all calls to step-by-step and manual exchanges. The post answer time-out condition, however, applies in the normal way.

(iv) FIR Relay Set Time-out (ARM). In ARM trunk exchanges, provision is made in the incoming relay set (FIR) for a 30-second time-out to operate upon the receipt of the clear-back signal from the called subscriber. On S.T.D. calls, metering continues during the time-out period and the time-out ceases if the called subscriber "re-answers" the call.

Line Lock-out. If a connection cannot be established due to congestion or "called subscriber busy" conditions, or if time supervision is applied, a signal is sent to the line relay equipment of the calling party. The line relay connects the caller to "try-again" tone and the exchange switching equipment is released. This is called "line lock-out" and obviates the unnecessary occupation of circuits and switching stages on calls to busy routes or subscribers' lines.

A further advantage of the line lock-out feature in the event of a cable failure causing short circuiting of subscribers' lines (PG's) is that the connecting equipment in the exchange cannot be blocked out since such circuits, by virtue of the register time-out feature, will be automatically set on line lock-out.

Normally, a connection is broken down immediately the caller clears and should be "B" party continue to hold on after the "A" party has cleared, he is immediately connected to line lock-out.

Service Tones. The existing standard ringing and dial tones will be used in crossbar exchanges and will therefore be indistinguishable from step-by-step exchanges. The interrupted 400-cycle tone, formerly termed "busy" tone, will be used in crossbar exchanges to indicate the subscriber busy or switching congestion condition. The same tone is also applied under "line lock-out" conditions and thus does not always indicate a busy condition. For this reason, an alternative term is necessary and "try-again" tone has been adopted to indicate to the caller that he should replace the receiver and try again later because the number or the connecting apparatus is engaged.

The term "number unobtainable tone" has been discarded in favour of "check number tone", the prolonged 400 cycle "beep" indicating to the caller that the number dialled is not connected and that the number should be checked in the directory. If the number has been dialled correctly, subscribers are requested to seek assistance from the "Special Services" positions.

Dial Tone Delay. With step-by-step exchange equipment, a short delay occurs in the connection of dial tone but, due to the short searching time of the subscriber's uniselector in finding an outlet to a free group selector, the presence of delay is practically unnoticeable. With crossbar, however, a slightly longer time is required for the marker equipment to find the calling subscriber, find a free link to a free register and establish the connection between the two. Dial tone is fed to the caller as soon as a register is connected and, under normal traffic conditions, dial tone is connected by the time the receiver is placed to the ear, that is, about half a second. Under heavy traffic conditions, a period of up to a few seconds may elapse before dial tone is received. Should the marker equipment be occupied at the instant a subscriber lifts his receiver, a short wait is experienced until a marker is available (see 8.4(i)).

Post Dialling Delay. The common control feature of crossbar necessitates that the controlling equipment receive a specific quantity of information in the form of dialled impulses before performing its particular task. On calls to crossbar exchanges, the register does not complete the release of its digital information until the entire number has been dialled. With calls to step-by-step exchanges, the release of information takes place as soon as sufficient digits are received to indicate that the call is for a step-by-step exchange.

This initial delay, together with the time taken for the subsequent switching to be performed, constitutes the post-dialling delay which, although small, can be quite noticeable if of more than a few seconds duration. As a general rule, the post-dialling delay will not exceed two seconds and, on rare occasions, a delay of four seconds may be encountered on calls through a wholly crossbar network. With calls to step-by-step networks, there may be an appreciable delay due to the slower switching speed of step-by-step equipment but, generally, this will not exceed four seconds. With S.T.D. calls, the post-dialling delay may be slightly greater than for local calls, particularly for a connection involving a number of transit switching centres.

Immediate Ring Tone. With standard A.P.O. ringing current and tone, a two-second pause occurs between successive ringing bursts. This means that after a connection to the called line has been established, a period of up to two seconds could elapse before ringing current and tone are fed to line.

With step-by-step working, since the connection is established with the dialling of the last digit, this period represents the maximum post-dialling delay apparent to the caller and is therefore acceptable.

By virtue of the register control feature of crossbar, however, this time would be additive to the normal post-dialling delay and could, in some circumstances, be intolerable. In order to overcome this disability, provision is made for a single burst of ring tone to be sent from the register immediately the connection is established and prior to register release, subsequent ringing current and tone being supplied in the normal way.

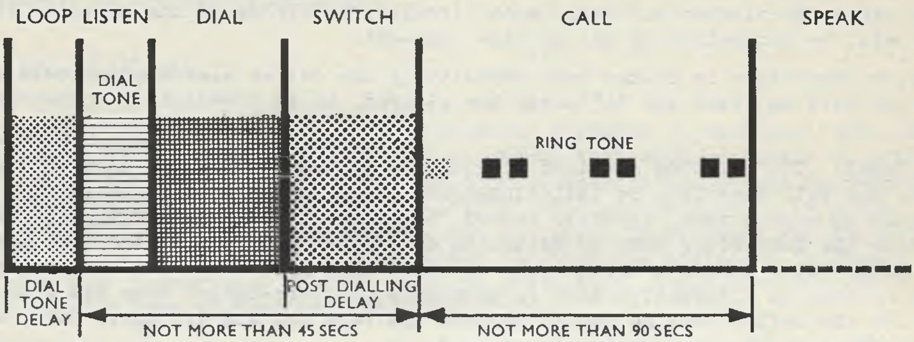


FIG. 47. SEQUENCES OF THE SYSTEM.

Grades of Service. For common control systems, switching plant and links are provided on the normal "probability of loss" basis but, in addition, it is also necessary to specify a "probability of delay" for the marker and register equipment.

Tentative busy hour standards are:-

(i) Marker Congestion. Not more than 1% of calls delayed more than 1.7 seconds.

(ii) Dial Tone Delay. Not more than 1% of calls encounter delay of more than three seconds.

(iii) Register Provision. Metropolitan exchanges - one call lost in 1,000. Country exchanges - one call lost in 500.

(iv) Overall Grade of Service for Local Networks. Not worse than one call lost in 80.

This corresponds approximately to a grade of service of 1-in-500 at each switching stage in seven-figure step-by-step networks and 1-in-200 in smaller rural networks.

8.5 Summary. The main characteristics of crossbar facilities which differ from step-by-step are:-

(i) Classification of subscribers' lines into up to 17 categories.

(ii) P.B.X. group numbering is random in 1,000-line section.

(iii) Metering with ARF equipment occurs at conclusion of local call. With ARK, metering takes place on answer by "B" subscriber.

(iv) Trunk access of varying degrees may be provided on a permanent basis and provision is made for limited variation by the subscriber.

(v) Improved facilities for tracing the origin of nuisance calls.

(vi) Interception service may be provided and controlled on an entirely centralised basis.

(vii) "Try-Again" tone is received if:-

(a) Dialling is not completed in 45 seconds.

(b) "B" party is "DA" for 90 seconds.

(c) "B" party clears for 90 seconds.

(d) "B" party holds after "A" party clears.

(viii) Time supervision feature prevents unnecessary holding of exchange equipment.

(ix) Delay in receipt of dial tone exists, but is generally not noticeable.

(x) Progress whilst dialling is not indicated.

(xi) Post-dialling delays of up to two seconds will be general and up to four seconds occasional.

(xii) Ring-tone occurs immediately the connection is established.

END OF PART 7.