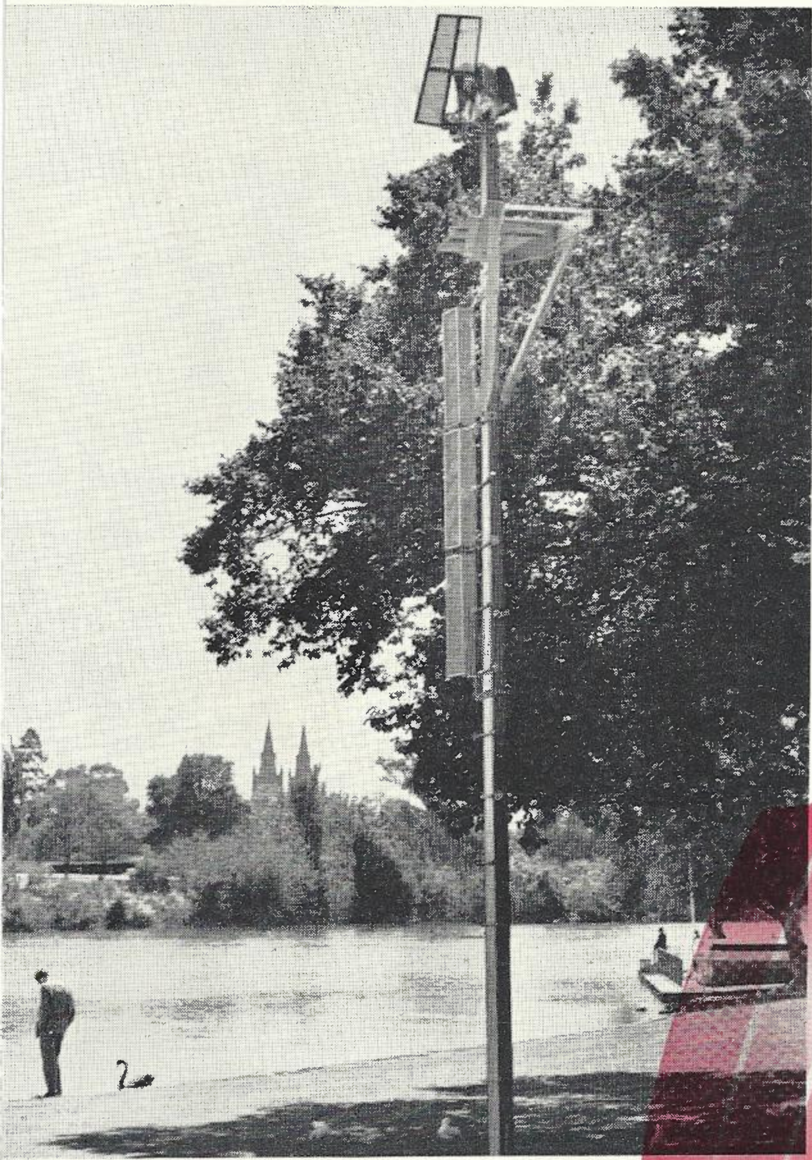
THE

Telecommunication Journal OF AUSTRALIA



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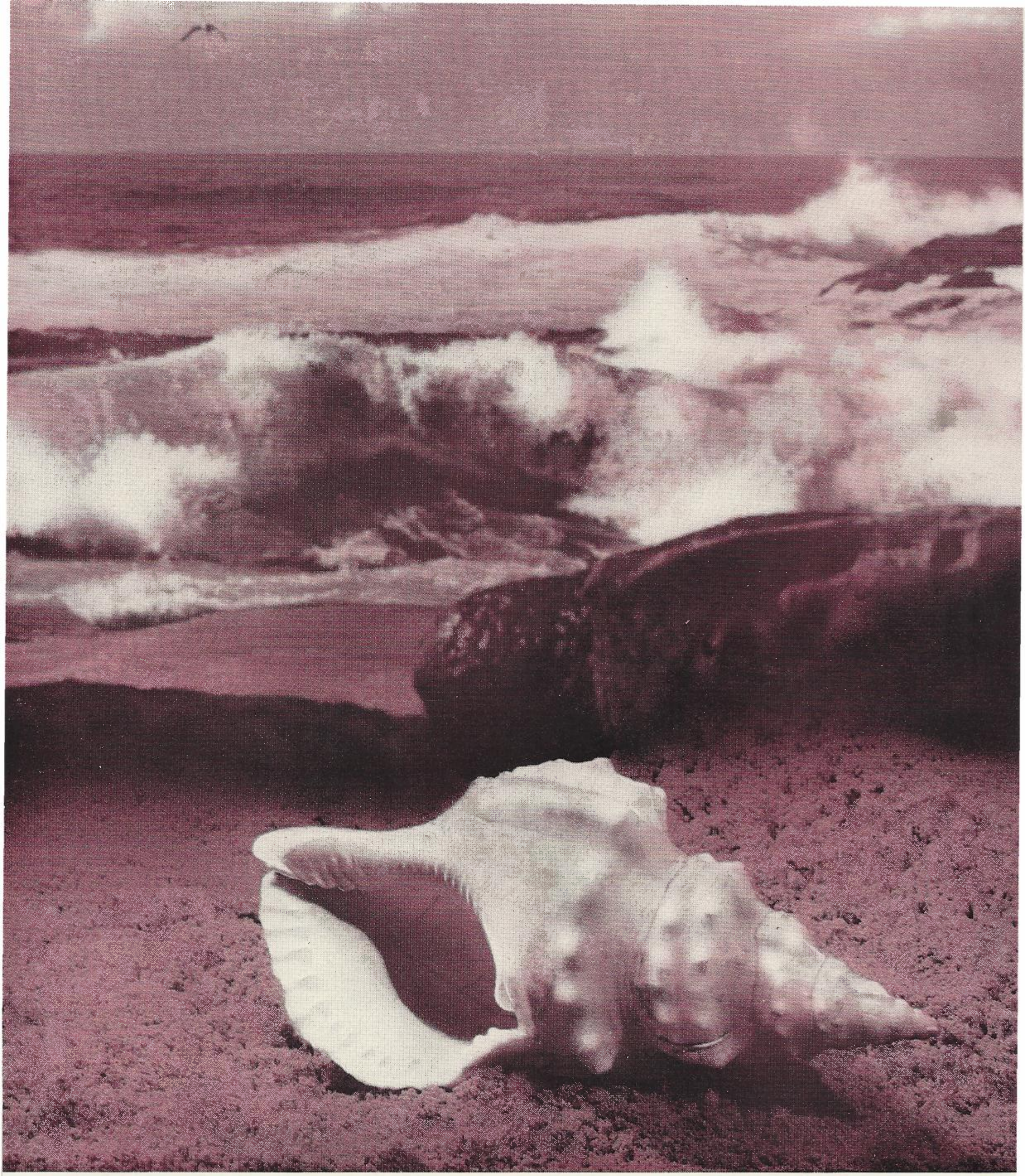

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CONTENTS

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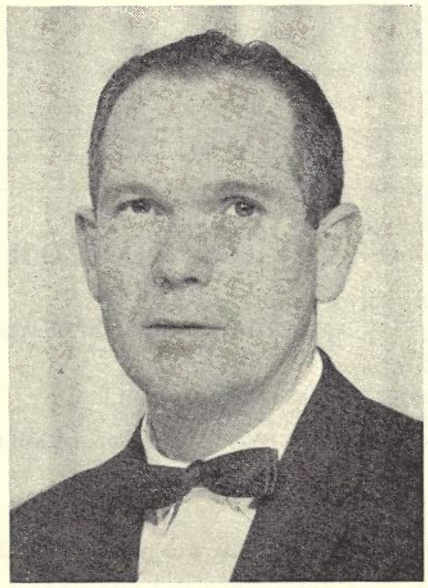
*For addresses see page (i)

CHANGES IN POST OFFICE MANAGEMENT

Mr. M. R. C. Stradwick, O.B.E.

Mr. F. P. O'Grady, M.I.E.Aust., S.M.I.R.E.Aust.



Mr. B. F. Jones, B.A., B.Ec.

Mr. M. R. C. Stradwick, O.B.E., has resigned as Director-General, Posts and Telegraphs and has been succeeded, as from the 28th September, by Mr. F. P. O'Grady, M.I.E.Aust., S.M.I.R.E.Aust. Mr. B. F. Jones, B.A., B.Ec., has been appointed Deputy Director-General, Posts and Telegraphs in place of Mr. O'Grady.

After forty-one years' distinguished service with the Postmaster-General's Department, Mr. Stradwick has joined the International Telephone and Telegraph Corporation as General Manager for the Far-East, Pacific, and Australian areas with headquarters in Hong Kong. He has also become a Vice-President of the International Standard Electric Corporation, New York. Full details of Mr. Stradwick's career with the Postmaster-General's Department were given in the February 1959 issue of the Journal, and the Society and the Board of Editors wish him happiness and success in his new venture.

Mr. O'Grady is well known to most members of the Society through his keen interest in its affairs and his many contributions to the Journal. Details of his career were given in the October, 1957 issue of the Journal. The Society and the Board of Editors are delighted that Mr. O'Grady's service has been rewarded by his promotion to the highest position in the Department.

Mr. Jones, who is 44 years of age, has occupied for the past seven years the position of Assistant Director-General (Postal and Transport Services) on the Headquarters Staff of the Post Office. He has made significant contributions to the development of postal policy not only in the Commonwealth, but in the international field, having led the Australian delegations to the Universal Postal Convention at Ottawa in 1957 and to a conference of Postal Administrations of Asian and neighbouring countries at Manila early this year. Prior to that appointment, Mr. Jones had been Assistant Director-General (Personnel and Public Relations) at Post Office Headquarters for three years. His earlier career was spent mainly in the Personnel Branch in Sydney and at Headquarters.

In extending congratulations to both Mr. O'Grady and Mr. Jones, the Society offers them full support for the future.

CROSSBAR SWITCHING EQUIPMENT FOR THE AUSTRALIAN TELEPHONE NETWORK

E. R. BANKS, B.E.E., A.M.I.E.Aust.*

Editorial Note: This article is reprinted from The Journal of the Institution of Engineers, Australia, Vol. 33, No. 4-5, April-May, 1961, with the kind permission of the Institution.

INTRODUCTION

This paper is intended as a summary of an investigation carried out over the past three years into the type of switching system best suited to meet the requirement for economic and efficient expansion of the Australian Telephone Network. As a result of this work, a register-controlled crossbar switching system of L. M. Ericsson design was adopted as standard. Part I of the paper describes briefly the circumstances leading up to the investigation and the factors underlying the analysis and decision. Part II describes the system adopted and Part III indicates the way in which the equipment will be integrated into the network.

PART I.—CHOICE OF A SYSTEM

Local Network Problem

Since the first automatic exchange was installed in Geelong (Victoria) in 1912, the Post Office has progressively developed the automatic local networks using step-by-step equipment and employing the Strowger and, later, the British 2,000 type and SE.50 bimotional selectors. Step-by-step control is one of the earliest and most widespread methods of automatic switching and had its origin in the invention by Strowger of the 100-point selector (see Fig. 1). A group of these basic units can be used for a 100-line exchange. As the network develops succeeding stages are added for each digit required, and it is readily apparent that such a system is inflexible (see Fig. 2). The routing of a call is tied to the numbering, and a given block of numbers can be used only in a certain area. Development of a network of the type shown in Fig. 2 can proceed without serious difficulty until the numbering limitations of six-digit working, a practical capacity of about 500,000 subscribers, are approached. By 1956 the Melbourne and Sydney networks were nearing saturation on a six-digit number basis following the very rapid post-war development, and the cost of converting to seven-digit working, where required, was estimated at up to £6 extra per subscriber's line for the necessary additional switching stage.

The prospect of adding another switching stage also implied the upgrading of all links between existing switching stages in order to maintain the existing overall grade of service provided to subscribers. The grade of service or probability of call loss over the complete connection is, to a first approximation, the sum of the loss probabilities in each link and, therefore, the addition of an extra link would require extra circuit provision on all previous links. Finally, impulses are repeated forward in a step-by-step network from exchange to exchange. The consequent restrictions on signalling limits on both subscribers' and junction lines necessary to minimise impulse distortion and ensure successful operation of the switch at the distant exchange were proving a serious economic and technical limitation with the present equipment.

Considerable savings were seen to be possible by the removal of the basic restriction that routing and numbering are tied together. Use could be made of a given group of junctions for two traffic loads, one of which occurred during the day and the other at night, whereas at present, for example, the junction plant in the city areas is practically idle during the night, whilst the reverse is true in residential areas. A second result of divorcing routing from numbering would be that traffic could be moved between two exchanges on the most economic route rather than over a rigid backbone of links and switches. In many instances this would mean the bypassing of several intermediate switching stages and consequent plant savings. For example, in Fig. 2 the dotted route from the first selectors direct to the fourth selectors could carry traffic destined for any one of 1,000 subscribers, bypassing two switching stages.

A limited amount of direct routing had already been possible with step-by-step equipment but only within the main exchange group of the calling subscriber.

*See page 154.

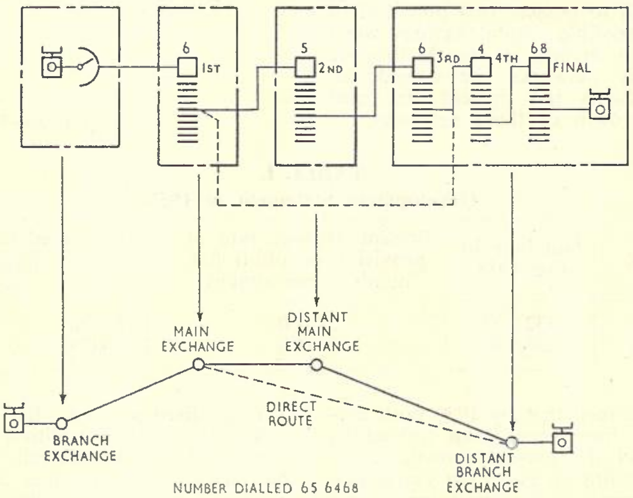


Fig. 2.—Call Routing in a Step-by-Step Network.

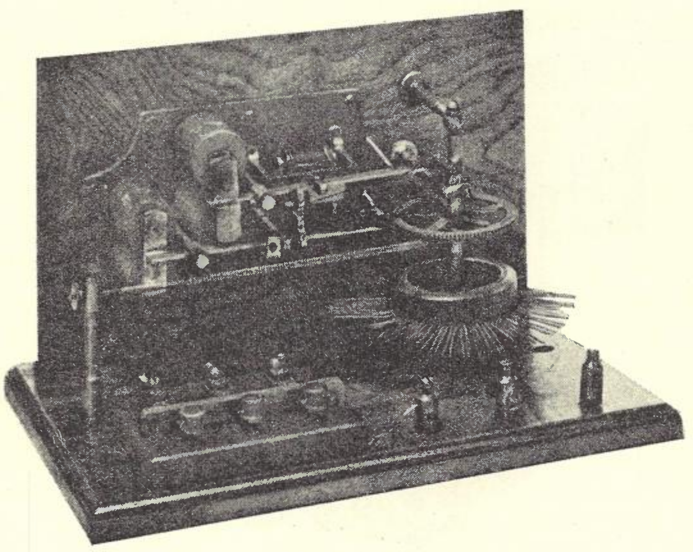


Fig. 1.—Original Strowger Switch, 1892.

It was clear that the possibilities for effecting considerable economies existed if a flexible and universal system of direct routing could be introduced. Improvement in signalling methods would also remove signalling limitations on junctions and subscriber's lines.

These technical possibilities for economic expansion in the local networks can be seen to possess real potential in terms of possible capital savings when the rates of growth in the Melbourne and Sydney networks are considered. Table I shows the present size and expected growth of these networks.

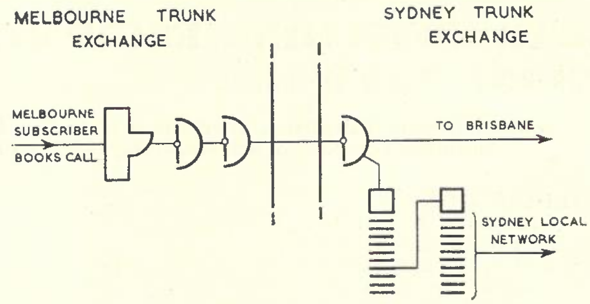


Fig. 3.—Trunk Connection, Melbourne to Sydney.

TABLE I.
Development Statement at 1958

Network	Numbers in use 1958	Present average rate of provision of additional numbers per annum	Estimated at 1980	
			Total	Rate of growth per annum
Sydney	332,000	25,000	1,124,000	79,000
Melbourne	273,000	20,000	1,100,000	77,000

It can be seen that by 1980 both networks will have more than trebled in size, in fact the present growth represents a doubling in every ten years. The major proportion of capital investment in the exchange and junction sections of a network is vested in the junctions, cable and conduits. The proportion at present is about 70 per cent. It is clear, therefore, that there is considerable scope for effecting economies in investment by adopting a switching system which will allow traffic to be carried over the shortest possible route to its destination.

Trunk Network

Since 1940, with the installation of semi-automatic transit trunk switching in Melbourne, the long distance trunk network has been developed using transit switching to eliminate the distant operator on long-distance calls. Fig. 3 shows a simple schematic of the routing for a trunk call from Melbourne to Sydney. The Melbourne trunk operator can dial direct to the subscriber in the Sydney network without the assistance of the Sydney telephonist. This mode of operation has been introduced at capital cities and provincial centres throughout the Commonwealth in the past 20 years. However, the growth of trunk traffic and the increasing cost of manual operation, together with the development of techniques in recent years to provide economically large blocks of long-distance channels by coaxial cable or radio, now make it feasible and necessary to consider the extension of subscriber control into the long-distance network. For subscriber-dialling of trunk traffic, Australia-wide numbering and charging schemes are necessary in order to simplify directory presentation and switching system design and operation. The study and development of a plan aimed at developing the Australian network for ultimate subscriber-dialling of all calls was commenced in 1956. This study soon highlighted the limitations of the present switching equipment in meeting this objective economically. In the Trunk Network the requirements for routing discussed for local networks apply also and, in addition, it will be necessary to automatically determine the charge rate for the call and to register the appropriate charge information on the subscriber's meter. The national number will be the local number plus between one and three national digits, and this eight-digit number must be received and interpreted by the switching equipment. For long built-up connections a high quality circuit must be assured, especially once the operator is removed altogether and is not available to reject the occasional noisy or low-volume connection, as she may do at present.

Rural Networks

The third problem facing the Post Office was the economic extension of continuous automatic service to rural

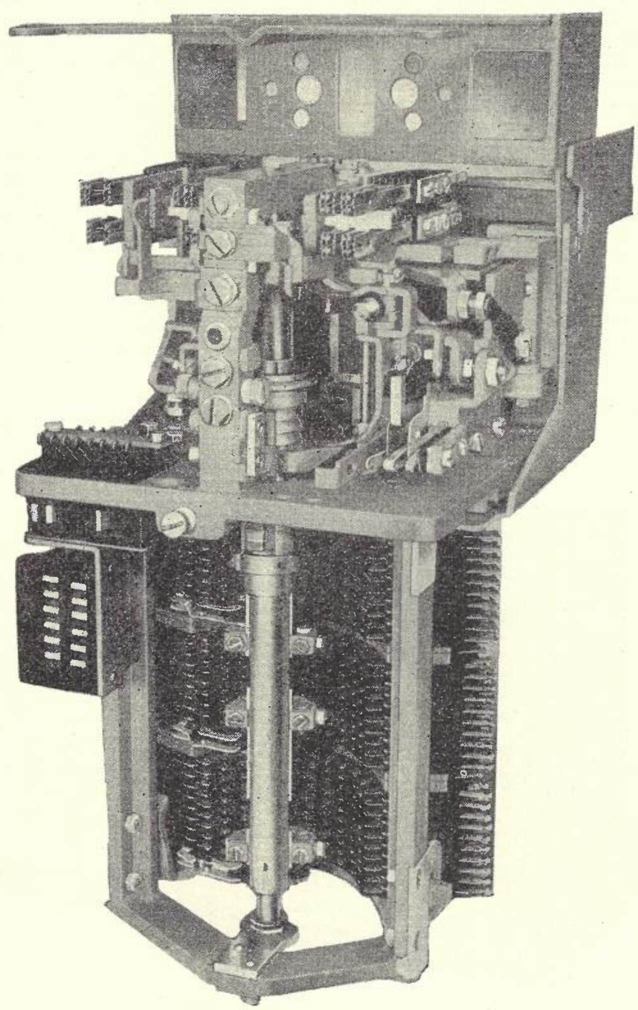


Fig. 4.—Bimotional Selector.

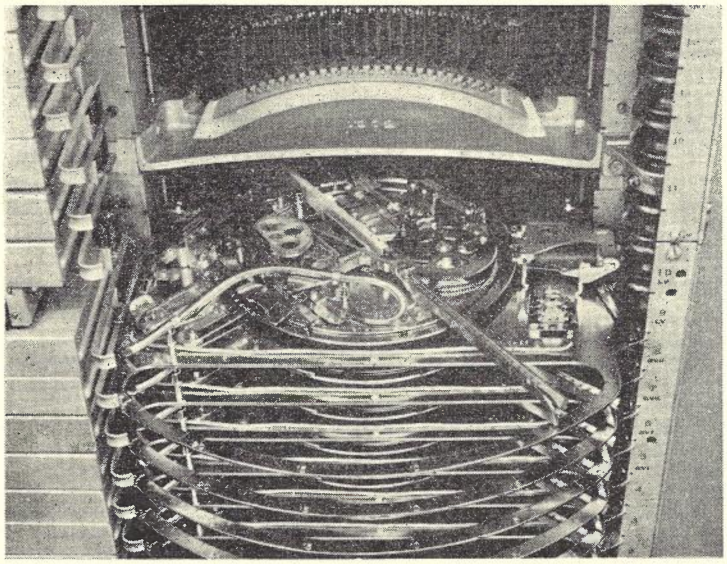


Fig. 5.—500-Line Selector.

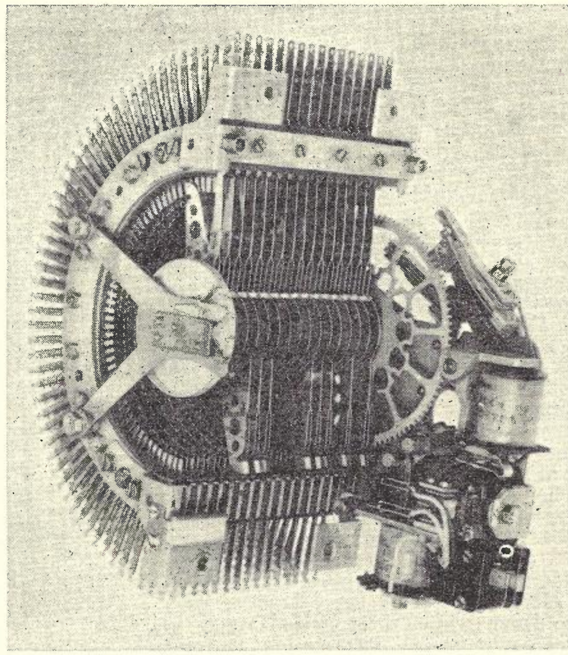


Fig. 6.—Motor Uniselector.

subscribers. The installation of the Rural Automatic Exchange (R.A.X.) in the post-war period went a long way towards eliminating the small manual exchanges of 200 lines or less. However, these units provided automatic access only between subscribers on the exchange in question, and the majority of these exchanges had as a parent the local provincial exchange, which was manual. With the proposal to introduce a national numbering plan and extended dialling, and to remove manual working, it became apparent that the present R.A.X., due to its design and trunking, could not be integrated readily in the closed-numbering areas proposed for these districts. Furthermore, the outstanding problem in the rural areas was the medium-size provincial town with an exchange of 200-1,000 lines for which Magneto or Common Battery (C.B.) manual equipment was being employed. Here, as in the trunk exchanges, the costs of operation and telephonists' facilities were rising to the level where it was economic to consider automatising the system. In these areas subscriber distance-dialling and automatic multi-metering were essential, and the step-by-step automatic switching equipment currently used in the large cities was not capable of providing for the economic introduction of such a scheme.

These three sectors of the network, local, trunk and rural, were therefore all in need of a new switching system which would facilitate economic expansion and provide for the ultimate complete automatisation of the system. To meet this requirement, a detailed examination of the various available switching systems was undertaken with a view to selecting the one most suited for the immediate and long-term Australian requirements.

Switching System Types

It is necessary at this stage to pause and review very briefly the main types of electromechanical switching systems which have been employed in telephone exchanges in the past 50 years.

Switching systems consist essentially of two elements, the switches or speech path connecting devices, and the controls. These controls are either concentrated in common units taken into use only to set the switches, or small control elements are permanently associated with each switch. The latter principle is usually termed step-by-step operation since the successive switches each take one digit and route the call one stage further.

These systems can be classified in four main categories identified by the type of switch employed:—

(i) The Bimotional Selector (Fig. 4), developed from the original Strowger patent, is used extensively in step-by-step switching systems and in the director system which employs a common translating register.

(ii) The 500-point Planar Switch (Fig. 5) is used in a register-controlled common-drive system on the rotate and thrust principle.

(iii) The Motor Uniselector (Fig. 6), developed by Siemens & Halske later by Siemens Bros., England (now A.E.I., Woolwich), has 16 arcs and 52 contacts per arc, providing a maximum of 200 four-wire outlets. This switch has been used in step-by-step and register-controlled systems, and may employ common drive as in the Rotary Systems used extensively in Belgium and France.

(iv) The Crossbar Switch (Fig. 7), developed from the patents of Betulander in 1896, has been used in both step-by-step and register systems, and has received increasing attention in recent years.

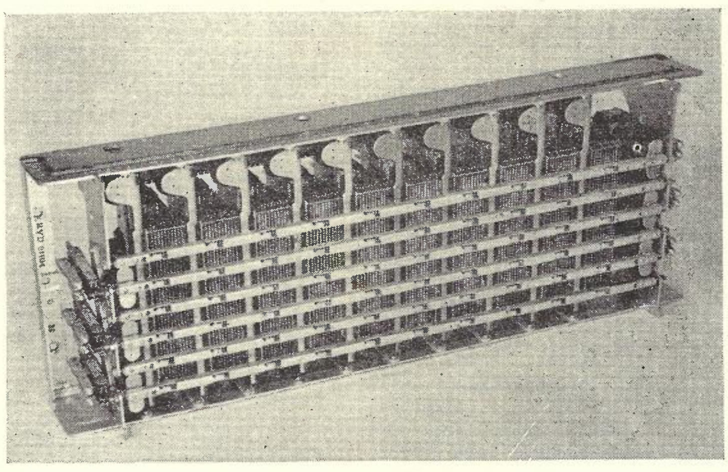


Fig. 7.—Crossbar Switch.

Register Control

The separation of call routing from the number dialled was seen as the fundamental requirement of the new system, and could only be achieved by the adoption of a register-controlled switching system.

In the original manual exchange the control intelligence was embodied in the telephonist. She identified the calling line, received from the caller the number he required, connected the call by the most direct available route and registered on a docket the appropriate charge. With the introduction of step-by-step working, the operator's intelligence was in effect distributed throughout the system. Each switch performed a small part of the routing function, and the meter associated with the subscriber's line switch registered the unit call charge when the called subscriber answered. The common control or register type exchange collects this control intelligence once more into a centralised unit.

Common controls require high-speed operation and high-speed signalling in order to overcome the necessary delay incurred while the register waits to receive sufficient information to start work. The development of reliable and fast-operating controls, providing rapid call connection and, at the same time, competing economically with the simpler step-by-step system, originated in the immediate pre-war era and, receiving considerable impetus from the technological developments of the 1939-45 period, have expanded rapidly since the war.

The London Director system is an example of register control applied to bimotional selectors. The required number is examined in the register and a routing code is pulsed into the step-by-step switching system. This code will vary depending on where in the network the caller originates his call. The problem here is that this routing code is pulsed out of the register at 10 c.p.s., the normal dialling speed, and delays after dialling of up to 20 seconds may result before the connection is established and ring is fed to both subscribers. Further, the "director", as the register is called cannot vary the route taken by the call to take advantage of changes in circuit loading with time. The programme is rigid, and routing is still tied to the numbering allotted to the routing code. The planar 500-point system is also slow, due primarily to the speed of setting of the large switch. The two electromechanical switching principles suitable for register control which have received the greatest attention in recent years have been the Crossbar and the Motor Uniselector.

System Comparison

Systems using these two techniques were closely compared during the study, and the crossbar principle chosen. Concurrently, the various crossbar systems were examined, and as a result, the register-controlled crossbar system employing linked trunking and developed by L. M. Ericsson, Sweden, was finally selected as the type of switching system best able to meet the A.P.O. requirements for the next 10-15 years. These decisions were taken after examining the available crossbar and motor uniselector systems against five basic criteria. It was considered that the system chosen should:—

(i) **Meet the Required Facilities and be in an Advanced Stage of Development:**
  - (a) Routing independent of numbering, economic and flexible alternate routing.
  - (b) Charging determination and registration for national dialling.
  - (c) High-speed operation, minimum post-dialling delays.
  - (d) The system should be developed and proved in service in the local, rural and trunk transit sectors of a network, and should have interworked successfully with step-by-step equipment.

(ii) **Comply with Modern Technical Performance Standards:**
  - (a) Signalling and Transmission performance should take maximum advantage of the latest developments in these fields.

(iii) **Be Suitable for Economic Local Manufacture.**

(iv) **Be Economic to Install and Maintain.**

(v) **Be Adaptable to Future Developments and, in particular, Electronics.**

These points will now be discussed and the two systems compared. In all comparisons reference is confined to systems in which the switches are used efficiently.

Facilities and Stage of Development

Alternate Routing: Both systems are available with register control and, therefore, routing can be made independent of numbering. As discussed above, the desirable situation is to be able to select for a given call the most direct route to the required destination. It can also be shown that the most economic arrangement of junctions in a network is one in which only the base load of traffic is carried on the direct circuits, the peaks being routed on the backbone route via the tandem exchange. In this way, overflows of traffic from several direct routes can be combined on the backbone route to make efficient use of the circuits. In fact, the concept of marginal utility is introduced and a specification developed such that traffic is carried on the direct route by the addition of circuits until the cost per unit of traffic (Erlang) of carrying the traffic direct is equal to the cost of carrying the traffic on the backbone route. Fig. 8 illustrates this principle of alternate routing.

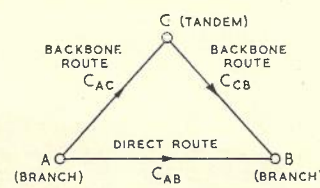
Studies in large networks, such as Sydney and Melbourne, indicate that, to take the fullest advantage of this alternate routing principle, any given call may require to be routed over one of up to four choices, that is, direct, first alternate, second alternate, and backbone. Further, it has been estimated that the total circuit accessibility required may vary between 500 and 1,000, depending on the size of the exchange. To ensure efficient operation in an alternate routed network, it is necessary that a choice be made of a suitable free circuit from all the possible available circuits on each of the four routes with a minimum of delay. To achieve this objective at a switching stage with minimum post-dialling delay, the equipment should be capable of:—

- (i) having prior knowledge of the traffic conditions on each of the possible routes;
- (ii) selecting at high speed a free circuit on a suitable route;
- (iii) positioning or setting the switch at high speed on the selected outlet.

The most efficient method of storing prior knowledge of circuits is to use a single common equipment which controls the operation of a single switching stage which has access to all routes from the exchange. Crossbar switches meet this requirement since they can be arranged in "link-trunked" arrays to provide any desired availability, and the two or three stage array can be set and controlled by a single marker unit. This concept of link-trunking will be further discussed below. However, motor uniselectors have a limited availability of 200 from a given switching stage and, to obtain larger availabilities, a further stage must be added. Attempts to control two stages of motor uniselectors simultaneously have proved complex and uneconomic, and have been abandoned in favour of sequential stage-by-stage setting. This stage-by-stage control means that, after an indication has been received, each switch must be set in turn, whereas the crossbar selectors can be operated simultaneously in about 40 milliseconds compared with about 360 milliseconds for the motor switches.

Testing of circuits in the crossbar system is electrical and is carried out by the marker. There is therefore no limitation to the number of circuits over which the hunt may be carried out. With the motor uniselector, however, the switch hunts at 200 steps per second. Therefore, to test a group of 50 trunks some 250 milliseconds are required compared with some 70 milliseconds for the crossbar scan.

Summing up, the crossbar switch is capable of providing single switching



C_{AB}, C_{AC}, C_{CB} COST OF CIRCUITS ON THESE ROUTES.

$_{N}E_{AB}$ TRAFFIC CARRIED ON N^{TH} CIRCUIT ON DIRECT ROUTE.

$E_{\overline{ACB}}$, ADDITIONAL TRAFFIC WHICH MAY BE OFFERED TO ROUTE $\overline{ACB}$ WHEN AN EXTRA CIRCUIT IS ADDED, TO PRESERVE THE SAME GRADE OF SERVICE ON THE ROUTE.

CIRCUITS ARE ADDED TO ROUTE AB UNTIL

$$\frac{C_{AB}}{_{N}E_{AB}} \geqslant \frac{C_{AC} + C_{CB}}{E_{\overline{ACB}}}$$

Fig. 8.—Principle of Alternate Routing.

stages of any desired availability under a single control, is faster in testing for free circuits and faster in establishing the final connection.

Charging: Charge determination and registration is possible with both systems, and depends primarily on the design of the register equipment.

Stage of Development: One of the primary considerations in selecting the particular crossbar system to be adopted was the extent to which it had been engineered and proved in service. When a new switching principle is devised and a new exchange system is developed, the first step is the construction and testing of a laboratory model or, more often, a private automatic exchange (P.A.X.) to be used in the factory of the developing manufacturer. The model having been successfully proved, the equipment is then ready for application to public networks. This next step may take up to 10 years, during which time the manufacturer and his customers must invest considerable engineering and design effort in the adaptation of the prototype exchange to the three sectors of a communications network, local, rural and trunk, and the solution of all the various interworking problems which will arise when any new plant is grafted on to existing equipment.

The objective in this study was to choose a system which would require the minimum redesign and adaptation in order to take maximum advantage of technology overseas and conserve our own limited resources for the not inconsiderable task of carrying out the inevitable interworking redesign which would be necessary. A switching system is a developed entity ready and tried for application to all three fields, whereas an exchange principle is the nucleus of the system. Of the available crossbar types the one chosen appeared on the evidence available, and, in the opinion of the author and other Post Office engineers who had visited overseas administrations and manufacturers, to be the most thoroughly developed and tested system available.

Technical Standards

One of the vital considerations was that the switching system chosen should possess a low psophometric noise characteristic. A built-up telephone connection consists of a large number of dry metal-to-metal contacts such as relay springs, switch wipers and switch banks. Across each contact there is a small potential difference which, under conditions of vibration, may generate a noise e.m.f. The problem is to ensure that the total noise on the circuit, which consists of the sum of the contributions from each contact, is kept to an acceptable level to ensure a good standard of transmission. This has important economic as well as aesthetic aspects since the speed at which information can be passed and comprehended is related to the signal-to-noise ratio of the channel.

In an endeavour to reduce circuit noise in nation-wide dialling networks, manufacturers of modern switching systems have introduced noble metal pressure contacts for the speech path connections. The quality of these contacts is of particular importance in Australia, due to the "ribbon" nature of our main line network and the large number of transit switching points which may be in tandem on a trunk call. Crossbar switches, due to the relay-like nature of their operation, used pressure contacts, and the contact material is a noble metal. The German E.M.D. motor uniselector was redesigned to use pressure contacts of noble metal in the speech path but the British motor uniselector still employs base metal high-pressure wiping contacts (see Fig. 6).

The present equipment, using base metal rubbing contacts, has a relatively poor noise performance by modern standards, and regular bank cleaning is necessary to minimise noise interference. Noble metal pressure contacts used on crossbar switches, have a resistance of a fraction of an ohm compared with resistances of 1 to 4 ohms after one million operations in the case of base metal rubbing contacts.

The method of signalling in a register network takes a different form from that in a step-by-step direct impulsing network. The routing information is passed between registers using high-speed coded voice frequency signals at a speed of 10 digits per second. This removes the restrictions on network development formerly imposed by the necessity to repeat impulses forward stage by stage. Only the line or supervisory signalling remains associated with the particular junctions. Thus, the resistance limits

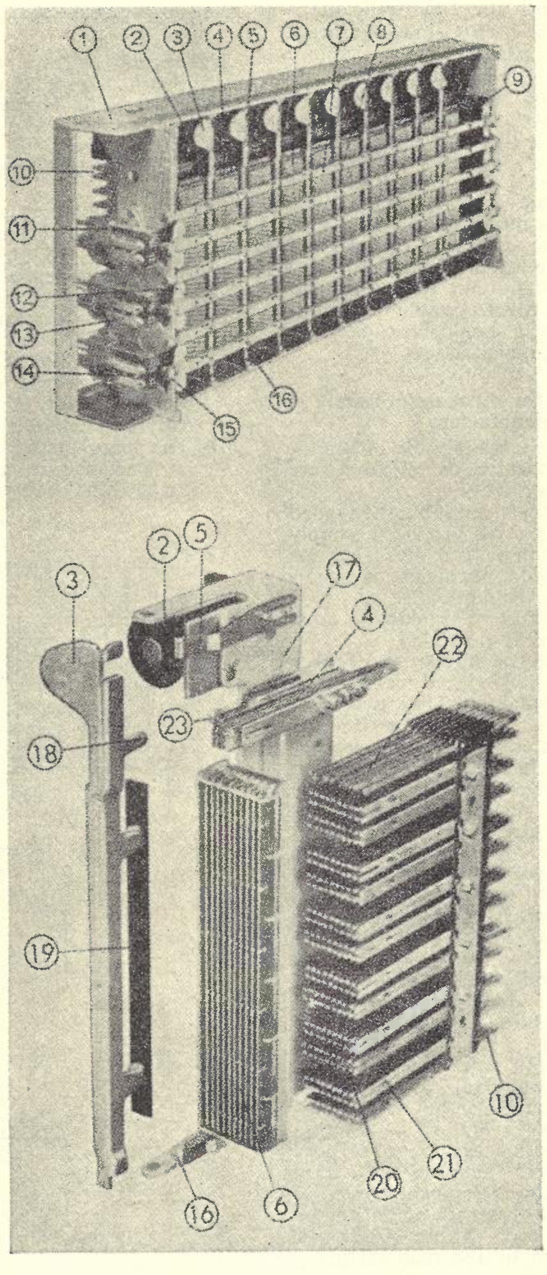


Fig. 9.—Crossbar Switch—Elements.

for junctions are governed only by the sensitivity of the pick-up and answer signal relays, and the use of sensitive reed relays for these functions will virtually remove the signalling limitation to junction resistance. Since with Registers the subscribers' dialled impulses are received and stored at the local branch exchange and do not require retransmission, the tolerance to impulse distortion can be increased considerably. The present dial-speed requirement of 9-11 i.p.s. can be relaxed to 7-22 i.p.s., thus considerably reducing, if not eliminating, dial maintenance and allowing a significant increase in subscribers' line resistance. The present resistance limit of 1,000 ohms is expected to increase to about 1,800 ohms which, as in the case of the junction limit, will permit an appreciable increase in the present transmission standard. These two relaxations in resistance limit will allow significant savings to be effected in our future external plant investment which, as mentioned above, comprises 70 per cent. of the local network investment.

The preceding discussion has centred on the technical facilities which must be met by the switching equipment. Of equal importance in a telecommunications network is that the equipment may be economic to purchase, install and maintain. In addition, in the Australian network it is important to ensure that to a maximum extent possible the equipment standardised should be capable of economic local manufacture.

Suitability for Economic Local Manufacture

In assessing the suitability of equipment for manufacture, two factors were considered important:—

(i) The equipment must be so designed that it can be produced simply and advantage can be taken of the latest developments in manufacturing techniques.

(i) The shop cost of production must be as low as possible.

Any telephone system consists of three main elements: racking and frameworks, relays, and switches. The two first elements are a common production problem no matter which system is considered and, in fact, the two Australian telephone equipment manufacturers have been producing relays and racking for the Department since the Second World War. However, by adopting crossbar there was a chance to simplify considerably the switch production problems. The crossbar switch consists essentially of a rectangular array of relays and springsets. The complete switch consists of a series of similar sub-assemblies (see Fig. 9) and at no stage are critical adjustments required during manufacture or assembly. The simple production and assembly requirements of the switch lend themselves to automatic methods. In contrast, the motor uniselector, which is a high-speed rotating mechanism, requires the use of expensive assembly jigs. Many of the operations involve close tolerancing and are of such a nature that they could not be readily automatised. Table II gives a brief comparison of the manufacturing requirements of the two switch types.

TABLE II.
Comparison of Switch Production Requirements

Date	10/20 Crossbar switches	200 Outlet motor uniselector
No. of piece parts	49 of which 13 are used in relays	135
Processes	Mostly presstools and stamping operations	Presstools and stampings for the banks, wipers and frame. Machine tools for the motor and gears.
Assembly	Rectangular non-critical assemblies	Careful jiggings and concentricity and bank alignment tests
Testing	Simple relay operations with no close tolerances	Close tolerances with critical speed requirements

The second essential consideration is that the cost of production of the switching system should be a minimum. It is possible to assess the likely relative costs of production of two switching systems when the following factors are realised:—

(i) The labour cost represents 75 to 80 per cent of the total costs for all types of electromechanical switching systems.

(ii) The number of control relays in a switching system does not vary significantly, from between 5 and 6 relays per line. This is independent of the type of control and applies equally to common control and step-by-step exchanges.

(iii) The main material component in an exchange is the speech path connection equipment or the crosspoints which, in assemblies, comprise the switches.

It follows from the above considerations that the exchange with the smallest amount of material in it will be the cheapest to produce and, further, the exchange using the fewest crosspoints or speech connections to achieve the required standard of service will possess the least material.

A study of this question of minimum crosspoint requirements shows that the number of crosspoints per subscriber's line can be made a minimum using crossbar switches in link-trunked arrangements. This is evident from the following simple example. Consider an exchange requiring 100 inlets and 100 outlets, and no congestion. There are three possible ways of achieving this result. Fig. 10 (a) shows the simplest

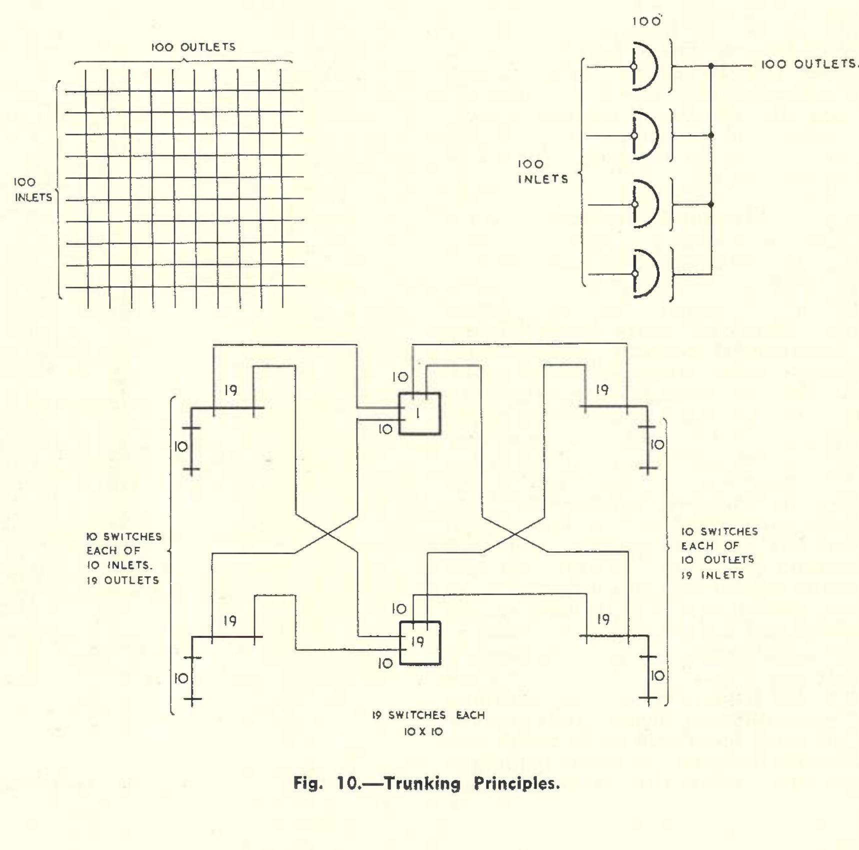


Fig. 10.—Trunking Principles.

arrangement, a single crossbar switch possessing 100 inlets and 100 outlets or 10,000 crosspoints. Fig. 10 (b) shows the same exchange using 100 outlet motor uniselectors or bimotional switches. 100 such switches are required utilising a total of 10,000 crosspoints. Both the above examples are cases of direct trunking, in which the free outlet from the switch is seized without first ensuring that at the next switching stage the associated inlet will itself have access to a free outlet. Fig. 10 (c) shows a link-trunked arrangement of crossbar switches so arranged as to provide the complete access with no congestion but using 5,700 crosspoints. In this switching stage the inlet is not connected to a link from the first switch until a complete path through the three switches has been tested and reserved for the connection. Crossbar switches may be arranged in linked arrays of two or three stages similar to that shown to provide any required availability. Clos showed that in this way an exchange could be trunked using the minimum possible number of crosspoints and that, from cases similar to the no-congestion example quoted above, exchanges having fixed standards of congestion can be derived. Finally, Clos demonstrated that a 10/20 crossbar switch is close to the ideal practical size for economic link-trunked arrays. Table II shows the relative number of crosspoints and relays per line for comparable exchanges using various switches for speech path provision.

TABLE III.

Exchange type	Crosspoints/line	Relays/line (approx.)
10/20 Link-trunked crossbar	20.0	6.0
22/52 Link-trunked crossbar	29.0	6.0
100 Outlet motor uniselector	65.0	6.0
200 Outlet motor uniselector	84.0	6.0

It can be seen, therefore, that the most suitable system from a manufacturing viewpoint would be a crossbar system with a 10/20 switch used in link-trunked arrangements.

Economic Installation and Maintenance

It follows from the above arguments that the system containing the least material should be the easiest to install. This, in practice, is proving to be the case. The three crossbar exchanges so far installed in Australia have each averaged between 5-7 hours/line for the exchange equipment compared with an equipment installation time of about 15 hours/line inclusive for a bimotional exchange. Bearing in mind that the three crossbar exchanges installed have been "first in" installations, the installation time could be expected to reduce further as familiarity with the equipment is gained.

An important cost in a telecommunications network is the maintenance charge for the exchange equipment. Crossbar equipment has the most favourable maintenance performance of any electromechanical switching plant, due mainly to the simple relay-like nature of the switch and, hence, the elimination of mechanical adjustments and the need for lubrication of moving parts. The only adjustments remaining are those associated with relays. A major problem is designing bimotional and motor uniselector switching systems is the integration of the relay circuitry with the operating tolerances of the mechanisms and motors, respectively. The result has always been a large proportion of marginal relays subject to close timing tolerances in the circuitry of these systems. With crossbar, the circuitry consists of simple logical blocks utilising for the most part "donkey" type relays.

Surveys of relative maintenance effort for various systems have been conducted in all countries, and Table IV is a summary of the general findings.

TABLE IV.

Equipment type	Staff per 1000 lines
Crossbar	0.1-0.3
British motor switch	0.4-0.5
German motor switch	0.5
SE.50 and 2000 type Bimotional switches	1.0-1.4

Future Developments

It is now possible to construct fully-electronic telephone exchanges, but the present rate of component development indicates that such exchanges are unlikely to be economic for some 10-15 years. However, it is clear at this stage that any exchange equipment purchased must be suitable for adaptation to electronic switching plant.

The main advantage of electronic control equipment is its speed of operation compared with relays. Therefore, to benefit from electronics, the switching medium must be capable of fast operation and overall simultaneous control from a single common equipment.

Conclusion

Taking all the above arguments together it becomes clear that the most desirable switching system for use in the Australian network is a link-trunked crossbar system, which has been fully developed and tried in service for local, rural and trunk transit applications, and has worked successfully with step-by-step networks. Of the systems on offer, the L. M. Ericsson crossbar equipment was chosen as most nearly fulfilling these requirements. This system, which uses 10/20 crossbar switches and link trunking, has been developed and proved in service in all applications and with a variety of other types of plant including step-by-step equipment. The next part of this paper will survey the origins of Crossbar Switching Equipment and describe briefly the system adopted for Australia.

PART II.—THE CROSSBAR SYSTEM

The crossbar switch was one of the earliest developments in automatic telephony. Betulander, a Swedish engineer, worked with the crossbar principle of switching in the early part of the century and, as a result, in 1912 he took out a patent for the first crossbar switch. The diagram in the patent application is shown in Fig. 11.

At the same time, development was in progress in the United States of America

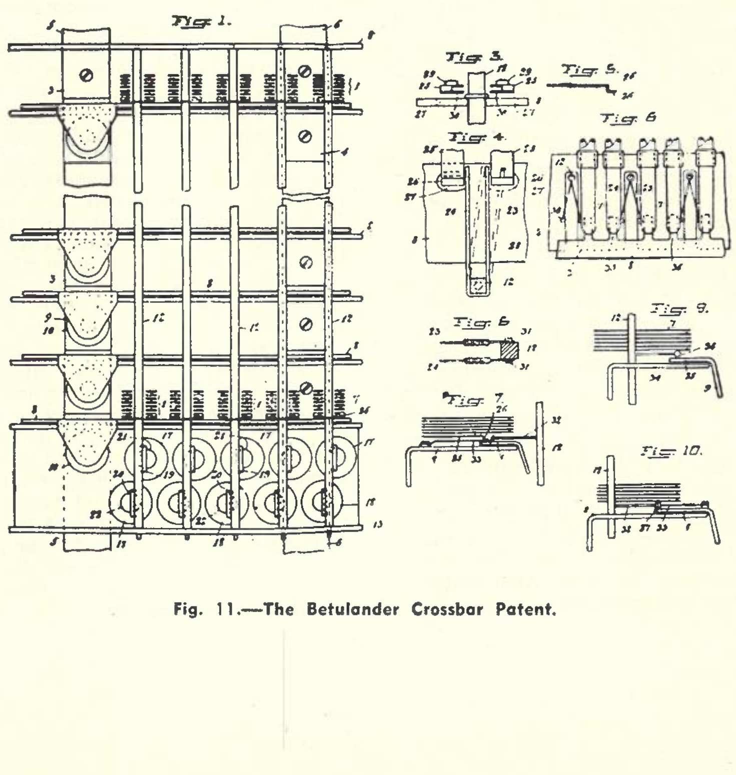


Fig. 11.—The Betulander Crossbar Patent.

along similar lines. In May, 1913, Reynolds of the Western Electric Company patented a selector with relay contacts actuated by a system of crossing bars which produced a direct and instantaneous connection between a series of contacts. The Reynolds switch did not arouse great interest, due primarily to the large capital investment required for its development and manufacture. The selector was rather complicated and possibly too expensive to manufacture with the facilities available at that time. However, 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. However, these crossbar switches and the relay system were at this time too expensive when compared with the Strowger system based on a switch first patented in 1891 by Almon Strowger of Kansas City, and referred to at the beginning of this paper (see Fig. 1).

The main reason that these crossbar switches proved too expensive in exchanges at this time was that the common controls, on which a crossbar exchange relies, were not sufficiently fast in operation or reliable in service. Relay design and manufacture was in the early stages and single contacts were still used with little, if any, spark quenching. The wide operating tolerances, relatively slow speed of operation and the use of separate impulsing relays for each selector, were simplifying the conditions which resulted in the extensive use of the Strowger switch for early telephone exchanges.

It was not until about 1936 that technical developments in the field of relay manufacture enabled the designers to introduce an economic crossbar switching system. This development of the relay and other switching components has accelerated since the Second World War until today a relay with twin contacts of special alloy, copper-silver or palladium-silver, with adequate quenching where necessary, and a reliable coil will give fault-free performance for 10 million operations or more. In addition, the development of high-speed signalling techniques using voice-frequency codes with transistorised oscillators and receivers small enough to mount in a relay space, allows dialled digits to be passed from a store in a register to a marker, at high speed. High-speed common controls are now available.

The Bell System in 1936 introduced the No. 1 crossbar system and, at about the same time, the Swedish Administration was experimenting with the application of crossbar to small rural exchanges as well as to larger city exchanges. From this second beginning 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. Table V demonstrates the recent general trend towards crossbar type switching by some leading manufacturers.

TABLE V

Manufacturer	Crossbar system	Previous systems
A.T.E. Liverpool, England	5004 5005A/B (Under development)	Strowger, 2000 type, SE.50 Siemens' motor uniselector (step-by-step)
Bell Telephone Manufacturing Co., Belgium	8B Crossbar and Pentaconta	8A, Crossbar 7 series Rotary Systems (Register controlled)
C.G.C.T. and L.M.T., France	Pentaconta crossbar	R6 and Standard Rotary Systems (register controlled)
L. M. Ericsson, Sweden	ARF 102 ARF (Swedish PTT) ARM 20/50 ARK 50 (In production)	ARF 101, ARF 50/51 ARF 30/50 Crossbar 5000 line system XY System (register controlled)
Mix & Genest, Germany	H.K.S. crossbar	Strowger and German motor uniselector
U.S.S.R.	Unnamed crossbar	500-line system and possibly Strowger
Siemens & Halske, Germany	ESK relay crossbar (Under development)	Strowger E.M.D. (step-by-step and register controlled)
Western Electric, U.S.A.	Bell Nos. 4A and 5 (In production for Bell Co. only)	Bell Crossbar System 1, 1A, 2, 2A and 4. Panel-Rotary, 100-outlet Strowger (register controlled)

A Comparison: Crossbar with Step-by-Step

As mentioned in Part I, the basic element in our present switching system is the bimotional selector. This switch steps vertically under the control of impulses received by the vertical magnet and then searches horizontally for a free outlet on the particular route associated with the level chosen. Thus, each switch receives one of the dialled digits and directs the call one step further towards its destination. Each switch has associated with it sufficient control equipment to recognise the dialled digit, select the appropriate level and find a free outlet.

The crossbar system, however, uses high-speed control equipment, registers and translators located centrally in the exchange, and these are associated only with a particular crossbar switch only whilst it is being set. The register in this system acts as a telephone operator, with the exception that the register operates at a speed far in excess of that possible by a human being. The register receives the dialled number into a store and, after examination of this information, proceeds to take into use the junction routes and switching centres which will enable the call to reach its destination using the most direct free circuits. The register equipment may test several routes to find a free circuit and, during the establishment of the call, it refers to the translator for route information and calls in high-speed voice frequency transmitters and receivers to pass the digital information to exchanges on the route to the called number. Having established the call, the register releases and is available to set another connection.

The application of the principle of common register control is possible only because of the high operating speed of the crossbar switch and the associated techniques of multi-voice-frequency high-speed signalling and high-speed register translator operator. A system of this type enables efficient use to be made of the existing switching and line plant. Register operation provides opportunities to take maximum advantage of flexibility in the use of junctions in the network and in the allocation of numbers to subscribers. With the Australian step-by-step system the junction routes used for a particular call are determined by the digits dialled, whereas, with the register crossbar system using suitable translations, the most direct free route can be used, and this may vary depending on the amount of traffic flowing in the network and its direction at any time of day. Thus, the junctions in the city business centre, which with the step-by-step system lie idle at night, may be used for residential traffic when register-controlled crossbar is introduced. With our step-by-step system, blocks of subscribers' numbers are allocated on a regional basis and, since subscribers' development is not uniform over the network, there is a shortage of subscribers' numbers in some areas whilst other areas have numbers to spare. With register crossbar equipment the allocation of numbers to subscribers in particular areas is far more flexible and number saturation in one area can be readily relieved.

The Crossbar Switch

The crossbar switch or selector, as the name implies, consists of a series of vertical bars or bridges and another series of horizontal bars. Fig. 7 shows a range of crossbar switches of various sizes.

These switches differ from the bimotional selector since they are not capable of setting up a connection without the assistance of an external control circuit. This control circuit receives the dialled digits and decides which inlet must be connected to a given outlet and then operates the corresponding horizontal or vertical magnets to close the relay contacts at the required intersection. Fig. 9 shows a crossbar switch of the type used by the A.P.O., and an enlarged and exploded picture of a typical bridge or vertical inlet.

The switch in Fig. 9 has 10 inlets or 10 vertical bridges, and 20 outlets, which are derived from the horizontal bars. Each bar will operate either to the top magnet or the bottom magnet associated with it thus lifting the selector fingers up or down. From five bars, therefore, 10 outlets are derived and the sixth bar operates as a wiper switching element in association with the other five to provide a total of 20 outlets.

Fig. 12 shows in detail the method of operation of the vertical and horizontal magnets to close a connection. To operate springset No. 6 in Fig. 12 the selecting magnet 6 tilts the selecting bar so that the selecting finger moves upwards over the flanges of the actuating spring and comes to rest against the projecting stop. Attached to the armature of the holding magnet is a vertical holding bar which normally moves into the recess of the actuating spring and, hence, does not operate the spring pile. However, when a selecting finger is moved from its normal horizontal position by the operation of the selecting bar, the outer extremity of the finger bridges the recess in the actuating spring so that, when the holding bar is operated, it comes into contact with the operated selecting finger and operates the appropriate springset. The selecting finger is held between the holding bar and the actuating spring by the pressure exerted by the holding magnet. Since the selecting finger is flexible, the horizontal bar can restore to normal and be used to assist in the setting of another call level and the first connection under the control of the holding magnet.

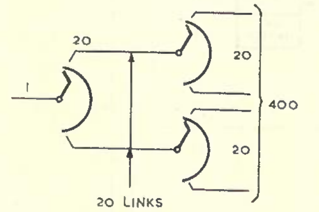


Fig. 13.—Link Trunking in Crossbar.

The Crossbar Switch as a Selector

Each vertical of the crossbar switch can be considered as a 20-outlet selector. Thus, a 10/20 crossbar switch consists of 10, 20-outlet selectors. Twenty outlets are not sufficient from a given selector stage to provide efficient trunking, and, in fact, this limitation to the number of outlets available is one of the disadvantages of bimotional switches. Crossbar switches can be arranged to provide for any number of inlets and outlets by a method known as link trunking. An illustration of this principle is given in Fig. 13, which shows how access is gained to 400 outlets from a given inlet using two ranks of selectors.

This principle of developing a selector stage from two partial stages of crossbar switches is used throughout the ARF exchange system, the type normally used in large city networks. The connections between the first and second partial stages are known as links, and the marker controlling the complete stage selects not only a free outlet but also a free link to connect the inlet to the required outlet. Hence, both partial stages are set simultaneously. Using this method of trunking, selector stages with any desired number of inlets and outlets can be constructed.

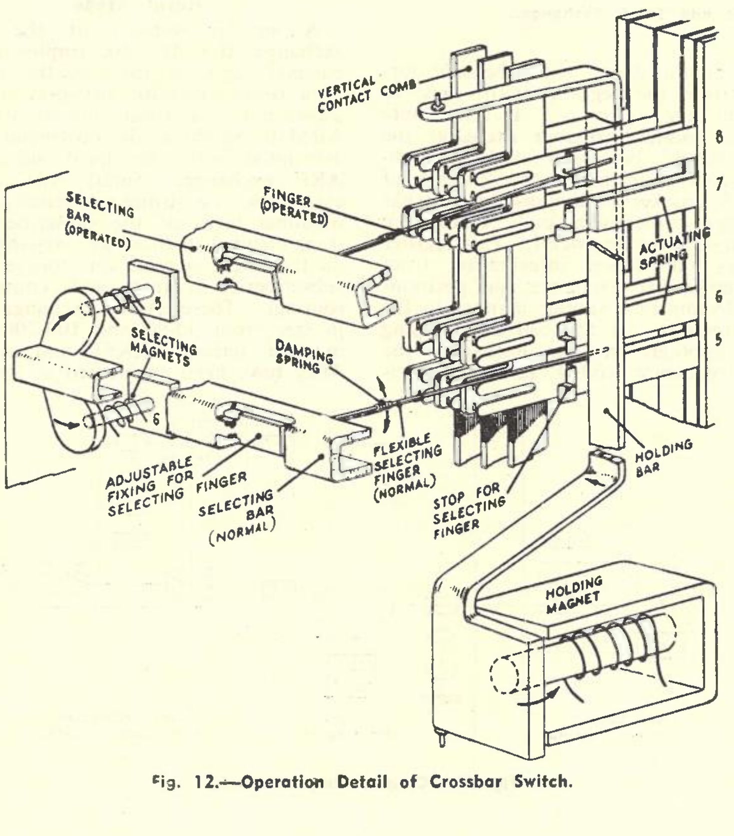


Fig. 12.—Operation Detail of Crossbar Switch.

Typical Crossbar City Exchange

The operation of a typical crossbar city branch exchange (ARF) is described below, with reference to the schematic diagram (Fig. 14).

Subscribers are trunked through two linefinder stages, SLA and SLB, in groups of 200 to the S.R. relay set. From this relay set access is gained through register access equipment to the local registers. The S.R. relay set provides transmitter battery feed and supervision for the calling subscriber. The group selector stage consists of two partial stages of crossbar switches arranged in units, each unit providing 80 inlets and 400 outlets. From this group selector stage, direct access is gained to the SLC and SLD stages of the subscriber's linefinder, final selector group. As well as these direct routes to 1000-line groups, a backbone route connects the group selector stage to the incoming group selector (GIV) and this route carries traffic not handled on the direct routes to the SL stage. The full SL stage provides access to 1000 subscribers. The SL stage is under the control of the SL marker (SLM) whilst the group selector or GV stage is controlled by the GV marker (CBM). Incoming calls from other exchanges pick-up Register I which controls the setting of the call through the GIV and SL stages. Outgoing calls from the GV stage may be routed either to other crossbar exchanges or to step-by-step exchanges.

When a subscriber removes his handset his line relay "LR" operates and indicates the call to the SL marker of the 1000-line group to which he belongs. The SL marker selects a free SR relay set and register and connects the calling subscriber through the SLA and SLB stages to this relay set and register. The marker is then released and the register transmits dial tone to the subscriber. The subscriber dials the wanted number, into the register. For a local call the register now controls the selection of the wanted subscriber.

First, the register seizes the GV marker associated with the GV or group selector unit to which the SR relay set has access. A code receiver KM in the GV marker receives from the register, by means of a high-speed signalling code, the digits required to select the correct outlet from the group selector stage. The GV marker connects the call through the required outlet on the SL

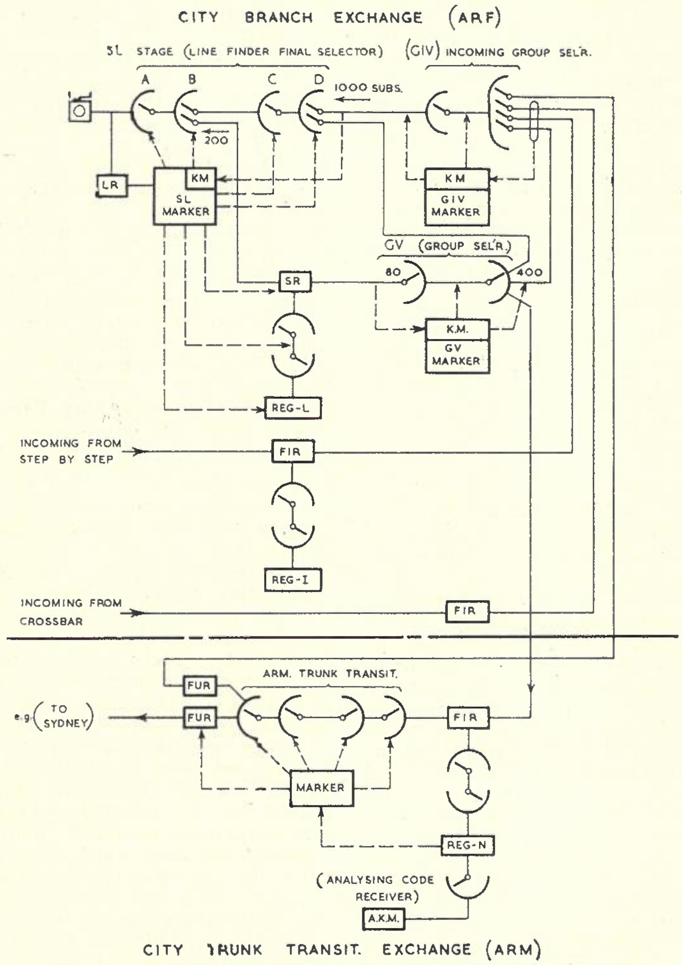


Fig. 14.—Crossbar City Branch Exchange and Trunk Exchange.

stage, and the SL marker is then seized. The GV marker releases as soon as it has completed the group selector connection. If there are no free outlets on the direct route to the 1000-line group required, the GV marker tests the route to the GIV stage, selects a free outlet and connects the call as before. The SL marker now calls for the three digits required to locate the subscriber in the particular 1000-line group already selected. These digits are also sent forward, using high-speed code, and are received by the receiver in the SL marker. The SL marker positions the four SL stages for the wanted subscriber and, having notified the register of the condition of the called subscriber, releases. The complete connection is held from the SR relay set which now transmits ringing current to the called subscriber and ring tone to the calling subscriber. At this stage, SR takes over control of the call, and the register releases. From this stage on, the supervision of the call under the control of the SR relay set is similar to the supervision in our present step-by-step exchanges.

For an outgoing call the GV marker selects the required outgoing route and identifies what type of signalling is required for the digits to be sent forward. For a route to a step-by-step exchange the digits would be sent forward from the register at 10 i.p.s. to position the selectors. If the route was to another crossbar exchange the digits would be transmitted in high-speed code direct to the code receiver of the GV marker at the distant crossbar exchange. Incoming calls from step exchanges seize Register I. This register receives the digital information from the step-by-step exchange and positions the selectors in a similar manner to the local register. If the call is incoming from another crossbar exchange, the multi-frequency coded information is taken into the code receiver (KM) of the GIV marker direct, and the call is completed in a similar manner to a local call.

Trunk Exchange

If the subscriber requires to call a destination outside the local network, for example a Melbourne subscriber calling Sydney, on receipt of the code for Sydney, "02", the Register L initiates action to connect the subscriber to a network register, Register N, at the trunk exchange. The trunk exchange equipment (coded ARM) consists of a selector stage built, according to requirements, of either two or four partial stages of switches, and controlled by common markets, registers and analysing code receivers. These trunk exchanges can be expanded in units of 200 lines up to a total capacity of 4000 trunks in and out.

The Register L proceeds to transfer the digital information into the Register N at high speed, and Register N assumes control of the call. The analysing code receiver (AKM) is called in to determine the charge rate to be applied, and when the called subscriber answers the receipt of the answer signal in the FIR-U causes meter pulses to be applied to the line at the rate appropriate to the call distance and charge. The routing of the call is controlled through the necessary transit switching stages by Register N. At each transit point the local code receiver calls for sufficient digits to enable the most direct free circuit to be taken into use as the next link in the connection. Having completed the selection in the transit exchange, the transit marker releases and the Register N talks direct to the next transit code receiver in the call.

Rural Areas

A smaller version of the ARM exchange, the ARM50, employing two partial stages, is used as the nucleus of a rural automatic network. Fig. 15 shows a typical rural network with the ARM50 located at the provincial centre associated with the local subscribers' ARF exchange. Small ARK (rural) exchanges, consisting essentially of a modified form of the subscribers' line stage element of the ARF exchange, rely on the ARM register for storage of the subscriber's number and control of routing. These ARK exchanges vary in size from 30-90 and 100-2000 lines in two series, ARK51 and ARK52. They have been engineered as unit type

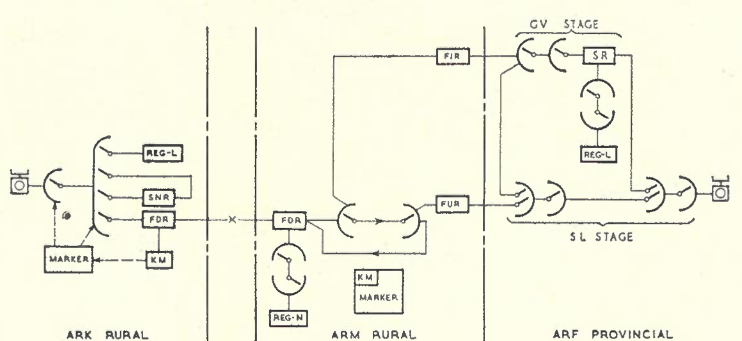


Fig. 15.—Crossbar Rural Network.

equipments in cabinets, and, as such, can be readily installed and moved when required. In spite of careful planning, it is often found that in areas where these exchanges are required initially, unforeseeable expansion occurs and the telephone facilities may need to be replaced by city branch exchange type equipment.

When the subscriber lifts his handset a junction is seized to the ARM exchange and dial tone returned from the register. The dialled digits are stored in Register N and, if the call is outgoing, the connection is established through the ARM exchange and on to the destination. However, for a local call the register returns instructions at high speed to the marker in the ARK exchange and the call is established on a local link, the junction being released. If all junctions are busy or out of service due to fault or calamity, the call is intercepted by an emergency local register in the ARK which will complete local calls only.

TABLE VI.

Allocation of Frequencies and Codes for Forward and Backward Signals between Registers.

Forward Signals

	Digit	1	2	3	4	5	6	7	8	9	0
1380	0	X	X		X			X			
1500	1	X		X		X			X		
1620	2		X	X			X			X	
1740	4				X	X	X				X
1860	7							X	X	X	X
1980	10	Used with above for 5 special signals									

Backward Signals

Frequencies: 1140, 1020, 780, 660

A SERIES

1 Send next digit
2 Restart
3 End of Selection
(Transition to B signals)
4 5 digits) MFC terminal
5 6 ") Transition to
6 7 ") 2A signals
7 5 digits)
8 6 ") SxS terminal
9 7 ") Transition to
10 Number)
length) 3A signals
unknown

B SERIES

1 Idle sub.
2 Busy sub.
3 No throwout.
4 Congestion
5 Idle sub., non-metering
6 Interception service and malicious call

2A SERIES

Call to Crossbar Subscribers

1 Send next digit
2 Restart
3 End of Selection
(Transition to B signals)
4 Send 1st digit decadic
5 " 2nd " "
6 " 3rd " "
6 " 3rd " "
7 Waiting place, Next digit
8 " " , Restart
9 " " , Same digit
10 " " , Previous digit

3A SERIES

Call to Step-by-Step Subscribers

1 Send next digit
2 Restart
3 End of Selection
(Transition to B signals)
4 Send Previous Digit
5 Send 1st digit decadic
6 " 2nd " "
7 " 3rd " "
8 " 4th " "
9 " 5th " "
10 " 6th " "

Congestion is always given as A3 (or 2A3, 3A3) + 1B4.
Waiting place signal is only given once in a call. If the signals 7-10 are received once more by the register, they are interpreted as 3A7-10.

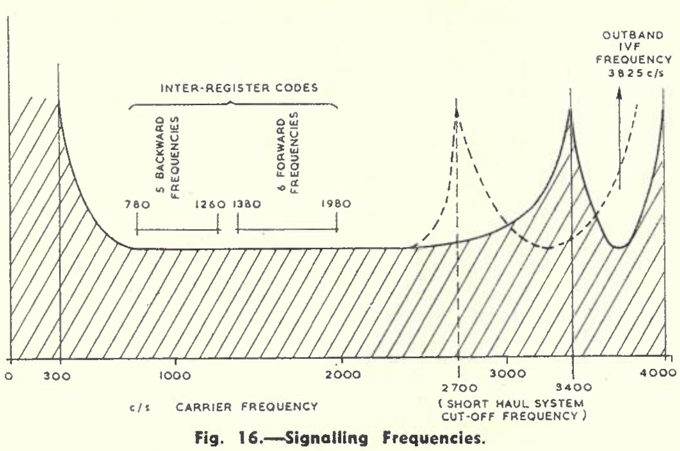


Fig. 16.—Signalling Frequencies.

Signalling

In telephony, signalling is the general term applied to the process of establishing, supervising and, when necessary, disconnecting a connection between two subscribers. There are two broad categories of signals, termed information and line signals. The information signals are the digits the caller dials to specify the party to whom he wishes to be connected. The line signals are those signals necessary to seize a junction to guard it against intrusion until the call is clear, to signal when the called party answers so that the call may be charged and to clear the connection after the conversation.

With a register-controlled system the information is stored in the register and passed to other registers or code receivers as required. The information signalling system is separate from the line signalling system, the former being associated with the registers and code receivers whilst the latter is associated directly and permanently with the junction or trunk line.

In the present step-by-step network the various trains of impulses from the subscriber's dial are used as they arrive, to position the selectors in the connection, each impulse train extending the call one step further towards its destination. By this means, the call is extended to the distant subscriber as soon as the last impulse train has left the caller's dial and positioned the final selector. Ring is fed to the called subscriber almost immediately and the caller receives ring tone.

With a register system, however, the wanted number is fed into the register and the system does not start selecting a route until three or four digits have been received. This is an advantage since the more information possessed before routing commences, the more intelligent can be the routing decision or, in other words the cheaper can be the route chosen. However, since delay has occurred, the switching and signalling system must switch and signal faster than the subscriber candial in an attempt to make up the lost time. The information used at the various stages for routing the call consists of the digits the subscriber has dialled. The digital information is held in the originating register and transferred as required to subsequent registers and code receivers using a high-speed coded system of signals. The code to be adopted for Australia is designed for error checking, each digit being represented by two frequencies, and receipt of any other number of frequencies is recognised as a false signal. The chance of speech imitation or crosstalk being recognised as a signal is thus virtually eliminated. These frequencies must be so located in the speech band that they do not interfere with the frequencies used for line or supervisory signals. Fig. 16 shows the channel frequency spectrum and the information signalling. Table VI sets out the codes for forward and backward signalling between registers.

The backward or reverse signals are used to call forward the next digit required by the code receiver, A, 2A and 3A series, to indicate the class of the called subscriber's line to the outgoing exchange, 1B series, so that busy or ring tone can be fed to the calling subscriber, and to indicate to the controlling register whether the call is to a crossbar or a step-by-step subscriber, A series. This last type of signal is necessary for two reasons:—

(i) If the call is to the step-by-step network, routing must be commenced as soon as possible because subsequent digits must be pulsed into the step-by-step network at 10 i.p.s. and full advantage cannot be taken of the fast signalling code. In the case of a call to a crossbar subscriber, the routing and switching may be sufficiently fast on a particular route (say a direct route) to cause a "waiting place" signal to be used. In this case the route is not seized until all digits have arrived in the store. If the route were seized earlier than this, the common code receiver equipment would be held for an inordinately long time waiting on the dialled digits from the subscriber.

(ii) For calls to crossbar destinations the register releases after an end-of-selection signal has been received from the distant code receiver to signify that routing is complete. However, in the case of step-by-step destined calls, no such end-of-selection signal is possible and, consequently, the register must release after it is satisfied that all digits required have been sent on. Therefore, a number length signal is transmitted to the register to indicate the number of digits required for the particular code dialled. Unfortunately, in our networks numbers of all lengths from 3 to 7 digits are in use spread randomly through the number range. Where the number length cannot be determined from the first four digits of the code dialled, the "don't know" signal is used and the register releases a short period after clearing its store. Finally, the register is also designed to release four seconds after it has cleared its store if no further digits arrive.

A description of the use of these backward signals is given in the section dealing with application in metropolitan networks.

The line signalling systems required in a crossbar network are required to perform only the supervision of the links between exchanges. The code of signals used is given below:—

Forward	*Reserve*
Seizure	Answer
Clear Forward	Clear Back
	Release Guard
	Blocking
	Meter pulses (when required on end links)

These signals can be achieved using D.C. loop signalling, utilising the two conditions, loop and open circuit. On derived circuits, a single voice-frequency can be employed using a pulse length code, 50 milliseconds pulse for seizure, 150 milliseconds pulse for answer, and so on. An alternative recently introduced is the utilisation of a channel just above the speech channel but below the carrier frequency, to carry a single frequency signal. The frequencies commonly used are 3825 or 3850 c.p.s. The advantage of this system is that the signals are isolated from the speech channel and, in consequence, simple loop and open-circuit conditions can be simulated. In addition, meter pulses can be sent back during conversation without interfering with speech.

Reference was made earlier to the Compelled Sequence method of signal transmission. This method is preferred for both outband line signalling and for inter-register signalling. The scheme is one in which the forward signal is sent until an acknowledgment is received at the outgoing end. This acknowledgment cuts off the forward signal and the break in turn cuts off the acknowledging signal. Further, the acknowledge signal in the inter-register case is used to indicate to the originating register the next signal required. This compelled sequence method is proof against most transient interruptions likely to occur on open-wire routes and transmission systems, and, due to the one-at-a-time flexibility of the procedure, only the information required at each centre is sent forward.

The simplified requirements imposed on the line-signalling equipment have resulted in an increase being possible in the allowable D.C. resistance limit of junction cables. The previous restriction imposed by the requirement to minimise impulse distortion has been removed in a crossbar network and the limiting condition is the ability of the receiver relay in the outgoing repeater to hold over the answer reversal. The allowable limit has been increased from 1,200 to nearly 4,000 ohms. Similarly, with register control, the pulses from the subscriber's dial only require to be identified by the register store receiving relays. The subscriber's line resistance can consequently be increased from 1,000 to 1,800 ohms. Both these relaxations will allow considerable savings to be achieved in the subscriber's and junction reticulation networks.

PART III.—APPLICATION IN A.P.O. NETWORK

As a result of these system studies and the consequent recommendations, the A.P.O. decided late in 1959 to standardise on the L. M. Ericsson crossbar equipment for supply, local manufacture and application in the network. An agreement was negotiated between the Department, the L. M. Ericsson Company, Standard Telephones and Cables Pty. Ltd. (Sydney) and Telephone and Electrical Industries Pty. Ltd. (Sydney) whereby the two local firms would manufacture crossbar for A.P.O. requirements. Considerable effort has since been directed towards the planning and programming for the initial supplies of equipment, both purchased direct from Sweden and manufactured locally, to ensure that the initial inter-working problems have been allowed for and to enable smooth introduction of the initial deliveries to commence in the 1961-62 financial year. The following sections indicate briefly the way in which the equipment will be integrated into the network.

Metropolitan Networks

There are three broad categories into which the initial crossbar installations can be grouped in city networks. New exchanges naturally will be installed exclusively with crossbar equipment, and examples of these currently on order from L. M. Ericsson are: Haymarket, 1961-62, 8,000 lines, a central city exchange in the Sydney network; Flinders, central city exchange in the Adelaide network, 1961-62, 5,400 lines; Cooma, a provincial centre exchange, 2,000 lines. Already installed and cutover in September, 1960, is Toowoomba (Queensland), 6,300 lines, a provincial local exchange which, together with two small exchanges, Sefton (N.S.W.) and Templestowe (Victoria), represent the present working crossbar equipment in the network.

In the second category are the crossbar extensions to existing step-by-step branch exchanges. To allow extension of these exchanges with crossbar, it is planned in each case to close them off when the current 1,000-line unit is fully allotted and, using one digit of the six-digit exchange code, open up a seven-digit 10,000-line crossbar section. The block schematic trunking for such an exchange is shown in Fig. 17.

The six-digit step-by-step exchange in this example has 10,000 numbers with code 53, and level 1 has been expanded to seven digits to provide a fresh 10,000-line group with code 531, XXXX, leaving 9,000 numbers on the step-by-step exchange with codes 53,2-0,XXX. Consider the original step-by-step calls. The uniselector connects the subscriber to a 1st selector in the main exchange (see Fig. 2), and a call for 53,XXX arrives via the 1st and 2nd selectors to the 3rd selector. If the call is destined for the step-by-step exchange, it continues to the final selector. If the code is 531 an interworking register is seized from level 1 of the 3rd selector and the remaining digits are received into the register store. The Register I picks up the GIV stage and feeds forward "IX". The GIV selects a free circuit to the required 100-line group and the SL stage then receives the last XXX and selects the wanted subscriber.

In the case of a call from the crossbar exchange, the pick-up procedure is as detailed in Part II of the paper. However, as mentioned above, when interworking into a step-by-step network it is necessary to determine whether the call is destined for a crossbar or step-by-step exchange. This can, in most cases, be determined by examination of the first four digits of the dialled number. If the call is to crossbar, the signal A5 or A6 is sent back to the register from the IGV code receiver. After this, all signals passed back are in the 2B series

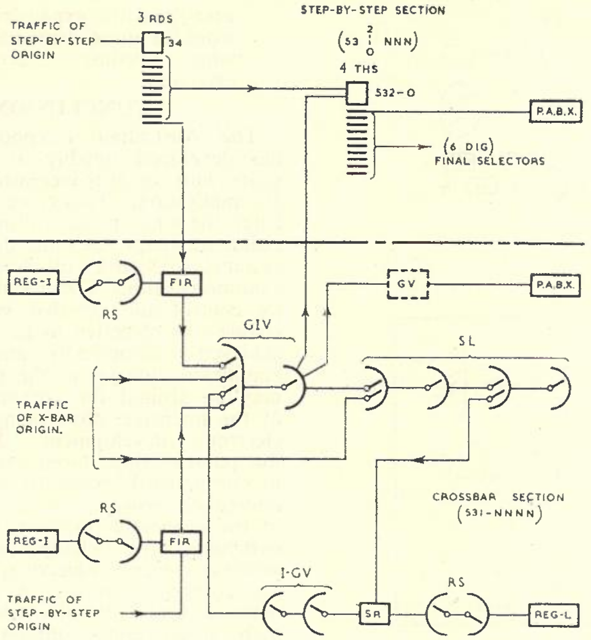


Fig. 17.—Extension of 6-Digit Step Exchange with 7-Digit Crossbar.

which has been designed for controlling a call through the step-by-step and crossbar network to a crossbar destination. Signals 2A, 5, and 7 are designed to allow for the case when the call is routed through a step-by-step switching stage. In this case the maximum flexibility is achieved if all digits are pulsed out decimally and another Register I is seized when the crossbar network is re-entered. For calls to step-by-step equipment, one of signals A7-10 is returned and the subsequent signal from the 3A series indicates from what digit the register must start when pulsing out into the network.

Incoming calls from the crossbar network arrive on the GIV and may be destined either for the crossbar or step exchanges. The first digit received will be the 3rd, and, if 1, the code receiver will call for the first X and route to the required 1,000-line group. If the digit is 2-0 the GIV will select a route to the appropriate rank of 4th selectors and send a revertive signal to the Register L to send the 4th and subsequent digits decimal.

The third application of crossbar equipment will be the introduction of the first selector stage and register, which are in effect the essential elements of the crossbar switching system, into step-by-step exchanges instead of or to replace D.S.Rs. (discriminating selector repeaters.) This requirement arises in one of two ways. Either on extension the D.S.Rs. or their earlier equivalent the S.S.Rs. (switching selector repeaters) are replaced, or a trombone trunked exchange is converted to a group selector branch by the introduction of a crossbar 1st group selector stage. A typical trunking diagram, showing the replacement of the D.S.R. with a crossbar group selector stage, is shown in Fig. 18. The D.S.R.

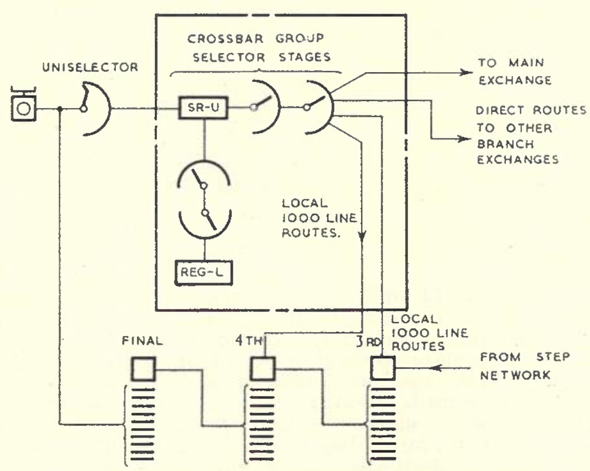


Fig. 18—Crossbar First Selector Stage in Step Exchange.

is used in some step-by-step branch exchanges to provide direct routes to other exchanges in the same main exchange area, that is, possessing the same first code digit. All other calls are routed via the main exchange first selectors. The crossbar GV stage places no limit on the code groups to which direct routes can be established and, thus, a large portion of the traffic load can be removed from the main exchange route. In addition, a direct route can be established from the GV stage to the trunk switching equipment to handle trunk traffic. This is not possible on the trunk code "O" using the present 2,000 type D.S.R.

Rural Networks

In the rural networks, the first requirement will be to minimize purchase of further R.A.X. equipment which cannot be readily integrated in the national numbering and switching scheme. For this reason, the initial bulk orders of equipment will contain a proportion of ARK country terminal exchange equipment. These small units, ranging in size from 30-2,000 lines, will cover a very large proportion of the requirements in country areas for automatic equipment, to take the place of the R.A.X. and the medium-sized manual exchanges. Where the exchange will grow beyond 1,500 lines in the 20-year period, or the proportion of local traffic is high, an ARF exchange would be considered, especially where the rate of growth is high.

The introduction of ARM transit equipment in country areas is also being planned to provide a core for the ARK exchange networks and to facilitate distance dialling.

Trunk Network

The present operator-controlled step-by-step trunk network is of basically different character from the step-by-step local networks for two reasons:—

(i) The number is open, or, in other words, the digits dialled by the operator to reach a certain location vary, depending on the location of the operator and the route she chooses to take. For example, a Perth operator calling Sydney via Adelaide may dial 80351, whereas an operator at Adelaide dials only 351. In the national numbering scheme subscribers or operators would always dial 02 for Sydney, no matter where in the Commonwealth they were and how they reached their destination.

(ii) The present method of signalling on long distance carrier telephone channels using 2VF has been designed especially for operator dialling, and the system would not be entirely suitable for use on a subscriber-dialled system with high-speed circuit seizure.

For these reasons, it is generally considered that the objective should be to retain this network as an entity and to build up in parallel a subscriber-dialled long-distance network linking progressively the local networks. The present network would continue to handle the traffic not catered for by subscriber-dialling facilities or to assist the subscribers requiring a telephonist to complete the call. The operators would

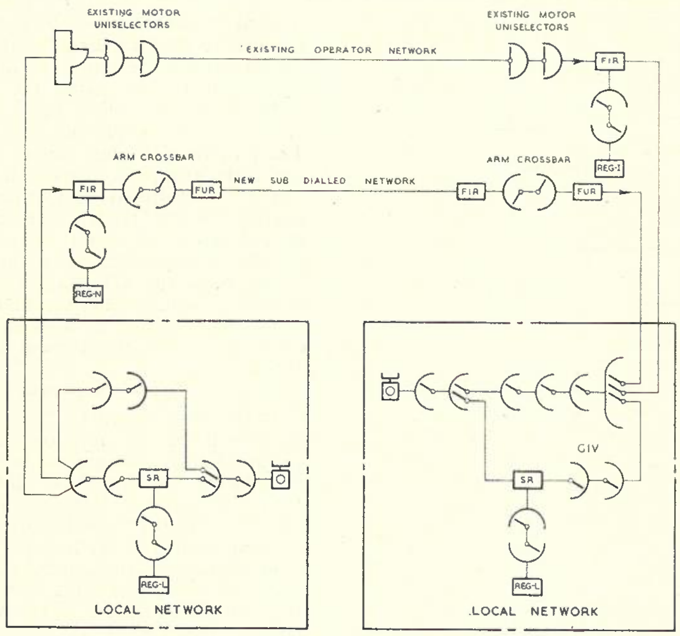


Fig. 19.—Development of Trunk Network with Crossbar.

have access into the subscriber network as shown in Fig. 19.

The first large-scale problem to be solved in the trunk network will be the provision for subscriber dialling out of the large capital city networks. This is becoming necessary in both Sydney and Melbourne, and will become important elsewhere to avoid further costly extensions to the manual trunk exchanges in these centres. To achieve S.T.D. from the large city networks, several additions and modifications to existing plant are necessary:

(i) The installation of a main ARM trunk transit exchange in the centre concerned. This installation would provide analysis for charge determination, routing and access-barring of subscribers who did not want their telephones used for long-distance dialled traffic.

(ii) The modification of existing meters in many exchanges to allow for multimetering.

(iii) The modification of repeater equipment to pass meter information back to the branch exchange from the central ARM transit.

Work is proceeding with the objective of solving the problem of meeting all three requirements. The resulting trunk transit exchanges will be the present-day equivalent of the 1940 Melbourne Trunk Exchange and the keystone on which the nation-wide S.T.D. network can be developed. This network will develop to fulfil two primary objectives:

(i) The progressive automatisation of the whole Australian network, and the consequent provision of a high-grade continuous automatic telephone service.

(ii) The steady reduction in manual operating, and consequent high costs, and the expansion of the network to meet demands for service with maximum economy and efficiency.

CONCLUSION

The Australian Telephone Network has developed steadily in the past 50 years with an ever-increasing degree of automatisation. Today, we are about to enter the final phase following the decision to adopt the concept of a single automatic network embracing the whole Commonwealth. The adoption of register control and crossbar switching will enable this objective to be progressively achieved economically and efficiently. Significant changes in the telephone art may be around the corner as a result of the intensive effort being invested in electronic development. However, at this point of time, faced with a doubling in our network every 10 years, and no immediate prospect of a firm solution of the economic problems of electronic switching, the change contemplated achieves several objectives. It allows for economic growth, it prepares the network for electronics which must be high speed and common control in nature, and it takes advantage of the latest engineered developments in the telephone switching art, developments which cannot be seriously threatened, on present information, for at least 10 years.

ACKNOWLEDGMENT

The author wishes to thank the Director-General and Engineer-in-Chief of the Postmaster-General's Department for granting permission to use material contained in this paper. Contributions towards the work underlying this paper have come from several Engineers in the Post Office whose assistance is appreciated and acknowledged. In particular, however, he wishes to acknowledge contributions by Messrs. C. I. Cruttenden, N. A. S. Wood, N. M. H. Smith and B. McKinley to the various phases of this investigation. The author also wishes to record his appreciation of the editorial assistance given him by Messrs. C. I. Cruttenden and C. J. Griffiths.

INDEX—VOLUMES 7 TO 12

A comprehensive index, covering the contents of volumes 7 to 12 inclusive, has been completed and is ready to be printed. It will be similar to the index for volumes 1 to 6 which was issued in February, 1948, and which has filled a very useful need to readers who refer at times to past issues of the Journal. However, it is not considered desirable for the printing costs to be shared by all readers of the Journal, some of whom will make no use of the index, and it has been decided to make a charge of three shillings (3/-), the estimated printing cost, for each copy. Any reader or organisation requiring the index is requested to fill in the slip included under the front cover and forward it, together with a remittance for three shillings (Australian currency, including postage), either to the State Secretary of the State of residence, or to the General Secretary if resident overseas. Australian subscribers could assist the Society greatly by forwarding remittances before the 20th November, as it is desired to make firm printing arrangements then with a view to distribution before the 20th December. Copies of the earlier index for volumes 1 to 6 are still available and can be supplied at a cost of 1/6 each, including postage.

LINE TRANSMISSION AND SWITCHING FOR THE AUSTRALIAN TELEVISION NETWORK

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THE GENERAL TELEVISION NETWORK

The geography of Australia and the pattern of settlement have resulted in a population distribution which presents a number of problems in the communications field. The concentration of the population in the capital cities has had a considerable influence on the manner in which television services have been provided. The problem of providing inter-capital television links has been accentuated by the rather localised interest of much of the television programme material. Only on relatively few occasions, such as International Tennis and Test Cricket Matches, has the need for simultaneous transmission in more than one city been so great that temporary inter-city links have been provided, using pooled radio link equipment More inter-city transmissions would undoubtedly take place if facilities were available. For this reason, provision was made in the Sydney-Melbourne coaxial cable project for a single bi-directional television link between Melbourne, Canberra and Sydney. The projected cutover date for this equipment is June, 1963; the Canberra-Sydney section will be completed late in 1962.

The recent approval for the establishment of National and Commercial Regional television transmitters has wrought a considerable change to the overall requirement. In the case of the National Regional stations, the programmes will be derived from capital city studios, and the Commercial Regional stations may also derive a considerable portion of the programme material from the capital cities. Plans have not yet been finalised for the Commercial programme requirements.

To provide for the National requirements, the Postmaster-General's Department is faced with establishing high reliability video and sound transmission channels between the Regional stations and their programme sources. A general plan showing the links required for the first stage of the Regional stations is given in Fig. 1. In the case of Canberra a link will be available from the Sydney-Melbourne cable, but this will be needed for inter-capital programmes and can not be used for Regional relay purposes. Further new facilities must therefore be provided for all Regional links, and in general the most economical method is to use broadband micro-wave radio systems. In most instances it will be possible to utilize existing equipment installations on broadband radio telephone bearers for the provision of these new links by simple extension of the equipment. Existing stand-by channels will be shared by telephone and television bearers. For Regional transmitters off the main broadband radio routes, short radio spur bearers can be provided economically. The siting requirements for radio systems and for television transmitters have many common factors, and thus, at the country end, the receiving terminal of the radio equipment will usually be in close proximity to the television transmitter site. Interconnection between the receiving terminal and the transmitter is thus reasonably simple.

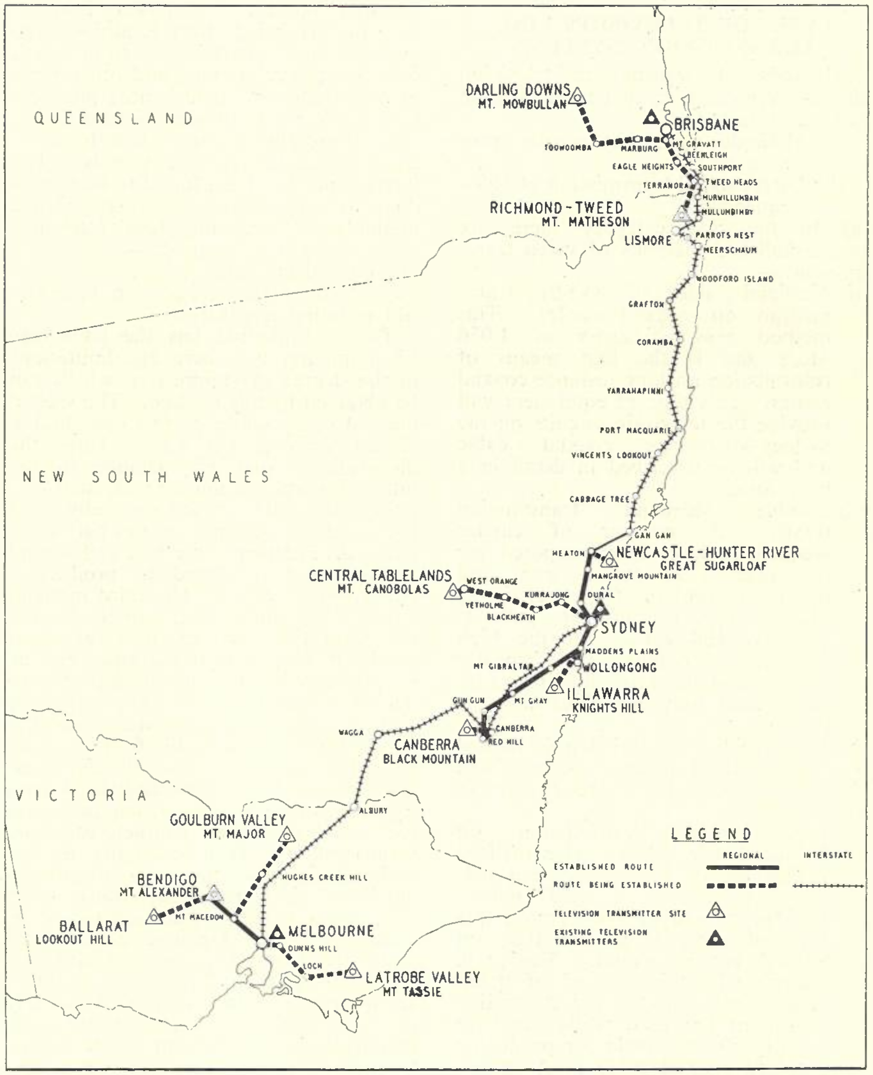


Fig. 1.—Existing and Proposed Television Stations and Connecting Links.

At the city end however, the problem is quite different. It is not easily possible to provide the radio link transmitting terminal at a convenient site near the programme sources. Recourse must therefore be made to some form of line transmission between television studios and the transmitting radio terminals. This paper is concerned largely with the problems involved in the provision of this portion of the overall links.

A need will arise also for controlling the connection and interconnection of programme material in the cities. A convenient method of doing this is to provide central Television Operating Centres (T.O.C.'s) with facilities for testing and monitoring circuits, and making the desired connections.

Television Outside Broadcasts (T.O.B.'s) also have a place in the scheme to be adopted. At present T.O.B.'s are provided by means of micro-wave radio links, and the link equipment is very effective. However, siting troubles do occur at some outside locations. Moreover, the expense of setting up and removing the equipment required for T.O.B.'s is quite considerable. If facilities were available at most of the more popular outside broadcast sites, considerable economies could accrue to the Station Operators. It is therefore expected that ultimately a network of television links will be provided to the most popular sites, and an additional function of the T.O.C.'s

* See Vol. 12, No. 6, page 466.

will be the switching of these T.O.B. links to the requisite studios. A similar pattern has already become evident in the United Kingdom, the U.S.A., and on the Continent.

TYPES OF TELEVISION LINE TRANSMISSION SYSTEMS

Methods of transmitting television signals over cables may be classified in two categories:—

(a) Methods using modulation processes, and

(b) Direct signal transmission at video frequencies.

(a) In the first category there are two established methods of video transmission:—

(i) Vestigial sideband (VSB) transmission on coaxial cables. This method uses a carrier of 1.056 Mc/s and is the best means of transmission on long distance coaxial routes. This type of equipment will provide the television circuits on the Sydney-Melbourne coaxial cable and will be described in detail in a later article.

(ii) Double sideband transmission (DSB). A number of carrier frequencies have been proposed for this method of transmission, and the most common frequency is 21 Mc/s. The transmission path is again coaxial cable, but the high frequencies reduce the repeater spacing and the method is therefore economical only for short distance use.

(b) Direct video transmission is limited to relatively short distance operation and in this category there are two main methods:—

(i) Direct video transmission on balanced pair cables. This method makes use of special screened balanced pairs with "foamed" polyethylene insulation. The loss on this type of cable is greater than on normal coaxial cables. The main reasons why this method of transmission was rejected for Australian conditions are that, while extensive facilities are available for producing standard coaxial cable in Australia, no foamed polyethylene pair cable has yet been manufactured here. New practices would need to be introduced for jointing the cables, and moreover a satisfactory and economical means of transmission using coaxial cables was available. It is worth while recording that some reduced definition television signals have been transmitted over ordinary telephone pairs for short distances, particularly in England.

(ii) The transmission of direct video frequency signals on coaxial tubes. This method has been selected as the most economical one for short distance use in Australia, and will now be discussed in detail.

DIRECT VIDEO FREQUENCY TRANSMISSION ON COAXIAL BEARERS

Use has been made of coaxial cables for direct video frequency transmission since the early days of television. There is however one important difficulty to be overcome; the problem of low frequency interference. At high frequencies the screening of a coaxial circuit is very good, but at lower frequencies the effective screening becomes poorer. At power frequencies, the screening effect is almost nonexistent, and interference from earth currents, power circuits, and other types of low frequency disturbances produces prohibitive noise on such bearers unless special precautions are taken to overcome these interference signals. The interference has been found to be largely due to longitudinal currents. Three methods of reducing low frequency interference may be used:—

(i) coaxial chokes.
(ii) anti-phase noise injection circuits.
(iii) isolating transformers.

The first method has the advantage of simplicity, but there are limitations in the degree of suppression which can be obtained by this method. The second method can produce perfect cancellation of interference, but suffers from the disadvantage that any change in the interfering voltage must be adjusted out, either manually or automatically, and the method becomes somewhat complicated. Frequently the first and second methods are combined to produce a better overall effect. The third method, which is the one chosen initially for use in Australia, can produce excellent results if a suitable transformer can be manufactured. The difficulties of producing a transformer with good phase and frequency characteristics over the band from 50 c/s to 6 Mc/s are formidable. However a suitable transformer has been produced in Japan, together with a method of compensating for the transformer characteristics by means of a special clamping device, while retaining all the other advantages of direct video frequency transmission on coaxial cables. This scheme is in wide use in the Japanese network (1) and the equipment is supplied by Nippon Electric Company (N.E.C.), Japan, which is an associate of the I.T. & T. group, the transformers being manufactured by Nippon Denji Kogyo Company. Isolation of the outer conductor of the coaxial tube from earth is required, but can be accomplished readily if the installation is planned with this aspect in mind.

N.E.C. DIRECT VIDEO-ON-COAXIAL TRANSMISSION EQUIPMENT

Circuit Considerations

The C.C.I.T.T. recommendations for Television circuits are restricted to a standard reference circuit of 2,500 Km, consisting of a maximum of three long distance systems in tandem. No standards have been established by the C.C.I.T.T. regarding the number of short links to be connected in tandem with the long distance systems. Situations can readily be envisaged where up to twelve short distance links may be involved in a long distance television relay, and the contribution of these short links to the overall system performance may not be negligible, particularly where complex switching operations are planned.

A primary factor in the design of any system is its signal to noise ratio. The Japanese noise objective for a comprehensive long distance circuit is a peak to peak signal to RMS noise ratio of 47 db for flat noise. The noise weighting network employed by the C.C.I.T.T. for non-uniform noise of other spectra has a loss of approximately 8.5 db for flat noise. Thus the signal to weighted noise objective is approximately 55.5 db. The corresponding figure of the C.C.I.T.T. recommendations is 52 db, but the actual noise power is similar, since the Japanese transmitting level of 1.4 volt is 3 db higher than the C.C.I.T.T. level. It was considered that the total permissible noise for the entire network should be divided by a 2 : 1 ratio, and assigned respectively to three long distance links and twelve short distance links. Consequently the signal to weighted noise objective for twelve short distance tandem connected links becomes 61.5 db.

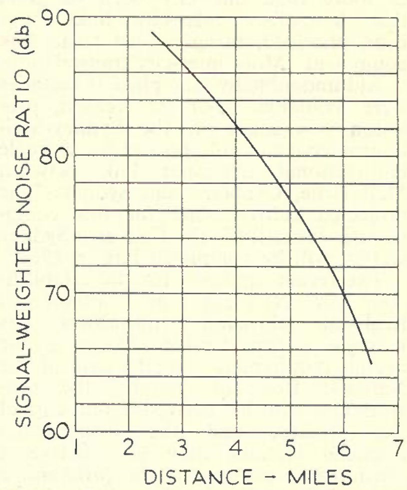


Fig. 2.—Relation between Link Distance and Signal-Weighted Noise Ratio.

It would be unrealistic to divide the contribution by each of the individual short links equally, because it is highly improbable that twelve links of maximum length would ever be connected in tandem. The designers therefore assigned an objective of 67.5 db for the minimum signal to weighted noise ratio of one short link, taking into account the distribution of actual circuit lengths, and the rapid decrease in weighted noise as the length of link becomes shorter than the maximum.

One of the main features of the N.E.C. design (designated "Type CV" equipment) is the fact that no transmitting terminal equipment other than a transformer is required. This fact is particularly advantageous in that it removes the need for the Department to maintain active transmitting equipment at the studios originating the programmes, and also allows semi-permanent T.O.B. circuits to be provided simply.

At the receiving terminal, three types of circuit layout have been considered:—

(i) a passive equaliser following a flat amplifier.
(ii) a flat amplifier following a passive equaliser.
(iii) a sloped gain amplifier.

The first plan requires a large power capacity in the flat amplifier, because the low frequency portion of the transmitted spectrum, which contains a large portion of the video signal energy, suffers minimum attenuation in the cable. The second method has the disadvantage that the signal to noise ratio is worsened by the loss of the equaliser. Where this method is to be used, a maximum span distance of approximately 3 miles would be obtained while meeting the noise objective of 67.5 db. The third method, which reduces the amplifier power requirements to a minimum, and also gives the best signal to noise ratio, allows a link of 6.8 miles to be obtained meeting the noise objective. The requirement of equalisers which can be adjusted to cope with the full range of cable lengths presents some difficulties. N.E.C. have solved this problem by means of a number of tandem-connected two-terminal networks with individual amplifiers, and the design is such that compensation of cable attenuation in 0.1 Km (0.06 mile) steps can be made by dial adjustments.

The requirement in Australia is slightly different to the original Japanese requirements, as the standard signal level in Japan was, at the time the equipment was designed 1.4 Volts peak to peak for a composite video signal, while the Australian standard is 1 Volt peak to peak. This means that to attain the same signal to noise ratio, the loss of the transmission path must be reduced by 3 db at the highest frequency transmitted. At 5 Mc/s, the loss of standard coaxial tubes is very close to 5 db per Km, so that the maximum permissible circuit length becomes 10.4 Km, or 6.45 miles.

Fig. 3 shows the relationship between circuit length and signal to weighted noise ratio. It is possible to use this curve to work out combinations of the number of links and their lengths which will meet a total objective to 61.5 db for the overall short distance link path. Some examples are given below:—

(i) Four 6.45 mile links.
(ii) Twelve 5.6 mile links.
(iii) Ten 5.3 mile links and two 6.4 mile links.

It should be noted that these distances are based on a weighted signal to noise ratio of 61.5 db, or approximately 3 db higher than the figure obtained by adding 6 db to the C.C.I.T.T. requirement of 52 db. If the lower signal to noise ratio can be tolerated, links up to 6.8 miles can be accepted with 1 Volt peak to peak transmitting levels.

The capability of the N.E.C. equipment is thus sufficient to provide for the majority of short distance transmission requirements without repeaters, which, added to the low capital cost of the system, is an additional reason why this system has been chosen for A.P.O. requirements.

Low Frequency Noise Suppression

As stated previously suppression of low frequency interference is the key to the realization of a practical and economical video transmission system employing coaxial cable. Fig. 3(a) shows how the interference due to noise currents is introduced to the system. Currents due to the wanted signal flow in opposite directions on the inner and outer conductors of the coaxial cable, while the interfering currents flow longitudinally (that is in the same direction) on both conductors. If the longitudinal path can be broken without affecting the signal path, or made to have a sufficiently high impedance to the longitudinal currents, the interfering signal appearing at the signal termination will be reduced.

Two methods have been developed to produce this effect. The method shown in Fig. 3(b), has been used in the United Kingdom for some time. To ensure adequate suppression of the longitudinal components, the impedance of the chokes must be high at all frequencies. Even with large chokes, the power frequency longitudinal suppression is often inadequate. Noise cancelling circuits are then also necessary. Fig. 3(c) shows the method of reducing longitudinal components by using a broadband transformer. Providing the capacitance between the line winding and the equipment side is kept very low, the impedance to the longitudinal path is high. However, with the best practical transformer, the longitudinal impedance at the high frequency end of the band is still not adequate. Additional longitudinal chokes are added to further improve the characteristics. Because the additional suppression is only needed at high frequencies, the inductance of the chokes, and hence their physical size, are both small.

In Japan, tests were made with 9 Km (5.6 miles) cables laid in industrial districts where severe interference could be expected. Interference observed at the end of each circuit was less than 0.05 mV. When the transformers were removed, the interference exceeded 20 mV. This is a suppression ratio exceeding 50 db. The noise in this test would have been mainly due to random earth currents, but tests were also conducted (over fairly short distances) to discover the effects of power line interference. The results were subsequently extrapolated to give a figure for the maximum length of a CV system link, that is 11 Km (6.8 miles). Results in Japan show that interference will not exceed 3 mV, even if a 3 phase power cable conducting a neutral current of 50 amps. is placed parallel to a CV system for a length of 11 Km, with a spacing of only 25 cm between the two cables. Tests were also made on coaxial cables carrying both the CV equipment and ordinary carrier telephone systems employing power transmission through one pair of the coaxial tubes. With full load current in the coaxial system, the measured interference voltage at the CV terminal was less than 0.01 mV. Noise due to dial pulses transmitted through telephone pairs within the same cable sheath was not observed, but some telegraph circuits with earth returns produced interference which was not negligible. When a metallic return circuit was substituted for the earth return, interference was reduced beyond the limits of measurement.

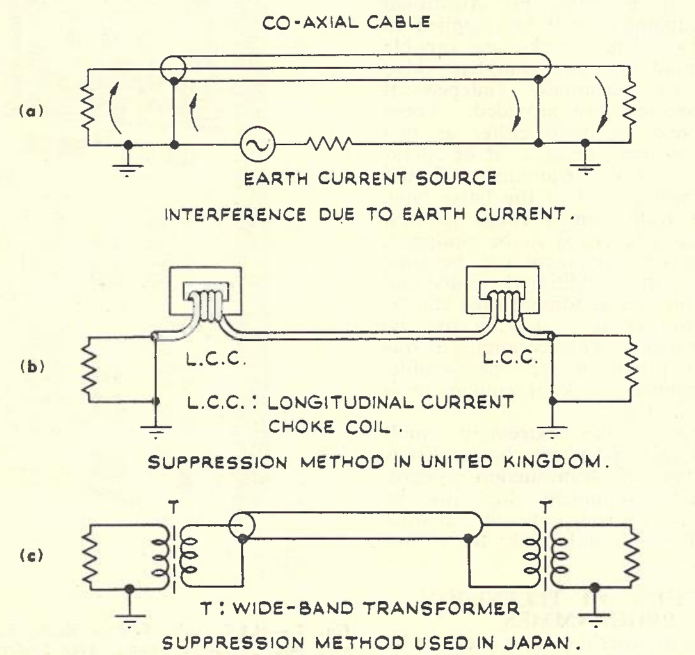


Fig. 3.—Interference due to Earth Currents, and Methods of Elimination.

Equipment Description

The block diagram of the CV system is illustrated in Fig. 4. The transmitting terminal consists of a wide band transformer and a small longitudinal coil, both accommodated in a box which may be wall-mounted. A photograph of this box is shown in Fig. 5. Where the transmitting terminal is located at a repeater station or at a large terminal, the transformer and choke are accommodated in space available in the rack.

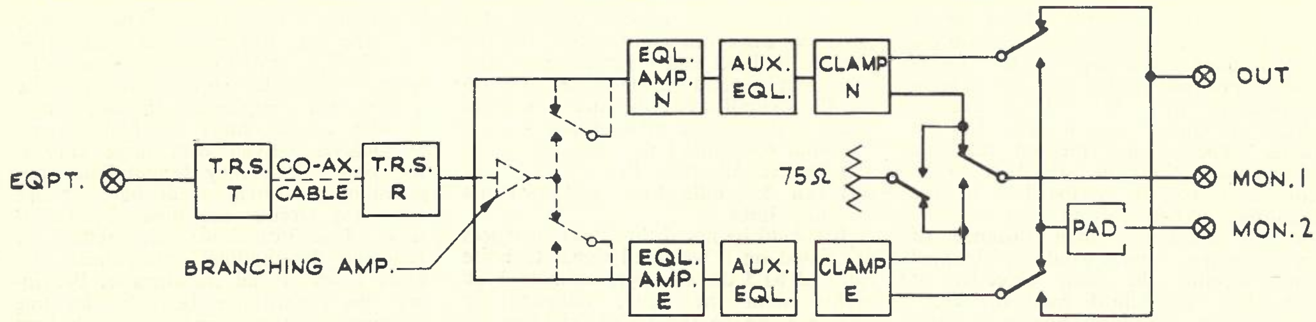


Fig. 4.—Block Diagram of the Japanese C.V. System.

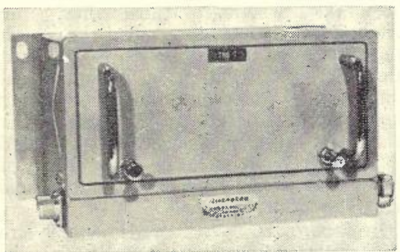


Fig. 5.—Wall Mounted Line Transformer.

The receiving terminal consists of a transformer panel, electrically identical with the transmitting terminal, an equalising amplifier, an auxiliary phase equaliser, and a clamper. The equalising amplifier contains 12 tubes, and uses five variable-slope amplifier stages to compensate for the loss characteristics of the coaxial cable, followed by a flat amplifier. Two types of amplifier are manufactured by N.E.C., the first being suitable for use up to 9.2 Km (5.7 miles), and the second up to 11.2 Km (7 miles), but the one used in Australia will be of the latter type in the interests of standardisation. The slope of the amplifier gain characteristic may be altered by means of dials on the amplifier, which are graduated for cable lengths in increments of 0.1 Km (0.06 miles), thus simplifying the equalisation procedure and increasing the flexibility of the equipment. Equalisation is accomplished by simply setting the dial pointers to the figures corresponding to the total length of the cable to be equalised. This procedure usually yields a sufficiently correct frequency characteristic, but in cases where special action is necessary to produce the best overall frequency response, use is made of the two adjustable mop-up equaliser stages, which may be considered as a preamplifier section of the amplifier panel.

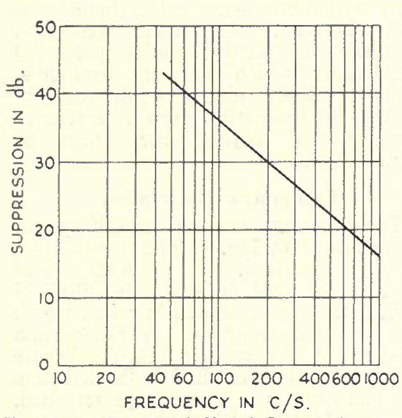


Fig. 6. — Unwanted Signal Suppression produced by the Clamper.

Where the cable section is longer than 6 Km (3.8 miles) an auxiliary equaliser is used. This equaliser has three dials which compensate for group delay distortions over a range of 0 to 84 milli-microseconds in increments of 12 milli-microseconds at 4 Mc/s.

Following the auxiliary phase equaliser is a clamper. This clamper consists of 3 flat amplifying stages and a diode clamping circuit. By means of the clamp, the crest of each synchronising impulse is held at a constant level. Thus the clamper effectively restores the DC component of the video signal, and suppresses miscellaneous kinds of noise and residual gain deviations in the frequency band below a few Kc/s. The effectiveness of the clamper is shown in Fig. 6. An alarm circuit is incorporated which operates when synchronising pulses are absent from the incoming signal.

A number of arrangements of the equipment are possible. For Australian use, the equipment will be supplied in 9 ft. racks. These racks are capable of accommodating two complete video repeaters or terminals. Independent power converters are provided. These terminals may be used either as two individual systems, or as a set of operating and standby equipment. Initial purchases will consist of the latter type. When the traffic on a route is such that several tubes need to be equipped, the changeover equipment can be used to supply the additional individual bearers, while an additional tube can be equipped to act as a standby for the working systems. The economies of this method of provision are considerable. A fully equipped rack of equipment is illustrated in Fig. 7.

To measure the extremely small differential gain and phase characteristics of this type of transmission system, special test equipment had to be developed. Typical overall characteristics of a 5.6 mile link are shown in Fig. 8.

SWITCHING OF TELEVISION PROGRAMMES

The type of switching equipment to be provided in the Australian network is

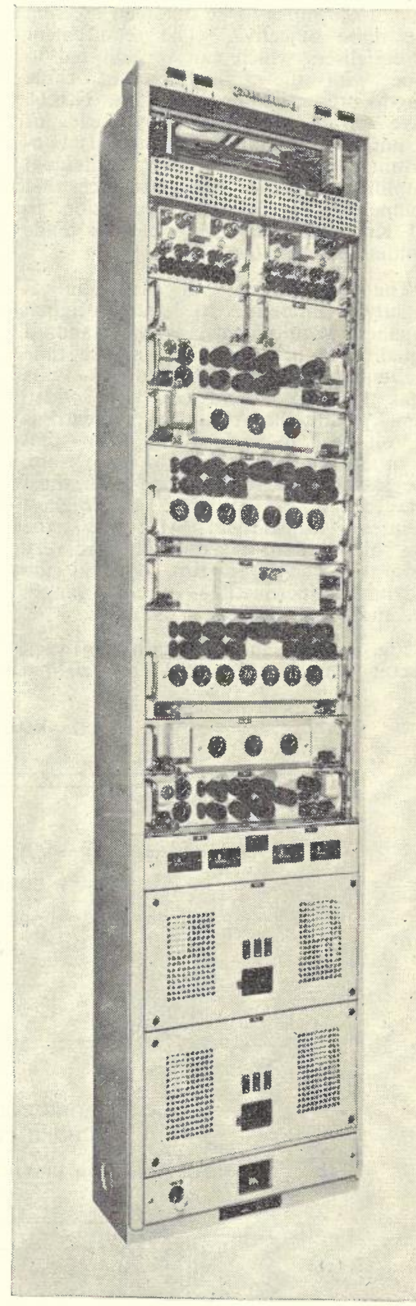
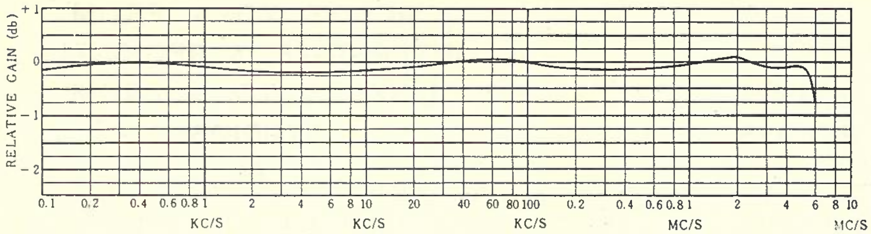
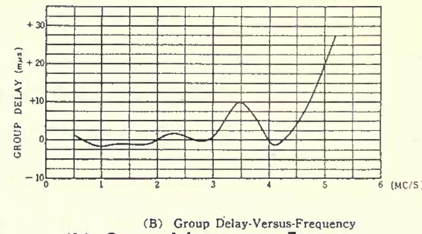


Fig. 7.—N.E.C. C.V. System Rack, Equipped with one Complete Change-over System Type C-2-31B.



(a) Gain versus Frequency.



(b) Group delay versus Frequency.

Fig. 8.—Gain and Phase Characteristics of a 5.8 mile C.V. Link.

rather difficult to determine at this stage of development. Little is known about the volume and complexity of the switching operations. This adds a further difficulty to those arising from geographical and equipment considerations. The location of future Regional stations and the expansion of facilities in capital city areas will have a considerable bearing on the alternative types of switching equipment to be installed at a future date. Experience with initial Regional and interstate networks is also necessary before the capacity of the switching equipment can be assessed. The public reaction to the initial television connection facilities will also have a major influence on the future capacity of switching equipment.

The first consideration of the switching equipment is the signal frequency at the switching point. Both VSB and DSB equipment can be switched at line frequencies. In systems using radio bearers, it is also possible to switch at the intermediate frequency of the radio system and this method is used to a limited extent on the Continent.

In a network encompassing several different systems of transmission, the only possible switching frequency is the direct video range, since all systems must ultimately come down to this frequency band. The use of any switching frequency other than the direct video band is further complicated by the need for the translation of the transmitted signals to a suitable common frequency band for test and monitoring requirements.

Switching systems, ranging from the simple "Patch" type to the most elaborate tape-programmed electronically operated switching devices are available. The cost of such systems varies as widely as the complexity. In the earlier stages, switching will be restricted largely to the capital cities, and the number of switching operations is expected to be quite small. Taking into consideration all the factors enumerated above, a simple type of "U-Link" switching panel will be used at the T.O.C.'s. As requirements expand, and more experience is obtained, consideration will be given to the installation of more complicated switching equipment.

The function of the equipment at the T.O.C. can be sub-divided into the following categories:—

(a) Switching of programmes, ranging from single period telecasts to semi-permanent relay links. In the first case rapidity of switching close to exact times is essential, in the latter case the requirements are quite uncritical.

(b) Monitoring of the picture and waveforms of the transmission. The number of programmes which must be monitored simultaneously will determine the number of picture and waveform monitors which must be provided.

(c) Line equalising and circuit testing. It is expected that the most effective method of testing will be the use of pulse and bar test signals, described more fully in a later section dealing with test equipment.

(d) Handling of T.O.B.'s. The method of handling most economically the requirements for T.O.B.'s depends largely on the equipment used. Since the number of lines laid permanently for T.O.B.'s will not be very large, at least in the early stages, equalisation of these lines should not be a great problem. Because the CV system equalisation is relatively simple, it should be possible to use only a small number of terminal equipments to cater for a relatively large number of T.O.B. lines.

Whatever type of equipment is used, categories (b), (c) and (d) are fairly straightforward in their equipment requirements. Requirements of category (a) will, as stated previously, depend largely on the volume of switching to be performed. To overcome the range of switching requirements, it is possible to sub-divide the circuits into two stages:

(i) **Infrequently Switched Circuits:** Circuits in this category will be those associated with semi-permanent links and T.O.B. circuits. Even with a high overall volume of switching, the switching requirements for these circuits will be so low that simple patch facilities should be adequate.

(ii) **Circuits with High Volumes of Switching:** Until the network develops both in extent and volume, there appears to be no requirement for high volume capacity switching equipment. At a later stage, when Commercial as well as National programmes are being handled, the simple equipment provided initially will probably become incapable of handling the amount of switching required. Provision can then be made for more sophisticated switching arrangements, a number of which have been described in the literature.

At no time, however, is it expected that the whole of the switching requirements in a T.O.C. will be handled on a single switching console. The evolution of switching equipment appears to be following a trend towards a "Matrix" or "Crossbar" pattern. In a larger installation, such as Sydney or Melbourne, upwards of 50 incoming lines and 30 outgoing lines will need to be handled at the switching centre. To handle this in a single matrix would require 1,500 cross points, a number which is formidable both from its sheer magnitude and from the physical size resulting.

Of the 50 + 30 lines, it may be anticipated that at least 25 + 15 can be considered in the "infrequent" category. It is therefore proposed to handle this type of switching requirement on a secondary or "concentrator" U-like type switching matrix, with enough tie-lines to the main switching console to handle any required connections to the main network. Ten tie-lines would appear to be sufficient for most purposes. Fig. 9 shows such an arrangement in block diagram form. Requirements on the main switching console would thus be reduced to approximately 40 incoming and 20 outgoing lines, in turn reducing the overall size to approximately one half. A console of this size can reasonably be handled by a single operator during quiet periods and two operators under very busy conditions. The amount of monitoring equipment will also be considerably reduced by this two-stage switching method.

Another advantage of this attack on the switching problem will be the flexibility possible with the introduction of new switching equipment and techniques. Advantage can be taken of all new advances in the art with the minimum interference to existing installations, and it will be possible to postpone the second step until more exact knowledge of the problems of television switching in Australia is available.

The sound channels required for the vision programmes will be switched at the T.O.C. Where U-Link panels are used for vision switching, similar facilities can be made to provide the sound switching facilities. When more complicated switching systems are installed, sound and vision will be switched simultaneously with a single switching operation.

TESTING EQUIPMENT

The test equipment required for the video network may be divided into three categories:—

(a) **Installation Test Equipment.** Equipment in this category is required mainly during initial installation of the systems. As previously stated, N.E.C. have developed special test equipment

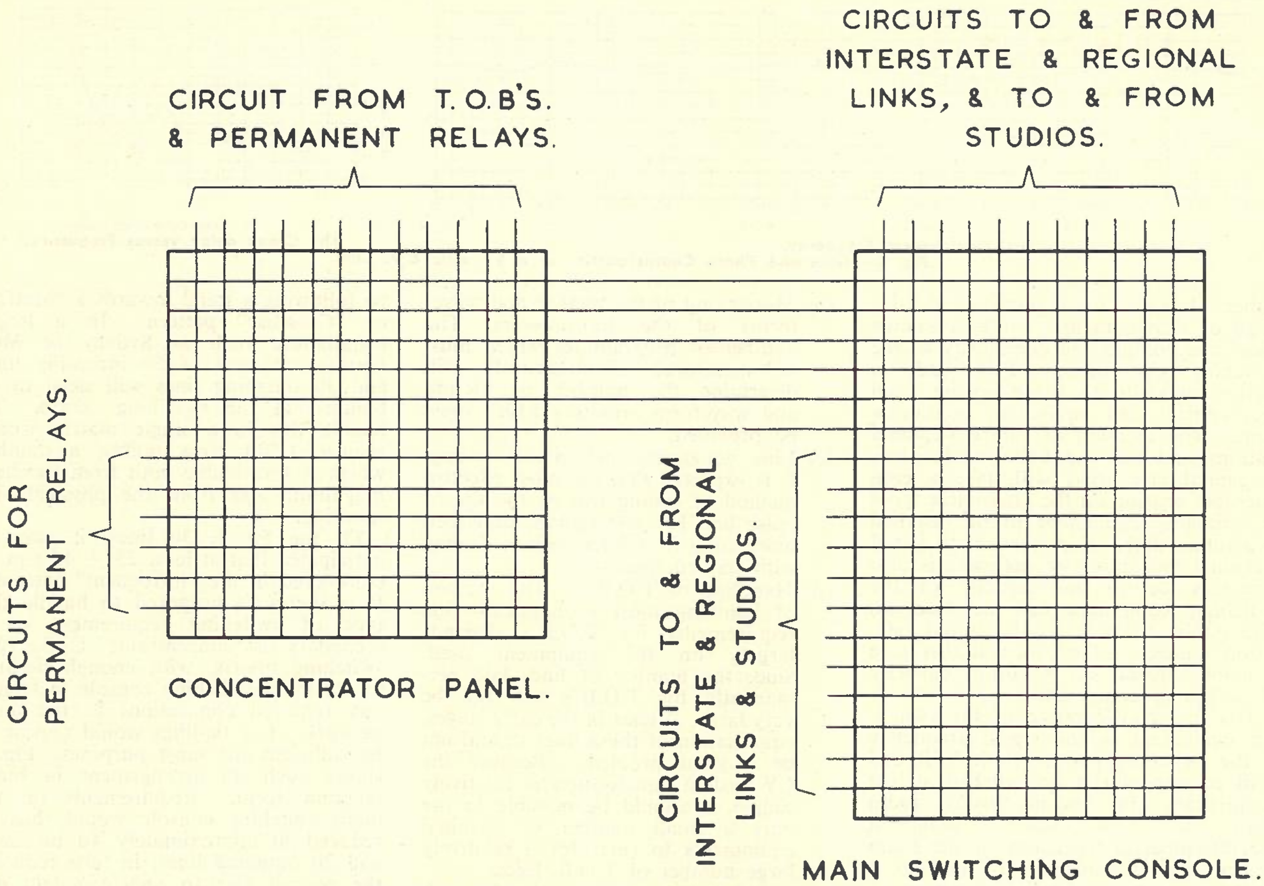


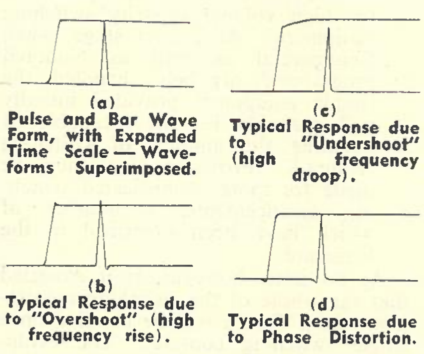
Fig. 9.—Block Diagram of a Two-stage Switching System.

for use with the Type CV system for making measurements of "differential gain and phase". This equipment will be used, at least initially, for making the installation line ups. When experience has been obtained with other types of test equipment such as the pulse and bar techniques covered in (c) below, it is possible that initial line ups can be made with the simpler equipment. It is expected that this will apply particularly in the case of T.O.B.'s.

(b) **Operating Test Equipment.** Picture and wave form monitors will be supplied at each T.O.C. to give the switching operator the means of checking on the vision programme quality. The number of monitors provided will depend on the amount of switching and the number of programmes passing through the T.O.C.

(c) **Maintenance Test Equipment.** Overseas experience has shown that accurate evaluation of the vision channel quality can be made by means of "pulse and bar" test equipment. This equipment transmits a special pulse of "sine squared" or "raised cosine" shape. The length of this pulse is chosen in accordance with the transmitted band-width. Following this pulse, a "bar" pulse is transmitted. This bar signal consists of a square wave of full modulation amplitude, with the transitions modified to have the same shape as the appropriate portion of the sine-squared pulses. An examination of these two pulses quickly enables the performance of the circuit to be evaluated. The history and full details of the method of pulse and bar testing are outside the scope of this paper, but are discussed thoroughly in Reference 2. Fig. 10 shows the correct pulse and bar pattern, and some typical defective results.

Equipment has been developed, particularly in the U.S.A., which injects pulse and bar or other test signals into the working programme, occupying the first three or four lines of the picture scan. These lines are not usually visible on a television receiver. The advantage of this method is that the transmission quality can be assessed during transmission of the programme; if necessary continuous evaluation can be made. It is possible that this method will ultimately be applied on all programmes, injected at the originating source, which will allow a critical estimation of the performance of each link in the overall transmission path.



(a) Pulse and Bar Wave Form, with Expanded Time Scale — Waveforms Superimposed.

(b) Typical Response due to "Overshoot" (high frequency rise).

(c) Typical Response due to "Undershoot" (high frequency droop).

(d) Typical Response due to Phase Distortion.

Fig. 10.—Typical Pulse and Bar Wave-forms.

CONCLUSION

A brief survey of the projected direct video television network proposed for use in Australia has been made. The network is planned for maximum flexibility, in view of the largely unforseeable requirements which will undoubtedly arise. The method chosen combines a very economical installation with adequate technical standards.

ACKNOWLEDGEMENTS

Acknowledgement is made to Koji Maeda, whose article, Reference 1, forms the basis of the description of the N.E.C. direct video-on-coaxial transmission equipment, and to the Nippon Telegraph and Telephone Public Corporation for their kind permission to publish the extracts. Acknowledgement is also made to the Nippon Electric Company for material incorporated in Figs. 5 and 7.

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(1) Koji Maeda, "Coaxial Cable Video Transmission System—CV System;" Japan Telecommunication Review, Autumn 1959, pp. 41-46.

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TECHNICAL NEWS ITEM

TESTING OF HOT TWIST JOINTS IN PLASTIC CABLES

The standard method of jointing polythene insulated cable conductors in the Postmaster-General's Department is the hot twist technique which was described in the February, 1960, issue of the Telecommunication Journal.

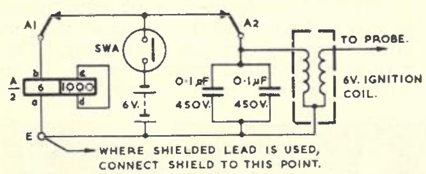
A need has been felt for a simple and speedy means of testing the effectiveness of the seal on completed joints. While the experience is that a competent cable jointer has no difficulty in producing good joints, the absence of a simple and effective test has led to lack of confidence by some jointers in their own work. A simple spark tester developed in New Zealand where the hot twist joint is also used, has proved extremely effective and the device has now been introduced in Australia. The tester is similar in principle to the ignition system of a motor vehicle. It consists of a dry battery power supply, either a telephone relay or a radio vibrator, an ignition coil and a probe.

The unit is used by moving the top of the probe over the completed hot twist joints. The return circuit is connected to a bared conductor in the joint and capacitive coupling within the cable completes the circuit. If a pinhole in the insulation is present it is detected immediately by a flash over of voltage from the tip of the probe to the conductor within the joint. The pinhole may be repaired by reheating the insulation or by remaking the joint. Apart from ensuring that satisfactory joints are made in the field the spark tester has great benefits as a training aid as it enables faulty techniques to be corrected very early in the training period.

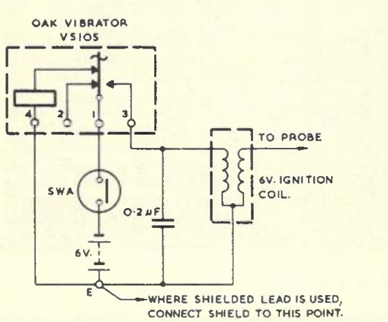
The circuits and oscilloscope traces of the outputs of the two models are shown in Figs. 1 and 2. Details of the outputs are:—

	Vibrator Operated	Relay Operated
Output pulses/sec.	220	44 (slightly irregular)
Max. Voltage—peak to peak	12 KV	22 KV
Pulse Duration (approx.)	1.2 ms	4 ms
Freq. of Osc. (approx.)	Initial 2.5 Kc/s Tail 9 Kc/s	2.5 Kc/s

Those familiar with spark testing in cable factories may question the effectiveness of the device. However, as the oscilloscope traces demonstrate, the wave shape is very different to that of the usual factory spark tester which has as power source a step up transformer connected to the 50 cycle A.C. mains, the secondary voltage being typically 5,000 volts. With this type of spark tester an insulation fault is revealed only if the search electrode of the tester makes near metallic contact with the portion of conductor exposed by the break in the insulation. The higher frequencies used in the testers described here give an effectiveness not possible with the 50 cycle tester. Wave shape of the types illustrated would, therefore, appear to warrant investigation for factory use.

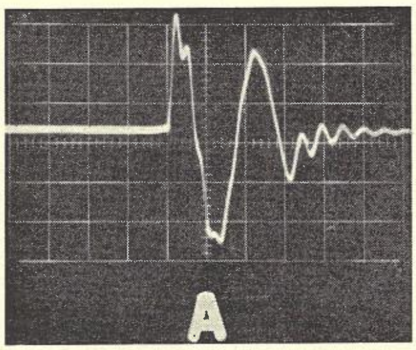


A

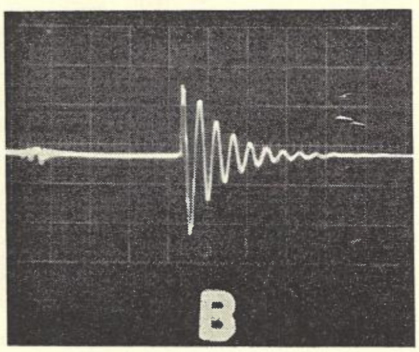


B

Fig. 1.—Alternative Circuits of Spark Tester.



A. Vibrator Operated. Time scale of photo is 1/5 millisecond/major division.



B. Relay Operated. Time scale of photo is 1 millisecond/major division.

Fig. 2.—Oscilloscope Traces of Output.

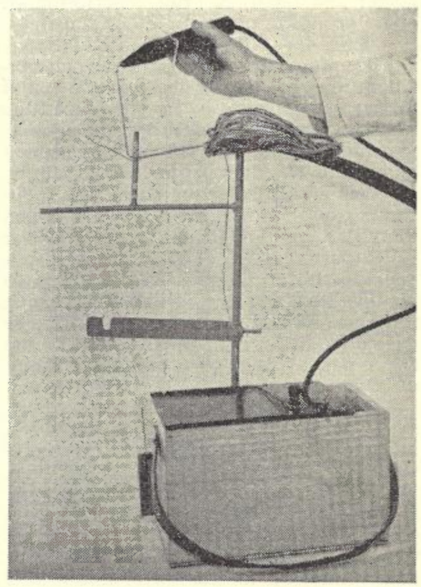


Fig. 3.—The tester in operation on the bench.

CROSSBAR GROUPING PLANS

*N. D. STRACHAN, B.E., A.M.I.E. Aust., A.M.I.E.E.**

INTRODUCTION

With the advent of L. M. Ericsson crossbar exchanges in Australia has come a part of the crossbar technique, the grouping plan. It is necessary to have a thorough knowledge and understanding of grouping plans, for they indicate in a subtle manner the way in which the inlets and outlets of verticals of crossbar selectors are connected together in the various stages. The symbols were used first by Dr. Jacobaeus in Sweden, and have been the subject of several articles in Ericsson Reviews and Ericsson Technics. This article has been written with the aim of informing the readers of this Journal of this important aspect of crossbar technique.

The article deals first of all with an explanation of the use of grouping plans; secondly with the symbols, and their meaning and the nature of grouping plans; thirdly with a detailed explanation of a grouping plan for the group selector stage; and finally a brief description of some grouping plans for other stages.

USE OF GROUPING PLANS

The plans are derived from a consideration of the traffic capacity and allowable congestion in the switching stages concerned, and show the manner in which the various switches are cabled and wired together in the partial stages. In the group selector stage the plan shows the manner of cabling between the GVA partial stage outlets and the GVB partial stage inlets. From it can be read the horizontals and verticals to be operated and the switches in which these are located, to connect a particular device from the inlet of a vertical of the GVA partial stage to a particular outlet of a vertical of the GVB partial stage.

The grouping plan for the subscriber's stage shows the connections from an inlet to a vertical in the SLD partial stage, through the SLC, SLB, and SLA partial stages to a particular subscriber. It also shows the connection from a particular subscriber to an SR circuit which is taken into use on outgoing calls and connected to the inlet of an SLB vertical.

From these plans the internal rack wiring is worked out and the cabling between the racks calculated. After installation of the exchange, the grouping plan is essential for the tracing of a call through the various stages of an exchange. It is in fact a shorthand way of indicating the connection of the various partial stages and contains more information than is at first apparent.

GROUPING PLAN SYMBOLS

Before dealing with the actual symbols used in a grouping plan it is necessary to know the composition of a vertical unit in a crossbar selector. The number of contacts is equal to the number of wires per circuit, of the circuits the selector switches. The maximum number of contact strips that can be accommodated in a vertical bridge unit is ten. In the subscribers' stage and the group selector stage the vertical unit has twenty outlets, therefore the maximum number of contacts per circuit is five. At Toowomba the number of wires in the various stages are:—

SLA — 4 wires per circuit.
SLB — 4 wires per circuit for outgoing traffic over verticals 1 to 5, 5 wires per circuit for incoming traffic over verticals 6 to 10.
SLC — 4 wires per circuit.
SLD — 4 wires per circuit.
GVA — 3 wires per circuit.
GVB — 3 wires per circuit.

A vertical unit in the group selector stage could be represented as shown in

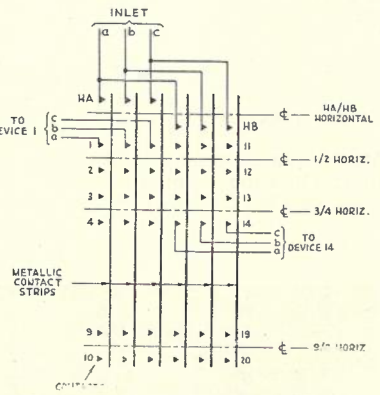


Fig. 1.—Vertical Unit—Front View.

Fig. 1. In the subscribers' and group selector stages there are ten such units in the crossbar selector. If the inlet is to be connected to outlet 4, the horizontals HA and H4 are operated to select the correct spring sets. The vertical armature is then operated to operate the springsets and thus complete the circuit. This is shown in Fig. 2. The circuit is completed from the inlet

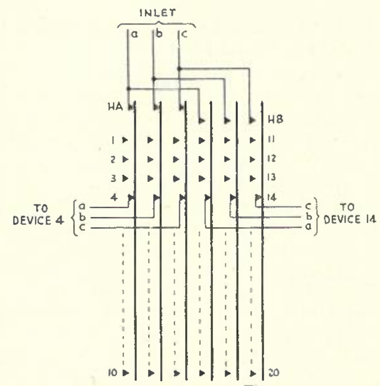


Fig. 2.—Vertical Unit—Front View with Spring Sets Operated.

of the vertical the HA contacts operated, the metallic contact strip, contacts 4 operated to the required device. It will be seen that all six contacts are operated when horizontal 4 and the vertical are operated, but as HB cannot be operated when HA is operated, the circuit connected to outlet 14 is not connected to the inlet of the vertical unit. If access were required to the circuit on outlet 14, then it would be necessary to operate HB in conjunction with H4. Fig. 3 shows a crossbar selector, and Fig. 4 shows the selector with the horizontal bars removed.

The vertical units can be commoned in two basic ways, referred to as horizontal and vertical multipling. Fig. 5 shows horizontal multipling. Here the outlet 1 of vertical 1 is commoned to

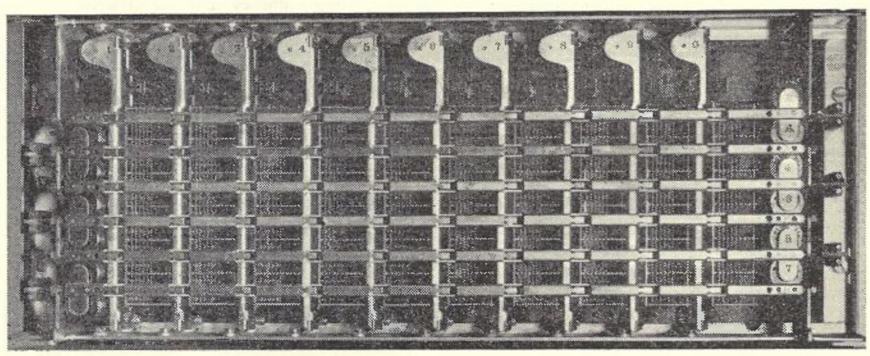


Fig. 3.—Crossbar Switch.

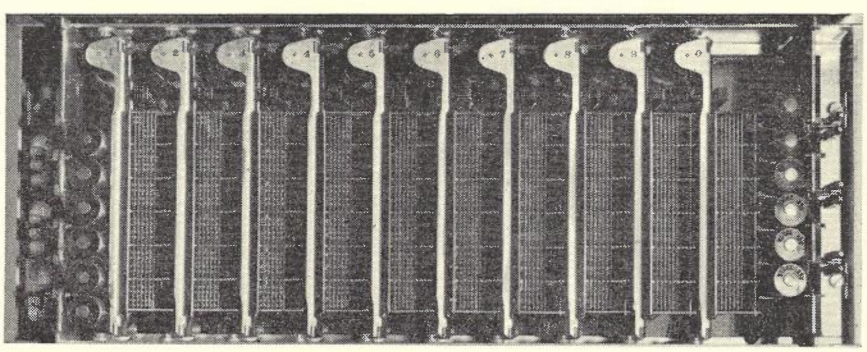


Fig. 4.—Crossbar Switch with Horizontals Removed.

*See Vol. 12, No. 4, Page 297.

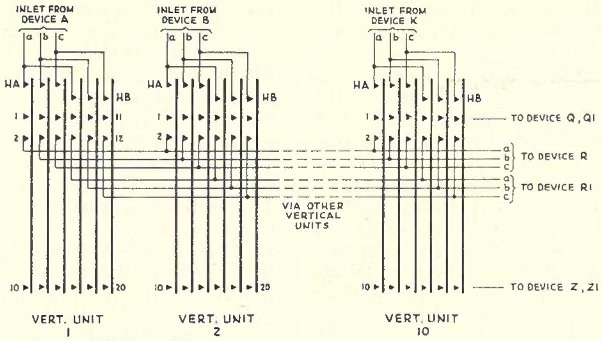


Fig. 5.—Horizontal Multipling of Vertical Units.

outlet 1 of vertical 2, and so on, and then connected to some device such as an outgoing relayset. In the figure, outlets 2 and 12 are shown multipled. In this manner any one of ten devices A to K can be connected to any one of twenty other devices Q to Z and Q1 to Z1. For example ,to connect device B to device R the horizontals HA and H2 must be operated followed by the operation of vertical 2. If it is desired to connect device K to device R1, the horizontals HB and H2 must be operated followed by the operation of vertical 10. It is assumed here that the ten verticals are in one crossbar switch.

Fig. 6 shows vertical multipling of vertical units situated in different crossbar selector switches. Outlet 1 of vertical 1, switch 1 is multipled to outlet 1 of vertical 1 switch 2, then to outlet 1 switch 3, and so on, and then to the desired device. In the figure, thirty devices (three switches of 10 verticals each) connected to the inlets of the verticals have access to 200 other devices, but any one device has access to only twenty of these devices. If, for example, device A1 is to be connected to device Q, the horizontals HA, H1 must be operated, followed by the operation of vertical V1 in switch 1. If device A2 is to be connected to device Q1, the horizontals HB, H1 must be operated followed by vertical V1 in switch 2.

It will be seen that this form of representing the vertical units of the switches would become very complicated when a large number of switches and racks are involved in a drawing. It can be simplified a little by using single lines in place of the different lines for each of the circuit wires. This is shown in Fig. 7, but even this does not simplify the drawing a great deal.

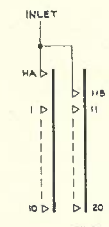


Fig. 7.—Vertical Unit Simplified.

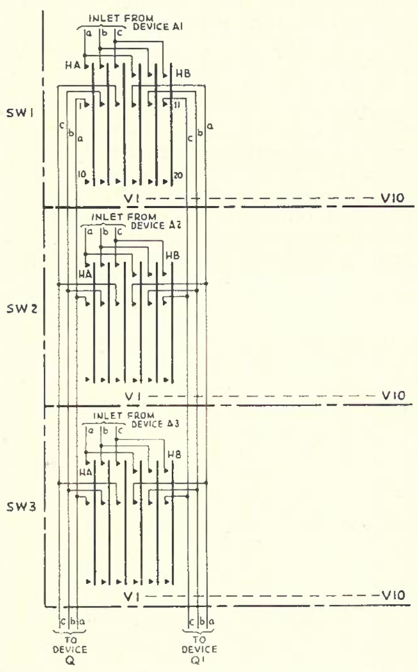


Fig. 6.—Vertical Multipling of Vertical Units.

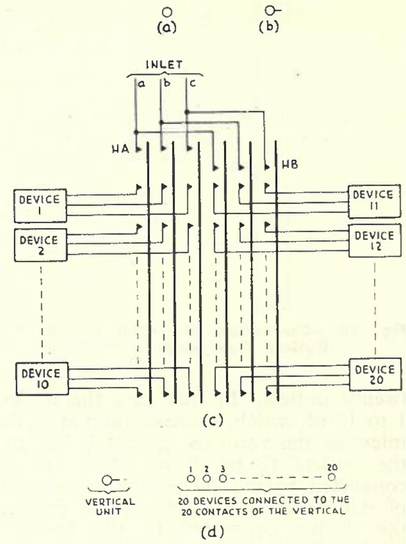


Fig. 8.—(a) Basic Symbol.
(b) Chicken Symbol.
(c) Vertical Unit.
(d) Vertical Unit in Chicken Symbols.

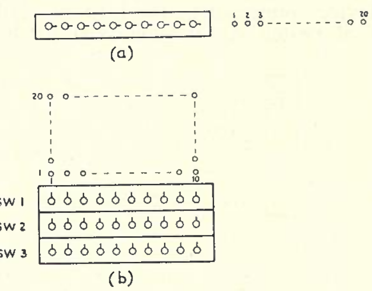


Fig. 9.—(a) Crossbar Switch in Chicken Symbols—Horizontally Multiplied.
(b) Crossbar Switch in Chicken Symbols—Vertically Multiplied.

Chicken Symbol: The symbol in Fig. 8 (a) is used to signify a device and is the foundation of the chicken symbol. The device can be a circuit such as an outgoing junction circuit, or it can be a vertical unit of a crossbar selector. When it represents the former it takes the form of a circle as shown in Fig. 8 (a). When it represents a vertical unit it is given a pointer as shown in Fig. 8 (b). This pointer indicates the direction in which the multiple of the vertical is to be found. This is the chicken symbol. Thus the symbol represents a vertical unit with its inlet and ten or twenty outlets. In Fig. 8 (c) a vertical unit is shown with the twenty outlets connected to twenty devices. In Fig. 8 (d) this is represented in chicken symbols. It can be seen how great is the simplification.

When used to indicate a crossbar selector switch, the ten chicken symbols are enclosed within a rectangle as shown in Fig. 9 (a). This figure also shows the horizontal multipling shown previously in Fig. 5. Fig. 9 (b) shows the vertical multipling shown in Fig. 6. The rectangles indicating the several crossbar selectors are placed adjacent to one another, and the pointer of the symbol points in the direction the multiple will be found; that is where the devices to which the vertical is connected are to be found. Thus it can be seen that the outlets of vertical 1 in switch 3 are connected to corresponding outlets of vertical 1 switch 2, which are in turn connected to the corresponding outlets of vertical 1 in switch 1, which are in turn connected to the twenty devices.

Let us consider now the case where the outlets of the verticals of one selector are connected to the inlets of the verticals of another selector as shown in Fig. 10. The outlets of the verticals in selector A are shown multipled and it is assumed that selector has only ten outlets. Outlet 1 from the verticals of switch A is connected to the inlet of vertical 1 in selector B. Outlet 2 from switch A is connected to inlet of vertical 2 in switch B, and so on. The letter C indicates the devices connected to the outlets of the verticals of switch B. All devices connected to the inlets of the verticals in switch A have access to the 100 devices connected to the outlets of switch B. The figure within the vertical unit symbol indicates the number of the vertical in the switch.

Fig. 11 shows a connection similar to Fig. 10 except that both selectors have

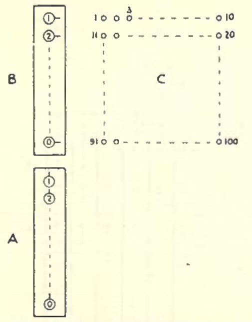


Fig. 10.—Connection of Switches with Ten Outlets from each Vertical.

twenty outlets. In this case the outlets 1 to 10 of switch A are connected to the inlets of the verticals in switch B1, and the outlets 11 to 20 of switch A are connected to the inlets of the verticals of switch B2. If it is desired to connect the device connected to the inlet of vertical 2 switch A to the device 189 in the group C, it is necessary to operate horizontals HA and H10 and vertical 2 in switch A, horizontals HA and H9 and vertical V10 in switch B1.

Again if it is desired to connect a device connected to the inlet of vertical 2 of switch A to device 199 in the C

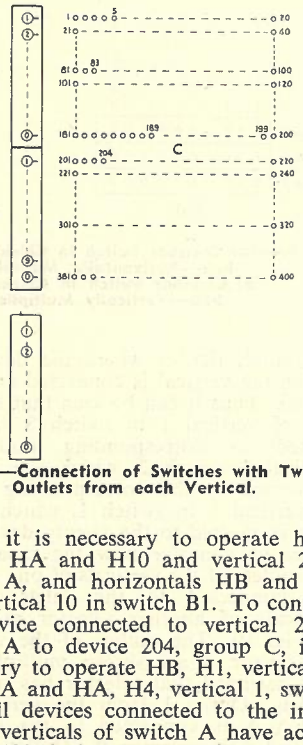


Fig. 11.—Connection of Switches with Twenty Outlets from each Vertical.

group, it is necessary to operate horizontals HA and H10 and vertical 2 in switch A, and horizontals HB and H9 and vertical 10 in switch B1. To connect the device connected to vertical 2 of switch A to device 204, group C, it is necessary to operate HB, H1, vertical 2, switch A and HA, H4, vertical 1, switch B2. All devices connected to the inlets to the verticals of switch A have access to the 400 devices connected to the outlets of switches B1 and B2. Figs. 10 and 11 are in effect grouping plans.

GROUPING PLAN FOR A GROUP SELECTOR STAGE

The group selector stage of a crossbar exchange type ARF 10 consists of a number of group selector units, the quantity depending on the traffic to be carried. Each group selector unit consists of two identical racks each having forty inlets. Thus a group selector unit has eighty inlets. Each rack has 200 outlets and so the unit has 400 outlets. A group selector stage is always expanded by adding one or more units. The 400 outlets are divided into routes, and any availability can be chosen: 5, 10, 20, 30, 40, 50, and so on. The outlets of the verticals which form the different routes are cabled to the I.D.F., and the twenty outlets forming route 1 from all the group selector units are placed one above the other in order that commoning the outlets to the next device (e.g., outgoing relay set), may be done easily. All routes are treated in the same manner.

Fig. 12 shows the grouping plan for the group selector stage. The layout of the face of the racks and a photograph

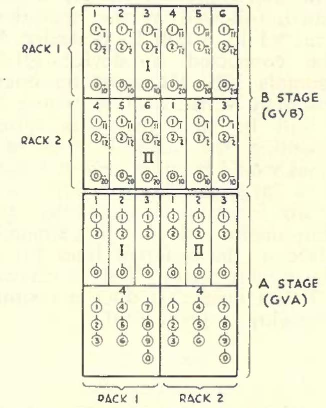


Fig. 12.—Grouping Plan—Group Selector Stage.

of the group selector stage at Toowoomba have appeared elsewhere (1), and it is essential to recognize that the dispositions of the selector switches on the grouping plan bear no relation to their places on the selector racks.

The group selector stage is divided into two partial stages A and B. The outlets of the verticals in GVA are connected to the inlets of the verticals in GVB. This wiring is done on the rear of the selector switches in the rack.

Upon examination of the A stage it will be seen that the outlets of verticals 1, 2 and 3 of switch 4 on both rack 1 and 2 are multipled to the outlets of all ten verticals in switch 1. Also the outlets of verticals 4, 5 and 6 of switch 4 are multipled to the outlets of all ten verticals of switch 2, and the outlets of verticals 7, 8, 9 and 10 of switch 4 are multipled to the outlets of all ten verticals of switch 3. The process by which such a combination was arrived at does not come within the scope of this article, which is concerned only with the comprehension of the plan.

Consider now the connection between the GVA switches and the GVB switches. The outlets of verticals 1, 2 and 3 of GVA 4 and the outlets of the ten verticals in GVA 1 are multipled. Consider rack 1 first of all. There are, by reason of the multipling, only twenty outlets from this section. The first ten outlets are cabled to the inlets of the verticals in GVB 1 in rack 1. The outlets 11 to 20 are cabled to the inlets of the verticals in GVB 4, rack 2. On the grouping plan the numbers within the chicken symbol indicate the number of the vertical in the crossbar selector, and the numbers outside the symbol indicate the number of the outlet in the previous stage. For example, vertical 1 in GVB 1 rack 1 has the subscript 1, and this means that the inlet of this vertical is connected to outlet 1 of verticals in the GVA stage. Again, vertical 1 of GVB 4 rack 2 has the subscript 11, and this means that the inlet of this vertical is connected to outlet 11 of the verticals in the GVA stage.

Further examination of the plan shows the outlets of verticals 4, 5 and 6 of GVA 4 multipled to the outlets of all ten verticals in GVA 2. Outlets 1 to 10 are connected to the inlets of the 10 verticals in GVB 2 in rack 1, while outlets 11 to 20 are connected to the inlets of the verticals in GVB 5 in rack 2. Again the outlets 7 to 10 in GVA 4 are connected to the outlets of all verticals in GVA 3. The outlets are 1 to 10 connected to the inlets of the verticals in GVB 3, rack 1, and the outlets 11 to 20 are connected to the inlets of the verticals in GVB 6 in rack 2. The connection of the inlets and outlets of the verticals of the switches in rack 2 are the same as rack 1. The outlets of the GVA switches are multipled horizontally.

The outlets of the GVB switches are grouped into 20 columns of 20 outlets each. To obtain this it can be seen that outlet 1 of vertical 1, switch 1 is connected to outlet 1 of vertical 1 of switch 2, and so on over the six GVB switches. Outlet 2 of vertical 1 switch 1 is connected to outlet 2 of vertical 1 switch 2, and so on over the six GVB switches.

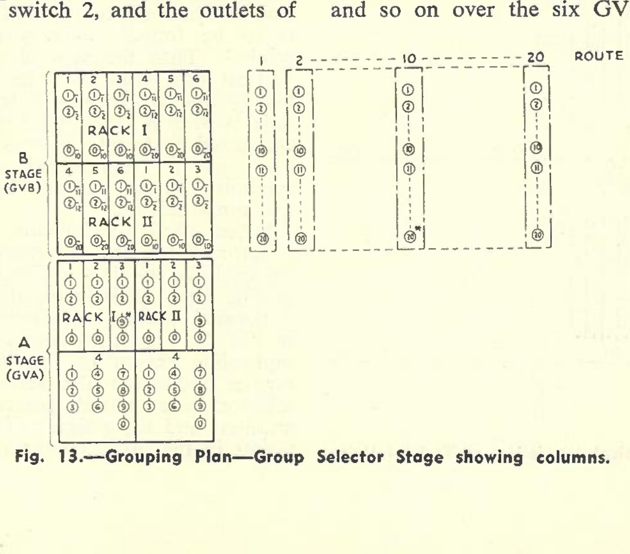


Fig. 13.—Grouping Plan—Group Selector Stage showing columns.

All outlets of the GVB switches are treated in the same manner. Thus the outlets of the GVB switches have vertical multipling. The outlets in each column are as follows. Outlet 1 of vertical 1 GVB switches, rack 1 is outlet 1 of column 1. Outlet 1 of vertical 2 GVB switches, rack 1 is outlet 2 of column 1. Outlet 2 of vertical 1 GVB switches, rack 1 is outlet 1 of column 2, and so on.

Fig. 13 shows the group selector grouping plan with connection of the twenty columns. It can be seen the outlets 1 to 10 of all columns are the outlets from the verticals of all GVB switches on rack 1, and that the outlets 11 to 20 in all columns are from the outlets of all verticals in all GVB switches in rack 2. Also it can be seen that the vertical of the GVB switch indicates the outlet in each column, while the horizontal indicates the number of the column. For example, the verticals 1 to 10 in rack 1 give access to the outlets 1 to 10 in all columns, while the operation of verticals 1 to 10 in rack 2 give access to outlets 11 to 20 in all columns.

SOME OTHER GROUPING PLANS

The grouping plan for the register finder for the SR circuits is shown in Fig. 14. The wiring of the crossbar switches is shown in Fig. 15. The vertical units are in this case have ten outlets each because the circuit from the SR circuits to the register requires ten wires. On each rack there are forty SR circuits and the register finder which consists of the register-finder marker and two crossbar switches RSV 1 and 2. This enables forty SR to have access to ten REG-L. The registers are connected to the HA and HB springs as follows:—

Vertical	HA	HB
1 & 6	REG-L 1	2
2 & 7	„ 3	4
3 & 8	„ 5	6
4 & 9	„ 7	8
5 & 10	„ 9	10

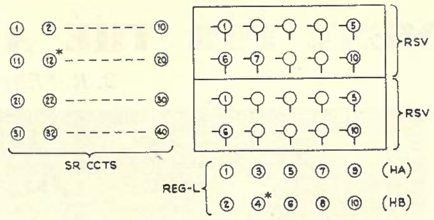


Fig. 14.—Grouping Plan—SR Circuits to REG-L.

Thus to select a particular register it is necessary to operate HA for odd registers and HB for even registers and a vertical. Horizontal H1 to 10 in a particular group of five verticals will connect the required SR. For example, in Fig. 14, asterisks indicate SR 12 and REG-L 4 and to connect these devices it would be necessary to operate in switch RSV 1, HB, H2 and vertical 7. Fig. 15 shows the wiring of the two crossbar switches and the spring sets to connect SR 12 to REG-L 4 are shown operated. The chicken symbols in Fig. 14 have two pointers each. This is because the HA and HB inlets are not commoned as on the other switches considered, but each set of spring sets is connected to a register. Thus from Fig. 14, HA of vertical 1 RSV 1 is commoned to HA of vertical 6 in switch RSV 1 and also to HA of vertical 1 RSV 2 and HA vertical 6 RSV 2 to REG-L 1. RSV 1 outlet 1 of verticals 1 to 5 is connected to SR 1. Outlet 1 of verticals 6 to 10 is connected to SR 11, and so on. These two crossbar switches are mounted in relay set bases and can be jacked out.

The grouping plan for the incoming register-finder is shown in Fig. 16. This connects the incoming circuits FIR to REG-L. In this case 64 FIR circuits have access to 20 registers. On each rack two such groups are located. Each group consists of a register-finder marker and four crossbar switches. It will be seen that each vertical has access to four registers. In these crossbar switches the horizontals are numbered 1 to 12 from the top of the switch, and the registers

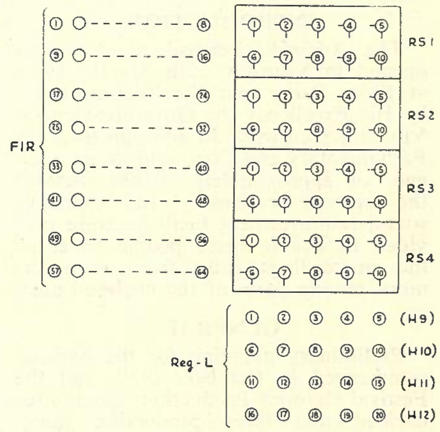


Fig. 16.—Grouping Plan—Incoming Register Finder.

are connected to the horizontals 9, 10, 11, 12.

The details of the grouping plan for the subscribers' stage are more complex than those explained here, and will therefore be the subject of a subsequent article.

ACKNOWLEDGMENTS

The author wishes to thank the Assistant Director Engineering, Queensland, for permission to use the material included in this article, and to acknowledge the help received in the production of photographs and drawings.

REFERENCE:

1. N. D. Strachan, "Toowoomba Crossbar Exchange"; Telecommunication Journal of Australia, Vol. 12, No. 4, page 231.

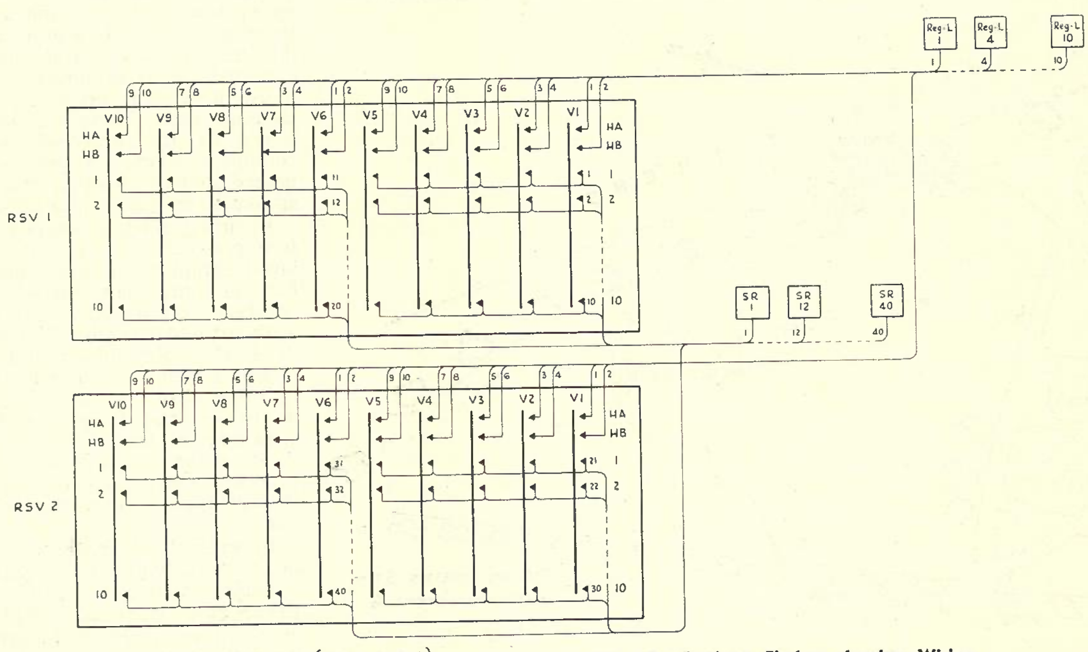


Fig. 15.—Register Finders showing Wiring.

SOUND REINFORCEMENT FOR THE ADELAIDE FESTIVAL OF ARTS

*B. R. PERKINS, B.Sc.** *W. G. SHAPLEY, B.E.**

INTRODUCTION

The Adelaide Festival of Arts was opened in Saturday 12th March, 1960, at Elder Park, near the Torrens Lake, by His Excellency the Governor-General Viscount Dunrossil. In addition to many Parliamentary and Civic leaders, an audience of approximately 30,000 attended the opening ceremony and extensive sound reinforcement facilities were provided to enable these people to enjoy the proceedings fully from even the more remote parts of the enclosed area.

GENERAL

Preliminary planning for the opening commenced in October, 1959, and the Festival Outdoor Productions Committee decided that three production stages would be used during the evening. These were:—

(a) The "Advertiser" Sound Shell.
(b) A temporary platform adjacent to the boat landing stage.
(c) The Band Rotunda.

Throughout the evening each of these locations became a sound source and therefore, to preserve realism it was necessary to arrange the loud speakers so that at all times the sound appeared to come from the appropriate direction. The positions of the three stages are shown in Fig. 1 and in a photograph of Elder Park (Fig. 2).

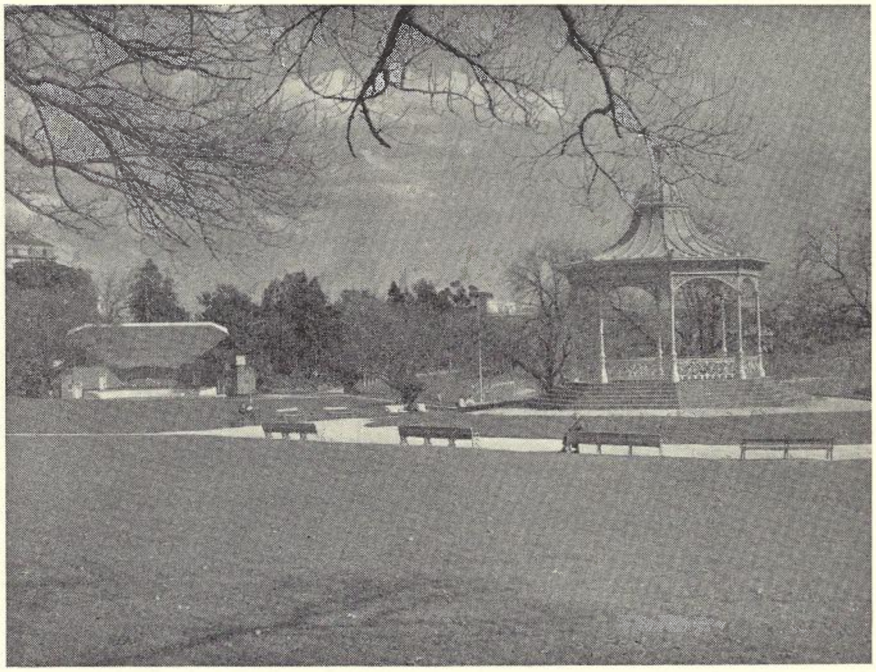


Fig. 2.—General View of Elder Park.

Two methods of providing the necessary sound re-inforcement were possible. These were:—

(1) Multiple loud speaker networks consisting of a large number of loud speakers operating at low power and each loud speaker covering a distance of approximately 100-150 ft.

(2) Large, high power loud speaker arrays covering distances of up to 500 ft. without appreciable reduction in sound intensity.

In view of the use of three production stages, method (1) would have required a large amount of delay equipment and extremely complicated switching arrangements. Furthermore, suitable loud speakers for erection in large arrays were readily available and for these reasons method (2) was selected and used.

The loud speakers chosen were Philips 5x6L 20-watt column speakers suitable for external mounting. The polar pattern of these appears as a very narrow beam in the vertical plane and a broad beam, approximately 90° either side of the speaker axis, in the horizontal plane. In addition a plot of "sound intensity" versus "distance from the column" shows a remarkably flat curve for distances of up to 100 ft. By stacking a number of these column speakers in a vertical array this flat intensity characteristic may be extended up to distances of 500 ft. or more, dependant upon the number of columns used. These characteristics resulted in the universal adoption of column speakers on this occasion and necessitated the erection of a total of 22 speakers in eight locations.

By using column arrays it was therefore possible to restrict the use of delayed sound to a minimum. In actual fact no more than two sets of delayed speakers were in use at any time. These were used to feed the Poplar Drive and north of the Rotunda, both difficult areas in which to provide sound reinforcement by other means. It will be apparent that the use of these delayed speakers created switching problems as the amount of delay at any instant depended on the production stage in use at the time. Further details regarding this will be given later.

In general all speaker arrays of two or more columns were fed from two amplifiers, that is approximately half of the speakers from each amplifier. In the event of an amplifier failure therefore, the fall in sound intensity would prob-

*See page 154.

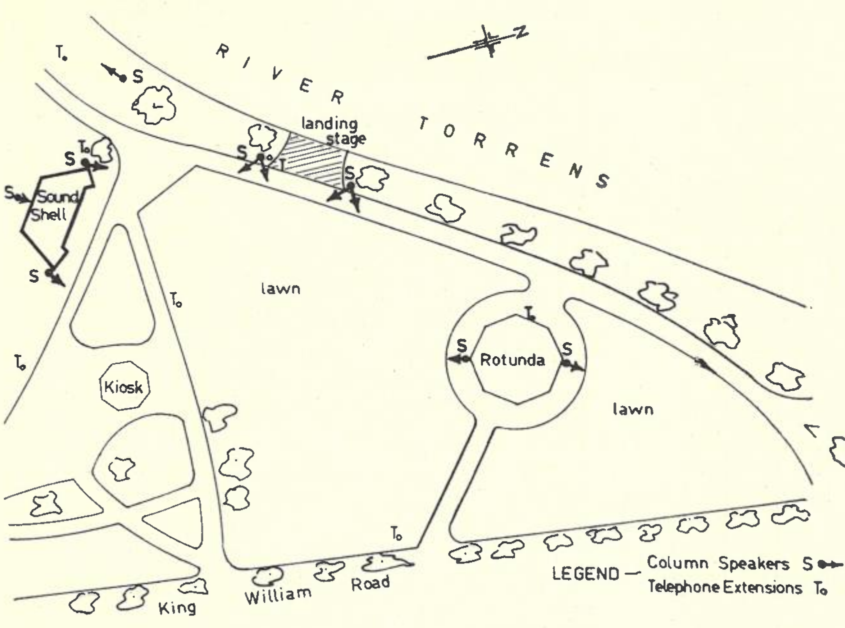


Fig. 1.—Geographical Layout.

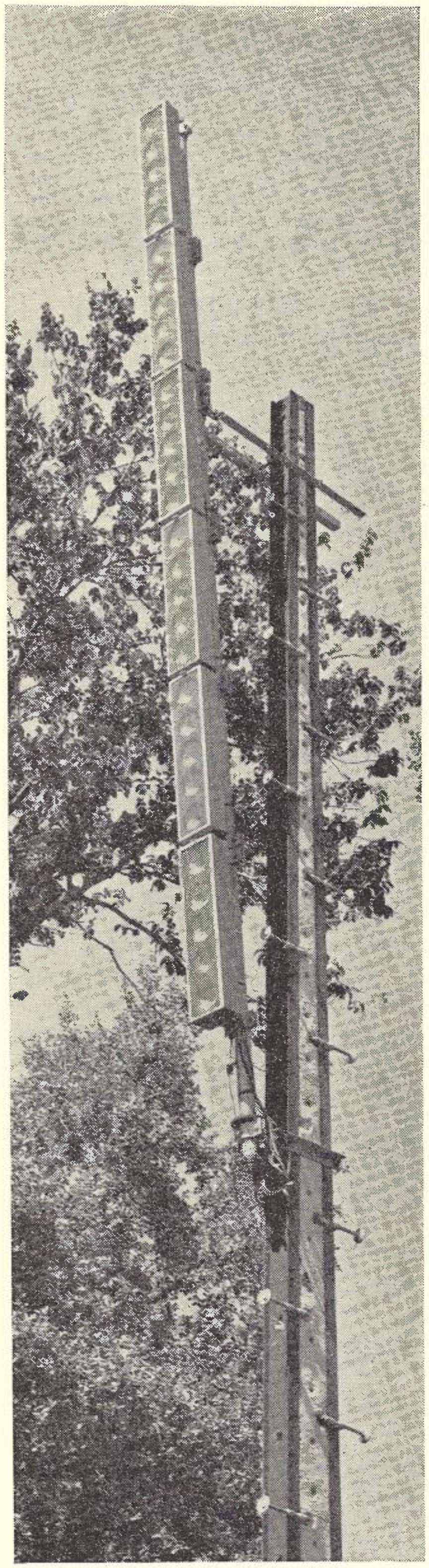


Fig. 3.—Loud Speakers behind the Sound Shell.

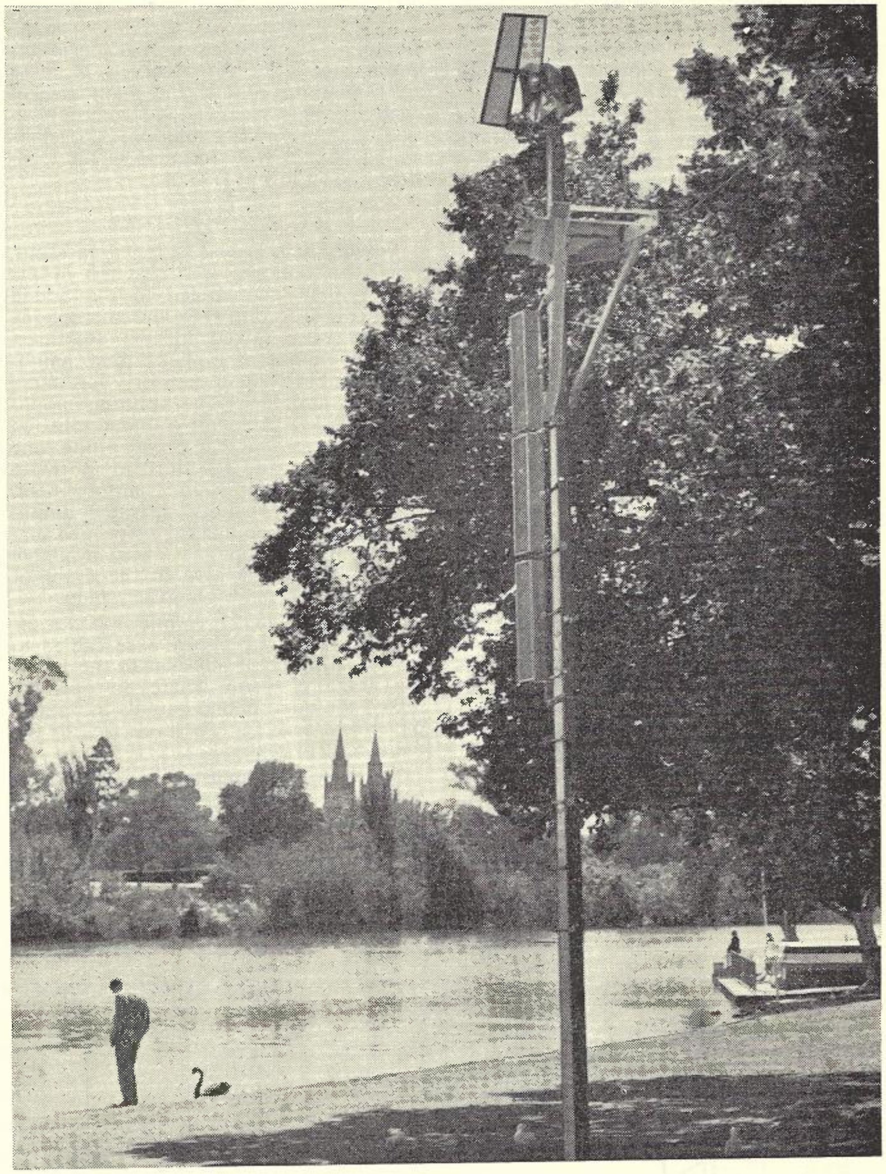


Fig. 4.—Loud Speakers for the Poplar Drive.

ably not have been noticeable to the majority of the audience.

In addition emergency facilities were also provided in the event of failure of the A.C. operated pre-amplifiers at the Sound Shell and failure of the mains A.C. supply. These emergency arrangements will be discussed later.

TIMETABLE

A brief outline of the evening's programme, giving some indication of the switching problems which were encountered, is shown in Table I.

It will be apparent that a considerable amount of switching was necessary and this was carried out in the Main Control Centre, at the rear of the Sound Shell.

MAIN CONTROL CENTRE

General. This control centre provided the facilities and equipment for selection of the programme source for sound reinforcement, the necessary amplification from +8 VU to speaker level and the distribution with appropriate sound delays to the various loud speaker locations. In addition, extensive monitoring facilities were provided.

Rack Layouts. There were three racks, the sound delay equipment rack and two amplifier racks, the latter each mounting four Philips 120 watt booster amplifiers with input faders for each amplifier

Table 1

Time	Item	Location
P.M. 6.00-7.15	Music	Landing Stage
7.25	National Anthem (6 bars)	Sound Shell
7.30	Fanfare	Landing Stage
7.35	National Anthem (complete)	Sound Shell
7.40	Speech (Governor-General)	Sound Shell
7.45	Concert	Sound Shell
9.35	National Anthem (complete)	Landing Stage
10.35	Music	Alternatively Landing Stage and Rotunda

and a monitoring speaker switchable across the output of each. The first amplifier rack also housed the main control panel with master volume control and source selection switch.

Source Selection. Mounted on the main control panel was a 2-position 8-pole selection switch. This switch allowed selection of programme material originating from either the Sound Shell or the Landing Stage to be fed to the input of the sound re-inforcement equipment racks via the master volume control. At the same time the appropriate delayed sound outlet from this equipment was switched to the input of each of the eight 120 watt amplifiers and also the 600 ohm line to the Rotunda. For example, in the case of programme originating from the Sound Shell the amplifiers feeding the column speakers located immediately behind the Shell (see Fig. 1) were switched to "direct" whilst the line to the Rotunda was switched to a delay corresponding to 500 ft., that is, the distance between the source and the remote column speakers. The sound delay unit was of the magnetic paper disc type, providing up to 4 delays ranging from 40 millisecs. to 1 sec.

Stand-by Equipment. A spare 120-watt amplifier was provided for emergency patching. A battery operated 20-watt amplifier with local microphone was also available for emergency announcements in the event of mains power failure.

Telephone Switchboard. The necessity for a telephone switchboard was realised during early planning as it was apparent that to control the sound system adequately, a number of observation points would be required at strategic locations around the area. As observers at these points had to contact the main control centre promptly, telephone communication was the simplest solution. Altogether six telephones were installed at the locations shown in Fig 1.

CONTROL POINTS

Sound Shell. Four suspended and four stand microphones were located in the Sound Shell and cabled to the Sound Shell control room. Here the microphone outputs were mixed in two amplifiers and the output of each of these amplifiers combined in a network feeding a splitting amplifier. The splitting amplifier provided three programme splits at +8 VU level, one for broadcasting, one for television and the third to the main control centre for sound reinforcement. An emergency battery operated amplifier fed from one central suspended and two stand microphones was available for immediate patching in the event of failure of the main amplifier chain.

Landing Stage. Three microphones on three-section floor stands were cabled to an operating point adjacent to the Landing Stage platform where an operator mixed the microphone outputs in an amplifier and fed +8 VU level back to the main control centre.

Rotunda. Two microphones were connected to a battery operated amplifier the output of which was then fed via key switching to two 70 watt amplifiers feeding the north and south column speakers mounted on the Rotunda. With the key in the normal position the output from the mixing amplifier wes fed to the two 70 watt amplifiers giving local sound reinforcement for the Rotunda. With the key operated, the input to the south amplifier was terminated and the north column speaker, fed by its 70 watt amplifier, was connected to a 600 ohm line from the main control centre providing delayed reinforcement for sound originating from either the Sound Shell or the Landing Stage.

LOUD SPEAKER LAYOUT

Sound Shell. Six column speakers (5 x 6 inch), mounted on a 60 ft. steel and concrete pole immediately behind the Sound Shell (Fig. 3) and angled slightly forward, gave adequate sound coverage from approximately 100 ft. to 500 ft. from the Shell. In addition one column speaker mounted on each wing of the Shell provided for sound reinforcement up to 100 ft.

Landing Stage. Seven column speakers were mounted on two poles on each side of the Landing Stage with speakers angled to give overall coverage.
on each side of the north and south sides

Rotunda. Four column speakers, two of the Band Rotunda and situated above the roof permitted high level sound with minimum acoustic feed-back.

South Bank Poplar Drive. Three column speakers stacked to give long-range coverage for the Poplar Drive are shown in Fig. 4.

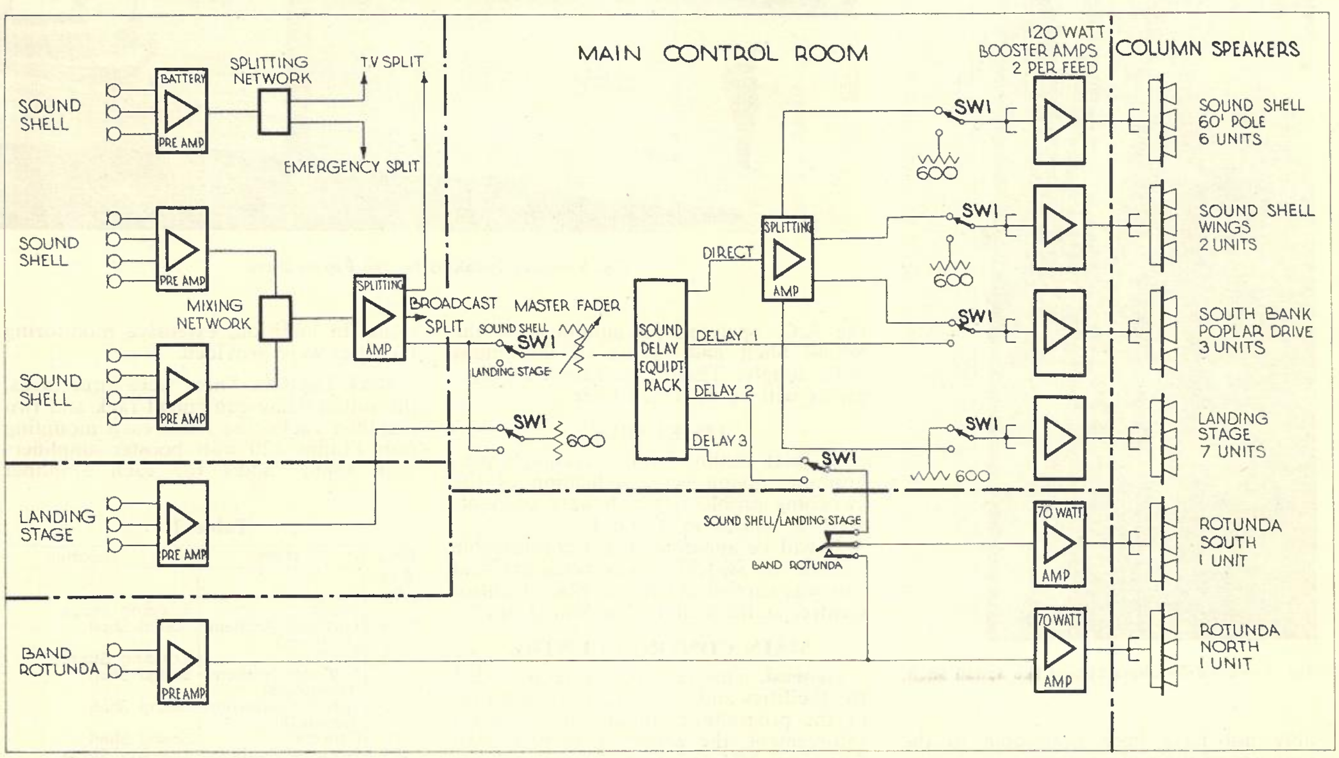


Fig. 5.—Schematic Circuit.

Sound Delay Details. Details of the sound delays used are given in Table II:

SCHEMATIC CIRCUIT

The schematic circuit is shown in Fig. 5.

CONCLUSION

Reports and comments from the audience, the Festival Committee, the Conductor and soloist, indicated that the sound re-inforcement system adequately met the requirements of the occasion and allowed the large audience present to enjoy fully the impressive opening ceremony of the Adelaide Festival of Arts.

Table II

Source	Column Speaker Locations					
	Sound Shell 60 ft. pole	Sound Shell Wings	Poplar Drive	Landing Stage	Rotunda South	Rotunda North
Sound Shell	Direct	Direct	Direct	Not connected	Not connected	.44 sec. (500 ft.)
Landing Stage	Not connected	Not connected	.18 secs. (200 ft.)	Direct	Not connected	.27 sec. (300 ft.)
Rotunda	Not connected	Not connected	Not connected	Not connected	Direct	Direct

PROGRESS WITH AUSTRALIAN MANUFACTURE OF L. M. ERICSSON CROSSBAR EQUIPMENT

A previous issue of this journal (The Telecommunication Journal of Australia Vol. 12 No. 2) in October 1959 announced the adoption by the Australian Post Office of the L. M. Ericsson type of crossbar system as the new standard for automatic switching in the Australian telephone networks. Reference was also made to the commencement of detailed planning for the manufacture of the new equipment by the two Australian manufacturers Standard Telephones and Cables Pty. Ltd., and Telephone and Electrical Industries Pty. Ltd., both of Sydney. Less than two years later, in August, 1961, the installation has commenced at Petersham (N.S.W.) of the first crossbar exchange fully adapted as the standard for Australian metropolitan networks In addition the first items of crossbar equipment to be manufactured in Australia have been completed. The latter form part of orders for a total of 40,000 lines of equipment placed by the Department with the two Australian firms for delivery in the 1961-62 financial year.

Fig. 1.—Mr. S. Cronstedt (centre), L. M. Ericsson, Stockholm System Design Engineer, at present associated with L. M. Ericsson Australia Pty. Ltd., Melbourne, discusses the functions of an incoming register circuit with Mr. E. R. Banks (left), Sectional Engineer, Network Planning at A.P.O. Headquarters, and Mr. N. A. S. Wood, Sectional Engineer Crossbar Co-ordination. Mr. Cronstedt is making a very valuable contribution as liaison officer for L.M.E. with the A.P.O. and the Australian manufacturers.

The crossbar project has proceeded through a number of distinct phases. The first of these included negotiations between the Department and the L. M. Ericsson Company to stabilise the facility and interworking design requirements for the optimum use of the crossbar system in Australian local networks. These negotiations commenced with a visit to Sweden in February, 1960 by an Australian Post Office team under the leadership of Mr. F. P. O'Grady then Deputy Director-General, and continued subsequently in Australia. For these later discussions the L. M. Ericsson Company sent to Australia an experienced system design engineer Mr. S. Cronstedt (see Fig. 1) to act as liaison officer. Mr. Cronstedt is now resident in Melbourne. In this same initial phase Australian manufacturers reached agreement with L.M.E. on a broad programme for the commencement of manufacture by assembly of imported pieceparts and gradual tooling to achieve 100% local production as early as practicable. Both S.T.C. and T.E.I. commenced building extensions of more than 50,000 sq. ft. to accommodate the new production layout which differs substantially from that for 2,000 type equipment.

The second phase since July 1960, has been one of intensive programming and co-ordination to ensure that timing of deliveries of specifications, circuits, wiring and testing instructions, and finally pieceparts for a total of 136 separate rack and relay set types from L.M.E. would allow the Australian manufacturers to make deliveries in the order and volume required for the Department's Works Programme. The main responsibility for this phase has been borne by two committees, the Main Crossbar Committee at managing

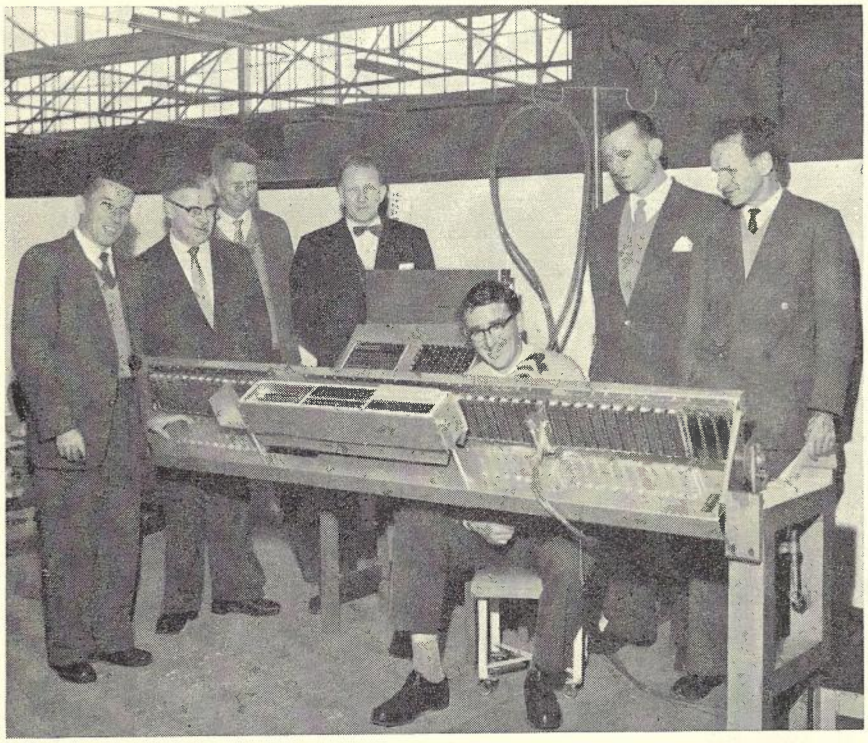


Fig. 2.—From left to right, Messrs. F. Holland (T.E.I.), J. Marchant (T.E.I.), W. Hearne (A.P.O.), K. B. Olsbro (L.M.E./A.P.O.), B. McNamara (T.E.I.), R. Langevad (A.P.O.) and A. Lackey (T.E.I) are present on the occasion of the acceptance by the A.P.O. of the first crossbar relay set rack manufactured by Telephone and Electrical Industries Ltd., Sydney. The T.E.I. personnel in the photograph are all associated with the testing of crossbar equipment and each of them has spent some time in Sweden, studying this type of system.

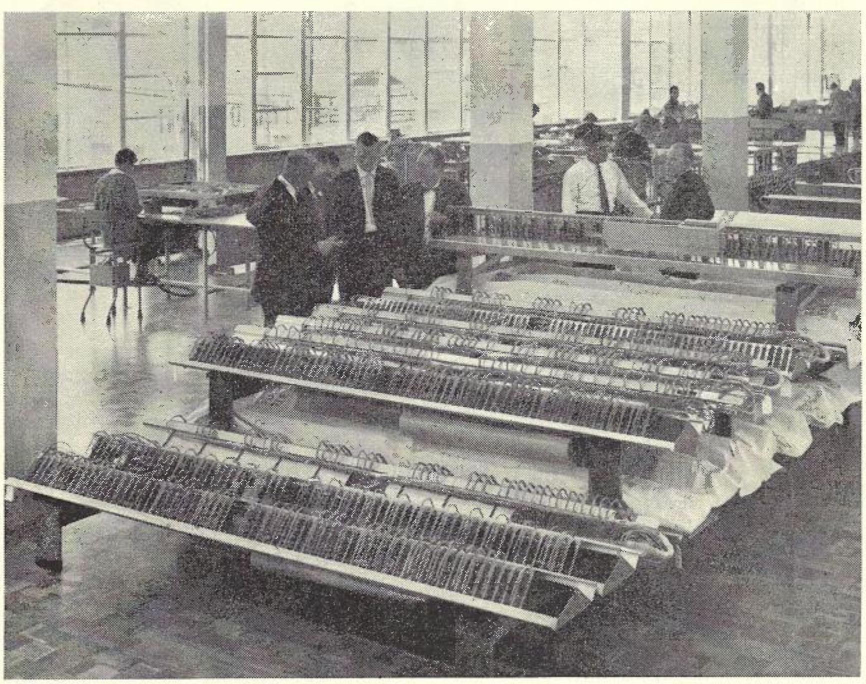


Fig. 3.—A view of the first batch of crossbar relay set racks manufactured by Standard Telephones and Cables Ltd. in their new building at Alexandria, Sydney. On the left, Messrs. H. Aitchison (A.P.O.), T. Lord (S.T.C.), R. Langevad (A.P.O.) and K. B. Olsbro (L.M.E./A.P.O.), and at the rear, Messrs H. Byett and S. Barber, both of S.T.C., discuss arrangements for final testing.

director level and the Technical Development Committee at senior engineer level. The Department provides the Chairman for both committees and the three manufacturers are represented.

The next phase, still current, began in April-May, 1961, when the first shipments of pieceparts for assembly in Australia were received. Since that time regular shipments in increasing volume have been advised and are being received. In this phase also, proving of new tools for parts to be made in Australia commenced and new building space was occupied by both S.T.C. and T.E.I. Cable form making for racks and relay sets also commenced with S.T.C. concentrating on small production batches and T.E.I. on pilots of selected items. In recent weeks both S.T.C. and T.E.I. have completed the first units of crossbar equipment to be made up from locally made and imported parts. These are illustrated in Figs. 2 and 3. In this most recent phase acceptance testing of the locally made equipment has assumed considerable importance. To assist the Department in this work the L. M. Ericsson Company has made available a senior engineer Mr. K. B. Olsbro who is an expert in this field. Mr. Olsbro will train the Department's staff in modern methods of statistical quality control of crossbar equipment production. These methods were already under investigation by the Department and the local manufacturers for application to existing production of 2,000 type equipment. Mr. Olsbro is resident in Sydney and will remain for a minimum of one year.

In summing up it can be stated that the project of introducing crossbar equipment into Australian manufacture is progressing very satisfactorily and all parties are confident that equipment finished to a very high standard will be supplied from the Australian factories in sufficient volume to enable a substantial installation programme to be commenced in 1962. This report would not be complete without some mention of the flow of information on installation and maintenance practices from L. M. Ericsson to the Department. The Department has received a considerable volume of drawings including master sheets suitable for reproduction and distribution to the six State Administrations. The processing of these drawings and the preparation of descriptions and instructions by the Department has commenced. To assist in this work the L. M. Ericsson Company has made available yet another experienced engineer, Mr. L. Estberger, who is now resident in Sydney. Mr. Estberger is well known in Australia for his association with the installation of the trial crossbar exchanges at Templestowe (Victoria), Sefton (New South Wales) and Toowoomba (Queensland).

N.A.S.W.

SOME IMPRESSIONS OF OVERSEAS SUBSCRIBERS AND TRUNK CABLE PRACTICES

*D. P. BRADLEY, B.Sc., B.Com., A.M.I.E.Aust.**

FOREWORD

This article is a continuation from one entitled "Impressions of an Overseas Visit by a Lines Engineer" which appeared in the June, 1961, issue of the Journal. It consists of a number of observations based on an overseas investigation of cable practices discussed in terms of Australian requirements. As pointed out at length in the previous article, overseas practice, however soundly based in the country of origin, may not be the best when transferred to the Australian geographic, social and economic environment and this point must be kept in mind when reading the following paragraphs.

TRUNK LINE FACILITIES

General

Demands for trunk circuits in Australia have been modest by overseas standards and have been met in general by open wire carrier systems for long distance working and by voice-frequency wire or cable circuits for short distances. A few carrier cable installations were made some years ago. The demand has increased substantially in recent years and extra steps taken to meet it include the use of coaxial cable or broadband radio systems providing large blocks of circuits between major centres, and V.F. cables or 12-channel carrier systems working on selected pairs in V.F. cables. There are no carrier systems intermediate between the relatively small capacity systems and the broadband systems except for a few 34 and 48 channel systems. This is generally in line with practices in England and the U.S.A.

In Europe, on the other hand, cable systems providing 48, 60 or 120 circuits on quad cables are widely used for long haul operations providing circuits to C.C.I.T.T. standards. The maximum frequencies used are 252 Kc/s for 60 channel working and 552 Kc/s for 120 channel working. The techniques used include the following:—

(i) Separate "go and return" cables of relatively small pair capacity are used. They are designed for low attenuation and cross-talk.

(ii) Repeater spacings are the maximum consistent with amplifier performance and cross-talk conditions (Fig. 1). Elaborate cross-talk suppression techniques are used.

(iii) Repeaters are housed in permanent buildings with self-contained power supply arrangements.

These systems have been intensively developed in Germany and a description of German practice indicates the general approach.

German Trunk Cable Practice

Two types of quads are used in German trunk cables:—

(i) Paper insulated, similar to the trunk type P.I.L.C. cable used in Australia, but of lower mutual capacity and capacity unbalance. Used for 60 channel working (252 Kc/s).

(ii) Styroflex insulated, similar to paper insulated pair cable but styroflex (flexible polystyrene) is used for insulation. Used for 120 channel working (552 Kc/s).

The cables are 5, 7, 12 and 14 quad, 20 or 40 lb. conductor. The following table gives some relevant characteristics of a number of trunk type cables:—

Country	Conductor	Mutual Capacity	Attenuation	Application
		M.F./mile		
U.K., U.S.A.,	20 lb (.036")	.066	6 db at 100 Kc/s	108 Kc/s
Australia	40 lb (.050")	.057	3.5 db at 100 Kc/s	108 Kc/s
C.C.I.T.T.	0.9 mm. (.036")	.053	4.2 db at 150 Kc/s	204 Kc/s
C.C.I.T.T.	1.2 mm. (.047")	.0425	3.5 db at 150 Kc/s	252 Kc/s
Germany (Styroflex)	1.3 mm. (.051")	.035	2.5 db at 150 Kc/s	552 Kc/s

Three general types of trunk cable have been used in Germany since the war:—

(i) **Balanced pair** (introduced in 1946).—Conventional quad type cable with paper or styroflex insulation. Separate "go" and "return" cables are laid. The styroflex cable is 7 quad (14 pair).

(ii) **One tube coaxial** (1950-1959).—Consists of one standard paper insulated coaxial tube laid in the centre of 8 quads (16 pairs) of 1.2 mm. or 1.3 mm. styroflex insulated wires. Separate "go" and "return" cables are laid.

(iii) **Eight tube coaxial** (1959).—Consists of eight standard paper insulated coaxial tubes laid around a core consisting of six miniature coaxial tubes and paper packing pairs. "Go" and "return" tubes are included in the one cable (miniature coaxial tubes are used in place of styroflex quads probably because excess cross-talk would occur with them, both at the low frequency end of the coaxial spectrum between tubes and quads, and between "go" and "return" quads in the one cable).

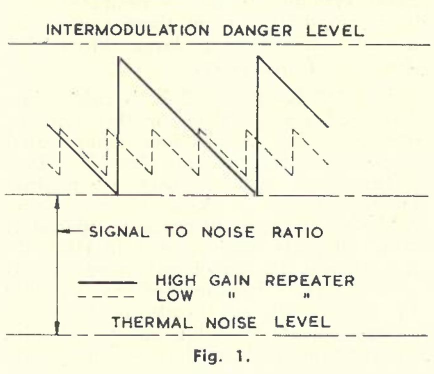


Fig. 1.

The dates shown are approximate only. The bulk of German trunk line cable services is provided by the one tube coaxial cable, the coaxial tube being used either for telephony or T.V., with 60 or 120 channel carrier systems working over the quad pairs. This design of cable is unusual and somewhat expensive because of the use of separate go and return cables. The extra cost is higher still because most of these cables are directly buried and are armoured. The use of separate go and return cables is necessary to meet cross-talk limits for 60 or 120 channel working on the quads. This design of cable has now been replaced by the 8-tube one which provides similar types of facilities with the miniature coaxial tubes being used for the services previously provided by the quads. Cross-talk between bearers is no longer a controlling factor and there is no longer need for separate go and return cables.

German trunk cables are operated with repeaters spaced as shown:—

60/120 channel quad cables, 18 km (11.2 miles).

Standard coaxial 4 and 6 Mc/s working, 9 km.

Standard coaxial 12 Mc/s working, 4.5 km.

Miniature coaxial 1.3 Mc/s working, 2.25 km (cabinet type).

Miniature coaxial extended frequency range (proposed), 1.125 km (cabinet type).

The repeaters are in brick huts; power supply is either local and fed over the pairs. The systems are co-ordinated so that the 18 km huts house repeaters for quad cables, standard coaxial and miniature coaxial tubes.

High frequency operation to 252 Kc/s or 552 Kc/s on quad cables has one major drawback, that is the difficulties and the expenses of capacity balancing, which also creates a maintenance and service difficulty in the time taken to put a repaired cable back into service because of the need to rebalance. This

* See Vol. 13, No. 1, Page 79.

problem exists with the 12 channel carrier cables used in Australia, but apparently only to a minor degree compared to 60/120 channel cables. The difficulties of capacity balancing are a major disadvantage of quad cable compared to coaxial cable.

Australian experience with coaxial cable is that the electrical problems of installation are minor ones and, from the point of view of jointing and testing, coaxial tubes are less of a problem and expense than the interspace carrier quads in the same cable.

In addition to cross-talk balancing problems quad carrier cables suffer another restriction. This is the third circuit effect — cross-talk between two circuits which have no direct coupling but both of which are coupled to the third circuit and hence to each other. This restricts the number of pairs in a carrier cable; the upper practical limit appears to be 24 pairs, which gives adequate circuit capacity at 60 or 120 channels per pair but means that V.F. layer pairs cannot be used. The use of layer pairs is often convenient and lower in cable cost and installation cost, the cost advantage arising from the saving in sheathing cost. The reasons why these cable systems have been developed in Europe, particularly Germany, and are not used in U.K. or U.S.A., are of some interest in case there is any thought of applying them in Australia. Probably the main reasons are different geographical and economic conditions; in West Germany there are many medium-size towns (100,000-800,000 inhabitants) fairly close together that have not necessitated the large blocks of trunk circuits provided by coaxial cables. This is in contrast to circumstances in the U.K. and U.S.A., where coaxial cables were applied as soon as they became available 20-25 years ago to handle the enormous requirement for circuits out of London, New York and other centres. In addition, the high cost of labour in the U.S.A. probably makes these cables unattractive economically because they require much more skill, care and time in manufacture and installation than alternative trunk systems. Cables of this type have never been made in the U.S.A.

Summarising the above, supergroup operation on special high quality quad cable compares unfavourably with coaxial operation for these reasons:—

(i) **Cable Costs.**—The need to lay two cables is the crippling factor in the cost of a balanced pair cable. Comparing a 4-tube coaxial cable with a 24/40 high quality quad cable, the coaxial cable costs are of the order of £3,500-£4,000 per mile installed, whereas the figure for the quad cable would be of the order of £4,500-£5,000. The difference is largely due to the need to lay separate "Go" and "Return" quad cables compared to one coaxial cable. The coaxial cable provides 21 supergroups or 2 T.V. circuits per pair of tubes using 6 Mc/s operation with potentially greater capacity at 12 Mc/s; there are also high quality 20 lb. interspace pairs available for 12 channel short haul operation. The quad cable has an ultimate capacity of 24 supergroups. Layer pairs can be provided on the coaxial but not on the quad cable.

(ii) **Repeater Costs.**—Typical costs for a coaxial repeater station are £1,600 for the building and £2,000 per pair of tubes for the equipment and for 60 channel carrier cable repeater stations, £5,000 for the building and power supply and about £500 per supergroup for the repeaters. Even allowing that twice as many repeater stations are required, these costs favour co-axial cable.

(iii) **Installation Problems.** — Field testing and jointing of pairs for 252 Kc/s operation is a difficult and expensive operation. By contrast the experience is that jointing and testing coaxial tubes is inexpensive given good staff and good supervisors; considerably more time is being taken to test, balance and joint the 6 interspace quads than the coaxial tubes in the Sydney-Melbourne cable and these quads are balanced to much less stringent standards than required for 252 Kc/s operation.

(iv) **Maintenance Problems.** — Any fault on the cable requiring piecing in of a new length requires rebalancing of the cable, which will be both expensive and time consuming.

(v) **Manufacturing Problems.** — High quality quad cable is recognised as the most difficult of all cables to make, and manufacture is in fact confined to a relatively few cable works in Europe. As an example of the difficulty, Australian manufacture of coaxial tubes has been set up in two factories and in each case electrical specification values for the tubes were fairly readily obtained and maintained in manufacture, but it has proved harder to meet and hold electrical requirements on the interspace quads which have to meet an easier specification than the C.C.I.T.T. Grade II.

A factor in future planning will be the presence of supergroup carrier equipment at most major centres due to the presence of coaxial or broadband radio systems. It seems desirable that bearers radiating from these centres be capable of carrying large blocks of channels if necessary.

The 252 Kc/s or 552 Kc/s cables just described are suitable for this type of operation but some less complicated cable system is obviously desirable. Two systems are available. One is a method of supergroup working over existing cables using low gain repeaters spaced at close intervals such as used in Holland; the other is the use of miniature coaxial cables. The first method is suitable where a cable is already in situ; the second where the cable has to be laid. Application in Australia, of course, depends on local conditions and cost factors.

Supergroup Operation on Quad Cable with Low Gain Repeaters

This scheme was developed in Holland some years ago to meet a particular local need — Holland is covered by an extensive network of V.F. trunk cables which were proving inadequate for requirements. The scheme enables up to 8 supergroups (480 channels) to be worked over one 54/20 quad cable. The application is a short haul one. (Ref. 1.)

The features are briefly as follows:—

(i) The cable is 54 pr./20 lb. to a European V.F. trunk type specification. The application is to existing cables.

(ii) The carrier systems are worked over the phantom circuits. Four circuits with a maximum frequency of 552 Kc/s are provided on eight quads of the cable; the repeater gain is 22 db at the maximum frequency.

(iii) "Go" and "return" circuits are worked in the same cable; two supergroups are transmitted in one direction over the phantom circuit of the "go" quad; and two supergroups return on a separate phantom.

(iv) The gain of the repeaters is restricted to about 20 db so that cross-talk limitations are kept to a minimum. In particular, balancing of the pairs is not required.

(v) A simple one valve repeater is used mounted in a concrete street cabinet about the size of a large pillar box.

The important feature of this technique is the use of short spaced low gain repeaters. Conventional practice is to use high gain repeaters spaced as far apart as cross-talk and amplifier design considerations will allow. This practice is long established and arises from the high proportional cost of building, and perhaps staffing, repeater stations and providing secure power supply to them. The cost of the repeaters proper are small compared to the overall plant and buildings associated with them. Once the practicability is established of cabinet housed repeaters, together with power supply over the speaking pairs themselves, then there is little advantage in maximum gain repeaters and short spaced low gain repeaters can be used with resultant savings in cross-talk, balancing and equalisation costs and the great financial advantage of two way working in one cable. Fig. 1 illustrates the difference between low gain repeater practice and the conventional high gain practice.

Compared to the use of conventional high quality low attenuation quad cables with high level repeaters, this technique appears to offer a simple solution to problems of spur routes from coaxial cable and short distance trunks. The attractions of the technique are that only one cable is required and existing cables can be adapted for the purpose with a minimum of rearrangements. Further, there are no building or power supply problems. Some problems with street mounted repeaters are discussed later, particularly the difficulties of providing hermetic sealing at reasonable price. The sealing problem, however, only arises with transistorised repeaters because a small source of heat such as that provided from a valve repeater as used in this application is sufficient to ensure a dry interior in the housing.

Miniature Coaxial Cable

Miniature coaxial cable (163 coaxial) is the latest development in trunk line communication. It is under active development in England, France and Germany, but does not appear to be arousing any interest at present in the U.S.A.

Briefly it is the same in principle as standard coaxial cable but is of small dimensions and therefore of higher attenuation. See Fig. 2. The top working frequency is lower and repeaters are more closely spaced. In both England and Germany 1.3 Mc/s (300 channels or one master-group) is the top frequency at present. Repeaters are spaced at about 2 miles. An important economic feature is that the repeaters are transistorised with power fed over the cable and mounted in street cabinets. The role of 163 coaxial cable is to provide circuits on routes which do not warrant the great circuit capacity of standard coaxial tube but require more circuits than can be economically met by carrier on quad cable. 60/120 channel carrier on cable installations are competitive in circuit capacity but the capital cost of 163 coaxial cable is expected to be less.

In construction, it is similar to standard coaxial tube and consists of an inner solid conductor .038″ in diameter, air dielectric with some type of plastic separator, a folded outer copper tube and lappings of soft iron tape. It is called 163 coaxial as the outside diameter of the tube is about .163″. A number of different methods are used to separate the inner and outer conductors. These include an extruded covering of foam polythene over the inner conductor, a Styroflex (flexible polystyrene) string wrapped around the conductor in a helix, and a method called the "balloon" type developed in France by the firm of S.A.T. in which loose stiff polythene tube is extruded over the centre conductor and crimped onto it at regular intervals.

The first two methods are probably inferior to the S.A.T. design. Foam polythene is not altogether acceptable because of electrical irregularities in manufacture and doubts about its aging properties; the Styroflex helix design presents a maintenance hazard because water entering the cable through a hole in the sheath can flow freely along the tube under gravity. The C.C.I.T.T. Conference at New Delhi in 1960 recommended the S.A.T. design and also recommended a repeater spacing of 6,000′ (to coincide with loading coil points) and an impedance of 75 ohms. This was a compromise between the existing designs of 65, 67 and 75 ohms. The 75 ohm tube has the advantage that the same testing instruments can be used without modification for both 163 and standard coaxial installations. On the other hand the inner conductor is thinner and its mechanical strength and rigidity may prove somewhat inadequate for jointing and handling in the field, particularly for aerial application.

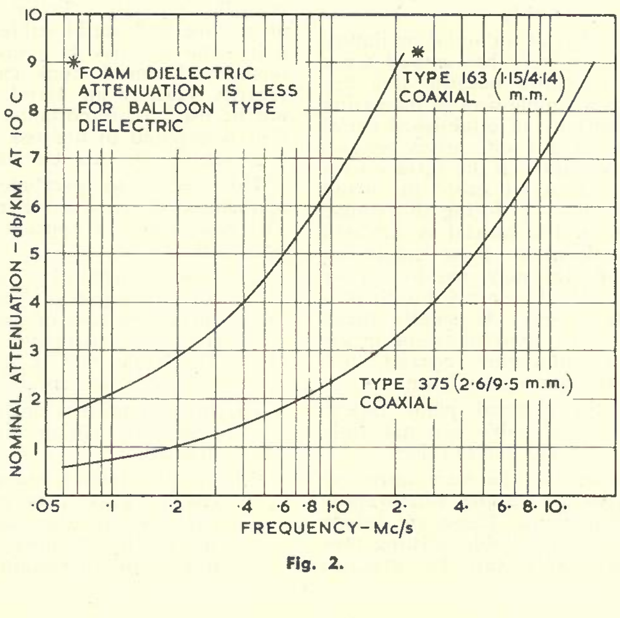


Fig. 2.

Application of 163 Coaxial Cable

Both the techniques and application of miniature coaxial cable are still in the developmental stage. In Germany, the tubes will not be used for international traffic. They will be incorporated as minor members of 8 tube coaxial cables and their circuits need not be to C.C.I.T.T. standard. The economical distance of operation is suggested as 40-100 km (say 25-60 miles). Installations in the U.K. are short distance ones (up to 30 miles) and Italian ones are of the order of 100 miles. C.C.I.T.T. standard circuits are provided in each case. The U.K. installations are spurs off main coaxial routes and the Italian ones form main routes. The cables are 4 or 6 tube foam polythene insulated with or without layer pairs and plastic sheathed. The cables are installed underground in conduit under gas pressure, but portion of the Italian installation will be aerial. These approaches are plainly different. In Germany the 163 tubes are minor members in a composite cable for short haul application — long haul traffic is handled by standard tubes in the same cable. The British and Italian approach is to use the 163 tubes in self-contained cables for long haul type circuits. The reasons for the German application are probably because of the need for large blocks of short distance circuits in place of 120 channel working on styroflex pairs. The difference between the proposed applications is evidence that the limits of economic application of 163 coaxial cable have not yet been established.

In each case, however, the full frequency range available in the tubes is being exploited at the expense of closely spaced amplifiers and the economic success of 163 coaxial cable depends on the development of cheap satisfactory transistorised repeaters suitable for outdoor housing. It is suggested that this may not be the most economical approach in all circumstances; it might be preferable to use a lower frequency range and more widely spaced amplifiers. This comment is made for two reasons, firstly because the cable costs of 163 tubes when manufacturing techniques are stabilised can be expected to compare very favourably with costs of quads, and secondly because the problems of satisfactory outdoor housings are probably more complex than is always appreciated.

163 tubes can be supplied as cables made up with the tubes as the major members with paper or plastic insulated layer pairs if required; or they can be supplied as composite cables with paper or plastic insulated pairs or with standard coaxial tubes. Plastic or metallic sheathing can be provided, depending on the application. A satisfactory design, for instance, would consist of a number of tubes included in a large P.I.L.C. cable. A possible field of use for such a cable would be as a composite junction cable where a series of exchanges are located along the same main duct routes, which is a common case in metropolitan networks. Paper quad pairs can be used for V.F. junction working between adjacent exchanges and carrier working between wider spaced exchanges via the 163 tubes.

Cable Costs for 163 Tubes

One of the major advantages of standard air core coaxial cable is its low installed cost compared to quad cables for similar channel capacity. Comparing coaxial tubes with quad pairs, the coaxial tubes are relatively simple to manufacture and test in the factory, and Australian experience is that installation, jointing and testing in the field present few problems. The material cost of a coaxial cable is relatively modest because of its small copper content, in fact one 4-tube coaxial cable is comparable in cost with two (i.e., "Go" and "Return") 24 pr./40 lb. high quality quad cables.

The same remarks apply to 163 coaxial tubes. For example, compare one 163 tube with 40 lb./mile quad cable for working one supergroup (60 voice channels). One pair in each of two quad cables would be required compared to one tube assuming that "Go" and "Return" are worked over it; the top frequency would be 552 Kc/s on the tube, 252 Kc/s on the quad pairs. Regarding cable costs, the two pairs required in the quad cables require 160 lbs. of copper per mile and occupy .02 sq. ins. of space in each cable compared to .03 sq. ins. of space in one cable and a copper weight of 120 lbs. per mile with the 163 tube. When techniques are fully established, manufacturing and installation costs will favour the 163 tube. Attenuation is about 5 db per mile at 252 Kc/s for the quad cable and 3 db at 552 Kc/s for the 163 tube.

This analysis suggests that the economics of operating 163 tubes at lower frequencies with wider amplifier spacing warrants investigation. One application, for instance, would be the use of 163 tubes as packing in place of quads in a standard coaxial cable with repeaters at the same spacing as the standard coaxial tube repeaters. A major advantage of this arrangement is that the repeaters would be installed in buildings and not in outdoor housings and, as discussed next, the provision of satisfactory long term outdoor housing for transistorised repeaters may prove a difficult problem.

Housing for Outdoor Repeaters

An important factor in the low cost of 163 coaxial cable is the fact that repeater buildings are not required. However, this means that apparatus which is usually designed to work in a secure indoor dust-free environment usually air-conditioned, is now housed in a small outdoor casing exposed to the elements and, if underground, to permanent moisture and corrosion conditions. Obviously the casing must provide a high degree of integrity of protection. Also it must be cheap and possibly it must be possible to open the casing for access to the apparatus. These requirements are difficult to meet. The problems are:—

(i) A permanent seal must be obtained with the door opening. If the cable is pressurised the unit should withstand an internal pressure of the order of 8 p.s.i. without too much leakage loss of gas.

(ii) The entry of the cables into the box must be gas tight and watertight.

(iii) The housing must be proof against environmental corrosion.

The second and third points can be secured by good textbook design but the first requires experience as well as careful design. Design of a cheap housing is proving a difficulty to manufacturers offering 163 coaxial systems. Two types seen, one for housing in manholes and one for direct burial, appear unsatisfactory, as a large area of opening depended on a pressure gasket for a hermetic seal; experience in the Lines Section with outdoor cabinets over many years shows that this is unsatisfactory. Entry of moisture could be expected with either design. Another housing has an autoclave seal which is sound but expensive. It is a manhole type repeater and a difficulty is that a manhole costs over £100 to construct.

It is possible to construct outdoor housings which are cheap and well sealed and which are suitable for above ground or manhole mounting. The aluminium cross-connecting cabinet used by the Department for the last six years is a first-rate type of housing. It has been well proved by over 1,000 in service and is completely and permanently sealed and the price is low. The interior is circular with an internal diameter of $10\frac{3}{4}''$ and a clear height of 20″ in one size and 36″ in the other size. There is a centre column 2″ in diameter for each type. This unit could probably be used as a repeater housing.

For preference the repeater should be directly buried. This is cheapest and permits minimum variation in ambient temperature. However the problems are substantial and may not prove to have an economic solution unless a suitable encapsulated "throwaway" repeater can be designed and is acceptable. Difficulties experienced in Australia with encapsulating loading coils in epoxide resin for direct burial suggest that the design of a satisfactory encapsulated repeater will not be an easy task.

The difficulties in practice which can be expected from the use of outdoor transistorised repeaters in moist temperate climates may well lead to a re-investigation of the merits of short spaced repeaters in favour of more widely spaced repeaters housed in buildings and with a lower top working frequency.

Aerial Installation of Miniature Coaxial Cable

The installation of an aerial miniature coaxial cable in Italy has caused some interest in Australia because this approach seems a simple way of increasing the circuit capacity of established aerial trunk routes. A difficulty arises because of the wide variation in the surface temperature of an aerial cable in inland Australia in summer during the course of 24 hours. A 163 coaxial system will probably work under these conditions but each repeater may require to be regulated compared to every fourth in a buried cable system. As simple cheap repeaters are an important factor in the economics of miniature coaxial, this factor weighs against aerial use.

Some of the external plant factors applying to aerial cable are not fully appreciated and are set out here.

Aerial cables can be very attractive in urban areas for reasons which apply only in urban areas. These are briefly that, if there is a suitable existing pole route, aerial cable can be installed cheaply, simply and quickly with a minimum of staff, plant and administrative effort, and without need to consult outsiders (municipal officers, road engineers, landowners, etc.). The costs are particularly favourable if the poles belong to the Electricity Authority ("joint use"). A further factor is that telephone service is often required in new suburban areas with unmade roads and footpaths and buried cable here is very susceptible to damage in the subsequent road making operations.

Aerial cable is not usually worthwhile if poles have to be erected especially for it.

Applied to trunk work, aerial 163 coaxial cable would be attractive in capital cost where it can be erected on existing pole routes. It has the further advantage that the plastic jacketed aerial cable will be cheaper in purchase cost than the metallic sheathed cable which would be preferred for direct burial underground use. Plastic jacketing is undesirable for directly buried use because it permits the passage of water vapour into the interior of the cable.

If there is no existing pole route, capital costs normally favour U.G. cable.

Maintenance costs favour U.G. cable because of the costs of pole renewal; fault incidence strongly favours U.G. cable. Well constructed U.G. cable routes in rural areas are largely immune to faults whereas aerial cables in rural areas are particularly susceptible to faults due to storms, fires, vandalism and accidents such as a car hitting a pole, as well as wear and tear due to exposure to the elements. The fire hazard is the major danger and experience over the last few years has proved that even a small grass fire will damage a plastic aerial cable or wire to such an extent that it must be replaced. Unfortunately the experience indicates that the only locations completely free from fire risk are urban areas where both the roadway and footway are paved; even the heat of a grass fire in a nature strip, for instance, has repeatedly proved sufficient to damage drop wire and aerial cable beyond repair. The fire risk is a severe limiting factor with aerial trunk cable and for security reasons an aerial cable could not be used for important trunk circuits if it is exposed to fire risk unless there is a secure alternate circuit.

This seems to preclude the aerial application of trunk cable in most cases. The cases where it appears likely to be acceptable are:—

(i) Where installed temporarily or for emergency purposes — the speed and ease of erection makes this an attractive application. The cable can be recovered and re-used elsewhere if required.

(ii) In mountainous or rocky country where trenching is extremely diffiicult.

(iii) In dry inland areas where the risk of grass fires is low (those parts where the herbage is so sparse in summer that it is insufficient to sustain a fire).

Radio and Cable

In discussing the merits of radio and cable for the provision of large blocks of trunk circuits with radio and cable engineers overseas there was a marked tendency for professional bias to be displayed and it was hard to find a balanced view. It was generally agreed that radio is better for point-to-point operation and cable is better when intermediate points have to be served, and it was agreed that economics should determine the changeover point. However, there seems to be no agreement on the comparative economics probably because coaxial cable techniques are old and well established and all relevant costs can be enumerated and evaluated, whereas radio is still in a stage of intense technical development and firm cost data is not available for the modern systems.

The position for telephone circuits in the different countries is as follows:—

Germany: Due to the terms of th 1945 Armistice there were restrictions on broadband bearers which were lifted about 1950. Intense development of radio circuits commenced then as this was the fastest way of providing circuits quickly. The view was also held that radio was the most effective technique. Since then, however, about 4,000 route miles of coaxial cable have been provided in the Federal Republic and the tendency is to provide new facilities by means of cable. One reason appears to be that frequencies and sites have been exploited to an extent that makes it difficult to provide additional radio facilities.

U.K.: Coaxial cable is used almost exclusively. This is probably because an extensive coaxial network was in service before microwave systems were commercially available and secondly because coaxial cable costs are lower in the U.K. than elsewhere because there is a country-wide conduit network available.

U.S.A.: An extensive coaxial cable programme was completed about 1950, at which stage microwave installations were accepted as the appropriate way of providing broadband facilities. However, recently the decision has been made to commence an extensive new coaxial cable programme, including a 4,000 mile long trans-continental cable.

Canada: There are no coaxial cables in Canada and microwave radio is widely used. There are special circumstances involved which are discussed later.

For Television relay the position is as follows:—

Germany: Radio is largely used. Cable engineers in Bundespost are of the opinion that this is the correct way to handle television. Nevertheless, the network of coaxial cables of the single tube type previously described is widely used for T.V. relay.

U.K.: Coaxial cable is used almost exclusively.

France: Radio is used exclusively because coaxial cable has not been capable of meeting the bandwidth requirements of the 825 line French T.V. system.

U.S.A.: T.V. circuits are provided on radio or coaxial cable according to their availability.

Dealing with the position in Canada, it is well known that there are no long distance coaxial cable installations and that the trans-continental telephone link is by microwave radio extending from coast to coast. Microwave radio is widely used on shorter routes. There are carrier telephone cables, including one connecting Montreal and Toronto and carrier working on open wire trunk routes is also used, but radio, overall, is the accepted technique in Canada.

The organisation of the telephone industry there differs from that in Australia and U.S.A. in that there is no national telephone authority. There are seven major operating authorities, including Bell of Canada, which is the largest and operates in Montreal, Toronto and surrounding areas. Canada Bell is about as large as the Australian organisation in local services but its trunk network is much smaller, being comparable territorially with that of New South Wales. Long distance and trans-continental trunk services are organized by the Trans Canada Telephone Services, a co-operative enterprise belonging to the major operating authorities, which oversights and co-ordinates long distance trunk working using the plant and facilities of the members. In addition the two railway authorities (C.N.R. and C.P.R.) own the only coast-coast wire facilities and extensive open wire and microwave facilities. To some extent the railways fill the role of a national trunk line service as their facilities are used for public telegraph traffic, programme and TV. relay, and are leased to the telephone companies as well as for railway purposes. The absence of one national authority with its own engineering staff and its own facilities appears a weakness. For instance, until the Trans-Canada microwave link was established in 1958, trunk traffic between the East and West coast had to be carried by A.T. & T. trunks in the U.S.A., being switched via Boston, Chicago and Portland, Oregon.

The population density and distribution in the Eastern States would appear to favour coaxial cable rather than microwave radio because of the large number of towns intermediate between the terminal centres. Nevertheless, radio appears to be accepted as the normal approach to any trunk line project for reasons which are peculiar to Canada. Firstly, cable laying is a difficult operation over much of Eastern Canada due to a rock shelf which makes laying costs high, particularly as the cable must be buried in the earth at a depth below the frost line, which is 4′-6′ below the surface. Secondly, the severe winter makes operation of open wire lines difficult due to heavy ice formation and the resulting possibilities of wire breakage.

Another possible factor is the absence of an engineering organisation equipped to plan overall trunk line projects on a national basis. The engineering of an exclusive Trans-Canada microwave link was a simpler project for the Canadian telephone authorities than engineering a combined cable-open wire-radio link because much of the engineering of the radio link could be carried out by the radio contractor.

A reasonable conclusion is that the Canadian approach is best in their organisational and geographical environments, but the circumstances which make it so do not exist in Australia.

No simple factors were seen to determine the marginal cases of radio versus coaxial cable. Furthermore, as rapid developments must be expected in radio technique it is clear that the boundaries between the two will keep on shifting. At the same time the continued lowering of the installed and maintenance costs of electronic equipment must be expected to move the margin of both coaxial cable and radio into shorter distance transmission compared to conventional V.F. or carrier cable installations. The important factor is to realise that radio and coaxial cables are complementary and not competitive and, as far as possible, all the factors involved should be assessed on an impartial basis before a decision is made in favour of one or the other. Further, the conditions in the comparison will vary between different countries and it is essential that the comparison be made in terms of Australian conditions and economics and that overseas practice be examined with caution.

Local T.V. Links

Local T.V. transmission is by coaxial cable or video pair cables; for very short distance work pairs in normal U.G. subscribers type cables can be used. The novel type to Australia is the video pair cable, which consists of two 40 lb. copper conductors coated with foam polythene of wall thickness .060″. Two wires made up as a twisted pair are covered with two lapped copper tapes. The video pair is, therefore, a low capacity fully screened balanced pair. The objections of electrical irregularities to the use of foam polythene do not apply because the dimensions of the pair are so large that the irregularities of foam polythene are not critical. Moreover, the video pair is always used as part of a composite paper insulated cable so that it must be in a dry environment where there is no risk of deterioration of the foam polythene. The price of a video pair assembled in a composite cable would be a little less than a coaxial tube assembled in the same cable.

Video pairs are used extensively in the U.S.A., where they are standard for short distance T.V. transmission. They are also used to a limited extent by the B.P.O. Coaxial tubes are used exclusively in Germany for T.V. purposes.

Video pair cable is not recommended for use in Australia from the External Plant point of view. Apart from any technical considerations the Australian cable industry has a heavy investment in coaxial cable plant and coaxial cable should be used for local T.V. purposes provided the economics in favour of video pair transmission do not heavily weigh against its use. Further, the introduction of a further type of cable into the network will impose problems of installation, maintenance and administration which must be considered in assessing the economics. The problems of introducing new types of cables are possibly not appreciated by all engineers and are worth mentioning.

For the cable manufacturer, a new cable type must be introduced in toto. An apparatus manufacturer can introduce a new item initially by assembly and final testing of fully imported components and then progressively increasing the locally made content as skill and experience are acquired. This is not possible with cable manufacture nor is it possible to pass some of the work out to specialist sub-contractors; and, if new types of plant are needed, heavy capital outlay is involved. Further, cable manufacture is not a scientific process but is largely based on experience and empirical methods. Consequently a new process cannot be installed and success automatically expected. Usually a process is only proved successful after a series of trial and error runs and the generation of a large volume of expensive scrap. The scrap piles of coaxial tubes to be seen at both Australian factories in the introductory stages of manufacture are evidence. Finally the cable maker who installs plant for a new process has no guarantee that it will ever run successfully in production. For example, one overseas firm after eight years' experiments and expensive outlay on plant has failed to produce extruded aluminium cable sheathing on a commercial basis.

For the Department, introducing new external plant techniques differs from new internal plant equipment techniques firstly because overseas experience is less of a guide. Line plant is installed outdoors and its usefulness is strictly governed by the environment; local conditions are therefore paramount. A satisfactory design in one territory may be unsuccessful in another. An example is the insect attack on plastic cable, which is unique to Australia among major telephone administrations. Internal plant by its nature is housed in secure indoor locations frequently in an air-conditioned atmosphere and the experience of other administrations can be taken as a guide to its behaviour in Australia. With Line plant, although the experience of overseas administrations is a valuable guide, some factors may arise which render their experience a somewhat doubtful and possibly even misleading guide in Australia.

Secondly, with internal plant, the emphasis with new development mainly is on system engineering — the specification, selection and integration of the new development into the existing network. Detailed electrical and mechanical design work is largely the responsibility of the makers who are large firms staffed and experienced for this work. With external plant, mechanical design and installation techniques are very important. Detailed design of all line plant items except cable is carried out by the Department and they are bought from manufacturers whose sole expertness is in manufacture, not in design or application. Manipulative and installation techniques may require intensive development; the development of long distance cable laying techniques, for instance, is a spectacular example and the manipulative techniques of coaxial cable jointing were investigated over four years before one jointing method was selected as standard. Consequently, after the major arrangements have been made to introduce a new technique, the Lines Section is still faced with a volume of detailed design work and subsequent purchase of material items, and with the development and introduction of installation techniques, including the supply of tools and material and the training of staff. Hence, a considerable volume of engineering work as well as a period of time is required in the Lines Section after the major Internal Plant engineering aspects have been finalised.

For these reasons the introduction of new cable techniques into the network must be carefully considered beforehand and only attempted if the advantages are evident and substantial.

SOME LOCAL NETWORK PRACTICES

Exchange Network Cabling in the U.S.A.

The striking feature is the widespread use of aerial cable, much of it on joint use poles. While the actual practice depends on local circumstances, the general rule is that ducts are provided only for cables larger than 1,200 pairs. Thus the bulk of the cable in the exchange area is aerial and aerial leads are taken right to the vicinity of the subscriber's premises, which are fed by drop wire from cable terminal boxes on poles in the older areas and from Ready Access terminals in the new areas. Bare copper wire is not used. Cable flexibility is provided by an extensive system of multipling. There is nothing used equivalent to cable terminal pillars but a limited number of pairs in main cables are brought out to pole mounted cross connecting cabinets.

Except for a few trial installations in residential areas, direct underground subscribers' leads are confined to heavily built up areas. Aerial cable is used everywhere else even in such places as large suburban business areas and areas with large blocks of flats, where the degree of congestion in the streetway is such that underground telephone and power feeds would be regarded as mandatory in other countries. It is regular practice, for instance, to feed a 50 or 100 pair aerial cable directly onto the first floor of a block of flats or similar sized buildings.

The aerial cable installation techniques have been intensively engineered and practices are in use which cause surprise when first sighted. Joints, for instance, are made at any point in the span by a jointer sitting in a bosun's chair suspended from the bearer wire. Branch cables leave the main cable run at any point in the span, the bearer wire of the branch cable being terminated on the bearer wire of the main cable run. Lead, stalpeth and plastic cables appear on the one pole route, the common installation on a pole route consisting of one or more lead or stalpeth main cables, a plastic distribution cable and drop wire leads. The power distribution voltage in U.S.A. is 110 volt and heavier service leads and more closely spaced transformers and more H.T. feeders are required than in Australia with 240 volt distribution. Consequently, it is a common sight to see streets in America lined with tall joint use poles carrying high tension lines at the top, low tension lines below them, major telephone cables and then finally distribution telephone cables and drop wire. In addition, power transformers, cable terminal boxes and telephone cross connecting cabinets are fitted as required on the same poles.

The poles are necessarily tall to give the statutory clearance between the different attachments. Elaborate staying of the route is essential because of the heavy load carried and the poles are consequently subject to a number of distinct side loads; being of softwood with a lower tensile strength than hardwood poles, it is common to see a pole with several distinct bows in it, according to the localised load over different sections of it. The whole impression created is one of rather hazardous construction; probably this comment is incorrect but certainly if a heavy vehicle hit a pole and knocked it down it could cause considerable chaos. In addition, the aerial work is so ugly that it is disfiguring. The ultimate is to be seen in Montreal, where there are miles of housing in the French Section consisting of two-storey single-fronted houses in terraces. Each house consists of two flats — one upstairs, one ground floor. There is an unfenced concreted communal backyard behind the terraces of houses about 50′ wide, down the middle of which runs a pole line carrying the power wires and telephone wires and each flat has an endless pulley type clothes line attached to the nearest pole. H.T. feeders were not seen on any of these backyard pole routes but at a corner house a wet sheet on a pulley clothes line was noted flapping against a transformer!

The Bell System is concerned with the bad public relations due to the ugliness of aerial construction, although the power authorities are the main offenders partly due to the thick house feeders required with the 110 volt system. Bell is endeavouring to improve the position with two approaches — erecting telephone poles along the rear fencing alignments of the housing blocks as is the practice with the power poles in Canberra, although the street power distribution poles largely offset these efforts to improve the appearance. Elsewhere full underground telephone distribution is used in association with U.G. power supply; both authorities lay cables along the rear fencing alignment and the Power Company has buried transformers at appropriate locations along the boundary line. The main feed to the area, both telephone and power, is aerial. The effect is attractive, particularly as the house blocks are entirely unfenced. This type of backyard construction is not so suitable in Australia, firstly, as here house blocks are commonly fenced and access is difficult. Secondly, it is more economical under our conditions to feed from the front of the house because house blocks in North America are smaller and the houses are situated approximately square in the middle of the block. Consequently, the length of feed of cable is the same whether the entry is from the front or the back of the block. In Australia, however, the house is usually sited closer to the front of the block and more feed is required if cables are laid along the rear of the blocks.

The Bell System charges the subscriber extra for a full underground feed and at present the application is confined to new housing estates where the cabling is done before the houses are erected. There is considerable enthusiasm for U.G. cabling, but they have yet to learn the maintenance pitfalls which we have discovered in 25 years' experience. Another point is that in established areas they will find that they cannot make the speedy connection of new subscribers that are possible with the simple form of drop wire connection they use at the moment.

Aerial cabling has the advantages of lower capital cost and speedier installation. Its disadvantages are possibly higher maintenance costs and adverse communal effects — ugliness, obstruction and possibly danger. Considering capital cost, conduit construction is much costlier than providing equivalent aerial support, particularly if the cost of the poles is shared with the power authority. Conduit construction is largely a manual labour operation and does not lend itself to mechanisation so that the relative cost of duct work can be expected to keep on increasing as wages increase. Further, the number of buried services in city streets now is becoming so great that space for ducts is becoming scarce and expensive detours may be necessary. Both these factors are more important in North America than elsewhere because of high wage levels and because the privately owned Bell System is subject to local government restrictions in its choice of duct routes. Nevertheless, the trend in Australia is the same.

Installation costs favour aerial cable because fewer manhours are required to erect cable on poles than to draw it into ducts. Further, long continuous lengths of large size cable can be erected aerially — full drums can be erected in the one length, unlike U.G. cable, where there are inherent restrictions on the length of cable hauled. Hence substantially fewer joints are required with large size aerial cable.

Further, since power poles are, of necessity, provided in every street in suburban areas, an aerial cable can go from the exchange to its destination by the shortest route, whereas a U.G. cable must go via the appropriate duct routes which, for economy in construction, are restricted in routing. Over an average large exchange area this feature of aerial cabling would save an appreciable mileage of cable.

Regarding speed of installation, aerial cable has two advantages; firstly, even if ducts are available, an aerial cable installation can be completed more quickly because fewer manhours are involved and less specialized staff and plant are used. If duct space is unavailable, cable relief becomes a major task, both in capital cost and in time, and it is here that aerial cable shows to great advantage. Particularly in new areas telephone services can be provided at short notice by aerial cable on the power poles, which are always provided at an early stage of land development, whereas a lengthy delay is inevitable if conduits have to be laid. Subscribers' distribution services can also be completed at shorter notice as it is much quicker to provide an aerial lead into a house than to provide a U.G. lead. This is one reason why the Bell System is able to connect new subscribers' services so rapidly.

As for communal aspects, in every way aerial cables are objectionable except for the one factor that space for utility services in the roadway or footway is so cramped in some areas that aerial cable may be attractive for this reason. The objections to it are the obstruction to traffic both vehicular and pedestrian which extensive poling can provide, the potential danger to the publc, particularly if poles carrying heavy loads of wires are blown down by storms or knocked down accidently and, finally, the ugliness, which is the worst factor and one which would not be tolerated nowadays anywhere. It is probably tolerated in America because it is a long established practice.

Regarding maintenance, aerial cable is usually thought to have a higher maintenance cost than U.G. cable. This is due to the cost of pole renewals and weather damage and also the extra maintenance cost of lead sheathed aerial cables which suffer deterioration of the sheath due to wind vibration and exposure to sunlight. Aerial cables installed since 1950 in the U.S.A. have been either stalpeth or plastic sheathed and the proportion of lead cables in service is decreasing. Furthermore, Bell policy is to place the entire exchange cable network under continuous flow gas pressure. Under these circumstances it is possible that maintenance costs, excluding pole renewals, are comparable with those for underground cable. In addition, there are several advantages in aerial cable, firstly mechanical damage is less likely, secondly corrosion troubles cannot occur, and thirdly aerial cable is not subject to the large outbreak of faults we have from time to time due to heavy downpours of rain causing water to flood portions of duct route which are normally dry.

It is reasonable to state that a very careful assessment of the problem would be required today to determine whether underground or aerial cables are superior in regard to maintenance costs. Particular factors which have improved the situation for aerial cable are plastic sheathing and continuous flow gas pressure and the underground cable situation has deteriorated due to the increased use of mechanical plant by construction bodies and the subsequent greater danger of mechanical damage.

Overall, extensive aerial cabling as used in the U.S.A. is both the cheapest and most expeditious way of providing telephone services and probably both the maintenance costs and the fault incidence would compare favourably with a full U.G. system. However, there are no prospects whatsoever of adopting these methods in Australia. The system is not technically equipped to do so at the moment because plastic (or stalpeth) cable is necessary and at the moment this is used up to 75 pair only. But the main difficulties would be objections from the community on the ground of aesthetics.

Bell System Cable Layout Practice

Cable network design is based on the use of non-taper multiple. Taper cables are used only where there is no possibility of the development exceeding the proposed taper, and the normal provision is either untapered or with one breakdown point to half the previous size. Generous multiple appearances are made and stub pairs are brought out to the extent of 3-4 times the pair capacity of the cable itself. Cross-connecting facilities are not widely employed and appeared to be a new innovation. In applications, cabinets seen were provided at the first and last stub point of the non-taper cable. At the first stub point pairs with continuous readings commencing from Number 1 were brought out to the cabinet and at the last points the pairs appearing in the cabinet had a continuous reading terminating in the last pair of the cable.

This approach of non-taper multiple applies to main, branch and distribution cables. Compared to other systems it is extravagant in the use of copper, particularly in the initial provision required, and could not be contemplated in Australia because of restrictions of capital funds. In fact, it is probably only the privately owned Bell System, with its ability to raise funds as required, that could use this method. It undoubtedly provides considerable economy in labour overall throughout the life of the cable considering installation, relief and rearrangements, and is therefore consistent with the Bell approach of using material to save labour.

Another advantage is that the many stub appearances allow for a big margin of error in forecasting and is therefore especially suitable for areas where the erection of multi-storey buildings is likely to influence the accuracy of forecasting in an unpredictable manner. This condition applies over much of urban U.S.A., and, combined with the American public's expectation that telephone service will be provided anywhere on application, suggests good reasons for the non-taper multiple practice.

Another factor suggested is that cases for higher rentals can be argued more readily before the Regulatory Commission to meet capital outlay on initial cable installation compared with capital outlay required for relief and rearrangement spread over the life of the cable.

No advantage can be seen in adopting the Bell System multiple techniques in Australia. They are undoubtedly well suited to their particular cost structure and organisational framework but are not suited to Australian conditions.

Continuous Flow Gas Pressure

Bell System policy is to equip all exchange cable networks with continuous flow gas pressure. Their system lends itself to the technique as there are no pneumatic blocks anywhere on the cable runs. Pillars or their equivalent are not used; cross-connecting cabinets are used to a limited extent but they are teed off the cable runs, and do not act as pneumatic blocks. Consequently, gas injected at the exchange has access to the ultimate cable terminal box and Ready Access Terminal.

One factor bearing on the decision to use continuous flow is, probably, the somewhat unsatisfactory mechanical nature of their cable design. Stalpeth sheathing, which is used exclusively for paper insulation cable, has a seam soldered thin steel member as the waterproof element in the cable sheath and a number of faults per mile are permitted in the sheathing which could allow the entry of moisture. The extra maintenance cost involved is offset against reduced manufacturing costs. Plastic cable is not checked for pinholes in the factory and again it is expected that somewhat higher maintenance costs will be encountered in the field which will be offset by economies in the factory. In fact the plastic cable has proved a maintenance problem because of pinholes when used underground and possibly Stalpeth sheathing has some disadvantage in this regard. Full gas pressure should give an adequate protection in each case. In addition to weaknesses in current design, large quantities of lead covered aerial cable are in use, most of it installed a decade or more ago, which must constitute a major maintenance hazard because of progressive deterioration of the lead sheath.

The introduction of continuous flow gas pressure is facilitated because the plastic cable sections of their cable networks are designed to be watertight and fairly elaborate joints are used which are substantially gastight; water barriers are not fitted. In Australia and in the B.P.O. network, even if it were possible to bypass the cable terminal pillars, excess loss of gas would possibly occur in the plastic joints because they are not intended to be hermetically sealed. Hence introduction of continuous flow pressure would probably have to be confined to main cables.

Ready Access Terminals

This fitting has been described in recent American literature. It is, in effect, a cable terminal box for use only with plastic aerial cable; it is suspended from the bearer wire of the cable and is not mounted on the pole. It consists of a metal framework with a synthetic rubber cover inside which are mounted one to five as required of 5 pair screw terminals tailed in the factory with plastic wire leads about 9″ long. In use, a short section of sheath is removed from the cable at the appropriate point in the span (which may be anywhere between the two poles where most convenient for the drop leads) and the fitting placed over this opening where it provides a sheath seal. The pairs, which are to be available at the R.A. Terminal, are cut, stripped and connected to the appropriate tails; the twist joint is covered with a silicone grease filled sleeve. Drop wire leads are terminated on the screw terminal, the drop wire clamp being held by a hook on the outside of the R.A. Terminal.

The advantages over the Cable Terminal box are that one joint is saved and installation time is reduced substantially; also the terminal can be better sited to feed the subscribers. It is also claimed that less skill is needed to fit an R.A. Terminal than to joint a plastic cable and fit a cable terminal box.

A weakness in the R.A. Terminal is that pairs in the distribution cable are multipled over a number of R.A. Terminals and frequent re-arrangement of pairs in them is the practice. Unless the work is done carefully, "birdsnesting" of the insulated wires in the Terminal will result and use of the wrong pair, splitting of pairs and similar troubles seem certain to arise in Terminals which have been installed for some time and regularly worked on.

In addition to aerial use, the 5 pair terminal units are used for above ground jointing of U.G. subscribers' distribution cable described previously. A 10 pair or larger cable is run along the rear alignment and at every second property line it is fed through a small jointing pillar consisting of one or more of the 5 pair terminals mounted at the top of a metal stake about 5′ long incorporating a covered riser; the terminal is covered by a cylindrical non-sealed metal cap. The stake is driven into the earth, leaving the terminal about 1′ above the surface; pairs in the cable are tapped in exactly the same way as described above for aerial application. Subscribers are fed by one pair U.G. drop wire leads. Normally four subscribers are fed from the one terminal. For rural subscribers, buried cables are tapped in the same way via above ground jointing pillars.

There is a limited scope for R.A. Terminals in Australia since they are suitable only for aerial cable and above ground jointing. Further, it is doubtful if they are as satisfactory as the normal arrangement for taking subscribers off aerial cables, which consists of a B.P.O. pattern joint attached to the pole and a Cable Terminal Box. Material costs are probably less, manhours probably comparable and the installation is undoubtedly superior to the Bell System one because there is no possibility of the "bird-nesting" trouble. The Bell System does not use pillar distribution and the R.A. Terminals, which readily provide a high degree of flexibility, are more valuable for this reason in the U.S.A. than in Australia; further, their plastic cable joint is much more elaborate, and saving one joint is hence more important in the U.S.A. than in Australia.

The application to U.G. distribution looks more promising except that damage due to vandalism might be expected. Development is taking place here along these lines, particularly for rural application, but based on the B.P.O. pattern joint. The B.P.O. joint should be somewhat more vandalproof and is also adapted to waterproofing; the R.A. Terminal is probably a little easier to install and is definitely easier for taking out subscribers' leads. Overall, there seems little to choose between the B.P.O. joint and the R.A. Terminal for this application, but given the B.P.O. joint as a standard item of stock, there seems no advantage in introducing a new stock item in the R.A. Terminal for this application.

Cable Entries and M.D.F.'s

These remarks are based on observations in six exchanges, two each in Montreal and Chicago and one each in Toronto and San Francisco. Individual features varied between the exchanges but all followed the same broad principles of cable entry. The oldest exchange visited was in San Francisco and was opened in 1933, and the newest was in Toronto and was not yet cut over; principles of cable entry were the same in each case. The striking feature in each exchange was the lack of congestion in the cable chamber. Compared to Australian practice there were three evident differences only:—

1. The cable bearers are two cables wide, not four wide as in Australia.
2. Island racking is provided in smaller exchanges; wall racking is provided as well as island racking in the large exchanges; in very large exchanges, more than one island suite may be provided.
3. The pothead joints are not necessarily placed immediately under the M.D.F. verticals which they serve.

In addition, entry to the exchange is always by conduit. Entry tunnels are not used. The number of ducts entering the cable chamber is strictly aligned with the number of positions available for cables on the bearers in the cable chamber in the ultimate. The ducts enter in groups of two wide, each group corresponding to a cable rack and the ultimate number of ducts vertically is the same as the ultimate number of bearers on the vertical.

Thus as many positions are provided for cable on the cable racks as there are ducts entering the chamber and they correspond both vertically and horizontally and each duct is associated with a particular position on a cable rack. Each duct and its corresponding rack position are in the same vertical and horizontal alignment; the rack extends to the end of the cable chamber and cables lead directly from the ducts on to the bearers. This suggests that duct entries are preferable to tunnel entries. Cables can be drawn into the ducts in any order and are placed immediately on the corresponding rack position. Crossovers of cable are unnecessary and the worst difficulty which can arise is that, if the outer position on the bearer is occupied, a cable will have to be manhandled over it to get to the inner position. This is a relatively simple task, since the bearers support two cables only.

Pothead joints are usually made horizontally not vertically. Those for the outer rack may be attached to the overhead structure of the racking so that they are above the aisle between the racks. Potheads are made at any horizontal point which is convenient and may be some distance from the M.D.F. vertical which they serve. Considerable lengths of tail may be involved.

Compared to Australian practice, a wider cable chamber is needed because of the use of two wide cable bearers against four wide bearers. However, since horizontal pothead joints are used, a saving of perhaps 2′ in depth results which probably compensates for the building cost of the extra width of chamber.

The Bell System techniques do not differ greatly from Australian ones, but appear much more effective as no congestion was evident in the cable chambers and quite plainly there would never be any difficulty in terminating in the building cables to the maximum capacity of the duct system.

Dealing with some other aspects of cable entry, in most cases the ducts entering the cable chamber were sealed with hydraulic cement, including the ducts in which cables have been installed. The cement was merely worked around the outside of the cable. A rubber and metal plug for sealing ducts similar in principle to the expanding plug used in the B.P.O. pattern cable joint was also seen.

Regarding riser cables, 300 pair textile insulated, lead covered appeared to be the size most widely used. These fit in with 300 pair line side M.D.F. verticals. Bell of Canada regularly use 900 pair risers. Here, the sheath is stripped from the cable immediately it emerges from the slot in the floor into the M.D.F. space and the conductors are separated into three groups of 300 pairs, one of which serves the immediate vertical and the other two serve the vertical on either side. The use of large riser cables avoids congestion in the cable chamber and also reduces the size and difficulty of making the pothead joints. The 900 pair risers are frequently used in association with 2,700 pair cables.

An interesting item seen was the M.D.F. Terminal Unit. This unit, recently introduced by the Western Electric Co., consists of a length of riser cable tailed in the factory to the line side M.D.F. termination fitting. It is supplied to the job with the correct length of tail, and installation merely requires screwing the fitting in the appropriate position on the M.D.F. vertical, jointing the tail to the U.G. cables and running jumpers as required. It avoids the labour on the job of cutting the riser cable to size, stripping and fanning out the end and terminating the wires on the M.D.F. tags. The M.D.F. fitting is a plastic unit into which protective apparatus can be plugged on lines requiring protection. The fitting originally terminated 300 pairs, but it proved cumbersome to handle and has been replaced by a 100 pair unit. This now introduces the problem that too many tails are taken from large cables and is introducing complexities in the pothead joint and in handling the riser cables which offset part of the gain due to factory termination. At American wages there is probably a worthwhile saving involved in factory termination of the riser cable, but this is doubtful at Australian costs.

In some of the exchanges visited there was running the full length of the M.D.F. a slot in the floor between the cable chamber and the M.D.F. room in place of the pipes. It is much easier to work the riser cable through the slot than to thread it through a pipe, and this feature is one that should be adopted. Fireproof slats are used to cover the slot.

As an example of Bell practice, Garden exchange, Toronto, is a brand new exchange. The cable chamber is double entry type and 72 ducts enter it. The average cable size in the life of the exchange will be about 2,000 pairs. In other words, about 150,000 cable pairs will eventually terminate there. A 5-1 ratio of pairs to subscribers appeared to be a typical ratio, which means that this exchange will have about 30,000 subscribers in the ultimate. The exchange had about 7,000 subscribers at cut-over. The M.D.F. verticals are 400 high protected and 800 high unprotected. The riser cables in the pothead are 900 pair textile insulated lead covered. The entry cables, wherever possible, are 2,700 pair 4 lb.

The M.D.F. in most cases was much like the Australian type except that all the protection appeared on the line side. The equipment side had tag blocks only and the line could not be opened on the equipment side. These tag blocks were horizontal, not vertical. In one exchange in Chicago, and a general rule in San Francisco, a double-sided cable terminal and test frame is used separately from the M.D.F. proper. This frame is immediately above the cable chamber and all the outside cables terminate and are protected on this frame. It has no jumpering facilities and permanent cables lead to a separate M.D.F., consisting of tag blocks only where the jumpering is carried out. This appeared of value in one case only, that is in an old building where equipment has been replaced by newer and more compact equipment. The building will accommodate more lines, but frame space is not available. In this case a larger number of cable pairs can be terminated and protected and the jumpering function carried out at some other point convenient to the equipment.

It is well known that telephone plant protection practices in the Bell System are much more stringent than in Australia. Details of their practices have been studied in connection here, but some of the factors determining their attitude towards protection are not very well known. Some of them are set out below, but, before stating them, the size and diversity of the U.S.A. and Canada should be mentioned and the variety of social, economic, climatic and geographic conditions which exist and the difficulties of making generalizations which are not misleading because of the number of exceptions which exist. For instance, power authorities range from bodies such as the Ontario Hydro-Electric Power Commission, one of the world leaders, to small local distributors. The position in the telephone industry is somewhat similar, ranging from the Bell System to the small independent operator. Likewise, the effectiveness and authority of regulatory bodies will vary widely. Protection rules are drawn up to meet probably poorer than average but not the worst possible conditions.

The universal application of joint use, particularly on poles carrying H.V. power wires, means that there is substantial risk of metallic contact with the power system and of heavy induced voltages. The danger is increased because both the mechanical and electrical standards of some of the power authorities are poor by Australian standards. Further, the Bell System has no superior legal status compared with the power authorities and cannot enforce operating practices on the Power Authorities in the way that Post Office telephone administrations can. Thus the telephone authority in North America must be prepared to cope with bad phase loading and sudden changes in phase loadings on H.V. lines. Voluntary power co-ordination takes place between the telephone and power systems but this does not have the force of Government Regulation and, further, the voluntary rules cannot be as favourable as rules drawn up and enforced by the Post Office. Further, in the U.S.A., there are a greater number of power authorities and while the average standard may be high, there are certain to be many who either cannot or will not operate their transmission and distribution systems in a manner that meets the reasonable needs of the telephone system.

Consequently the Bell System is forced to take more stringent steps than other telephone administrations to protect its plant from power operations.

Another factor is the Undewriters' Regulations. There is a great fear of fire in the U.S.A.; for instance, it is quite marked the number of public places where smoking is forbidden and the way people always faithfully observe the prohibition. The factors contributing to the fire risk in some areas are inadequate building regulations and lax electricity wiring rules. For instance, "do it yourself" house wiring is legal and commonplace; the practice is not as lethal as it sounds because the system operates at 110 V. However, there is obviously considerable fire risk involved. As a result, the Underwriters' Regulations are stringent and conservative. The Bell System protection practices conform to their regulations.

Bad lightning conditions in the U.S.A. are a factor influencing protection practice. Comparing the two countries the isoceraunic level in almost all the settled part of Australia is under 20, whereas most of the U.S.A., including the most densely populated areas, exceeds 30, and over a large part of the country is in the 40-60 range.

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A PENTACONTA CROSSBAR P.A.B.X.

*K. V. SHARP, A.R.M.T.C.**

INTRODUCTION

With the opening of the Myer Chadstone Shopping Centre, Melbourne, on 4th October, 1960, a 200 extension C.G.C.T. Pentaconta Crossbar Trada 18 ES P.A.B.X. was cut into service for Myer Emporium Ltd. Installation work was carried out by Standard Telephones and Cables Pty. Ltd., under the direction of Mr. G. Migniot, a representative of the manufacturing company, Compagnie Generale de Constructions Telephoniques. At the time of cutover 150 extensions were connected. Incoming and outgoing exchange lines totalled 20 and 15 respectively. Incoming lines are provided from Motor Uniselector Large Group Final Selectors at Oakleigh Exchange and outgoing lines are allotted scattered numbers throughout the exchange number range. The purpose of this article is to provide an introduction to the principles of Pentaconta Crossbar working as applied to this P.A.B.X., and to discuss trunking, facilities, switchboard operation, installation techniques and other points of interest.

THE PENTACONTA CROSSBAR P.A.B.X. SYSTEM

The basic unit in the Pentaconta system is the crossbar switch, which, employing the well known principle of horizontal bars coupled with a doubling or switching bar, provides 52 outlets any one of which can be connected to one inlet. To provide 52 outlets the switch is made up of 13 horizontal bars called selecting bars and a 14th bar, the doubling bar. Each selecting bar, in conjunction with an operating bar under the control of a magnet known as the vertical magnet, is capable of closing two spring pile ups — an upper and a lower. Hence we have $2 \times 13 = 26$ outlets. The 14th bar is used to divide these 26 outlets once again into two series to give $26 \times 2 = 52$ outlets (Fig. 1).

FIG.1.

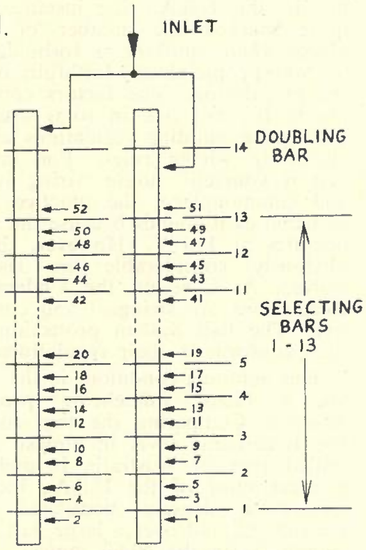

Fig. 1.—Arrangement of 52 Outlet selector. Connection of any outlet to the inlet requires operation of 1 selecting bar plus the doubling bar.

Usually four wires are available for each inlet and each outlet. However, it is possible to add to the spring pile-ups to provide five wires. By employing the 14th bar as a selecting bar, instead of a doubling bar, it is possible to obtain either 8-wire or 10-wire circuits. However, the number of outlets available from the selector is then reduced to 28, i.e., 14×2. This principle is exactly that employed by the more familiar L.M.E. crossbar switch, but has been extended, by the addition of more horizontal bars, to increase the number of outlets available.

THE MULTISWITCH

Individual crossbar switches, shown in Fig. 2, are mounted side by side in a frame to form a multiswitch. The multiswitch in the P.A.B.X. has 19 crossbar switches mounted. Horizontal multiplying over the multiswitch is employed, the 52 outlets, therefore, being available from any selector. (See Fig. 3.) Each electromagnet for either horizontal or vertical bars has a set of "off-normal" contacts associated with it. These are operated by an extension off the armature and are used for control purposes. Contacts in the selectors are made of precious metal and in all cases are twin contact type. Commoning wires for connection of inlet to outlet are of rectangular cross-section with a layer of precious metal 0.1 mm. thick over the contact side. The multiswitch frame is

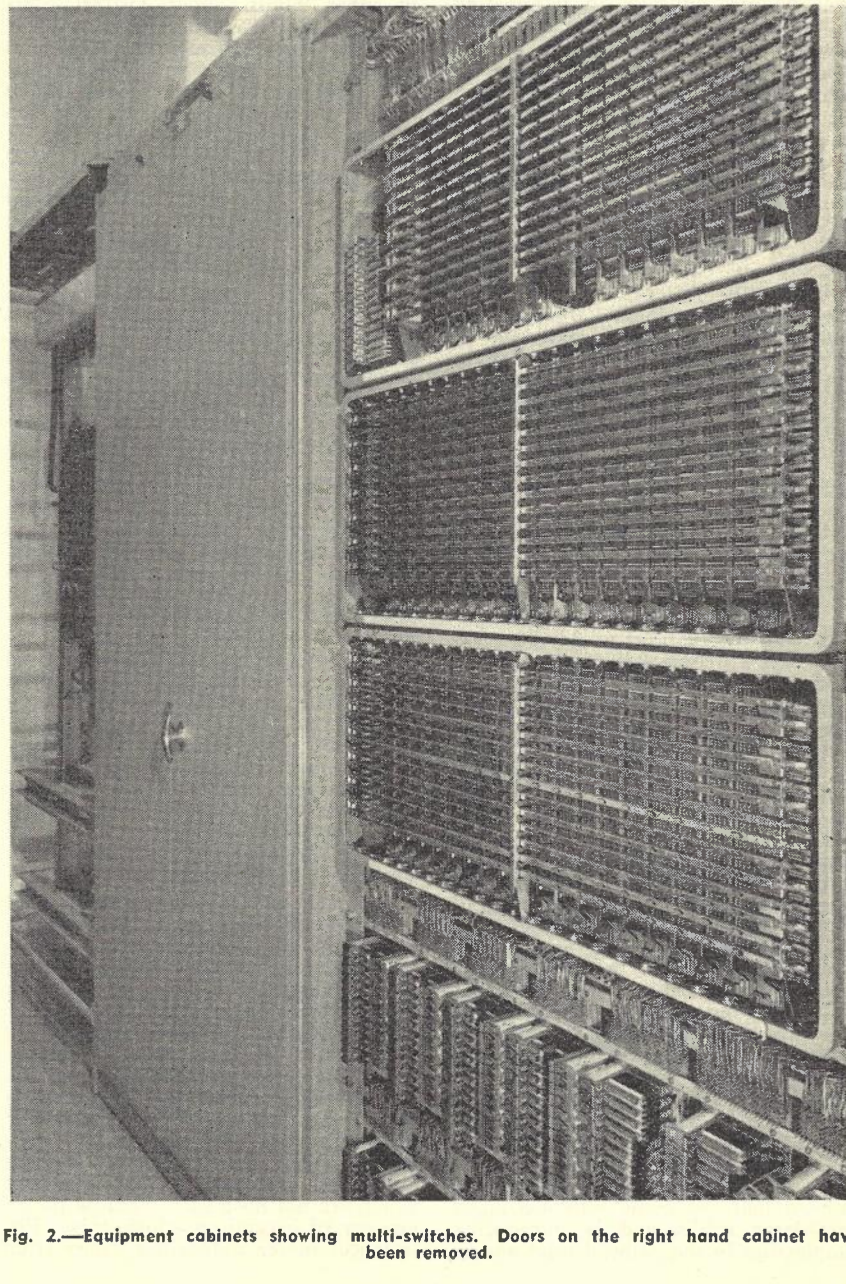

Fig. 2.—Equipment cabinets showing multi-switches. Doors on the right hand cabinet have been removed.

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*See page 155.

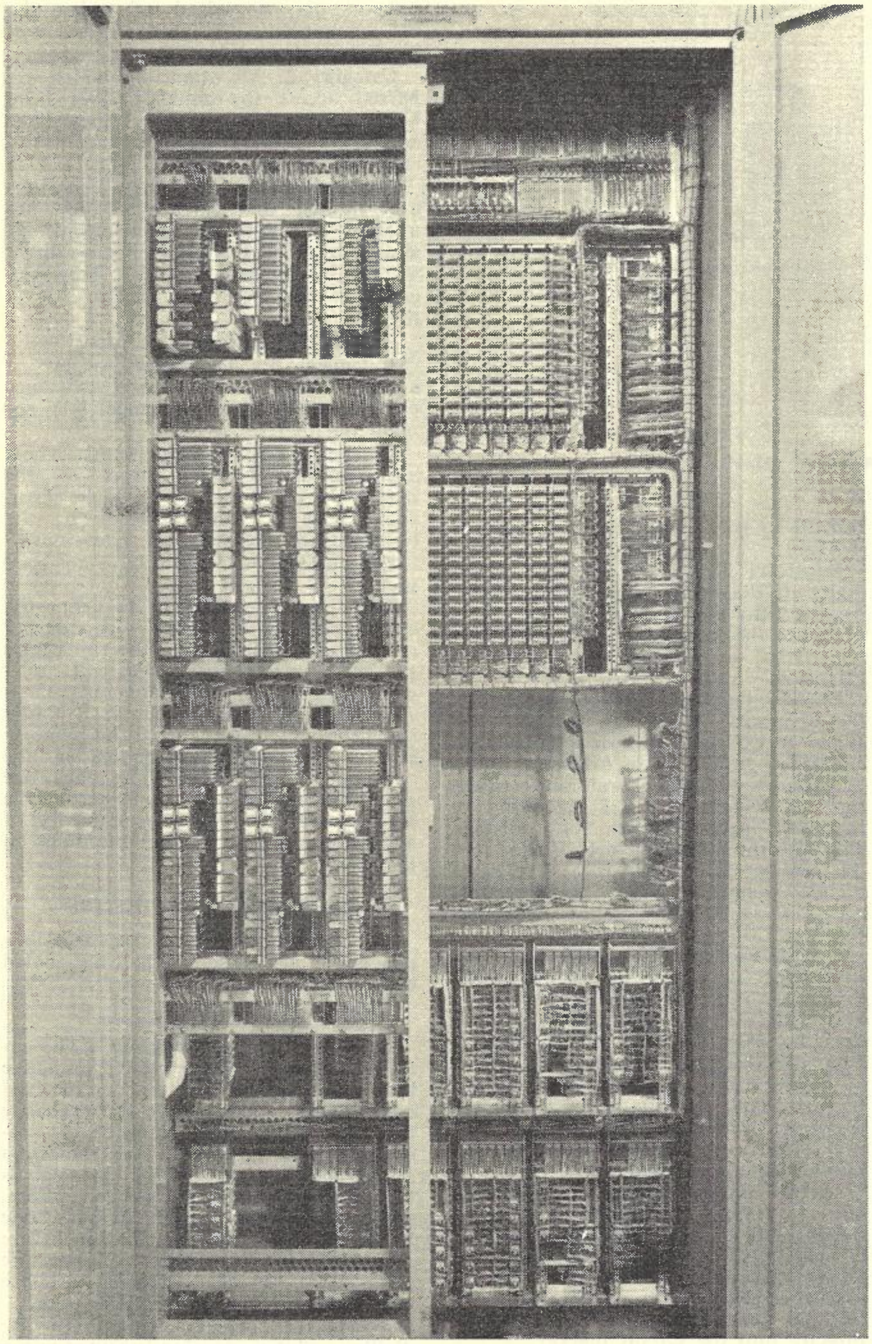


Fig. 3.—Rear view of multiswitches, showing horizontal multipling. Receivers can be seen on the left, and rear view of marker-translators bottom right.

of sheet metal with stiffening ribs to provide rigidity. Dimensions of the multiswitch are 2′ 11″ x 1′ 3¼″. Mounted also in the multiswitch frame are some of the relays associated with the control of the multiswitch magnets.

RELAYS

Several different types of relays, including high speed relays are used in the equipment and on the normal relays used for control purposes, variations of coil and armature types are employed. Armatures and coils are used which can operate any number of spring piles up to three, the springsets being mounted side by side. Hence the widths of both armatures and coils vary, narrow coils and armatures are used for one springset and wide for two springsets or more. The yokes used mount from one to three springsets and one to three small coils or one large coil.

Residual gap on relay armatures is determined by means of a shim-like palette which is welded to the face of the armature opposite the pole-face. To alter the residual gap the armature is changed, a range of armatures being available each with a different residual palette. As in the multiswitch all relay contacts are precious metal and twin type contacts. All types of contacts (make-before-break, changeover, etc.) are employed, including many "x" contacts. Tensioning of contacts is done by means of a common spring and a lifting card, the contact springs themselves not being adjusted for tension. Fig. 4 shows some of the relay types employed.

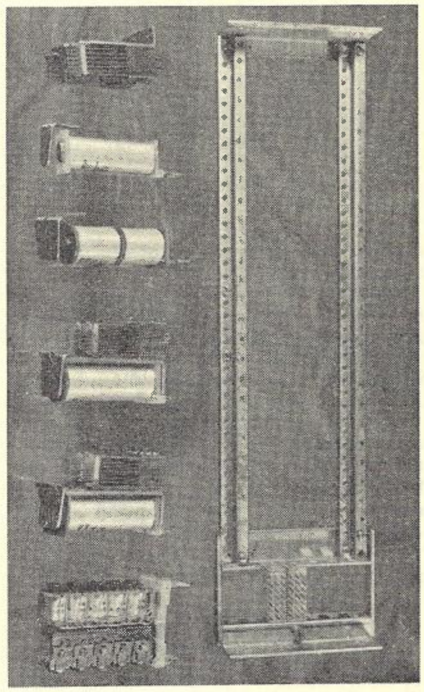


Fig. 4.—Relay types used in the P.A.B.X. On the left is shown a code storing relay.

SIGNALLING

All internal signalling within the Pentaconta equipment is done in two out of five code, i.e., by having a coding system whereby digit information is changed from loop-disconnect impulses, as generated by a standard telephone dial, to earth potential applied on any two wires selected out of a possible five wires connecting sections of equipment together. The 2/5 selection provides 10 combinations, exactly the number required, and has the added benefit of error-detection insofar as over-information or under-information is concerned, i.e., equipment designed to receive two and only two earths will immediately recognize an error condition if one or more than two earths are received.

EQUIPMENT MOUNTING

All equipment is housed in crackle finish metal cabinets measuring 3′ 4″ x 7′ 9¼″ x 1′ 4″ and fitted with swing type locking doors. Five cabinets are installed, three on one side and two on the other with the multiswitches facing each other. The cabinets can be opened from either side and space at the back of the cabinets is used for the mounting of relay sets, magnetic counting relays which are used for circuit distribution,

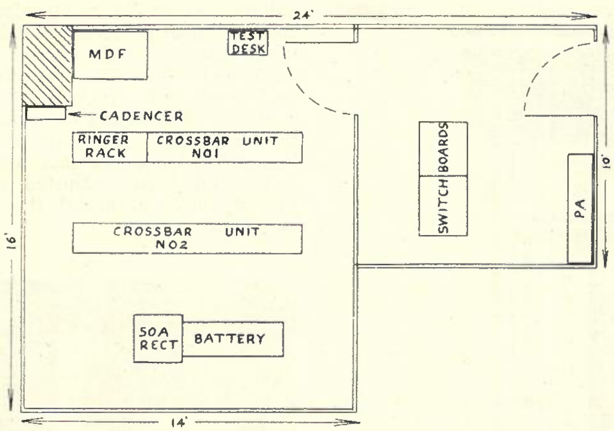


Fig. 5.—Plan of Equipment layout.

digit or code storing relays and markers and receivers.

Metal work inside the cabinets is finished in the golden-bronze coloured zinc chromate plating which has become very common in latter years, particularly in equipment of European manufacture. A cadencer, in which various cadence pulses are generated for time control of circuits in the P.A.B.X., and a small test desk are both wall mounted separate from the main equipment cabinets. All equipment, with the exception of the operators' positions is in a room 16′ x 14′ x 14′ high. A plan of the equipment layout is shown in Fig. 5.

SOLDERLESS WRAPPED CONNECTIONS

Termination of internal wiring inside the cabinets is completely unsoldered. All connections to tag blocks, multi-switches, relays, etc., have been made employing the process of solderless wrapping. This process consists of pressure wrapping a bare wire around a terminal which is usually square or rectangular, and which must have sharp corners. The wrapping is done with a small electric drill fitted with a special bit. The bit slides over the terminal whilst the wrapping wire, already stripped, is fed into another hole nearer the circumference of the bit. As the bit rotates the wire is wrapped around the terminal. The wire tension on the terminal provides a very clean and very tight termination. During wrapping a complex set of tensile and compressive stresses is developed between the wire and the terminal. These provide the binding and contact forces between the wire and the terminal and enable a gas-tight seal to be made at the contact surfaces. For further information on the process of solderless wrapped connections, the reader is referred to Reference 1.

DEFINITION OF TERMS

(Refer Fig. 6.)

Junctor: A relay set through which the speech path is permanently established whilst a call is in progress is termed a junctor. Hence we have shown on the trunking diagram relay sets designated Feed Junctor (F.J.), Call Back Junctor (CBJ), Night Service Junctor (NSJ).

Receiver: The relay set into which digits are dialled and then stored before passing into the marker and translator is termed the Receiver. Dial tone is also fed from a receiver to a calling extension.

Encoder Register: Signals generated by the operator's keyset are in 2/5 code. When an exchange call, or a call via an assistance circuit to an extension, is to be originated by the operator it is necessary to convert this 2/5 signalling to loop-disconnect impulses for transmission into the automatic network, or into the receiver in the P.A.B.X. The complicated relay set which performs this function is known as an Encoder-Register.

Circuit Finder: The multiswitch used to connect operators' circuits to either exchange lines or internal circuits is known as a circuit finder. This selector uses the 14 horizontal bars as selecting bars and therefore has only 28 outlets. Since there are 35 exchange lines and four assistance circuits connected to the P.A.B.X., vertical multipling over two multiswitches is used to provide the full number of outlets required.

Circuit Marker: The circuit marker is used to control the selecting and connecting of a predetermined operator's connecting circuit to an external or internal circuit, i.e., exchange line or assistance circuit. The 2/5 code generated by the operator's keyset is received directly into the circuit marker.

FACILITIES
SERVICE CATEGORIES

As is usual practice in P.A.B.X. installations it is possible to bar some extensions from access to certain facilities. The extensions, therefore, must be grouped into categories which will define the degree of barring which is to be applied. The following categories have been used:—

Category 1: Call back junctors which use line circuits. and unallotted lines are given this category and are barred from being connected to an extension on a local internal call. Selection does not take place and busy tone is fed back to the calling extension. Call back junctors may be seized only when the call back facility is required: this will be discussed later in this section.

Category 2: All extensions which are barred access to exchange lines have been allotted this category; they have access, however, to all other extensions, assistance circuits, and tie lines.

Category 3: Semi-restricted extensions are allotted this category. They are allowed access to all other extensions, assistance circuits, tie lines but no **direct** access to exchange lines. However, access to exchange lines is allowed via the operator.

Category 4: Unrestricted extensions.

Category 8: Tie lines; access is allowed to all extensions and assistance circuits but not to exchange lines or other tie lines.

Category 9: Assistance circuits. These are two-way circuits direct to the operator's positions over which extensions may call the operator or the operator has access to all extensions.

Categories 5, 6, 7 and 0 have not been used.

The strapping necessary to define the category of any extension is carried out on a small tag block on the top centre of the cabinets housing the call finder equipment and the extension line relays. This tag block is covered with a plastic shield on which is engraved the numbering of the tag block indicating the extension appearances. The tags are readily accessible and so it becomes a simple matter to alter the category of any extension by changing strappings on the block.

EXTENSION FACILITIES

The facilities available to extensions depending, of course, on their designated categories are as follows:—

Exchange Line Access.

(a) **Direct Access (Outgoing):** The extension dials 0, a free outgoing exchange line is seized and dial tone is received from the exchange. When the exchange line is seized the extension is reselected over the Trunk Final Selectors and Trunk Selectors. If the extension is barred access to outgoing exchange lines, the category check results in busy tone being fed to the calling extension before marking or selection of an exchange line takes place. If all exchange lines are busy the extension receives busy tone.

(b) **Indirect Access (Outgoing):** By dialling "9" the extension is routed to the operator, who dials the required number and reverts the call to the calling extension.

(c) **Incoming Calls:** All incoming calls are received on the operators' positions, the desired extension is obtained by the operator and the incoming exchange call is transferred to the required extension. This operation is dealt with more fully later under the heading "OPERATORS' FACILITIES".

The Call Back Facility.

This facility is available to any extension connected to an exchange line, incoming or outgoing, and is not affected by whether the connection was made by direct or indirect access.

(a) **Call Back to Another Extension or Tie Line:** With the exchange call connected, the extension dials "2" and is connected to a Call Back Junctor, while a "hold" is applied to the exchange line. The number of the second extension is then dialled over the call back circuit after receipt of dial tone. Ring is received at the second extension and the call is answered. If transfer of the exchange call to the second extension is now required, and the second extension is not barred access to exchange calls, transfer is completed by the first extension replacing his handset. The exchange call is then connected to the second extension by reselection via trunk selectors and trunk final selectors and the call back circuit is released. Successive calls back may be made any number of times. If transfer to the second extension is not required, the first extension dials "1" and the exchange line is reconnected to the first extension, the second extension being released. Further calls back may be made if required.

(b) **Call Back to the Operator:** In the case of a call back to the operator, the extension does not dial "2" but simply "9" for the operator. Call back junctors are not used for call back to the operator, the connection being affected via the exchange line circuit. The operator answers and is connected to the calling extension via the circuit finder and operator's connecting circuit, the exchange line once more being supplied with a "hold". Transfer of the call to the operator is again effected by the extension replacing the handset, while reversion of the call to the extension is again achieved by the extension dialling "1".

(c) **Abandoning a Call Back:** If, for any reason, the extension wishes to abandon the call back before all digits of the second extension have been dialled and hence selection of the second extension completed, the extension simply depresses the switch hook for about one second. The call back circuit is then released and the extension is reconnected to the exchange line.

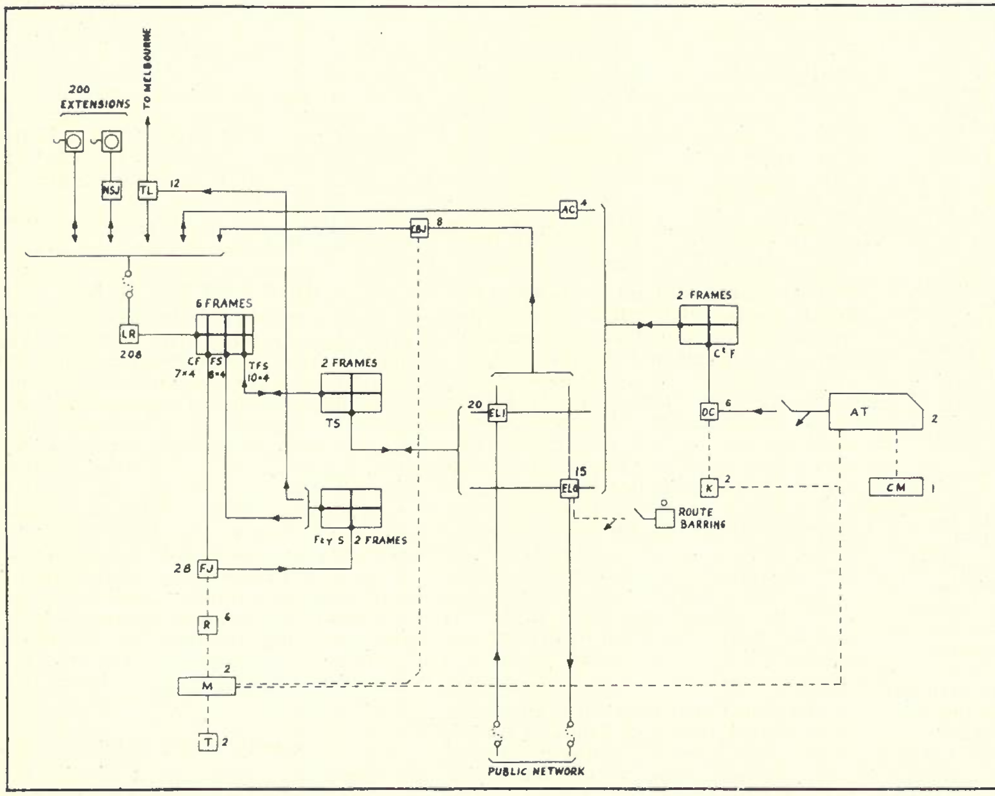
(d) **Faulty Operation during Call Back:** Any faulty operation during call back results in the return of the line to the operator. If, for example, the depressing of the switch-hook for abandoning the call back was too prolonged, or the first extension restored his handset before the second extension answered, the exchange call would appear as a "recall" on the operator. Extensions in category 2 may be called in call back for information but cannot receive a transfer, nor originate a call back, since calls back can be originated only by extensions in communication with exchange calls. Extensions in category 3 may be called in call back and receive a transferred exchange call. When in communication with an exchange line a semi-restricted extension may originate a call back and transfer.

OPERATORS' FACILITIES

(a) **Call to an Extension:** The operator calls an extension over one of the assistance circuits. The encoder register is used to change the 2/5 code signals to loop disconnect impulses for reception in the receiver, via the feed junctor, and the call is established as a local call. The full establishment of a local call and other calls will be discussed fully under the heading "TRUNKING".

(b) **Answering an Extension:** The operator can receive calls from extensions via the assistance circuits the call being indicated by a lamp on the operator's position. The appropriate button is pressed and the operator is connected to the assistance circuit via an operator's circuit and the circuit finder selector.

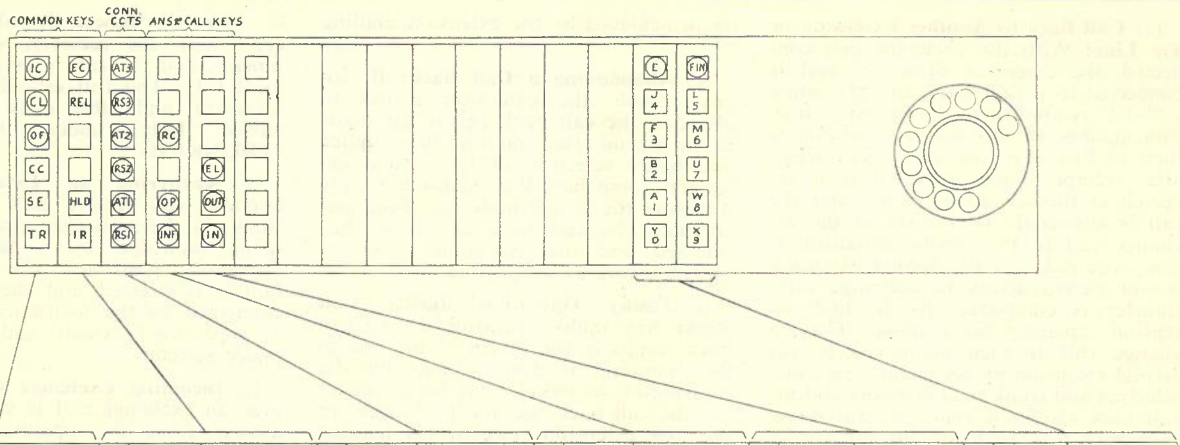
(c) **Incoming Exchange Calls:** Whenever an exchange call is waiting on an answer from the operator, the "IN" lamp on the operator's position lights. Only one "IN" lamp is installed per operator's position and it remains glowing until all incoming calls have been answered. To answer a call the operator presses the button associated with the "IN" lamp, and is connected via an operator's connecting circuit and the circuit finder to an incoming exchange call. At present, exchange line calls are answered with priority of answer being given to the lowest numbered line. This has the disadvantage that at busy periods, with most incoming lines calling, the late numbered lines, e.g., 16-20, may wait a considerable time for answer, while lower numbered lines are answered, released, recall and are answered again, possibly several times, if holding time is short. Modifications are at present in hand to incorporate a gated queueing



LEGEND	
AC	ASSISTANCE CIRCUIT
CBJ	CALL BACK JUNCTOR
CF	CALL FINDER
C^{t}F	CIRCUIT FINDER
CM	CIRCUIT MARKER
FJ	FEED JUNCTOR
FS	FINAL SELECTOR
FtyS	FIFTY SELECTOR
K	KEYSENDER (ENCODER REGISTER)
LR	LINE RELAY
M	MARKER
NSJ	NIGHT SERVICE JUNCTOR
OC	OPERATOR'S CIRCUIT
R	RECEIVER
T	TRANSLATOR
TFS	TRUNK FINAL SELECTOR
TL	TIE LINE
TS	TRUNK SELECTOR
ELI	EXCHANGE LINE INCOMING
ELO	EXCHANGE LINE OUTGOING
AT	ATTENDANT SET

NUMBERING SCHEME
0 DIRECT ACCESS EXCHANGE LINES
200 TO 399 EXTENSIONS
400 TO 599 SPARE (EXTENSIONS)
6 TIE LINES
7 CREDIT AUTHORIZATION
8 SPARE
9 OPERATOR

Fig. 6.—Trunking diagram and legend.



DESIGNATION	BUTTON	LAMP		DESIGNATION	BUTTON	LAMP		DESIGNATION	BUTTON	LAMP		DESIGNATION	BUTTON	LAMP		DESIGNATION	BUTTON	LAMP		DESIGNATION	BUTTON	LAMP	
		STEADY	FLASHING			STEADY	FLASHING			STEADY	FLASHING			STEADY	FLASHING			STEADY	FLASHING			STEADY	FLASHING
IC		INTERNAL CONNECTION		EC		EXTERNAL CONNECTION		AT3		AUTOMATIC TRANSFER FREE	BUSY									E		EXTERNAL CALL	ERROR
CL	CLEAR (CANCEL INTERNAL CONNECTION)	BARRED ACCESS	ERROR	REL	RELEASE (CANCEL INTERNAL CONNECTION)			RS3	RESEIZE CONNECTING CIRCUIT NO3	SEIZURE	HOLD									FIN	FINISH	KEY SET SEIZED	
OF	OFFER	BUSY 1st DEGREE	BUSY 2nd DEGREE					AT2		FREE	BUSY	RC	ANSWER RECALL	EXCHANGE LINE RECALL									
CC	CHAINCALL							RS2	RESEIZE CONNECTING CIRCUIT NO2	SEIZURE	HOLD					EL		EXCHANGE LINE GROUP					
SE	SPEAK EXTERNAL			HLD	HOLD			AT1		FREE	BUSY	OP	OPERATOR CALL			OUT	SEIZE OUTGOING EXCHANGE LINE	ALL LINES BUSY					
TR	TRANSFER			IR	INTERNAL ROUTING			RS1	RESEIZE CONNECTING CIRCUIT NO1	SEIZURE	HOLD	INF	ANSWER INFORMATION CALL	INFORMATION CALL		IN	ANSWER INCOMING EXCH LINE	CALL					

Fig. 7.—Keyset layout and code indicating significance of lamp signals.

system to ensure that calls are answered in the order in which they arrive. The calling line may be "held" by the operator pressing the "hold" button. The operator may then continue with other operations on the remaining operators' connecting circuits. The hold facility can be applied only to calls which have been answered by the operator and on which switching has not been commenced. Having answered the incoming call the operator determines the required extension number and proceeds to direct the call. The "IR" (internal routing) key is pressed and the required extension number is keyed on the push button dialling keyset on the operator's position. The "FIN" button is pressed at the end of dialling and ring current is fed to the required extension. The operator may now transfer the incoming call to the extension without waiting for the extension to answer, or may receive an answer from the extension before transferring. Transfer is effected by pressing button "TR". When transfer is complete the exchange line is connected to the required extension via the exchange line circuit, trunk selector and trunk final selector.

Transfer, however, can be prevented by the following:—

(i) The called extension may be barred access to exchange calls, in which case the operator receives busy tone and gets a flashing lamp indication on the board.

(ii) The called extension may be busy, indicated by a steady glowing of the "OF" lamp, no busy tone being returned to the operator.

The operator now has two alternatives:

(i) The call may be "parked" and will wait for the connected call to conclude and the extension to become free, before sending ring to the extension (equivalent to the "camp on busy" of the C. and C.A. type P.A.B.X.). To do this the operator simply presses the "TR" transfer key as normal. The "parking" facility can be applied only if the extension is "first degree busy", i.e., a call in progress and no other call parked. If the extension is "second degree busy", i.e., a call connected and another parked, the "OF" lamp will flash on and off, instead of glowing steadily. The operator can hold the third call on the operator's circuit if required, although this may restrict the answering of incoming calls, since calls are not cleared from the operators' circuits until the required extension answers.

(ii) The operator may, by holding the "OF" button depressed, intrude, with warning tone, on the existing call and offer the next call. This facility has special use in offering incoming trunk line calls to a busy extension.

(d) **Outgoing Call on Exchange Line**: By depressing the "OUT" button the operator is connected via an operator's connecting circuit and the circuit finder to a free line in the outgoing exchange line group. Dial tone is received from the exchange and the required network number is set up and transmitted from the operator's keyset. The network number can be either dialled in the ordinary way or can be punched up on the push button keyset. If the push button keyset is used the encoder register must be used to convert the 2/5 code signals into loop-disconnect impulses for transmission into the automatic network. In this case the digits are stored in the encoder register and retransmitted over the exchange line.

(e) **Chain Calls:** If, when the operator is connected to an exchange call, it is found that several extensions are required in succession by the one caller, the operator may, by depressing the "CC" button before transfer of the exchange call to an extension, cause the call to revert to the operator when the first extension hangs up, provided, of course, that the caller still holds the exchange line circuit. The operator can then transfer the call to the second extension required. This facility may be used as many times as required.

(f) **Tie Line Calls:** The operator has access to the tie lines and calls are made to these in the same way as calls to extensions except that the tie line prefix must be set up and transmitted from the keyset first. Dial tone is then received from the distant P.A.B.X. and the wanted number in the distant P.A.B.X. is then set up and transmitted. Since tie line calls must be set up via an assistance circuit and a receiver the encoder register is again called into use.

REDUCED SERVICE

This condition is introduced by means of a single locking type telephone key and is provided for the reception and transfer of exchange line calls at times when the switchboard is not staffed, but there is someone in attendance on a number of the extensions. Incoming calls are indicated by the ringing of bells suitably placed throughout the building. Any extension may answer the call by lifting the handset and dialling "9"; the call thus answered may be transferred to another extension by the use of the call back and transfer facility already discussed. If more than one exchange line is being received the bells will continue to ring, to exchange ring current, until all the calls have been answered.

GROUPED LINES

There are eight groups of six lines available which have "rotary" facilities, if such a term can be applied to crossbar equipment. The groups must be called from the first number in the group otherwise the group facility will not operate and the number called will be rung normally. One of these groups is used for the assistance circuits.

TIE LINES

Twelve both-way tie lines are provided between the Chadstone P.A.B.X. and the Myer City Store. These also serve as Credit Authorization lines. For normal tie line usage the extension dials "6", waits for dial tone, and then dials the required extension in the distant P.A.B.X. For Credit Authorization the extension dials "7", waits for dial tone, dials the required credit number and passes the information required in the credit section to the answering extension. By operation of a key in the credit section, and the subsequent reversal applied to the tie line, an "OK" is stamped on the customer's docket at Chadstone. Discrimination between Credit and normal tie line usage is made by means of a relay set for each tie line in the P.A.B.X. equipment at Myer City Store.

TRUNKING (REFER FIG. 6)

Local Selection (Internal Call).

The calling extension lifts the handset, loops the line and operates the line relay. All free receivers are located and a free feed junctor is chosen and connected to a free receiver. The selection bars necessary to locate the calling extension on the call finder frame are now set and the category of the extension is passed to the receiver. The vertical magnet on the call finder frame now operates and the extension is connected to the receiver via the feed junctor. The extension receives dial tone from the receiver and the horizontal selecting bars are released, the connection being held by the vertical magnet. The extension now dials the required number into the receiver (three digits). The marker is now called for and seized if free and the marker in turn seizes the translator. The category of the calling extension is passed into the translator as well as the stored digits. The translator seizes the final selector frame and sets the selecting bars corresponding to the called extension. At the same time that the fifty selector frame is marked indicating the free links to the final selectors and the selecting bars set to connect one free link. End of selection signals are now sent to the marker and the categories of the calling and called party are compared. If connection is authorized, the marker tests the called line. If the line is free the fifty selector vertical magnet is operated as well as the final selector vertical magnet. The cut-off relay in the called party's line circuit is operated and ring and ring tone are fed out from the feed junctor. The receiver, marker and translator are released. If the called line is busy no connection is made through fifty selector or final selector, the call finder vertical magnet is released and busy tone is fed to the calling party from the call finder frame. When the called party answers ring and ring tone are removed by the feed junctor and through connection is established. The feed junctor is held throughout the call.

Direct Access to Exchange Line.

Selection of the called extension in this case proceeds exactly as for a local call up to connection of a receiver. The extension now dials "0" for an exchange line. The receiver recognizes this digit and calls for the marker without waiting for further digits. The marker and translator are seized and the caller's category and the dialled digit passed to the translator. On receiving this digit the translator sends a signal back to the marker — the marker feeds the signal back via the receiver and the feed junctor to the call finder frame. This signal results in the selecting bars, corresponding to the calling extension, being reset in the call finder frame of selectors. An end of selection is now fed back to the marker. The marker meanwhile has proceeded with the selection of an exchange line, after checking that the caller is entitled to access to exchange lines. An exchange line is seized and marks the trunk selector frame through which it is reached. The selecting bars are set and an end of selection signal is sent to the marker. The vertical magnets in the trunk selector and the trunk final selector are now operated. The horizontal bars release and connection is held by the vertical magnets. The call finder magnet is now released and in turn the feed junctor receiver, marker and translator are all released. The calling extension is trunked via line relay set, trunk final selector, trunk selector, exchange line circuit to an exchange line.

Connection of Operator to Incoming Call.

An incoming call via an exchange line circuit is indicated by a glowing lamp on the operator's position. By depressing the appropriate button the operator

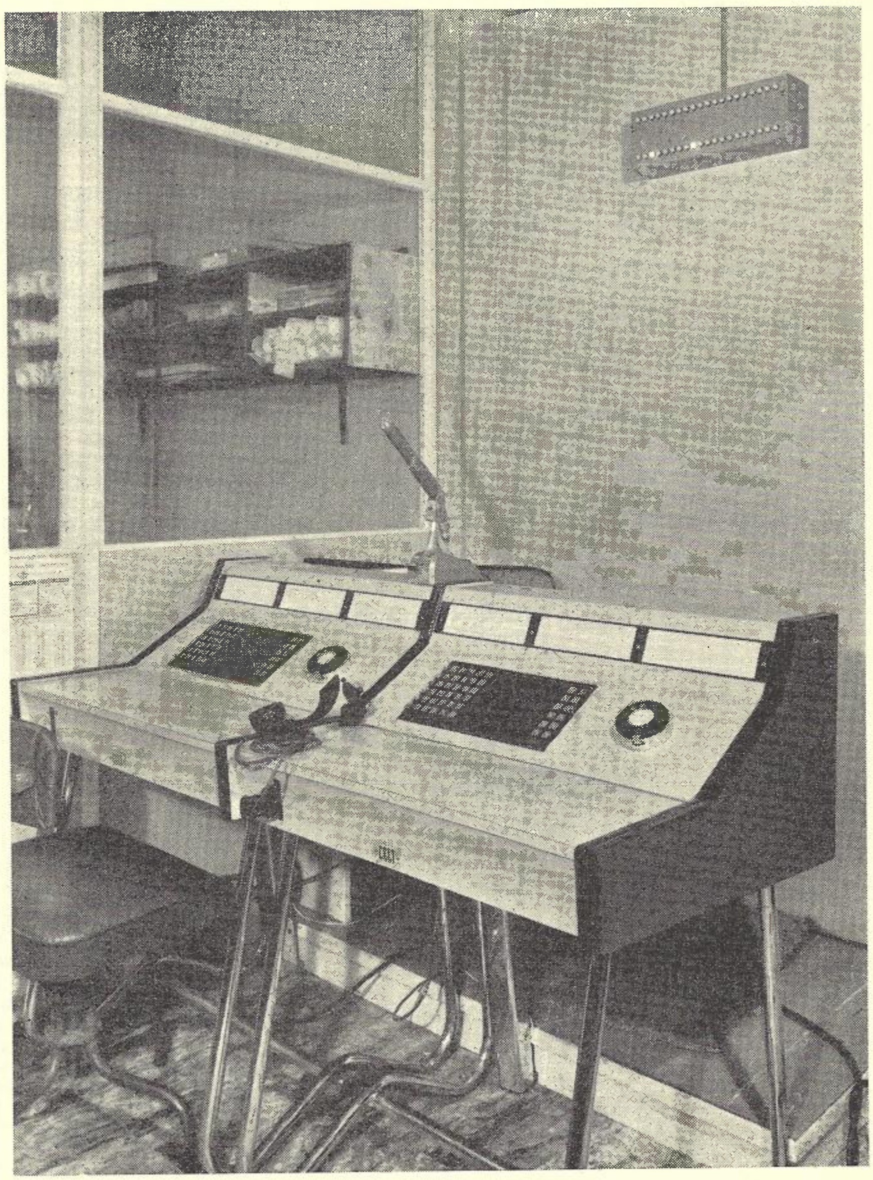


Fig. 8.—Operators positions, showing on the wall the exchange line indicating lamp strip.

seizes an operator's connecting circuit and calls into operation the circuit marker. The circuit marker controls the operation of a circuit finder by first positioning the required selecting bars for reception of the incoming call and then on receiving an end of selection signal by operating the circuit finder vertical magnet. The circuit marker is then released, the selecting bars are released and connection is maintained through the circuit finder by the vertical magnet. The exchange line is trunked via an exchange line circuit, circuit finder, operator's circuit to the operator's position. Since trunking of any call through the P.A.B.X. is a variation in detail only of the above three operations, it is not proposed here to give detailed trunking for any other calls.

LOAD DISTRIBUTION

In order that certain pieces of equipment are not continuously used while others are idle for long periods, load distributors have been incorporated to ensure selection, in turn, of various relay sets. Load distribution, in the form of magnetic counting relays, has been applied to feed junctors, outgoing exchange lines, and circuit finders. In addition, priority changing circuits have been included for such circuits as marker-translators (two in use) and operators' circuits (three per operator).

TIME SUPERVISION

Timed throwouts are provided in the equipment and applied mainly to the common equipment in order to prevent excessive unnecessary holding time of this equipment.

Feed Junctor Distributor: When a calling extension is being selected, if a feed junctor is not seized by the feed junctor distributor within two seconds, the timing circuit comes into operation and steps the distributor to test the next feed junctor. This process is repeated until a feed junctor is seized.

Receiver: With a calling extension connected to a feed junctor and received via a call finder selector, throwout takes place if a digit is not dialled within sixteen seconds. The extension is released from the feed junctor and the receiver and call finder selector are also released. Busy tone is sent to the extension from the call finder frame of selectors. Time supervision applies in between digits as well as before the first digit is dialled.

Marker-Translator: Once the marker-translator is seized and connected to a receiver a timing circuit comes into effect to ensure that digital information is passed from the receiver to the marker translator within two seconds. If the information is not passed the marker-translator, receiver, feed junctor, call finder selector are released and the extension is fed busy tone and must call again.

Incoming Call Throwout: If a caller hangs up before receiving an answer from the operator, the exchange line relay set is released after sixteen seconds. The call indication to the operator is cancelled. Pulses for the timing circuits are provided from the cadencer.

OPERATORS' POSITIONS

Two operators' positions are installed and are of the push-button cordless type. A full layout of the switchboard keyset, together with the significance of the lamp indications on the keyset is shown in Fig. 7. Some push buttons have lamps built into them so that the buttons themselves light on the application of signals. The buttons are then depressed to initiate the appropriate action. In addition some buttons have no operational action but are equipped with lamps. These are used solely for supervision. An example of one of these is the "E" or "ERROR" lamp on the dialling keyset. The two positions are mounted on chrome plated tubular steel frameworks and the tops of the tables are covered in laminated plastic. Keys for the switching to "reduced service", "bell cut off" for reduced service, etc., are mounted under the lift-up table top. Sufficient space is also provided under the table top for the storage of telephone directories, staff notes, etc. Telephonists' headsets are of the standard lightweight type, modification to the original switchboard circuit being necessary to improve transmission and reception.

Mounted on the wall of the switchboard room are two strips of 20 lamps, the top row indicating exchange line calls incoming, but not yet answered, the bottom row indicating exchange line calls answered, transferred and still in connection with an extension. (See Fig. 8.)

POWER SUPPLY

Power for the P.A.B.X. is supplied from an auto-control 50 amp. S.T. & C. rectifier and an enclosed cell battery of 200 AH capacity. The battery is mounted in a standard type battery cabinet.

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1. S. J. Elliott, "Solderless Wrapped Connections"; Bell System Technical Journal, Vol. 38, No. 4, page 1033.
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3. M. Verne, "Trada Pentaconta Private Automatic Branch Exchanges", Electrical Communication, Vol. 34, No. 1, page 3.
4. A. Mehlis and K. Klinkhammer, "Crossbar Citomat. A Development in Medium Sized Private Automatic Branch Exchanges", Electrical Communication, Vol. 34, No. 1, page 21.

LETTER TO THE EDITORS

Circuit Laboratory,
9 Spring Street,
18th August, 1961.

Dear Sir,

You may wish to publish the following problem in "Toppled-ology" for the recreation of your readers:

"Given six straight conductors of equal length, 1, and equal resistance, R. Arrange in a network so that the D.C. resistance across any one of the six conductors is always R/2, and, if a battery is applied across any one of the six conductors, only five of the conductors will carry current. The conductors may be joined at their ends in any configuration but must not be deformed otherwise."

Yours faithfully,

G. A. M. HYDE.

AMMONIA MASER OSCILLATOR

A. M. J. MITCHELL, K. G. ROOTS* and G. PHILLIPS**

Editorial Note: This article was published originally in "Electronic Technology", Volume 37, Number 4, April, 1960, and is reprinted with the kind permission of Her Majesty's Stationery Office, the United Kingdom Ministry of Aviation, and the Editor of "Electronic Technology". The equipment described is in use in the Postmaster-General's Department Research Laboratories as part of the Australian national frequency and time service.

INTRODUCTION

The operation of an ammonia maser was first described by Gordon, Zeiger and Townes.[1] We have built several ammonia masers since 1957 and record here their principles of operation, construction and performances as frequency references.

PRINCIPLES OF AN AMMONIA MASER

When electromagnetic radiation is transmitted through gases it is absorbed much more at certain frequencies than at others. The frequencies at which this marked absorption (resonance absorption) has been observed to take place extend from the visible down to audio frequencies. Atoms and molecules behave rather like radio stations and will "receive" radiation from their surroundings at the frequencies to which they are tuned and, under certain circumstances, will radiate energy at these frequencies.

In a molecular gas such as ammonia, for instance, the atoms and electrons constituting the molecule rotate, vibrate, and perform complicated motions about their centres of mass as the molecules themselves move about at high speeds, colliding with each other. The internal energy of each molecule is the vector sum of the energies of all the constituent parts. It has been found experimentally that internal energy of molecules may only vary by discrete amounts, and not continuously, so that in a volume of gas there will be molecules having internal energies E_1, E_2, E_3 . . . E_n, but no molecules having energies between these values. A molecule having internal energy E_1 will absorb energy from a radiation field so that its new energy is E_2 if the relation $h\nu_1 = E_2 - E_1$ holds, where ν_1 is the frequency of the radiation and h is Planck's constant. Similarly, $h\nu_2 = E_3 - E_2$ and $h\nu_3 = E_4 - E_3$ . . . so that the gas will absorb energy from the radiation at frequencies ν_1, ν_2, ν_3 . . . . . . ν_n. An analogy is the behaviour of a network of resistors and reactances which will absorb energy from a supply of varying frequency at discrete frequencies which turn out to be resonance frequencies of parts of the network.

Molecules which interact with a radiation field of frequency ν_1 and, as a consequence, increase their energies from E_1 to E_2, will tend to revert to their original state after the field has been removed. They will do this by radiating an amount $h\nu_1 = E_2 - E_1$ to their surroundings in the form of radiation of frequency ν_1. This process is known as relaxation by spontaneous emission.

Molecules whose internal energy is E_2 may also interact with the radiation field of frequency ν_1 and decrease their energy to E_1 by emitting a quantity or quantum $h\nu_1$. This process is stimulated emission, and the emitted radiation is in phase with the radiation field.

The probability that a radiation field of frequency ν_1 will interact with molecules of energy E_1 and excite them to state E_2 with accompanying absorption is approximately equal with the probability that this field will interact with molecules of energy E_2 and cause stimulated emission and transition downwards to state E_1. Thus, if a volume of gas containing equal numbers of molecules in states E_1 and E_2 were irradiated at frequency ν_1, the amount of absorption would be balanced by the emission, and there would be no observable effect. However, the distribution of molecules in the various energy states at ordinary ambient temperatures is a Boltzmann one, according to which

$$N_{E1} = N_{E2}\, e \frac{-(E_2 - E_1)}{kT}$$

where k is Boltzmann's constant and T the temperature in °K. The value of

$$\frac{E_2 - E_1}{kT}$$

for the 23870-Mc/s line of ammonia, when $T = 300°K$ is approximately 1/250, so that $N_{E1} = N_{E2}\,(1 + 1/250)$. The lower energy state has a slightly greater population than the higher one.

Thus, when a volume of gas is irradiated with a frequency ν_1, causing transitions between the levels E_1 and E_2, there will be a net absorption of energy, since there will be more molecules available to absorb energy than to emit energy. In practice, instead of ν_1 being a sharp line, broadening due to a number of causes (pressure, Doppler effect, wall collisions) takes place, and absorption takes place over a finite band of frequencies of which ν_1 is the centre frequency. Since this centre frequency is a natural constant of the gas, it may be used as a frequency reference. For such an application it is desirable to locate the centre of the band accurately, and the narrower the line, the easier this becomes. One way of reducing the line-broadening effect is to make use of the gas in the form of a molecular beam. Unfortunately, the number of molecules per c.c. present in the beam is only a very small fraction of those present in an absorption-cell experiment, so the signal-to-noise result of such an experiment is too low to be of any practical use. In such an experiment, only the difference in molecular populations of levels E_1 and E_2 is effective in demonstrating absorption — in the case of ammonia, only approximately 1/250th of the number present in the lower level.

However, if the molecules could be separated while in flight into a beam of high-energy and a beam of low-energy molecules, not only would the signal-to-noise ratio improve by a factor of about 250 but, if the experiment was carried out to measure the interaction of the radiation with the high energy molecules, only an emission of energy of frequency ν_1 would be observed. This is what happens in an ammonia maser. A diverging beam of ammonia molecules passes through a region of non-uniform electric field, the direction and gradient of which is such that the low-energy molecules are deflected outwards from, and the high-energy molecules inward to, the centre of the beam. A full explanation of these effects involves quantum mechanics, and is beyond the scope of this article. Only a simplified account will be given here; but for a fuller account, the reader is referred to a discussion by Slater[2].

The accepted configuration for the ammonia molecule is a pyramid of small altitude, with the nitrogen atom lying close to the plane of the three hydrogen atoms. This, of course, is only an instantaneous snapshot, for the molecule and atoms forming it are in a constant state of rotation and vibration. The nitrogen atom vibrates backwards and forwards through the plane of hydrogen atoms between symmetrical positions on either side. The amplitude of vibration is greater for the higher-energy (E_2) molecule than for the lower-energy (E_1) molecule. If the nitrogen were to remain on one side of the plane of hydrogen atoms, the molecule would have a dipole moment, the nitrogen end of the molecule being negative. Because the nitrogen is vibrating, the average dipole moment will be zero. However, when the molecule comes under the influence of an electric field, the nitrogen atom no longer vibrates to symmetrical positions on either side of the hydrogen plane, but goes further on one side of the plane than on the other. The nitrogen atom thus spends more time on one side than on the other and quantum mechanics show that it is opposite sides for the high- and low-energy molecules. Dipole moments of opposite sign are created and, in a field gradient, the molecules will move in opposite directions.

The low-energy molecules land on surfaces cooled to liquid nitrogen temperature and become frozen there. The number of high-energy molecules in the beam which goes on, now greatly exceeds the number of low-energy molecules. This beam passes through a high-Q microwave cavity tuned to the transition frequency ν_1. Inherent noise power over a small bandwidth centre at ν_1 in the cavity stimulates transitions downwards from E_2 to E_1 with consequent emission of energy by the molecules. This emitted energy increases the field strength in the cavity. Oncoming molecules see an increasing field and more suffer transitions —and so the field builds up. When the rate of emission of power from the molecular beam balances the power lost to the cavity and waveguide connections, any further increase of emission of

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power by the beam results in a sudden rise in output to the maximum power output possible from the beam (i.e. by analogy with electronic-valve circuits, the maser has begun oscillating). The transitions taking place in the cavity are stimulated by the electric field in the cavity, so are in phase with this field. The output from the cavity is thus a coherent output of frequency ν_1, the transition frequency.

DESCRIPTION OF APPARATUS

Ammonia Supply and Vacuum Tank: The gas supply is obtained from a commercial anhydrous ammonia cylinder without special purification. Ammonia passes from the cylinder at 150 lb./sq. in. through a reduction valve with an outlet pressure of 14 lb./sq. in. and via a tap, into a reservoir tank of 3-litre capacity where the pressure is maintained at 200 mm Hg. Ammonia then passes through a needle valve into the main vacuum chamber, shown in Fig. 1.

Main Vacuum Chamber: This chamber consists of three main pieces; a top plate which carries the collimator, the electrostatic state separator, and an annular tank for liquid nitrogen. Also a standard commercial glass tube of 4-in. internal diameter and a short metal collar which carries the cavity and waveguide connections.

This chamber is mounted on a 4-in. diam. silicone oil diffusion pump, suitably baffled to prevent pump oils reaching the cavity. Rubber O-ring seals are used to couple each demountable item to the next in a vacuum-tight manner.

Collimator: Several types of gas collimators have been used. The first type used was made from 0.25 in. wide nickel or stainless-steel foil 0.0007 in. thick. About 30 in. of foil is passed between two gear wheels so that corrugations 0.002 in. deep and 0.004 in. wide are produced across the width of the foil. A plain foil is laid over the corrugated foil and the two foils then wound round a mandrel of 0.1 in. diameter. This assembly is pushed into the collimator housing and thus provides about 7,000 narrow channels 0.25 in. long through which the ammonia passes to form a beam of molecules down the axis of the vacuum chamber.

The second type of collimator we used was made for us by E.M.I. Research Laboratories in a manner similar to that which they used for klystron grids. Aluminium wires about 0.005 in. diameter and several inches in length were plated with nickel. These wires were then packed into a containing tube of internal diameter 0.125 in. where they

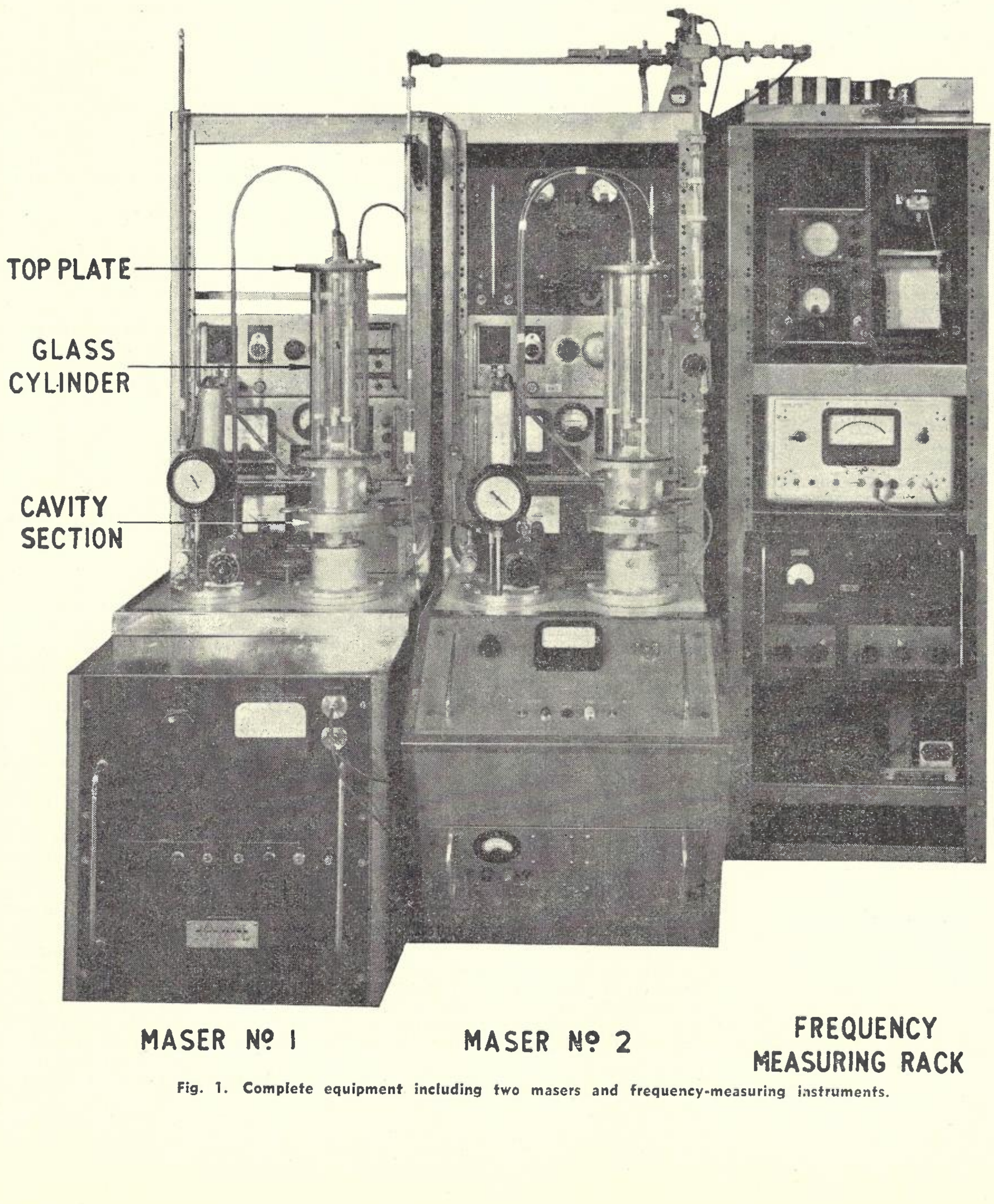

Fig. 1. Complete equipment including two masers and frequency-measuring instruments.

were welded together by a combination of pressure and sintering. The solid rod thus obtained was sliced into lengths of 0.125 in. and the aluminium dissolved out using caustic potash leaving behind a very regular honeycomb of nickel tubes.

This collimator proved to be more efficient than the first type we used.

For demonstration purposes, where efficiency is unimportant, we have found that a single tube of about 0.1 in. bore and a few inches in length will produce enough collimation for an oscillation signal to be observed.

Focuser or State Separator: The focuser comprises a cylindrical cage of 8 rods of 16 s.w.g. silver-plated silver steel, 12 in. long (Fig. 2). The inside diameter of the cage is 0.4 in. The rods are supported at each end in p.t.f.e. rings. Alternate rods are connected by a silver-plated brass ring at the lower end of the focuser and taken to earth. The remaining rods are connected by a similar ring near the top of the focuser and this ring is taken to an e.h.t. terminal in the top plate of the vacuum tank. Since voltages of up to 20 kV d.c. may be applied to the focuser, care is taken to avoid sharp points, and the focuser is carefully cleaned before assembly.

Focusers as short as 4 in. may be used, but are less efficient.

Microwave Cavity: The cylindrical cavity is designed to resonate in the TM_{010} mode where the resonant frequency is a function of the bore diameter only. A typical cavity is made from brass, carefully bored, silver-plated, reamed and then polished to a calculated diameter[3] of 0.37850 in. which is approximately 50 micro-inches less than the diameter corresponding to the transition frequency. The cavity length is 4 in. and wall thickness $\frac{5}{16}$ in.

A non-inductive heater winding of copper wire is wound in close contact with the outside of the cavity and fastened down with shellac. This heater, which is electronically controlled, maintains the cavity within ± 0.01°C. of the temperature at which the cavity bore is expanded to the diameter which corresponds to the transition frequency. Thus, in operation, the cavity temperature is approximately 40°C.

The cavity is joined mechanically to the output waveguide in such a way as to insulate it thermally from the waveguide and waveguide mountings. In this design, an equilibrium temperature of the cavity of 20°C. above the waveguide temperature for one watt of electrical power supplied to the heater is a measure of the thermal insulation achieved.

Sleeves of 0.375 in. length and inside diameter 0.325 in. are fitted at each end of the bore to close the cavity electrically while allowing free passage for the ammonia molecules. A coupling hole 0.087 in. diameter and 0.020 in. depth is provided halfway along the length of the cavity. A thin mica window held in position with O-rings provides a vacuum seal between the cavity and the waveguide connections. An additional measure we have adopted to reduce variation of heat loss from the cavity is to keep the surrounding metal at the temperature of the laboratory water supply. We have observed that this varies by only 1°C. throughout the day whereas the ambient air temperature may change by as much as 10°C.

Detection and Display Circuits: The superheterodyne detection system shown in Fig. 3 is used. Local oscillator power is provided by a 2K33 klystron fitted with water cooling to improve frequency stability. This power, at an adjustable level, is fed to a 1N26 mixer crystal which also receives the power to be detected from either one or two masers. Isolators and magic Ts are employed to minimize direct coupling between the masers or between either maser and the klystron. The output from the mixer crystal is matched to an i.f. amplifier by an *LC* circuit.[4] The i.f. amplifier, operating at 30 Mc/s with 2-Mc/s bandwidth and 80-dB gain, is followed by diode detection and an audio amplifier of 2-kc/s bandwidth. The audio output is applied to the Y plates of a c.r.o.

To observe the output from one maser only, the other maser is switched off and the klystron frequency swept ± 5 Mc/s by a sawtooth reflector voltage at 25-c/s repetition rate. The centre frequency of the klystron is adjusted to be either 30 Mc/s above or below the maser frequency. The instantaneous frequency difference between the klystron and the maser frequency will thus sweep repetitively across the pass-band of the i.f. amplifier. The X-plates of the c.r.o. are fed with a sawtooth waveform synchronized to the klystron reflector modulation so that the shape of the i.f. response curve is displayed on the c.r.o. screen. The amplitude of the response curve is proportional to the amplitude of the maser oscillation whereas the width of the curve is, of course, the width of the i.f. amplifier response.

If the second maser is now made to oscillate, beats between the two masers can be observed as a modulation on the i.f. response display. The actual difference frequency between the masers can be obtained by reducing the klystron frequency modulation to zero, and using a c.r.o. time-base of appropriate frequency. The beat frequency can be measured on a direct-reading frequency meter and permanently recorded on a pen recorder.

OPERATION OF MASER

From experience, it was known that a separator voltage of 18kV and a gun pressure of 0.75 mm Hg will produce oscillation if the maser cavity is tuned to the correct frequency. The cavity temperature controller was set to give successively higher cavity temperatures and the amplitude of the display noted at each temperature. Typical results are shown in Fig. 4, indicating that maser oscillation can occur over a small range of frequencies. The cavity controller is designed so that a change in its setting of 1.0 corresponds to 5°C. change in cavity temperature. For the silver-plated brass cavity used, the temperature coefficient of its resonant frequency is calculated to be 0.47 Mc/s °C. Thus, the width of the curve in Fig. 5 measured at $1/\sqrt{2}$ maximum height (i.e., half maser power) is 2.6 Mc/s. It will be shown later that the corresponding change in maser frequency is about one thousandth of the change in cavity resonant fre-

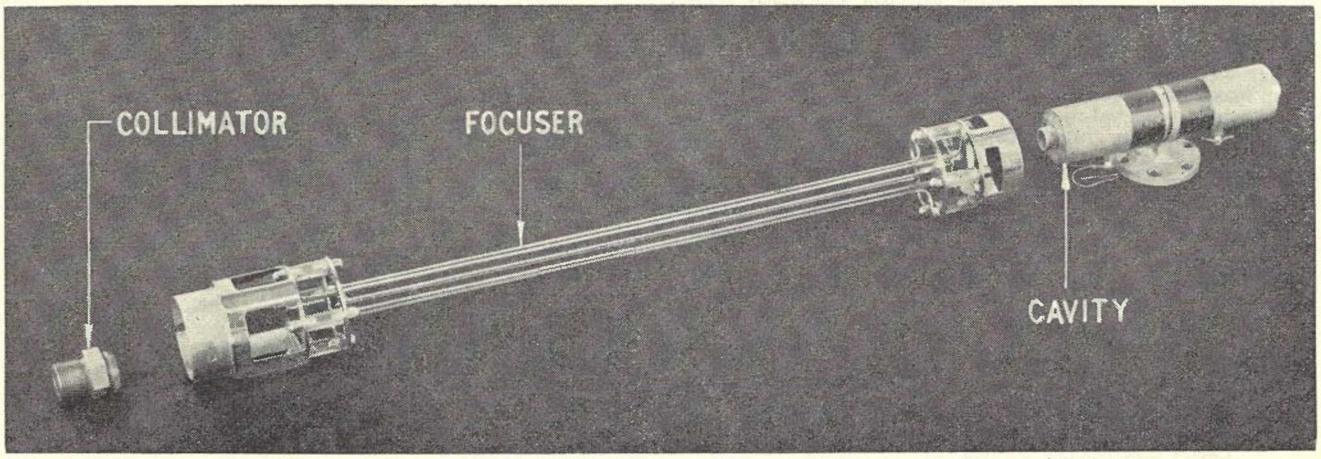

Fig. 2. The collimator, focuser and microwave cavity. The heater winding round the outside of the cavity is electronically controlled to maintain the temperature within ± 0.01°C.

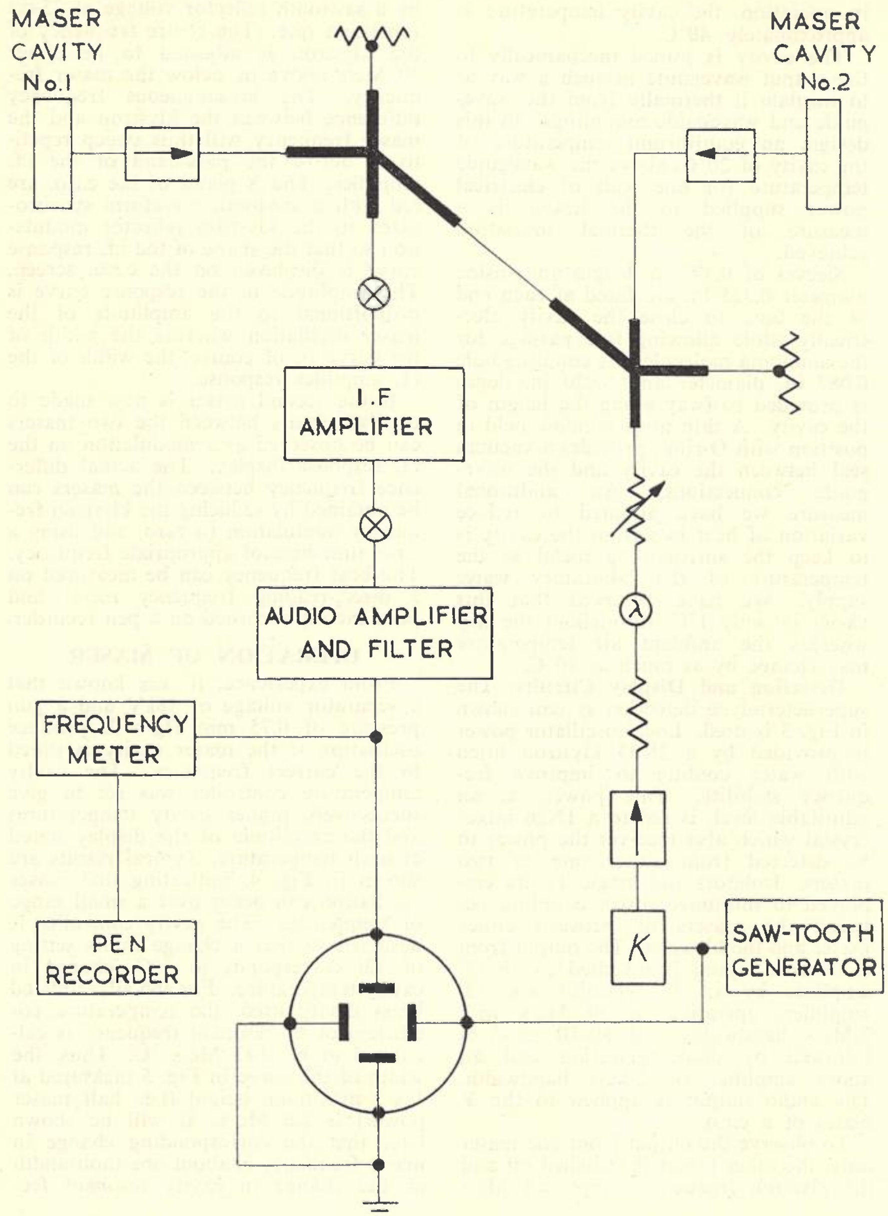

Fig. 3. Maser detection and display system.

quency, namely 2.6 kc/s. The cavity controller was then adjusted to give maximum maser power (of the order 10^{-10} W) and, with a signal-to-noise ratio of 30 : 1, the cavity resonant frequency

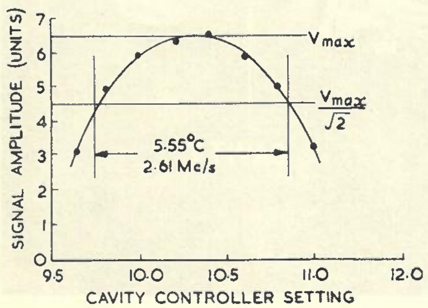

Fig. 4. Maser oscillation amplitude vs. cavity temperature.

could be set to about ± 0.1 Mc/s.

With this cavity frequency setting, the variation of maser oscillation amplitude with separator voltage and gun pressure was studied and typical results are shown in Fig. 5. It will be noted that there is a threshold gun pressure below which no oscillation can be obtained no matter how much the separator voltage is increased. The efficiency of the separator appears to reach a limit above a certain voltage and, since the cavity requires a definite number of high energy molecules to maintain oscillation, there will be a definite threshold gun pressure. In Fig. 5, this is 0.1 mm Hg and is equivalent to a total ammonia flow of 2.9×10^{16} molecules/sec. This value is two orders higher than theoretically necessary. No work has yet been reported indicating much higher efficiencies of the separator-gun combination. Fig. 5 also indicates a threshold separator voltage of 7 kV. As the gun pressure is increased, a cloud of ammonia molecules may form near the gun exit and so degrade its beam-forming properties. The number of high-energy molecules entering the cavity would not then increase very rapidly with gun pressure and a threshold separator voltage would be observed.

FREQUENCY OF MASER SIGNAL

Pulling Effects: No complete theory exists to predict accurately the dependence of oscillation frequency on maser-operating parameters but one can write, approximately[5]

$$f_0 = f_e + \frac{\Delta f_e}{\Delta f_c}(f_c - f_e)f(n)$$

where f_0 = oscillation frequency of maser

f_e = emission line frequency (23,870 Mc/s)

Δf_e = half width of emission line (3×10^3 c/s)

f_c = resonant frequency of cavity

Δf_c = half width of cavity resonance

$f(n)$ is a factor which is a function of beam flux, geometry of the separator system, separator voltage, etc. It is of the order unity.

For a microwave cavity of the type used in our experiments, $\Delta f_c = 3 \times 10^6$ c/s corresponding to a Q of 4,000.

Thus, if the cavity frequency is detuned from the emission frequency by 1 in 10^7 the oscillation frequency will change by about 1 in 10^{10}. This effect could be reduced by using lower Q cavities but no significant improvement can be obtained since the necessity for higher beam flux for oscillation causes difficulties in maintaining an adequate vacuum. It is possible to use other transitions in ammonia gas for which Δf_e is smaller, but they gave considerably smaller power outputs and an unacceptable signal-to-noise ratio. The line-width can be broadened by applying a magnetic field across the cavity (Zeeman effect) and so enhance any pulling effects existing.

To investigate the dependence of maser oscillation frequency upon operating parameters, two very similar masers were constructed and their outputs mixed. One maser was operated under fixed conditions to provide a convenient reference frequency.

An arbitrary choice was made to operate the second maser with 1 mm Hg gun pressure and 18 kV separator voltage because this gave an output of satisfactory signal-to-noise ratio. To study the effect of separator voltage on oscil-

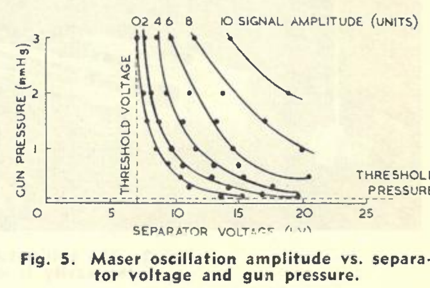

Fig. 5. Maser oscillation amplitude vs. separator voltage and gun pressure.

lation frequency, the cavity temperature was set at an arbitrary value and the beat frequency between the two masers noted. The *change* in beat frequency as the separator voltage was set first to 20 kV and then to 16 kV was recorded. This procedure was repeated for a range of cavity temperatures. Results are shown in Fig. 6 as plots of beat-frequency change (for the stated *increases*

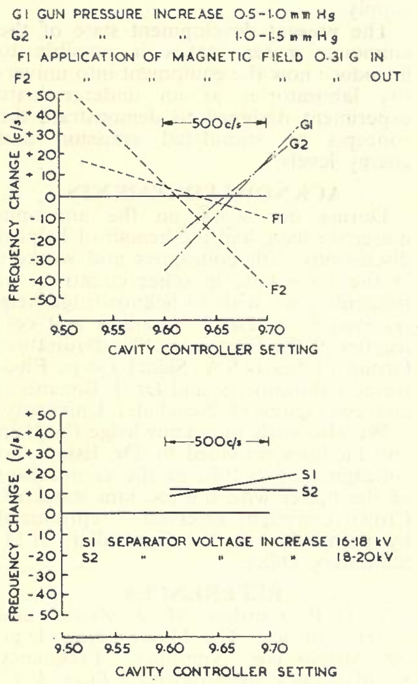

Fig. 6. Change in maser frequency vs. increase in value of operating parameter. For each line, the remaining parameters are held constant at their normal values; viz., gun pressure, 1 mm Hg, separator voltage 18 kV, magnetic field zero.

in separator voltage) for various cavity temperatures. Similar experiments were carried out with variations in gun pressure while the separator voltage was held constant. Finally, two coils in an approximate Helmholtz arrangement were set up to produce a steady magnetic field normal to the cavity axis in the region of the coupling hole. The change in beat frequency due to the application of the field, both in one direction and reversed, was noted. It will be noted that the pulling effect due to magnetic field depends strongly on the direction of the field. This is not expected on theoretical grounds and in this case was probably due to a standing field in the cavity caused by the earth's field and its distortion by nearby steel panels on electronic equipment. From the results with no applied magnetic field, 1 mm Hg gun pressure and 18-kV separator voltage the oscillation frequency decreased with cavity temperature at the rate of 960 c/s/°C.

The parameters investigated, namely, gun pressure, separator voltage, magnetic field and cavity temperature, appear to be the main factors governing the frequency stability of our masers, but we have some evidence that the quality of high vacuum obtained and presence of air in the ammonia also have some effect on the frequency. However, it was decided to attempt the measurement of frequency stability using the results described above as a guide to the choice of values of operating parameters.

Frequency Stability: Inspection of Fig. 6 shows that there is no unique cavity temperature which can be chosen to give zero pulling effects. For our purposes we considered that variations in magnetic field could be ignored in the laboratory and, since the pulling effects of separator voltage did not vary greatly with cavity temperature, it was decided to set the cavity temperature to give minimum dependence on gun pressure. Our aim was to obtain a frequency stability of ± 1 in 10^{10} or ± 2.4-c/s change in maser frequency. This requires a cavity temperature stability of 2.5 milli-degrees C and, with the controller used, this stability was certainly approached judging by the results obtained. We were unable to propose an independent method of checking the temperature stability achieved. Gun pressure can be easily held to 1.0 ± 0.2 mm Hg so that frequency variations due to this cause will be negligible with a cavity setting of 9.665. At this setting, separator voltage changes of ± 2 kV on 18 kV cause frequency changes of ± 14 c/s so that the tolerance on separator voltage for a frequency change of ± 2.4 c/s would be ± 0.4 kV or $\pm 2\%$. This is easily achieved on the stabilized separator voltage supply used. The first maser was set up to give a stable frequency in the same way and it is of interest to note that the beat frequency between the two masers under the chosen conditions was 150 c/s. Clearly the masers are not identical and the reason has not yet been investigated.

It was decided to estimate the relative stability of two adjacent masers as an approach towards determining the stability of either. The use of standard-frequency transmissions to provide a reference frequency was rejected on the grounds that the short-term phase fluctuations due to the transmitter crystal and changes in the propagation path would be greater than the fluctuations in maser frequency we expected to observe. It was realized that correlated changes in frequency between the two masers would not be measured. Although such changes are expected to be small, we hope later to be able to operate the masers in separate environments and investigate the point.

Fig. 7 shows the variation of beat frequency with time and was derived as follows. The two masers were operated continuously for 4 hr and a plot of beat frequency with time obtained on the pen recorder chart. Over the whole four-hour period the beat frequency did not vary more than 12 c/s. The time constant of the frequency-measuring system was 5 sec. As a rough estimate of the stability over shorter periods than 4 hr. the chart was divided into four consecutive one-hour lengths. The range over which the beat frequency wandered in each of the four one-hour sections was measured. The average of these four ranges is plotted in Fig. 7 together with the minimum and maximum range. The first 40, 20, 10, 5 and 1 minute lengths in each of the four one-hour sections was treated similarly. It can be seen that the stability of the beat frequency is high over periods of minutes and gradually deteriorates as the time interval chosen increases. The reasons for these long-term changes is being sought.

In May, 1959, the S.R.D.E. ammonia maser (No. 5) was operated at N.P.L. and its frequency measured against the caesium atomic resonator (9 192 631 770 c/s). The mean frequency of 46 readings over a two-hour period was 23 870 129 145 c/s with a standard deviation of 6.2 c/s. A similar set of 82 readings taken after a partial dismantling and re-assembly gave an average frequency of 23 870 129 115 c/s with a standard deviation of 4.6 c/s. There is a significant difference between these averages of 1.3 parts in 10^9 which has not yet been investigated. Since this work at N.P.L., considerable improvement has been made to the cavity temperature controller and the technique of operating the maser. We consider this is reflected in our recent results, of which Fig. 7 is a typical example.

DISCUSSION OF RESULTS

The major cause of frequency drift in our masers seems almost certain to be inadequate temperature stabilization of the cavity. With a brass cavity, the temperature must be held within a few milli-degrees C to obtain a stability of ± 1 in 10^{10}.

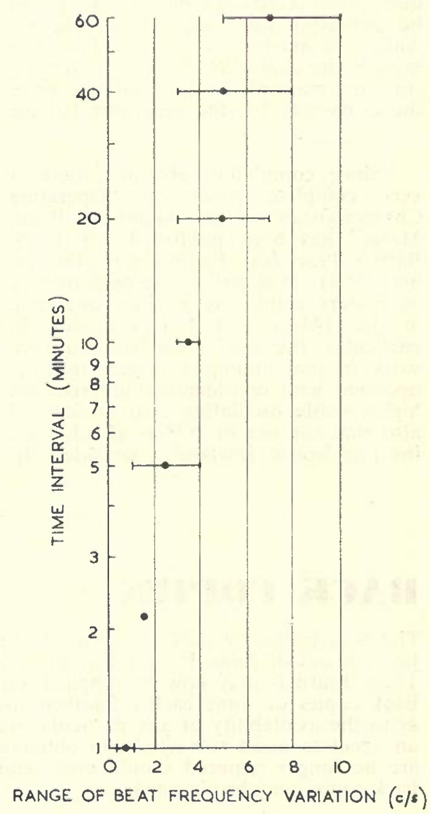

Fig. 7. Variation of beat frequency with time.

A much larger tolerance could be permitted if a low thermal-expansion coefficient material were used. However, in this case the manufacturing tolerance on the cavity bore would necessitate unacceptably large heating power to tune the cavity to the correct frequency and means of pre-setting the cavity frequency (for example a small dielectric plunger) would be essential. Although such a plunger would be temperature-sensitive, the permissible temperature variation might be quite large if the plunger affords fine tuning only. Such a device has been used by Vonbun[6]. Alternatively, a pair of coupled cavities could be used, as suggested by Bonanomi[7] in which the ammonia beam passes through one cavity only. Such a system can be operated over a temperature range of say 1°C. without pulling the oscillation frequency.

However, the resonant frequency of the cavity *will not* depend only upon the temperature and the dielectric plunger. Corrosion of the bore or dimensional changes due to ageing may well shift the frequency and one therefore seeks an alternative method of deciding the setting point of the cavity frequency. The pulling effects depicted in Fig. 6 offer possibilities in this direction.

In principle, the master oscillation frequency can be frequency modulated by a cyclic variation of gun pressure, separator voltage or magnetic field. A cavity frequency adjustment can be made such that the depth of modulation is zero, corresponding to the points where the plots in Fig. 6 cross the zero frequency shift axis. It will be noted that three quite distinct settings of the cavity can be achieved this way, depending on which parameter is varied. For our masers, the choice lies between gun pressure or magnetic-field variations since the cross-over for the separator voltage variation will be so far from those of the other parameters that their adequate stabilization would present great difficulty. It will be desirable to frequency modulate at say 100 c/s, which eliminates the possibility of using gun pressure modulation. Hence magnetic-field modulation appears the only promising method. Vonbun has proposed such a method which is used to servo the cavity on to the correct frequency[8].

CONCLUSIONS

The results of our investigations to date show that the ammonia maser gives an output of about 10^{-10} watt at a frequency of approximately 23870 Mc/s. The signal-to-noise ratio is at least 30 : 1. For a specified set of operating parameters, the frequency of the output is stable to better than 1 in 10^9 over periods of 4-hours duration, although during our investigations there have been occasions when a stability of ± 3 in 10^{11} over an hour has been observed.

Some of the reasons for drift are not yet understood and it is hoped that further investigation will lead to a daily stability of ± 1 in 10^{10}.

We have not yet investigated the long-term stability (over periods of several months) but are preparing to do this, by making use of daily transmissions from several United States transmitters which are to be servo-controlled by atomichrons (caesium beam-frequency standards) situated in the induction field of the transmitters.

The use of the ammonia maser as a frequency standard necessitates resetting it to the same frequency every time it is taken down and reassembled. We have made a preliminary study of ways of doing this, but have not yet enough evidence to predict the possibilities. The use of $N^{15}H_3$ instead of $N^{14}H_3$ might lead to greater reproductibility* since the resonance line for $N^{15}H_3$ is narrower (N^{15} has no electric quadrupole moment and does not contribute to broadening the line). We plan to try this isotope in small sealed-off robust models which are being made for S.R.D.E. under contract.

If the problems of making a sealed-off small portable maser can be solved, the robustness and stability make it an attractive proposition for navigational methods for fast aircraft or missiles by principles dependent on phase comparisons between a signal received from a distant maser source and a local maser at the point of measurement.

Its use in a satellite should be much easier, since the atmospheric pressure throughout the orbit is generally much less than the pressure of 3×10^{-6} mm Hg which is the upper pressure for satisfactory maser operation. Provision could be made to allow the used ammonia to escape into space and, since the consumption of ammonia, when working is only a few c.cs at N.T.P. per day, it would be easy to provide a 1,000-day supply.

The present development state of the ammonia maser makes it possible to introduce now the equipment into university laboratories as an undergraduate experiment designed to demonstrate the concepts of stimulated emission and energy levels.

* Since completion of this article, a very complete paper on "Operating Characteristics of an Ammonia Beam Maser" has been published (by F. S. Barnes, *Proc. Inst. Radio Engrs.*, December, 1959). It describes the performance of masers employing cavities operating in the TM_{011} and TM_{012} modes. In particular, the results confirm our own work in that ammonia masers may be operated with considerably different yet highly-stable oscillation frequencies and also that the use of $N^{15}H_3$ should ease the problem of resetability considerably.

ACKNOWLEDGEMENTS

During our work on the ammonia maser we have had the benefit of helpful discussions with colleagues and workers in the same field in other countries. In particular, we wish to acknowledge help received from Dr. F. Vonbun and colleagues of the Frequency Standardisation Group of the U.S.A. Signal Corps Electronic Laboratories, and Dr. J. Bonanomi and colleagues of Neuchatel University.

We also wish to acknowledge the help and facilities provided by Dr. Essen and colleagues of N.P.L. in the comparison of the maser with the caesium standard.

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LINE CONCENTRATORS—AN INSTALLATION AT BOX HILL (VICTORIA)

*G. MORRIS, A.M.I.E.Aust., A.M.I.E.E.**

INTRODUCTION

By far the greatest increase in subscriber development since the war has been the increase in the demand for residential services, and the cost of providing these services must inevitably be greater than that of providing service to business subscribers. Residential areas are usually more distant from the exchange than are business premises and this involves laying larger and longer subscribers' cables to meet demand, needless to add, at considerable cost. Residential development is not easy to foresee and in most cases it is not possible to lay distribution cable as soon as the demand exists with the consequence that a back log of waiting applicants soon arises. Each residential subscriber requires the same amount of exchange equipment per line as the business subscriber though the revenue earned from the residential subscriber is considerably less than from the business subscriber. If tariffs are increased to compensate, demand could fall and this would result in an undesirable drop in revenue.

A need, therefore, exists for some method of providing a service to residential subscribers which is:—

(i) Cheap.
(ii) Flexible so that service may be quickly given to subscribers in areas where distribution pairs would normally be insufficient.
(iii) Capable of serving enough subscribers to enable the postponement of cable relief until future requirements are better known.

Such a method is the line concentrator. Briefly the line concentrator enables a number of subscribers to be served by a lesser number of subscribers' cable pairs and in all respects should provide the same service to the subscribers as if individual cable pairs were used. In other words, the subscriber should be unaware of the presence of the line concentrator.

ECONOMICS

The economics of providing line concentrator equipment is related to the cost of providing the same service by cable relief. As this latter component varies from one location to another, an accurate assessment is hard to make.

An investigation in 1958 showed that, on information available, the initial and maintenance costs of line concentration equipment would have to be considerably less than they were at the time to make it a generally economical proposition. For this reason, line concentrator equipment in future is expected to make use of such developments as transistors, semi-conductor diodes, dry reed glass sealed switches, nickel cadmium batteries and a minimum of moving parts.

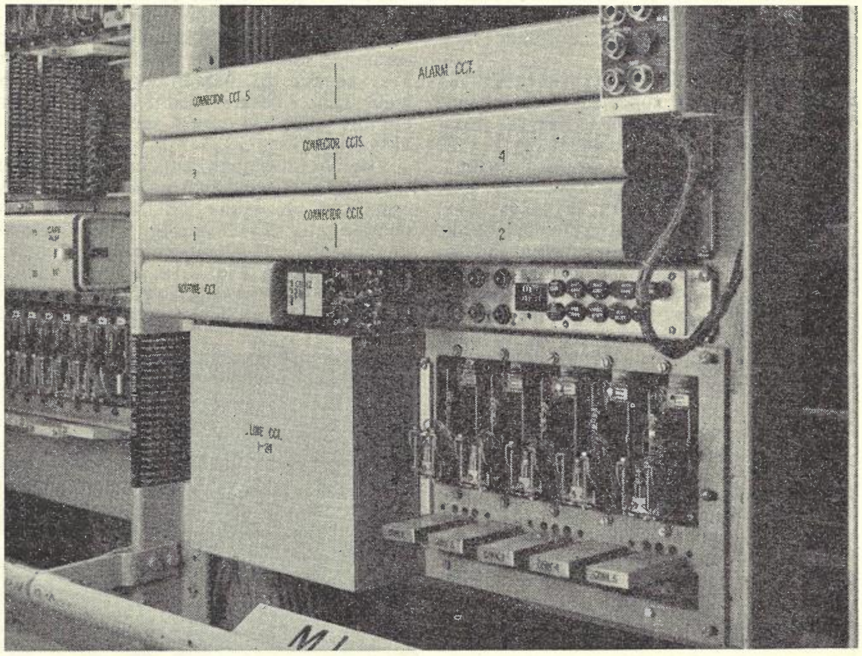

Fig. 2.—Line concentrator exchange unit installed in the Box Hill Exchange.

Though hard to assess economically there are benefits in being able to provide service in advance of costly cable relief and this is of particular importance where the subscribers concerned are grouped together as, for example, in a block of newly erected flats. The cost of maintenance of the equipment is important in the determination of the economics of line concentrators and for this reason, the trend in design is towards improved reliability of components and automatic withdrawal from service of faulty circuits.

Savings by use of concentrators are more likely to be incurred as the route distance from the exchange increases.

LINE CONCENTRATOR PRINCIPLES

It is well known in telephony that a subscriber uses the phone for only a fraction of the time that the service is available and this principle of exchange trunking can be extended to the connection of subscribers to the exchange. For example, the line concentrator equipment at Box Hill (Vic.) is capable of serving 23 subscribers via 5 cable pairs. Units of other manufacture can serve 50 subscribers with 10 pairs and 11 subscribers with 3 pairs. The duplex system is an application of the same principle where two subscribers are served by one cable pair. With such small numbers of subscribers and pairs it is important that the subscribers served have a low to average calling rate otherwise congestion will result.

The principles of operation can be understood by reference to Fig. 1. The equipment consists of two units, one in the exchange and the other called the remote unit, in the vicinity of the subscribers concerned. These subscribers are connected to the remote equipment. A smaller number of cable pairs connects the remote unit to the exchange unit. Since the maximum number of simultaneous originating calls cannot exceed the number of pairs, only one exchange line circuit per pair is required but provision is made to connect the appropriate subscriber's meter when a call is originated. The final selector appearances of the connected subscribers are also connected to the exchange equipment of the line concentrator.

Originating Call. By lifting the handset, one of the 23 subscribers is connected, in the remote unit, to one of the cable pairs connecting the remote and exchange units. In the exchange unit, an exchange line circuit is available to each of the pairs and the subscriber is now connected to the exchange line cir-

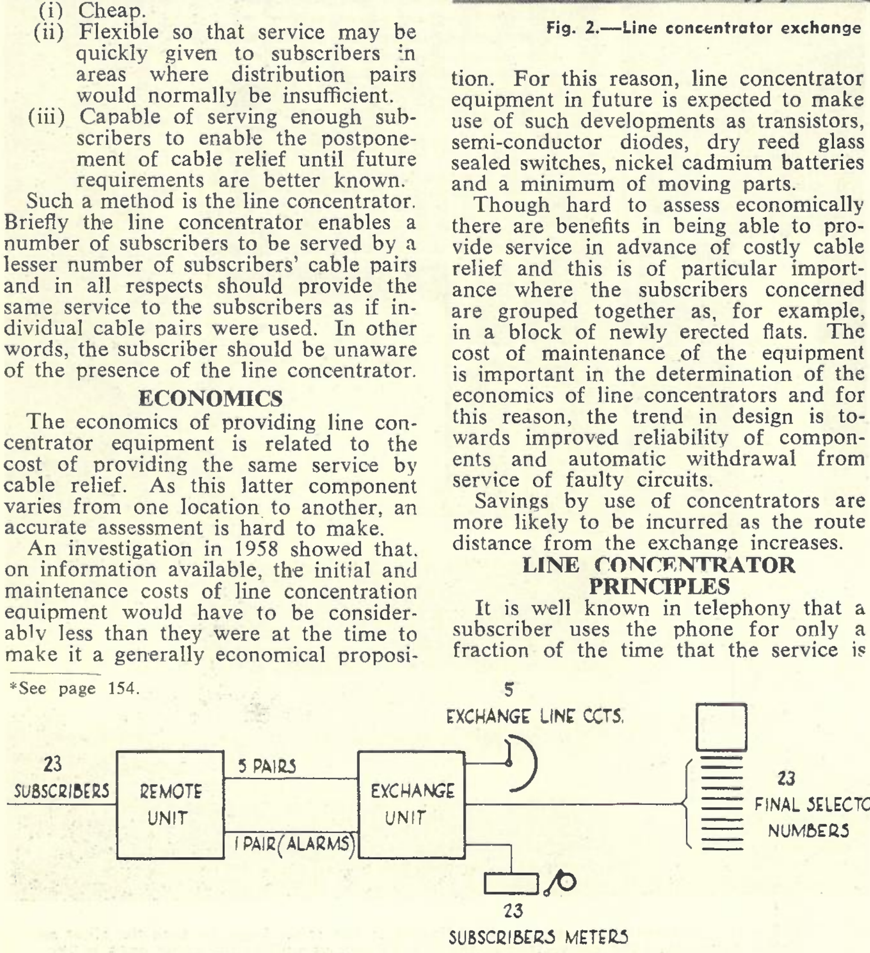

Fig. 1.—Basic application of the line concentrator.

*See page 154.

cuit associated with the pair selected. The subscriber now receives dial tone and may proceed with the call. With the connection of the line circuit, the exchange unit connects the appropriate subscriber's meter so that an effective call may be registered. When the caller restores the handset, the equipment restores to normal.

Terminating Call. When the last digit of one of the 23 subscribers has been dialled and if the number is free, the final selector will send ring tone back to the calling subscriber and ringing current forward to the exchange unit. The exchange unit selects a pair which is then connected to the final selector bank appearance of the number being called. At the same time, the remote unit connects the remote end of the selected pair to the required subscriber. The ringing current is now connected to the line of the called subscriber and the call proceeds normally.

OTHER ASPECTS

There are certain other aspects of a line concentrator which are of importance and these are listed below.

Components. These should be reliable and fault free. Low cost may be achieved by good design lending itself to ease of manufacture but good quality material in important places is sound design, e.g., moving parts and contacts.

Circuit Design. Good circuit design incorporates the automatic withdrawal from service of faulty parts, low current drain, little or no shunt or series components introduced into the subscriber's line and high speed of operation. A minimum of components will assist in achieving a compact and light unit.

Physical. Minimum size of exchange and remote units is important, particularly the latter unit where weight is also important. These factors facilitate rapid and easy installation and improve the possibilities of finding a suitable location for the remote unit.

Power Supplies. It is better if the remote unit obtains its power from the exchange. This gives greater flexibility as location of sites can be made without regard to the availability of commercial supply. It also helps to reduce the size of the remote unit and also eliminates the maintenance required by batteries.

Testing. It should be possible to remotely test the switching functions of the remote unit. It is also important to be able to test, from the exchange, the cable pairs of the subscribers connected to the remote unit.

Alarms. Indication is required at the exchange of faulty equipment and whether or not service is affected.

BOX HILL LINE CONCENTRATOR

The Box Hill line concentrator was installed as a trial of a locally designed and produced unit. Due to it being a 'one only' product and its initial cost high, it does nothing to demonstrate the economics of the use of line concentrators; neither does it employ components specially designed to be conducive to low fault incidence and low maintenance charges. Despite these shortcomings, it has provided service to a number of subscribers who would otherwise be without it for a number of years and it is also providing information on the finer points of facilities required in such units, particularly those associated with testing.

The equipment was manufactured in the Melbourne Postal Workshops to a circuit designed in the Headquarters Circuit Laboratory to provide line concentrator facilities with standard automatic exchange components. The unit was cut into service in November, 1959, with eight subscribers served by three finder circuits and has given satisfactory service so far.

The circuit components comprise 3,000 type and 600 type relays and uniselectors employed in finder circuits. The exchange unit shown in Fig. 2, is mounted on a shelf 2 ft. 9 in. wide. The remote unit, shown in Fig. 3, is accommodated in an 1800 pair cable cross-connection cabinet case and is mounted on hinged frames for easy access to the rear of the equipment. The upper part of the cabinet housing the equipment also contains the rectifier and this part is hermetically sealed. The battery, comprised of sealed type nickel cadmium accumulators, stands on a drawer tray in the lower part of the cabinet and this section is ventilated.

The unit has a capacity of 23 subscriber's with an additional subscriber's number used for testing. Five connectors are available, requiring five pairs between the remote and exchange unit and a further pair is used for alarms and testing.

OPERATION

The facilities of the unit are the same as those described in the principles of operation. Of particular interest is the method whereby the remote and ex-

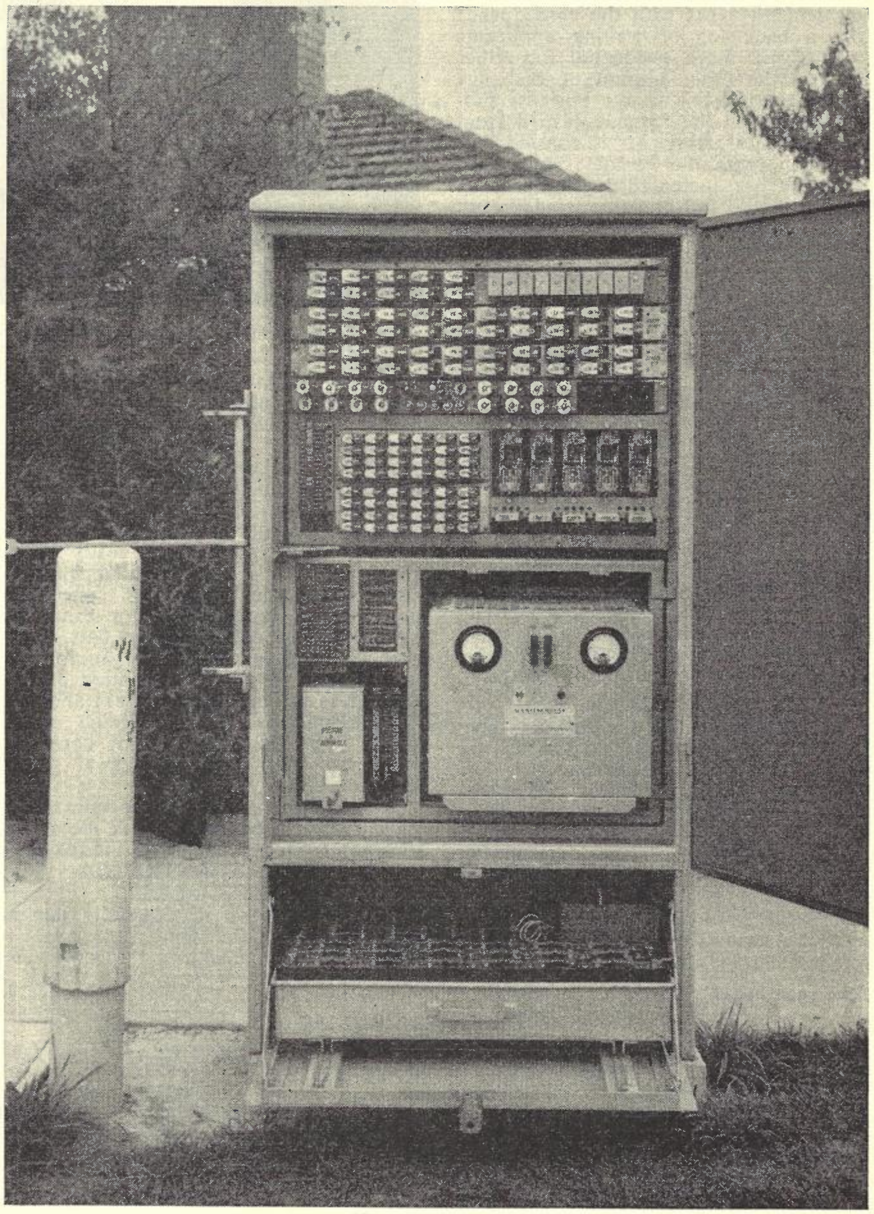

Fig. 3.—Line concentrator remote unit. Adjacent to the cabinet can be seen the pillar on which is terminated the connection to the remote unit as well as the cable pairs to the exchange and the connected subscribers.

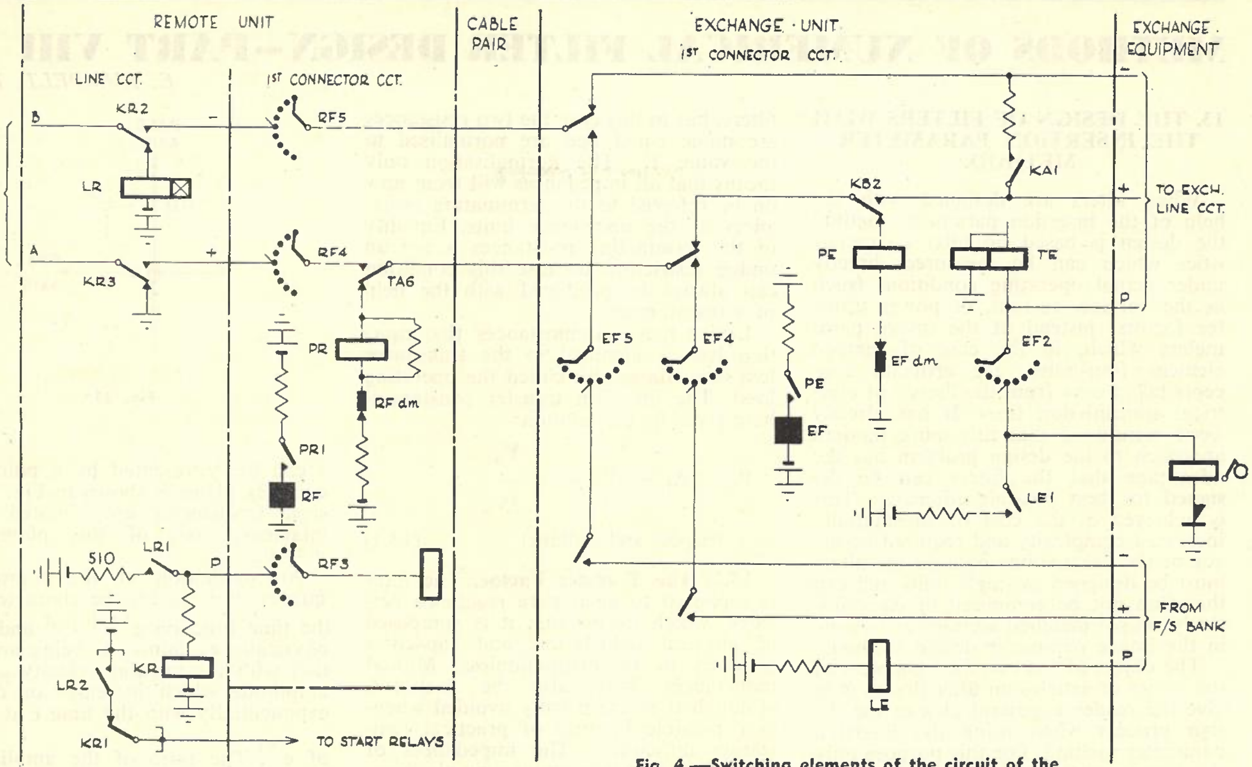

Fig. 4.—Switching elements of the circuit of the Box Hill line concentrator.

change units select one of the interconnecting pairs and arrange for the connection of the subscriber to the exchange equipment. It is in this respect that various systems differ and in which the field for ingenuity is wide. A matter of terminology arises which must be stated before proceeding. Up till now the pairs connecting the remote and exchange units have been referred to as pairs. This is satisfactory when thinking in terms of the block diagram. On closer scrutiny we become more interested in the manner in which connection is made to these pairs and we come to refer to the interconnection by the name of the circuit which performs it. For example, in crossbar equipment the interconnection is made via links, so we speak of the common circuits as links. In the Box Hill unit the interconnection is made by connectors (operating as line finders) and we shall now refer to these elements as connectors.

The following description of the searching stepping process may be followed by referring to Fig. 4 which contains only those components required to understand these operations. Further detail is considered unnecessary to the understanding of these operations and would tend to confuse.

Originating Call. When the subscriber lifts the handset, the completion of the line loop operates relay LR in the remote unit. The start relay of the first available connector is operated. The remote unit starts the exchange unit circuit of the selected connector via a circuit using the negative leg of the connecting cable pair. The exchange line circuit is pre-looped at KA1 so that dial tone will be on the line by the time the finder circuits have operated and connected the subscriber to the selected connector circuit. With the earth returned on the private of the line circuit, a circuit is completed for the operation of pulsing relays PR in the remote unit and PE in the exchange unit via the positive leg of the connecting cable pair. The associated connector finder magnets operate and the interrupter contacts open causing the release of both PR and PE. This results in the release of the finder magnets and both finders take one step. The interaction continues until the remote finder steps to the contact of the calling subscriber, whereupon the drive is cut due to the private bank of the remote finder being marked with a 510 ohm battery. In the exchange unit, the meter of the calling subscriber is connected to the private of the line circuit via a bank contact of the exchange finder. The private of the final selector appearance of the number is earthed to render the number busy to incoming calls. The calling subscriber's line is switched through to the line circuit and the call proceeds in the normal manner. At the completion of the call the finders return to the home position and are available for another call.

Terminating Call. After the last digit of the called subscriber's number is dialled, the final selector applies earth to the P wire to guard against intrusion. Ringing current and ring return battery are applied to the negative and positive wipers and ringing tone is returned to the calling subscriber. Call indicating relay LE in the exchange unit operates to the earth on the private. Using the negative leg of **each** unoccupied connector circuit to initiate the action, the pulsing relays of each unoccupied connector circuit are switched to the positive legs of the connector circuits and all unoccupied connectors in both exchange and remote unit begin to search. The first exchange finder to reach the final selector appearance being called stops, the others continue to drive to the home position and are available for other calls. Drive is cut by the operation of drive cutting relay TE to the battery on the appropriate contact of exchange finder bank EF2. The ring is extended through to the subscriber and the call proceeds in the normal manner. At the conclusion of the call, the finders restore to the home position and are again available for use.

CONCLUSION

A need exists for a cheap and rapid means of providing service to residential subscribers and, whilst the Box Hill unit has not satisfied the first of these requirements, it has achieved a further objective of quickly providing service to an area where none was previously available. It has provided information and experience, which will be of benefit in assessing the suitability of line concentrator units of other types and manufacture. We may expect interesting developments in this type of equipment in attempts to reduce the initial and maintenance costs and to improve its reliability.

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METHODS OF NUMERICAL FILTER DESIGN — PART VIII

E. RUMPELT, Dr.Ing.*

13. THE DESIGN OF FILTERS WITH THE INSERTION PARAMETER METHOD.

When filters are designed with the help of the insertion parameter method the design is based on filter characteristics which can be measured directly under actual operating conditions (such as the voltage, current, or power transfer factors) instead of the image parameters which, in the case of lumped element four-poles, are artificial concepts taken over from the theory of electrical transmission lines. It has already been mentioned that this more modern approach to the design problem has the advantage that the filters can be designed for best possible efficiency. This is achieved at the cost of substantially increased complexity and required accuracy of the calculations because the filters must be designed as single units and can therefore not be composed of comparatively simple matched sections as is done in the image parameter design method.

The object of the two final chapters of this series of articles on filter design is to give the reader a general idea of the design process when using the insertion parameter method. For this purpose only the bare essentials of the theory as required for filter design are dealt with. An operating condition and a type of insertion loss specification have been chosen which frequently apply in practice, but which are only special cases of the possible varieties. The methods of tackling the numerical problems described are those employed by the author in numerous practical designs, but several other methods are known. Which method is preferred depends to a large extent on the available aids. The methods described require a desk calculating machine with a size of its registers adequate to attain the necessary accuracy of the calculations, the templates mentioned in Chapter 6, and a few ordinary drawing utensils.

For a thorough study of the insertion parameter theory, several textbooks are listed at the end of this chapter. The list is headed by the now classical Doctor's thesis of S. Darlington who pioneered the insertion parameter method in the U.S.A.

13.1. The Operating Condition. The operating circuit chosen for the subsequent considerations is shown in Fig. 20.

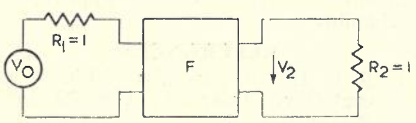

Fig. 20.

The filter, F, is inserted between a voltage source with e.m.f. V_0 and internal resistance R_1, and a load resistance R_2. It is the usual operating condition for filters, but in this case the two resistances are made equal and are normalised to the value 1. The normalisation only means that all impedances will from now on be referred to the terminating resistances as the impedance units. Equality of the terminating resistances is not an undue restriction because this condition can always be produced with the help of a transformer.

Under these circumstances the insertion loss is identical to the transducer loss (sometimes also called the operating loss). The insertion transfer constant is here given by the relation:

$$P_L = A_L + jB_L = \ln \frac{V_0}{2V_2}$$

(nepers and radians) .... (13.1)

13.2. The Transfer Factor. The filter is supposed to be a pure reactance network, which means that it is composed of physical inductances and capacities assumed to be dissipationless. Mutual inductances may also be included, although they are usually avoided whenever possible because of practical realization difficulties. The impedances of these filter components are simple functions of frequency, and if the filter circuit and the component values were known it would be a straightforward matter to calculate the voltage ratio $V_0/2V_2$ in Eq. (13.1) as a function of the component impedances. When making this calculation the voltage ratio $V_0/2V_2$, which shall be called the **transfer factor,** ensues as a rational function of the frequency which can be expressed as the quotient of two polynomials.

We are, however, confronted with the opposite problem, that is, to synthesize a reactance fourpole having a transfer factor which satisfies given specifications for the insertion loss via Eq. (13.1). To make a physical realisation of the reactance fourpole possible, certain mathematical conditions must be fulfilled by its transfer factor as a function of the frequency. Before dealing with these conditions we shall consider the concept of the complex frequency.

13.3. The Complex Frequency Parameter s. In ordinary filter design we are finally interested only in the steady-state response of the filters, that is, their response to voltages and currents which are oscillating sinusoidally with a constant amplitude and a certain frequency f or angular velocity $\omega = 2\pi f$. But in order to obtain simple mathematical criteria for the realizability conditions of the transfer factor it has been found convenient to introduce the complex frequency parameter.

$$s = \sigma + j\omega \quad \text{.... .... (13.2)(a)}$$

and investigate the properties of the transfer factor of reactance fourpoles at complex frequencies.

Any value of the frequency parameter s can be represented by a point in the complex plane as shown in Fig. 21. Physical frequencies are situated on the imaginary axis of this plane where $\sigma = 0$.

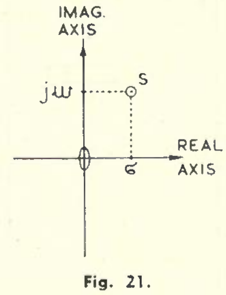

Fig. 21.

An oscillation of the complex frequency $\sigma + j\omega$ can be characterised by the time function $e^{(\sigma + j\omega)t}$ and may be physically explained as being an oscillation with the angular velocity ω and an amplitude which increases or decreases exponentially with the time t at the rate of $e^{\sigma t}$. The ratio of the amplitudes of two successive complete cycles (following cycle divided by preceding cycle) of such an oscillation is $e^{\sigma/f}$. If σ is positive (in the right half of the complex plane) this ratio is larger than 1 and the oscillation increases with time. If σ is negative (in the left half of the complex plane) the ratio is smaller than 1 and the oscillation decays with time. For $\sigma = 0$, that is, anywhere on the imaginary axis, the ratio is equal to 1 and the oscillation is sustained at a constant amplitude. This is the steady-state condition.

13.4. The Transfer Factor as a Function of s. With the frequency parameter s the impedance of an inductance L is sL and the impedance of a capacity C is 1/sC. These are real expressions and when the transfer factor of a reactance fourpole is calculated from the impedances of its components in terms of s, the result is a real, rational function, H(s), which can be written as the quotient of two polynomials of s, E(s) and G(s), with real coefficients:

$$H(s) = \frac{E(s)}{G(s)} \quad \text{.... .... (13.3)(b)}$$

If the transfer factor is to be evaluated at physical frequencies, s need only be replaced by $j\omega$:

$$\frac{V_0}{2V_2} = H(j\omega)$$

The insertion loss is:

$$A_L = 20 \log_{10} | H(j\omega) | \text{ in db} \quad .... (13.4)$$

*See page 298, Vol. 12, No. 4.

(a) Other symbols frequently used instead of s are p or λ.

(b) It should be mentioned here that frequently the reciprocal of H(s) is referred to as the transfer factor. The terminology used in this article has been taken essentially from papers by Prof. H. Piloty who was one of the pioneers of the insertion parameter method in Germany.

13.5. Conditions of Realizability. The condition that the polynomials E(s) and G(s) must have real coefficients is necessary for physical realizability of the transfer factor, but it is not sufficient. It has been proved that the following additional conditions must be fulfilled:

(a) The roots of the numerator polynomial, E(s), must be restricted to the inside of the left half of the complex s-plane.

(b) The denominator polynomial, G(s), must be either even or odd, which means that the powers of s in the individual terms of G(s) must be either all even or all odd.

(c) The degree of G(s), that is, the largest power of s in its terms, must not be larger than the degree of E(s).

(d) The magnitude of H(s) anywhere on the imaginary axis of the complex s-plane, that is, $|H(j\omega)|$ for all values of ω, must not be less than 1.

The roots of E(s) are the zeros of the transfer factor (the values of s where H(s) becomes zero) and it can be shown that these zeros are the modes of free oscillation of the filter terminated by the resistances R_1 and R_2 in Fig. 20. These modes would all be excited if, for example, an impulse were fed into the circuit by the voltage source. Owing to the power consumption in the terminating resistances the oscillations so produced in the filter must gradually decay. This means that the complex frequencies, s, of the free oscillations must all have negative real components, which is stated by condition (a).

Condition (b) is necessary because the filter is supposed to be built up of reactances only. Fulfilment of this condition can be verified by inspection.

The roots of G(s) are poles of the transfer factor (values of s where H(s) becomes infinite) and they are consequently also insertion loss peaks of the filter. For best filtering efficiency these poles should all be situated at physical frequencies in the stop-band of the filter, in other words, on the imaginary axis of the complex s-plane. Condition (b) is thereby fulfilled.

Condition (d) means that the insertion loss cannot become negative at any physical frequency and this follows from the circuit arrangement of Fig. 20 as with $R_1 = R_2$ the maximum value which the output voltage V_2 can assume is $V_0/2$.

Condition (c) is strictly speaking redundant because it is covered by condition (d) when very large frequencies are considered.

The design process described subsequently is so arranged that these realizability conditions are always complied with.

13.6. The Characteristic Function. For the purpose of obtaining from the transfer factor a fourpole matrix, such as the transfer matrix, from which the filter components can be calculated, a further function of s is required which is called the characteristic function, K(s), of the filter. It is related to the transfer factor through the following equation:

$$H(s)H(-s) = 1 + K(s)K(-s) \quad \ldots\ldots (13.5)$$

The characteristic function is also a real, rational function of s and can be written as the quotient of two polynomials:

$$K(s) = \frac{F(s)}{G(s)} \quad \ldots\ldots\ldots\ldots (13.6)$$

As indicated by the symbol used, the denominator polynomial, G(s), is identical with that of the transfer factor. The numerator polynomial, F(s), must have real co-efficients but no further realizability conditions have to be met. The realizability of K(s) can therefore be ascertained by simple inspection, and this makes it very easy to obtain a permissible characteristic function.

For this reason it is preferable to start the filter design with the characteristic function and not with the transfer factor. The former is determined in such a way that the insertion loss specifications are met, and hereafter the transfer factor is calculated from K(s) with the help of Eq. (13.5).

The insertion loss is obtained from the characteristic function via Eqs. (13.4) and (13.5). The frequency parameter s in K(s) is substituted by $j\omega$ and, as $K(-j\omega)$ is conjugate complex to $K(j\omega)$, we get with

$$K(j\omega)\,K(-j\omega) = |K(j\omega)|^2$$

the relation:

$$A_L = 10 \log (1 + |K(j\omega)|^2) \quad \ldots\ldots (13.7)$$

Eq. (13.7) shows that the zeros of $K(j\omega)$ are the frequencies of perfect transmission ($A_L = 0$) and the poles of $K(j\omega)$ are the frequencies of perfect suppression ($A_L = \infty$). For best filter efficiency all zeros and poles of K(s) should therefore be located on the imaginary axis of the s-plane, the zeros in the pass-band and the poles in the stop-band.

This efficiency condition together with the realizability conditions requires the following general expression of the characteristic function:

$$K(s) = c\,s^r \frac{(s^2 + a_1^2)(s^2 + a_2^2)\ldots(s^2 + a_m^2)}{(s^2 + b_1^2)(s^2 + b_2^2)\ldots(s^2 + b_n^2)} \quad \ldots\ldots\ldots (13.8)$$

In this formula c is a positive or negative, constant factor, the exponent r may be zero or a positive or negative integer (usually not larger than 3), a_1 ... a_m are angular velocities of perfect transmission, and b_1 ... b_n are angular velocities of perfect suppression (insertion loss peaks). All these parameters determine the insertion loss characteristic of the filter and must be chosen in such a way that the insertion loss specifications are met. This should be achieved with a minimum degree of K(s), that is, with smallest possible values of r, m, and n, because this degree is a measure of the required number of filter components. One method of doing this in a systematic way will be described in Chapter 14.

13.7. Calculation of the Polynomial E(s). Once the characteristic function, K(s), is known, the numerator polynomial, E(s), of the transfer factor can be calculated from the relation:

$$E(s)E(-s) = F(s)F(-s) + G(s)G(-s) \quad (13.9)$$

which follows from Eq. (13.5). Because G(s) is an even or odd polynomial we have

$$G(s)\,G(-s) = \pm\, G^2(s)$$

where the positive sign holds if G(s) is even, and the negative sign if G(s) is odd.

When K(s) is formed in accordance with Eq. (13.8) the same applies to F(s):

$$F(s)\,F(-s) = \pm\, F^2(s)$$

but only one of the two polynomials F and G can then be odd.

E(s) is found from Eq. (13.9) by calculating the roots of the polynomial E(s)E(–s) and combining in E(s) all those roots which have negative real parts. The calculation of these roots requires the main effort of the filter design (unless an electronic computer is available). In the case of general insertion loss specifications it must be done by means of an iterative process of approximation with an accuracy which depends on the degree of the transfer factor and on the abruptness of the transition from pass-band to stop-band. Under certain circumstances not all the roots of E(s)E(–s) need be determined. More about this will be said in Chapter 14.

E(s)E(–s) is an even polynomial with real coefficients. Its roots are therefore either real (in practice not more than 2) or conjugate complex in pairs, and half of them are situated in the right hand side of the complex s-plane, the other half in the left-hand side, symmetrical with respect to the imaginary axis. (Roots on this axis are excluded because of realizability condition (a). If such roots were contained in E(s)E(–s) they would also be contained in F(s) and G(s), and could be cancelled in the characteristic function.)

Designating the roots of E(s)E(–s) in the left half-plane by s_1, s_2, ... s_k, the polynomial E(s) is given by the expression:

$$E(s) = h\,(s - s_1)(s - s_2)\ldots(s - s_k) \quad (13.10)$$

The constant factor h is the positive square root of the coefficient of the term in E(s)E(–s) with the highest power of s.

The expression of Eq. (13.10), when expanded, yields a polynomial with real and positive coefficients because the roots are either negative real, or they are conjugate complex in pairs with negative real parts and the combination of any such pair of roots in a quadratic polynomial gives real and positive coefficients:

$$(s + a - jb)(s + a + jb) = s^2 + 2as + a^2 + b^2$$

As all the roots selected for E(s) are situated in the left half of the complex s-plane, realizability condition (a) is fulfilled. The other conditions are also met provided that the characteristic function was permissible, and we have thus obtained a realizable transfer factor which satisfies the insertion loss specifications.

13.8. The Transfer Matrix and the Driving Point Impedances. The four elements A, B, C and D of the transfer matrix of the filter, which are defined in accordance with Fig. 22 by the equations:

$$V_1 = A\,V_2 + B\,I_2$$
$$I_1 = C\,V_2 + D\,I_2 \quad \ldots\ldots\ldots\ldots (13.11)$$

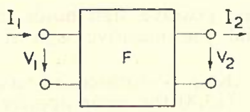

Fig. 22.

can be calculated from the transfer factor and the characteristic function with the following formulae:

$$A = \tfrac{1}{2}\,[H(s) + H(-s) - K(s) - K(-s)]$$
$$B = \tfrac{1}{2}\,[H(s) - H(-s) - K(s) + K(-s)]$$
$$C = \tfrac{1}{2}\,[H(s) - H(-s) + K(s) - K(-s)]$$
$$D = \tfrac{1}{2}\,[H(s) + H(-s) + K(s) + K(-s)]$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13.12)$$

The elements A and D are even rational functions, the elements B and C are odd rational functions of s.

It should be mentioned here that the sign of K(s), that is, the sign of the constant factor, c, in Eq. (13.8), has no influence on insertion loss and phase-shift but it has an influence on the impedance characteristic of the filter. It can be seen in Eq. (13.12) that by changing the sign of K(s), the transfer matrix elements A and D on one hand, and the elements B and C on the other hand are interchanged.

The input impedance of the filter can be calculated from Eq. (13.11), and with $R_2 = 1$, $V_2 = I_2$, it is:

$$Z_1 = \frac{V_1}{I_1} = \frac{A + B}{C + D} \quad \ldots\ldots\ldots (13.13)$$

This shows that by changing the sign of K(s) the input impedance of the filter is inverted. The same applies to the output impedance. The filter circuit is altered accordingly.

With the help of the transfer matrix a filter circuit can be found and the values of its components calculated. When a conventional ladder structure is desired, less calculating work is required if the realization is carried out from one of the driving point impedances of the filter in conjunction with the insertion loss peak frequencies. The driving point impedances can be calculated from the elements of the transfer matrix as follows:

Open-circuit impedances:

$$Z_{1oc} = A/C \qquad Z_{2oc} = D/C \ \ldots (13.14a)$$

Short-circuit impedances:

$$Z_{1sc} = B/D \qquad Z_{2sc} = B/A \ \ldots (13.14b)$$

13.9. Realization in Ladder Structure. The realization of the filter starts with the drawing of a circuit diagram in ladder structure, as known from image parameter filters, which in its impedance character is compatible with the driving point impedances derived from the transfer matrix, and which produces all the insertion loss peaks given by the pole frequencies of the characteristic function. Next a driving point impedance is selected which has the same degree as the characteristic function so that all component values can be calculated from it. This calculation is then carried out with the help of criteria which can be derived from the circuit diagram by inspection.

Let us assume, for example, that the ladder circuit starts with a capacity as a shunt branch followed by a parallel resonant circuit as a series branch, and so on. The criterion for calculating the first shunt capacity is that its impedance must be identical with the driving point impedance of the ladder circuit at the resonant frequency of the following parallel resonant circuit which, of course, produces an insertion loss peak at that frequency. This must be so because at that frequency the parallel resonant circuit has an infinitely large impedance and thus disconnects the rest of the ladder circuit from its first shunt capacity. After removing this capacity from the circuit by subtracting its impedance from the driving point impedance, the residual impedance function has a pole at the resonant frequency of the parallel resonant circuit. The latter can now be calculated from its resonant frequency and from the criterion that, after subtracting the resonant circuit impedance, the pole of the residual driving point impedance function at that frequency must have disappeared.

In this way the circuit components are calculated and removed from the ladder circuit one by one until all component values have been obtained. The process does, however, not yield the transformation ratio of a matching transformer which may have to be added to the ladder circuit following the last circuit component. To find the transformation ratio, the value of the last circuit component is calculated again, but this time from a driving point impedance of the opposite end of the filter where it is the first component. The ratio of the two values gives the (impedance) transformation ratio of the transformer, always assuming that the terminating resistances are the same at both filter ends. Alternatively the value of the terminating resistance following the last circuit component can be changed accordingly.

High-pass filters and frequency-symmetrical band-pass and band-stop filters can be derived from low-pass filters in the same way as has been shown earlier in Chapter 8. The insertion loss specifications of such filter types are transformed by means of a suitable reactance transformation into those of a low-pass filter which is then completely designed. Thereafter the circuit components are transformed back to the filter type which originally was desired, maintaining the general network arrangement of the low-pass filter.

13.10. Allowance for Dissipation in Filter Design. The filter design with the insertion parameter method permits allowance to be made for dissipation in the circuit components with the object of reducing in the pass-band the insertion loss distortion due to dissipation. The physical reason for this distortion has been outlined in Chapter 11. Compensation can be achieved by introducing mismatch between the filter impedances and the terminating resistances to such an extent that the insertion loss due to dissipation and the insertion loss due to mismatch add up to a constant value throughout the pass-band.

In the corresponding mathematical process use is made of the dissipation coefficient ε of the filter components as defined in Eqs. (11.1) and (11.2). It is assumed that the dissipation coefficient is the same for all inductances and capacities, and that it is independent of the frequency. By the first assumption no serious error is caused if a suitable average value is chosen for ε, in accordance with Eq. (11.10). The second assumption is, as a rule, not a good approximation to the physical facts because ε increases with frequency and may be regarded as a constant only in comparatively narrow frequency bands (c).

The principle of the distortion compensation is that the complex frequency parameter s in the transfer factor H(s) is replaced by $(s - \varepsilon)$:

$$H'(s) = H(s - \varepsilon) \quad \ldots\ldots\ldots\ldots (13.15)$$

The transfer factor is thereby predistorted. If now a filter were designed (as a pure reactance fourpole) with the transfer factor H′(s) and were built with dissipative components having the dissipation coefficient ε, then the filter would have the actual transfer factor $H'(s + \varepsilon)$ which is identical with the original and desired transfer factor H(s).

However, if H(s) is a realizable transfer factor, then H′(s) is normally not realizable in this simple form and certain modifications of the method must be made. It is expedient to introduce the substitution $s \longrightarrow (s - \varepsilon)$ only in the numerator polynomial, E(s), of the transfer factor and leave the denominator polynomial, G(s), unchanged. The substitution would destroy the even or odd character of G(s) which is one of the realizability conditions. Fulfilment of this condition could be restored by multiplying the predistorted transfer factor, H′(s), with $G(s + \varepsilon)$ in numerator and denominator, as $G(s - \varepsilon) \cdot G(s + \varepsilon)$ is again an even polynomial. But apart from the undesirable increase of the degree of the transfer factor by the degree of $G(s + \varepsilon)$ and a corresponding increase of the number of circuit components required for the realization, the insertion loss peaks are no longer situated at real frequencies and it would therefore be necessary to use perfectly coupled inductances in the circuit. The practical difficulties of constructing such inductances with adequate approximation to the theoretical requirements are so great that they are avoided whenever possible.

The error of insertion loss which is made in leaving G(s) unchanged can be calculated using the relation.

$$\Delta A_L = 20 \log \left| \frac{G(j\omega)}{G(j\omega + \varepsilon)} \right| \quad (13.16)$$

ΔA_L is always negative. In the stop-band it can cause a marked reduction of the theoretical insertion loss, particularly in the vicinity of insertion loss peaks. These are reduced to finite values which, however, can be improved by means of

(c) S. Darlington, to whom this method is due, has also treated the case of unequally dissipative inductances and capacities, and the case of a uniform dissipation coefficient which varies with frequency in a certain way.

the same methods which were discussed for image parameter filters in Chapter 11. Apart from that, allowance can be made for the insertion loss reduction when the characteristic function leading to H(s) is set up.

In the pass-band the error ΔA_L is in most cases negligible when compared with the error due to frequency variations of the dissipation coefficient. Only when there is a very abrupt transition from pass-band to stop-band may the effect of ΔA_L be noticeable. It can be approximately compensated by a proportionate reduction of the value of ε.

The substitution $s \longrightarrow (s - \varepsilon)$ in the numerator polynomial E(s), shifts its roots in the complex s-plane by the amount ε to the right towards the imaginary axis. As these roots must remain inside the left half of this plane, owing to realizability condition (a), it follows that ε is limited to a value which must be smaller than the smallest (negative) real part of all the roots of E(s). In fact, ε should not be larger than about 60% of this smallest real part for the following reason:

Shifting the roots of E(s) closer to the imaginary axis has the effect that the magnitude of $E(j\omega - \varepsilon)$ is smaller than that of $E(j\omega)$. This means that realizability condition (d) is violated if the transfer factor has been calculated in accordance with the procedure described in paragraph 13.7. Fulfilment of condition (d) can be restored by multiplying the predistorted transfer factor with a constant factor k which is so chosen that

$$k \mid E(j\omega - \varepsilon)/G(j\omega) \mid \geq 1$$

at all real frequencies. The value of k is in the order of size of the ratio

$$\frac{\text{smallest real part of roots of } E(s)}{\text{smallest real part of roots reduced by } \varepsilon.}$$

There is a practical advantage in keeping k as small as possible because the multiplication of the transfer factor by k increases the insertion loss of the filter by the flat amount of 20 log k. The discrimination between stop-band and pass-band insertion loss is not affected but the signal level at the filter output is reduced by 20 log k (in db).

Taking into account what has been said so far in this paragraph, the filter design proceeds as follows:

From a characteristic function complying with the insertion loss specifications the transfer factor $H(s) = E(s)/G(s)$ is calculated. The substitution $s \longrightarrow (s - \varepsilon)$ is introduced into the numerator polynomial E(s) yielding

$$E'(s) = E(s - \varepsilon) \quad \ldots \ldots \ldots \ldots (13.17)$$

A constant factor k is determined so that

$$k \left| \frac{E'(j\omega)}{G(j\omega)} \right| \geq 1 \quad (13.18)$$

at all real frequencies. The new transfer factor is

$$H^*(s) = k \frac{E'(s)}{G(s)} \quad \ldots \ldots \ldots \ldots (13.19)$$

The original characteristic function can no longer be used for calculating the elements of the transfer matrix owing to the change of the transfer factor. The relation of Eq. (13.9) must still be maintained and serves for obtaining the new characteristic function

$$K^*(s) = \frac{F'(s)}{G(s)} \quad \ldots \ldots \ldots \ldots \ldots (13.20)$$

With the new numerator polynomial of the transfer factor this relation is now somewhat rearranged:

$$F'(s)\, F'(-s) = k^2\, E'(s)\, E'(-s) - G(s)\, G(-s) \quad \ldots \ldots \ldots \ldots (13.21)$$

The polynomial F'(s) is obtained by calculating the roots of the right-hand side of Eq. (13.21). The roots can be distributed to F'(s) and F'(–s) in an arbitrary way, as long as those of F'(s) are symmetrical to those of F'(–s) with respect to the origin of the complex s-plane. (This is implied in the symbolism used for the two polynomials.)

With the help of H*(s) and K*(s), and Eq. (13.12) the elements of the transfer matrix are calculated and the filter can be realized in the usual way.

When deriving a frequency-symmetrical band-pass or band-stop filter from a low-pass filter by means of a reactance transformation, the actual average dissipation coefficient of the band-pass or band-stop filter components cannot be directly applied in the design of the low-pass filter, but must be multiplied by the factor

$$f_{co}/(f_{c2} - f_{c1})$$

where f_{co} is the cut-off frequency of the low-pass filter, and f_{c1} and f_{c2} are the lower and upper cut-off frequency, respectively, of the band-pass or band-stop filter. Only in the case of comparatively narrow pass- or stop-bands can a good accuracy of the dissipation compensation be expected.

All conventional types of ladder filters (excepting band-pass filters under certain conditions) calculated in this way require a transformer with a transformation ratio which is essentially determined by the constant factor k. Inserted between a source and load with equal resistances it produces a loss of approximately 20 log k due to mismatch. The transformer can be omitted if the terminating resistance at the respective filter end is altered accordingly.

Dissipation-compensated filters have impedance characteristics in their pass-bands which may vary within wide limits, depending on the size of k. This is necessary to produce the required insertion loss by mismatch. As a consequence the pass-band insertion loss of such filters is very sensitive to variations of the terminating resistance at the high-impedance end and care must be taken that this resistance is reasonably constant within the pass-band.

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LETTER TO THE EDITORS

STANDARDISATION IN ELECTRONICS SYMBOLS AND TERMINOLOGY

34 Toolangi Road,
Alphington, Victoria.

Sirs: Freedom and conformity are usually regarded as opposites. If one has to conform, then one is not free, and vice versa. Actually it is not quite so simple. When we come to specific cases we often find that conformity in one field is an essential prerequisite for freedom in another. Until this conformity is established it is very difficult to make further advances.

The field of electronics is no exception. Conformity in terminology and symbols makes it possible for people all over the world to understand each other with relative ease. In this respect the language of electronics is far ahead of most kinds of human communication. The main reason is that electronics developed only after communication between nations was well established. Ordinary languages, on the other hand, arose in isolated communities in prehistoric times and did not mutually influence each other except when there were wars, mass migrations or other special circumstances.

Three basic requirements must be met before satisfactory human communication can take place. Firstly, the information must be transmitted with accuracy and freedom from interference. (The irrelevant flourishes in bad handwriting are as much a source of Q.R.M. in written communication as static is in radio communication. "Hi Fi" and "Lo Fi" applies to writing and speech as well as to amplifiers.) The second requirement is that the information should be meaningful to all concerned and the third requirement is that it should mean the same thing to all concerned.

One of the biggest single achievements in electronics is the American system of numbering valves. This fulfils all three requirements mentioned above and is well on the way to becoming an international standard. Valve type 6V6 for instance means one thing only from Tokyo to Timbuktoo.

The British valve manufacturers, by contrast, have failed lamentably in the past even to establish intelligible communication between themselves. It is impossible to estimate how much has been lost in wasted time, unserviceable equipment, wasted effort, frustration, and lost overseas trade through the lack of elementary standardisation.

One example appearing in a war time book of equivalent valves, is that of a 4-volt double diode triode. The following were listed as equivalents: 11A2, DDT, TBC14, A23A, HD4, ACDDT, DH42, ACHLDD, TDD4, SS4DDTAC, DT41, ACHL4DD, DDTR, DD436, DDT4. Fifteen different designations for what is in effect the same thing! It is disturbing to see that transistor coding appears to be tending towards a similar state of chaos.

Another source of confusion is the use of ambiguous words, the meaning of which is usually vaguely taken for granted. What exactly, for instance, is a receiver? It could be a radio receiver, a television receiver, a telephone receiver, a letter receiver, an air receiver, a garbage receiver or even a receiver of stolen property.

The opposite situation where two or more words are used to mean the same thing can be even more confusing, especially to students. A young student, after reading various text books, could be forgiven for believing that the old type radio receivers, using valves, coils and condensers, required an aerial, while the modern ones, with electron tubes, inductors, and capacitors, are so much more efficient that they only need an antenna.

A stage can be reached where means of communication become means of spreading confusion and actually hinder intelligible communication.

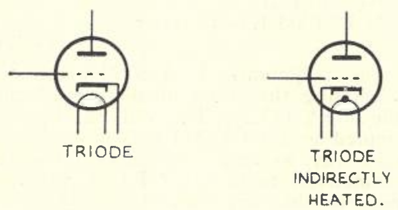


Fig. 1.

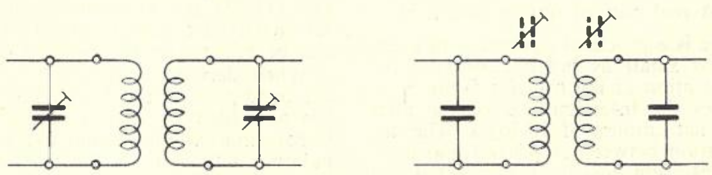


Fig. 2.

Figs. 1 and 2 give an example of this sort of thing. They appeared in a publication intended to teach the fundamentals of radio. In Fig. 1 the implication is that an irrelevant spot on the heater has something to do with the symbol, and in Fig. 2 it is implied that the I.F. transformer is only tuned when the inductors have adjustable cores. Nobody is infallible but if those who take on the responsibility for producing text-books for students are too busy or careless to avoid mistakes such as these, they would be better not to produce anything.

Finally, and perhaps most important of all as a language of universal communication are the graphical symbols. Here credit goes to the British Standards Association for producing in B.S. 530 what is the most logical, thorough and comprehensive specification of graphical symbols for telecommunication in existence today.

Although the language of electronics did not suffer the geographical isolation which caused the differences in ordinary languages, it did suffer to some extent from the isolation associated with specialisation.

Modern electronics arose from the development and coming together of three branches of technology; wireless, telephone and electrical. Carrier systems, computers, automation and similar developments have brought these three branches of technology into one field. It is significant that Supplement 2 of B.S.530 deals with graphical symbols used in waveguide technique, while Supplement 5 lists functional symbols for switching diagrams, which are mainly used in connection with computing devices.

But in spite of this effort to unify the language of the radio, telephone and electrical branches, there still remain some confusing differences, particularly in what is sometimes called industrial electronics. Not many radio people, for instance, would be able to make sense of the time delay relay circuit shown in

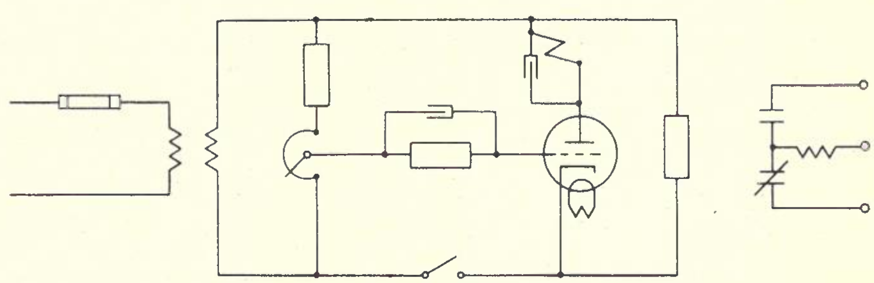


Fig. 3.—"Industrial" Circuitry.

Fig. 3. The peculiar "resistance capacity" combination at the right hand end is actually nothing of the sort. A glance at Fig. 4, which is the same circuit expressed in the language of radio, shows it to be the change-over contacts of a relay in series with an output winding of the mains transformer.

There is something to be said, after one recovers from the initial shock, for the practice of showing the various transformer windings detached from each other, provided they are adequately coded. After all it is normal to do this with relays, keys and switches, and can sometimes save long and involved runs of conductors. Of course the practice of detaching parts of a com-

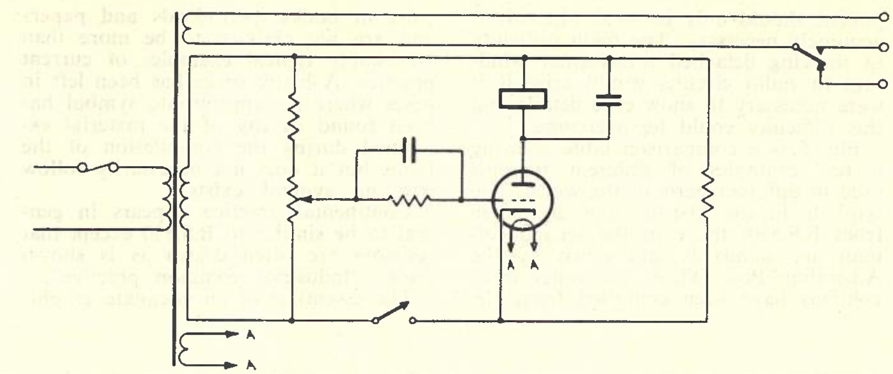


Fig. 4.—"Telecommunication" Circuitry.

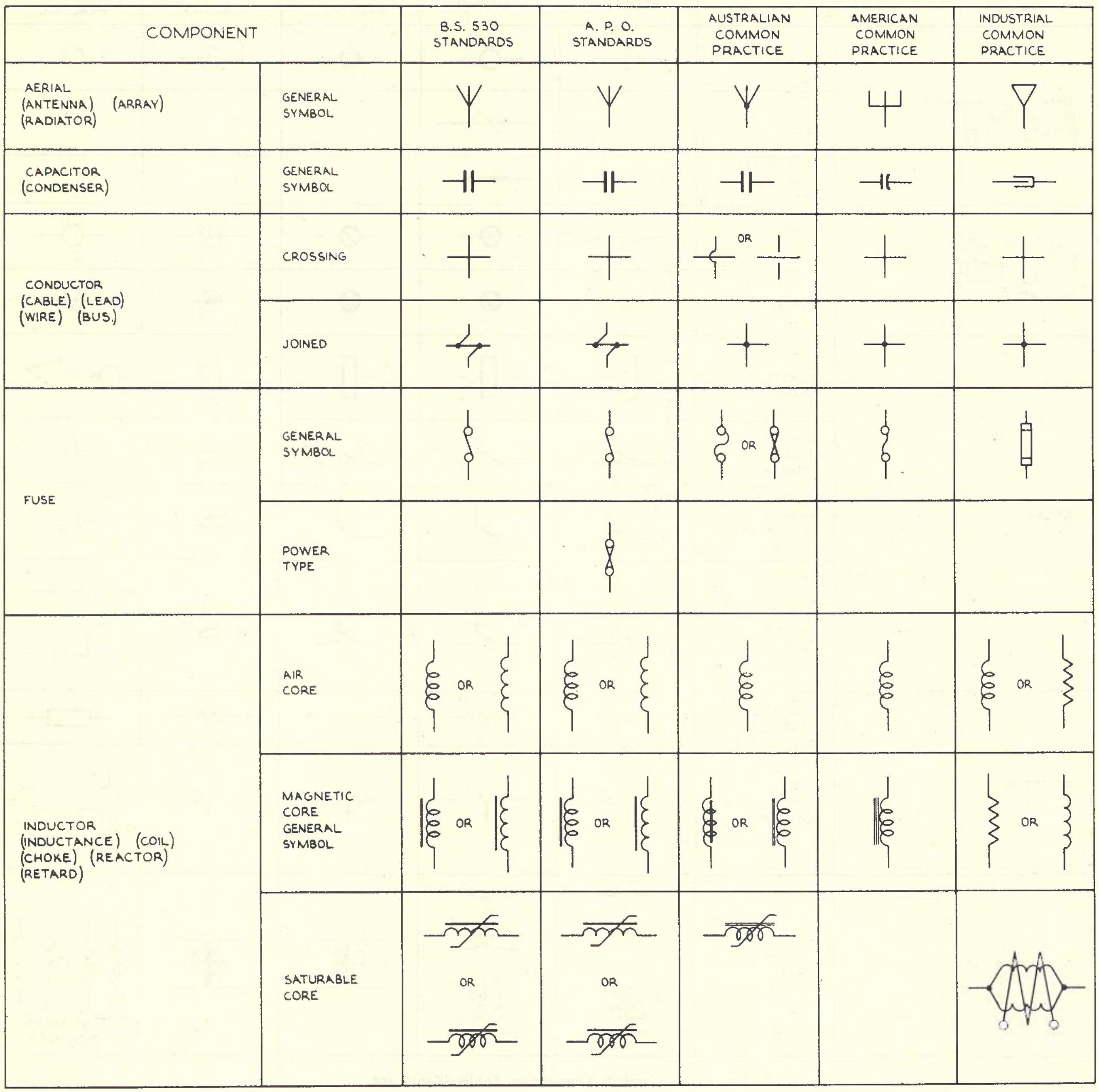


Fig. 5(a).—Symbols Comparison Table.

ponent should only be used where it is genuinely necessary. The main difficulty in showing detached transformer windings in radio circuits would arise if it were necessary to show core details, but this difficulty could be overcome.

Fig. 5 is a comparison table showing a few examples of different symbols used in different parts of the world. The symbols in the first column are taken from B.S.530; those in the second column are standards laid down by the Australian Post Office. The other three columns have been compiled from circuits in books, periodicals and papers and are not claimed to be more than reasonably typical examples of current practice. A blank space has been left in cases where no appropriate symbol has been found in any of the material examined during the compilation of the table, but it does not necessarily follow that no symbol exists.

Continental practice appears in general to be similar to B.S.530 except that resistors are often drawn as is shown under "Industrial common practice".

The essentials of an adequate graphical symbol are that it should be distinctive and easy to draw. The need for each symbol to be distinctive often makes it difficult to introduce any piecemeal change in a system of symbols. If the rectangular resistor symbol used in industrial practice were altered to conform with B.S.530, it could easily be confused with a detached transformer winding or an inductor unless the sawtooth version of these was deleted.

There seems little merit in the industrial version of relay contacts. They look too much like what is widely accepted

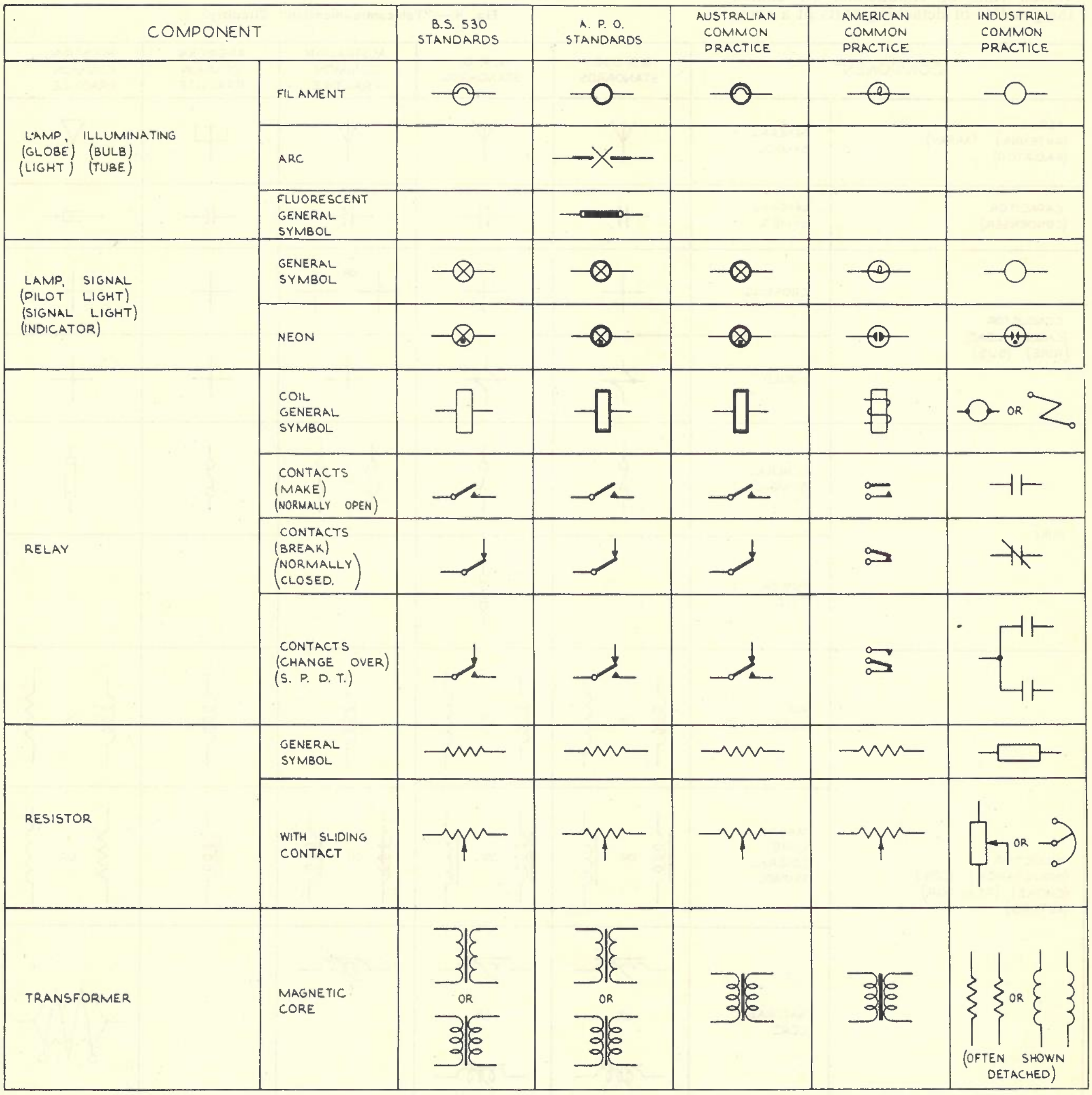


Fig. 5(b).—Symbols Comparison Table—Continued.

as a normal capacitor symbol, even including the American standard symbol shown in Fig. 6.

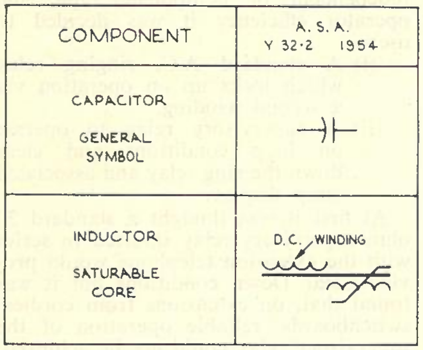


Fig. 6.—American Standard Graphical Symbols for a Capacitor and a Saturable Core Inductor. No alternative is given for either of these symbols.

The B.S.530 symbol for a relay coil allows for information about resistance, multiple windings, types of slug, etc., while the industrial relay coil symbols are more limited in their scope.

There are other minor differences in the various sets of symbols. Some have a little more detail than necessary but the general tendency seems to be towards a gradual simplification wherever this can be achieved without losing the identity of the symbol. In particular there is a tendency to use only one thickness of line for conductor and symbol. The lamp symbols of B.S.530 are an example of this and no doubt the capacitor symbol will eventually follow suit.

The American Standards Association has produced a publication (Y32." 1954) entitled "American Standard Graphical Symbols for Electrical Diagrams". This superseded five separate publications and covers purely electrical as well as telecommunication symbols. A feature of these symbols is that one thickness of line is used throughout, although a general note allows a thicker line to be used if required for emphasis. The symbols are similar to those already shown in Fig. 5 and in most cases the symbols shown under "Industrial Common Practice" in Fig. 5 are listed as alternatives to the more conventional ones. Two exceptions worth noting are shown in Fig. 6.

The American standard permits the joining of four conductors at right angles with a dot, "only if required by space limitations", a directive which seems to be largely ignored in common practice. The fact that the dot is optional in the case of an ordinary junction does not help in improving readability or in reducing errors.

The best way of distinguishing between conductors which cross and those which join seems always to provide a fruitful source of argument. But after years of contending with grimy schematics, often photographically reduced, it is hard to find a justification for anything but the simple rule that two lines crossing at any angle signify a pair of conductors crossing, regardless of dots, fly spots, holes in the print or anything else.

No mention has been made in this letter about methods of presenting the circuit as a whole. This subject deserves at least an entire article in itself. However, it is hoped that the present letter will help in the interpretation of circuits using unfamiliar symbols and that it will serve to draw attention to the need for developing and maintaining standardisation in electronics.

Yours, etc.,

R. E. HARTKOPF

LETTER TO THE EDITORS

THE ANALYTIC STUDY OF SPEECH

Research Laboratories,
Melbourne.

Sirs: There has been intense activity in the past 20 years, which is still continuing, in the field of speech bandwidth compression and analysis-synthesis systems. In general, an experimental approach has been adopted, the minimum of speech analysis being undertaken to provide a basis for the construction of electrical apparatus. That this approach is sterile is apparent from the genesis of a great variety of systems which will produce speech of minimal quality but none of which can compare with a broad-band system.

Study in this field is unlikely to be profitable. It has a twenty-year history not marked by any significant advance. It requires a great variety of complex hardware in order to fashion even a model of part of a system although complete systems are required for evaluation by present techniques. Activity has been so widespread during this time that it is difficult to envisage that an approach based on the elementary understanding of the speech process which obtains at present has not already been considered at some time and place.

There is a real need for further study of the speech process with the well defined intention of impressing the knowledge so gained into economic development of orthodox communication systems. Such study would be in line with modern trends in speech and hearing research which is being carried out in the linguistic and philological as well as the psycho-acoustic field but does not seem to have been applied in the field of telecommunications since Fletcher's work prior to World War II. Initially, the aim might well be to procure statistics of speech (both natural and transduced). Recently there have been developments (by the Japanese and others) in the time domain analysis of speech which shows much more promise than the frequency domain analysis pursued hitherto. The equipment developed in order to pursue such studies would have in addition considerable general utility. It is possible to envisage an instrument which would, when applied to any speech link, give a direct indication of the transmission performance of that link.

Further objects of research in this field would be to elucidate the relationship between speech information rate (25 to 50 bits per second) and the channel capacity (500,000 bits per second) needed to achieve this rate between humans, and to provide an exact basis for the design of speech links in which the various parameters, noise, distortion, intensity and bandwidth, may be economically chosen for a given level of communication efficiency. In this connection the term "communication efficiency" also has an exact meaning referring to the communication of ideas and involving linguistic and philological considerations.

It is desirable at this time to give some thought to international speech communication and it may well be that communication efficiency as defined above, would have a national attribute arising from the linguistic factors involved. Finally, it is apparent that, although the analytic study of speech proposed here has as its primary aim the development of the art of telephony, significant contributions to the basic understanding of the speech process would be made with widespread repercussions in the broadcasting, public address, speech reinforcement, etc., fields.—Yours, etc.,

J. M. BRYANT

TELEPHONE FACILITIES IN THE SYDNEY STOCK EXCHANGE

*A. B. WILSON**

Editorial Note. At the official opening of the new Stock Exchange the visual signalling system was the subject of comment by overseas visitors, who said it compared more than favourably with overseas systems. The Secretary of the Stock Exchange has since indicated that requests for information on the system have been received from the managements of the London and New York Stock Exchanges.

INTRODUCTION

On 13/9/60 the Sydney Stock Exchange moved to new premises in 20 O'Connell Street, Sydney. Due to the unprecedented growth of exchange business in recent years the inadequacy of the telephone facilities in the old exchange had been a matter for some concern and when it was proposed to move to new premises the Stock Exchange Committee decided to seek the Department's advice in providing a larger and more efficient telephone system.

Accordingly a conference was convened between the P.M.G. Engineering Division and the Stock Exchange Committee. This meeting resolved the following basic considerations:—

(i) An individual telephone service be provided for each Stock Exchange member.

(ii) A method of visual signalling be provided, as the noise of Exchange trading precluded the use of bells; further, bells do not permit easy discrimination when several telephones are grouped together.

(iii) Any indication of a visual signal should be prominent and discernible from any section of the Exchange floor.

(iv) It was naturally desirable that any installation be such as to harmonise with the modern decor of the internal appointments.

The success of these latter features can be gauged from Figs. 1, 4 and 5 appearing later in this article, and proves an excellent example of the benefits of adequate planning when projects are in the initial stages.

Immediate requirements were 70 services with an ultimate of 90 services being envisaged. As similar facilities were to be provided in the Sydney Greasy Wool Futures Exchange in March, 1960, where some 20 services would be installed, it seemed prudent to regard the smaller installation as a prototype where any circuitry difficulties could be corrected before commencement of the larger Stock Exchange project.

FACILITIES REQUIRED:

After discussions with both subscribers it became evident that required facilities would be:—

(i) On reception of A.C. ring to provide a lamp display.
 (a) Greasy Wool Exchange, 2 lamps.
 (b) Stock Exchange, 3 lamps.

Fig. 1.—Telephone Booth Visual Indicator.

(ii) Lamp display to clear down when call is answered.

(iii) Restore to normal at completion of call.
Other factors to be considered were:—
 (a) Type of ringing signal.
 (b) Periodicity of ring.

From a consideration of Table 1 it can be seen that some equipments provide an intermittent type of ring whose periodicity is dependent upon the diligence of the P.B.X. Operator: in order therefore to ensure effective signalling independent of equipment, type, and operator efficiency it was decided to use:—

(i) A standard A.C. ringing relay which locks up on operation via a second winding.

(ii) A supervisory relay to operate on loop conditions and clear down the ring relay and associated lamp display.

At first it was thought a standard 30 ohm supervisory relay inserted in series with the extension telephone would provide Clear Down conditions but it was found that, on extensions from cordless switchboards, reliable operation of the supervisory relay could not be achieved; this was due to the undivided type of transmission feed and the fact that the operator's transmitter formed a direct shunt in the battery feed circuit; it was therefore found necessary to provide switch-hook auxiliary springs on those telephones connected to cordless switchboards, the supervisory relay being operated from the auxiliary springset when the hand combination was lifted.

In the case of the Stock Exchange project where 70 services were required, auxiliary switch-hook springs were fitted to all telephones; this removed any restriction on the type of terminal equipment into which the extension telephones operated and also ensured reliable operation under all circumstances.

To guard against confusion due to the necessity of replacing any of the telephones on maintenance, it seemed advisable to adapt some type of indicator or label to show the special nature of these telephones: Fig. 1 illustrates the type of indicator adapted, the area on the dial label containing the words

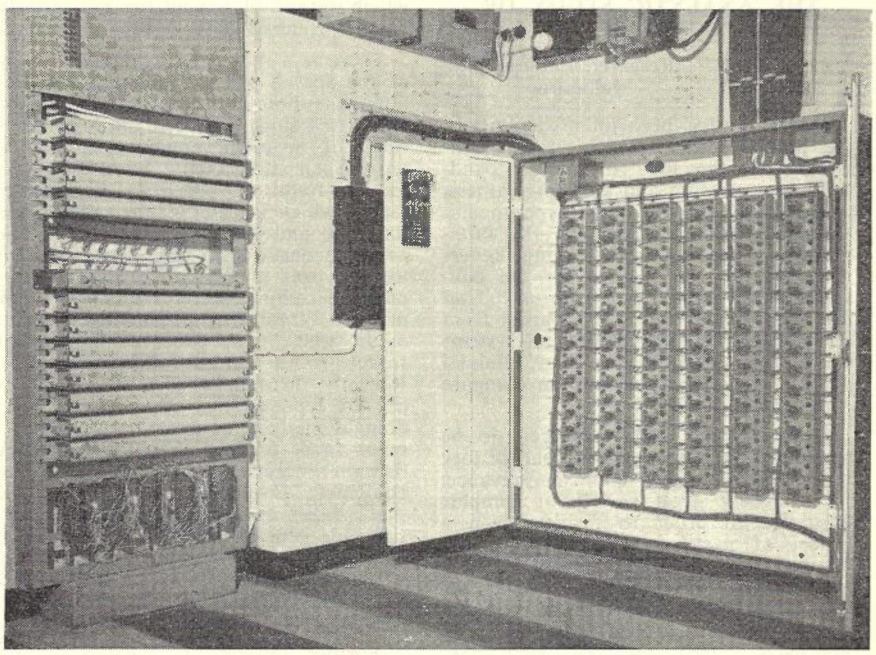
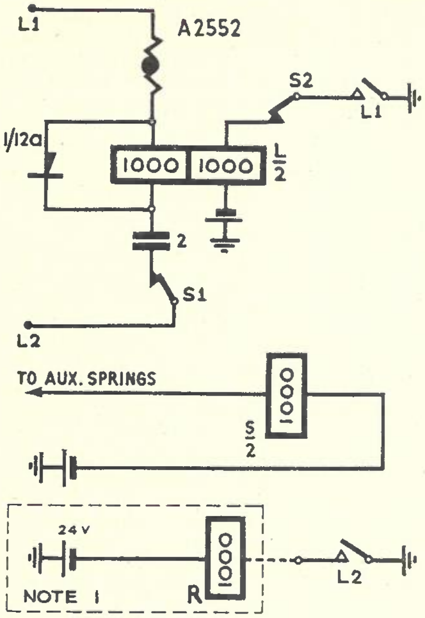


Fig. 2.—Relay Rack and 240/24 Transformer.

* See Vol. 12, No. 6, page 465.



NOTE 1. RELAY R PROVIDED BY SUBSCRIBER

Fig. 3.—Visual Signal Circuits.

(Listen before calling, pull dial round to stop and let go) was coloured in red using the silk screen printing process and then the words (Special Telephone Auxiliary springs on switch-hook) inserted in black print; Fig. 1 also shows the visual signal fitted above the telephone registering an inward call.

As the visual signal lamps were to be installed 14 feet above floor level and be of 40 Watt rating for effective illumination and having regard to possible difficulty in gaining access to the Exchange trading floor during business hours for maintenance purposes, it was arranged for the Stock Exchange Committee to provide the lamps and fittings and part of the associated relay equipment. This equipment consists of 24 Volt plug-in type relays mounted in a metal cabinet, one relay per circuit, a total of 90 relays being provided.

Power for the lamps and relays is drawn from a 240-24 Volt transformer also privately owned; Fig. 2 shows the P.M.G. rack and to the right of the picture the privately owned relay cabinet; in Fig. 2 can be seen the 240-24 Volt transformer placed just above the private relay rack, the Standard 80/80 terminating box to be seen between both relay racks is the sole connection between private and P.M.G. equipment.

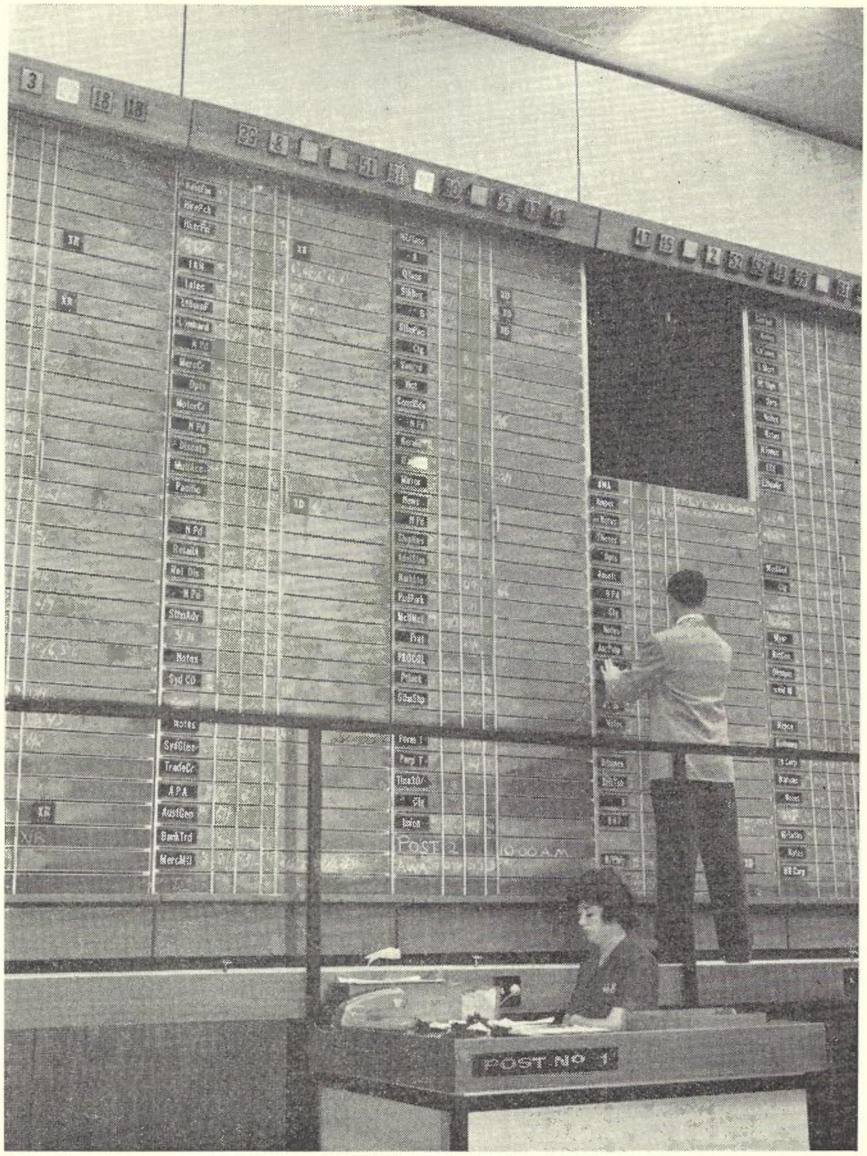


Fig. 4.—Lamp Display Above Posting Board.

Power supply for P.M.G. relays was provided from two standard 50 Volt battery eliminators; these units can be seen at top right of the P.M.G. relay rack.

TABLE 1

Types of Equipment and Signalling Employed.

Equipment Type	Signalling Type	Periodicity
Exchange Line P.A.B.X. Extn.	33-1/3 cycle A.C. Ring	Continuous until call answered or abandoned
P.B.X. Extension	16-2/3 cycle A.C. manual ring 33-1/3 cycle A.C. power ring 50 cycle A.C. power ring	Persists for period of magneto generator and/or ring key operation
Magneto type Intermediate Telephone	16-2/3 cycle A.C. manual ring	Persists for period of magneto generator operation
External Extension from Intercommunication Telephone	± pulses at 50 Volt. Battery at 16-2/3 cycles	Persists for period call button is depressed

INWARD CALL:

A.C. ring operates L relay, Fig. 3, which locks on its second winding via L1 operated and S2 normal, L2 operated extends earth to operate relay R and R springset lights lamp display, when call is answered relay S operates to ground via telephone switch-hook auxiliary springs, S1 operated removes operate winding of L relay from across the line and S2 operated releases relay L1 at completion of call S relay restores. Battery supply to these P.M.G. relays is fused, 1 strip of relays per fuse, a fuse alarm consisting of a 50 Volt red lamp is provided on top half of relay rack.

Fig. 5.—Complete Telephone Booth Installation.

Fig. 4 shows the lamp display just above the chalk board on the north wall of the Exchange, a similar lamp display is placed on the East wall; Fig. 4 also shows that two inward calls have registered and have not been answered, the double appearance of some lamp numbers indicates that the Exchange Member whose extension number is 51 has two such telephones usually mounted in adjacent telephone booths.

Fig. 5 shows the complete telephone booth installation; it is also interesting to note that some Exchange Members have interstate private lines and that such services are rendered distinctive by having a red glass shade fitted to the display lamps.

CONCLUSION:

The individual nature of the telephone facilities in the new Exchange has greatly improved the efficiency and speed of conducting this type of business, one Member stating that even the internal office procedure had been altered to take advantage of the improved facilities. The success of the Greasy Wool Futures Exchange has resulted in tentative plans being made to expand into the handling of other commodities and it is anticipated that demands for this type of equipment will continue.

TECHNICAL NEWS ITEM

OBJECTIVE ATMOSPHERIC RADIO NOISE RESULTS

Equipment to make objective measurements of atmospheric radio noise was put into service at Cook, South Australia, in July 1958, to obtain information for the National Bureau of Standards of the U.S.A. Since August 1958, the equipment has been recording, completely automatically at eight frequencies between 10 kc/s and 20 Mc/s, the level of atmospheric radio noise power once per hour. The equipment is serviced by the Postmaster-General's Department in South Australia and the records from it are analysed at the Department's Research Laboratories in Melbourne, before despatch to the National Bureau of Standards which publishes the data together with that from 15 other stations throughout the world.

The direction of arrival of atmospheric noise is also measured manually once per day at a frequency of 14.7 Mc/s.

Results of these measurements have indicated to date that—

(i) Median noise power levels are greater in summer than in winter by anything between a few and a score db.

(ii) The seasonal fluctuation varies with frequency.

(iii) The diurnal fluctuation varies with frequency, maximum noise levels occurring at night and minimum levels during the morning from 8 a.m. to noon.

(iv) The seasonal median noise level varies little with the direction of arrival at 14.7 Mc/s, the range between maximum and minimum being 3 db.

(v) The number of highest noise levels per season from a given direction is greater for easterly directions (0°—180°) than for westerly directions (180°—360°).

Man-made noise at Cook is lower than at most other stations but it is not low enough to allow measurement of the lowest atmospheric noise levels at 545 kc/s and 2.5 Mc/s which occur in winter during the morning hours. As regards (iv) the small range observed is largely the result of the wide beam-width of the antenna employed for the measurements (60° between 3 db points).

The measurements will be continued over a whole sun-spot cycle (11 years) in order to ascertain the effect on the noise distribution.

SUBSCRIBER ATTENDED 5 + 20 LINE P.A.B.X.

*A. MORTON, Grad.I.E.E.**

INTRODUCTION

Ericsson Telephones Ltd., London, designed a P.A.B.X. (1) in 1949 which provides for a maximum of five exchange lines and twenty extensions but does not require a manual switchboard. One of these units was installed in Melbourne in 1955 to serve a section of the P.M.G. Research Laboratories. The P.A.B.X. has given satisfactory service, although it lacks the additional facilities of later type models. An improved design known as the Mark 2 model was introduced in 1955, followed by the Mark 3 (2) in 1958.

FACILITIES

The 5 + 20 P.A.B.X. provides an internal system directly linked with an outside telephone network. Access to the public exchange is obtained by dialling a single digit, usually "9" or "0", whilst incoming calls can be answered by any designated extension. Any extension can be completely or partially barred exchange facilities whilst an extension with full facilities can originate, answer, transfer or receive transferred calls.

The Mk. 2 and 3 models cater for a second group of exchange lines or tie lines. However, the total number of exchange and/or tie lines cannot exceed five.

EQUIPMENT

The equipment is mounted on a rack 5′ high by 2′ 6″ wide, which is designed to stand on the floor and be supported from a wall by brackets at the top of the rack. Fig. 1 shows the Mk. 1 unit in situ; in this case additional support has been provided because the rack is bolted to a partition instead of a wall.

The P.A.B.X. works on a linefinder principle employing uniselectors and relays. The layout of the equipment can be seen in Fig. 2. Later models have similar layouts except that they have two shelves of uniselectors and the fuse panel and terminating tag blocks are located behind the uniselectors.

A uniselector and a panel of relays are associated with each exchange line. There are three local links in the Mk. 1 model and four in the other models to cater for internal calls. Two uniselectors and a panel of relays are associated with each link.

Twin type relays are used for the extension line circuits. These relays which use a common yoke and buffer block take up less room than 600 type relays. Twin type relays as well as 3,000 type relays are also used in the exchange line and local link circuits.

A separate panel is provided for the ring and tone circuits. A circuit incorporating a vibrating relay is used to provide dial tone, ring tone and ring current. Busy, N.U. and intrusion tones are generated by a self interrupting relay, condenser and resistance circuit. In the latest model transistor oscillators are used to generate 25 c/s current for ringing purposes and 400 c/s current for the various tones.

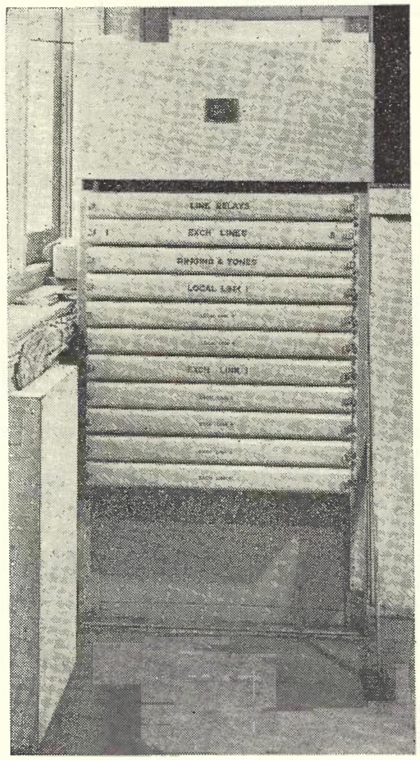


Fig. 1.—5 + 20 P.A.B.X. Rack in Situ.

All the panels, except for the top two, are wired to plugs which mate with jacks, to which the rack wiring is connected. This allows the panels to be removed for maintenance purposes.

The uniselectors are mounted on a hinged shelf fastened by two thumb screws and are grouped to facilitate straight multiple wiring. Fig. 3 shows the shelf swung down to allow access to the multiple.

The equipment uses 50V. D.C. and is normally powered by a battery eliminator mounted on the rack below the relay panels. The Melbourne unit uses a 1.5 amp. rectifier with a 90 A/H battery located close to the rack. With the eliminator scheme if the power fails the exchange lines are automatically switched through to selected extensions in order to maintain contact with the public telephone network.

Both front and rear covers are provided for protection against dust and damage. In the latest models individual covers are provided for each relay panel as in the Mk. 1 model. However, instead of just a cover over the uniselectors as shown in Fig. 1 a hinged cover is provided which completely covers all the equipment.

Ordinary type telephone instruments are used incorporating a non-locking press button for transfer and/or consultation calls.

TRUNKING AND NUMBERING

An outline of the trunking is shown in Fig. 4. Only three local links are provided in the Mk. 1 model, this being sufficient where there is little internal traffic. To cater for heavier traffic the Mk. 2 and 3 units are provided with four links.

The extensions are divided into three groups in the Mk. 1 model as follows:—

01- 09 (9 lines)
11- 19 (9 lines)
001-002 (2 lines).

With the latest model it is only necessary to dial two digits when calling any extension.

OPERATION

Internal Call — Upon lifting the handset, a start signal is extended from the extension line circuit to the free local links. The linefinder (L.F.) uniselector of one of the links searches for the calling line which is marked from the line circuit. When the calling line is found dial tone is received from the local link. The required number is then dialled and the C.S. uniselector of

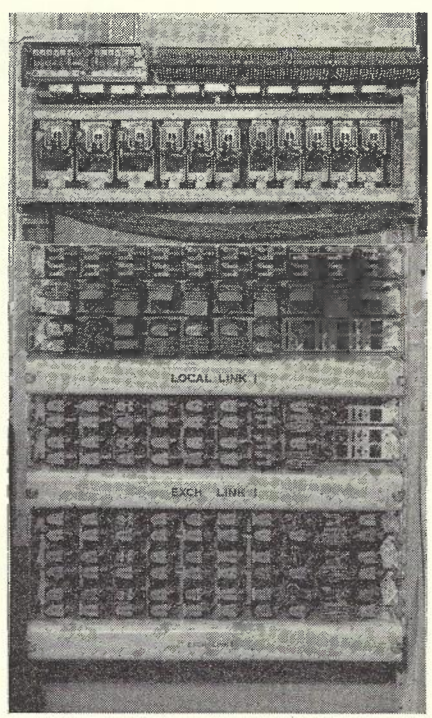


Fig. 2.—Equipment Layout.

*See page 155.

the local link steps to the outlet associated with the wanted extension. Ring tone is received if the required extension is free, or busy tone if engaged. If a spare number is dialled busy tone is received (N.U. tone with the latest model). The first extension to replace the handset at the conclusion of the call releases the connection.

Outgoing Exchange Line Calls — A local link is seized upon lifting the handset and dial tone is received when the link finds the calling extension. The appropriate digit is dialled and the C.S. uniselector of the local link steps accordingly. Conditions are then established for the linefinder associated with a free exchange link circuit to hunt for the calling extension. When the calling line is found the local link is released for further calls. If the public exchange is automatic then dial tone will be received. The required number is then dialled, the impulses being repeated by the exchange link circuit.

Outgoing Tie Line or Second Exchange Line Group Call—In the case of the Mk. 2 and 3 models provision is made for a second group of exchange lines or tie lines, and the digit eight is dialled in order to gain access to these lines.

Incoming Exchange Line Call—Attention is drawn to an incoming exchange line call by the ringing of a special bell, or bells, positioned within hearing of all designated extensions. The first of these extensions to lift the handset causes the appropriate exchange link uniselector to hunt and find the extension. The incoming call is then switched through to the extension.

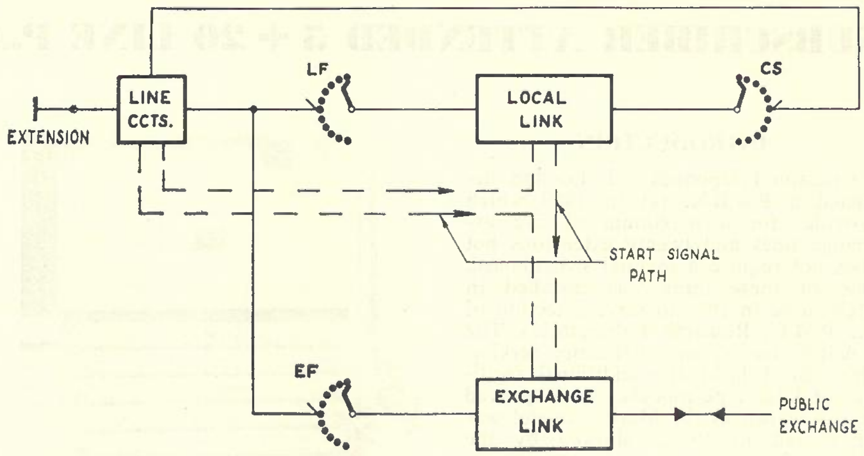


Fig. 4.—Trunking Outline.

Incoming Tie Line Call — The tie lines are associated with line circuits, so that a caller can obtain a local link and proceed as described under "Internal Call". Busy tone (N.U. in the case of Mk. 3 units) is returned if the caller dials the exchange line or tie line access digits.

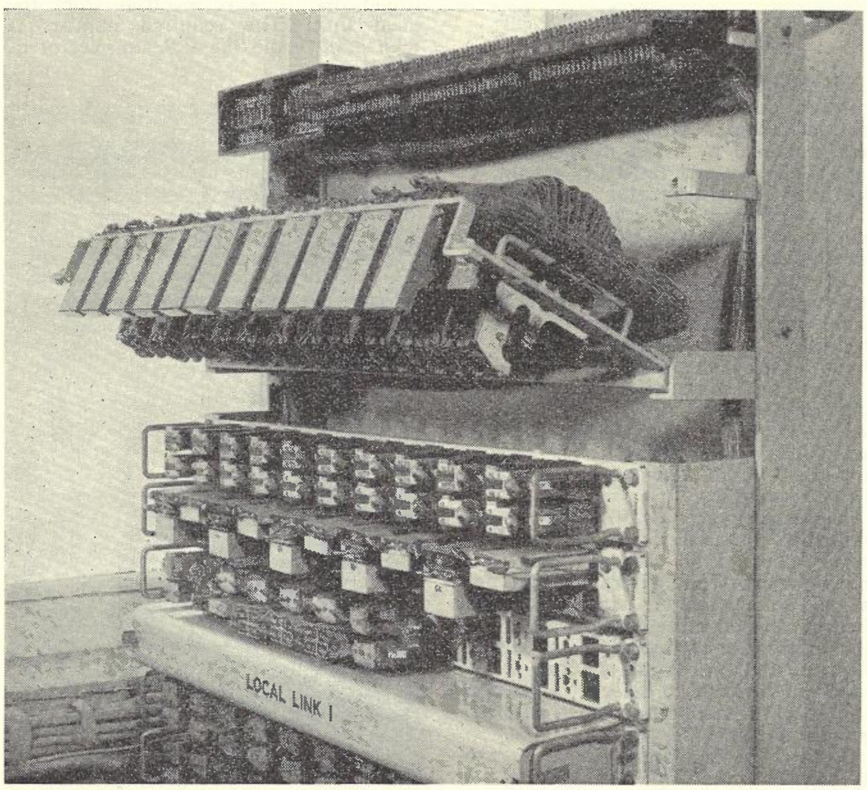


Fig. 3.—Uniselector Shelf in Down Position. Note Twin Type Relays of Line Circuits below Uniselectors.

Transfer and Consultation Calls—An extension engaged on an exchange line call and wishing to transfer the call or consult another extension, momentarily operates the press button on the telephone. This causes a holding loop to be connected across the exchange line and connects the extension to a local link so that the required internal number can be dialled. When the called party answers, the calling extension replaces the handset if the call is to be transferred. The exchange link finder then searches for the called extension. When the extension is found the local link releases and the exchange hold loop is disconnected.

If the internal call is only for consultation purposes, the exchange connection can be re-established by again momentarily operating the instrument press button.

Should the required extension be engaged on an internal call busy tone is received by the calling extension, but intrusion tone is superimposed on the conversation of the local call, to give warning that an extension is calling. On hearing the intrusion tone both extensions should replace their handsets, when the required extension will be automatically rung and, on answering, will be connected to the calling extension.

If the required extension is engaged on an exchange line call, N.U. tone is received by the calling extension and intrusion tone is not connected. However, with the later type models extensions can be given a "right of way" facility enabling them to intrude on any engaged extension.

MAINTENANCE

There are three main advantages of this unit compared with the "C" type P.A.B.X. These are as follows:—

(1) There are no bimotional switches.
(2) The circuits are not as complex.
(3) There are fewer moving parts.

This results in maintenance costs being less than those associated with a "C" type unit.

MARK 3 UNIT (ADDITIONAL FACILITIES)

Additional facilities have been provided in the Mk. 3 model. These are as follows:—

(1) Local links, Exchange links, and Tie Line Circuits can be busied by removal of test jack links.
(2) Extension line is locked out if dialling is delayed or if the inter-train pause is excessive. Lock-out also occurs if an extension fails to clear after a local call. A P.G. alarm is provided, with facilities for extending the alarm.
(3) If the linefinder of the local link or the exchange finder fails to locate the appropriate extension within 20 seconds then the start signal is transferred to an alternative finder.
(4) If, on an incoming exchange line call, the exchange finder fails to locate the extension line within approximately 20 seconds, the call is routed directly to a selected extension.
(5) An exchange line call is re-established in approximately 20 seconds if the transfer of the call is unsuccessful due to incorrect transfer procedure.

CONCLUSION

The latest 5 + 20 P.A.B.X. is a great improvement on previous models, and with a few further minor modifications could result in the unit becoming an attractive proposition to many small business organisations. The unit costs approximately half that of the C type P.A.B.X.

REFERENCES

1. Ericsson Bulletin No. 22, P. 12, January, 1951.
2. Ericsson Bulletin No. 40, P. 3, January, 1960.

TECHNICAL NEWS ITEM

EXPERIMENTAL INSTALLATION OF NEUTRALIZING TRANSFORMER

The Postmaster-General's Department in co-operation with the Electricity Commission of New South Wales is installing an experimental ten-line neutralizing transformer at Yass Substation.

Neutralizing transformers are used for the protection during fault conditions of communication, tele-metering, pilot-wire relays, and other control circuits required by power authorities for the operation of large high voltage substations. Service continuity on these circuits is of importance and a neutralizing transformer is designed to maintain this continuity and to prevent damage to the circuits, to terminal apparatus or to the staff using telephones and control equipment within the substation during an earth fault at the substation.

In a power transmission line originating from a substation it is usual for each phase to be fed from a star-connected winding directly connected to earth at the neutral point. The load currents circulate in the three line wires and no part flows in the earth connection of the transformer. If, under fault conditions, one phase wire is short-circuited to earth, a short circuit current will circulate through the fault and through the neutral earth. At Yass Substation the probable voltage rise has been calculated as 4,500 volts based on an expected maximum fault current of 9,000 amps. through a sub-station earth of 0.5 ohms. The substation earth at a high voltage substation is usually extended over the whole area enclosed by the substation and all structures on the site are bonded to earth. Thus the whole of the substation area under fault conditions is raised in potential. The voltage of the ground outside the substation above remote earth is a reciprocal function of the distance from the substation earth.

Communication circuits entering the substation will be at remote earth potential and the full voltage rise of the substation will appear across the insulation of the conductors and the equipment to which they connect. A neutralizing transformer compensates for this voltage difference by transferring the rise of potential within the substation to the cable pairs without making metallic connection and without causing appreciable current to flow in cable pairs.

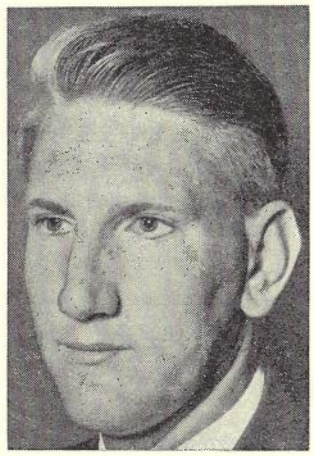
The neutralizing transformer is essentially a potential transformer having two sets of windings and operating on open circuit. The primary winding consists of a single conductor with one terminal connected to the substation structure or earth electrode systems and the other to an earth sufficiently outside the area of influence of the earth fault current to allow most of the potential rise of the substation to be applied across the primary winding. A secondary winding consists of the same number of turns as the primary winding, connected with same polarity. The potential difference between the station structure and earth is then transferred to the secondary circuit, thus bringing the telephone or other equipment concerned to the same potential as its surroundings while leaving the line on the exchange side of the transformer substantially unaffected. The transformer contains only one primary winding and a secondary winding is provided for each wire of the communication circuits entering the substation.

In order to keep the resulting voltage difference between the communication circuits and the substation ground as low as possible, it is necessary to keep the current in the primary winding low and operate the transformer at a low level of saturation. As it becomes necessary to compensate for higher differences in voltage, the size of the transformer will increase. The present transformer weighs about eleven hundredweight and its cost is about £200. Future designs to compensate for rises in substation earth potentials up to 10,000 volts are expected to require substantially larger transformers of the order of two to four tons.

The installation of the Yass neutralizing transformer is proceeding and experience gained with this installation will help in determining the practical field of use of neutralizing transformers in the future provision of communication circuits into high voltage substations.

OUR CONTRIBUTORS

E. R. BANKS



B. R. PERKINS

E. R. BANKS, author of the article "Crossbar Switching Equipment for the Australian Telephone Network" joined the Department in 1948 as a Cadet Engineer and completed his training and the Degree of B.E.E. at Melbourne University in 1952. In this year, Mr. Banks shared the Dixson Scholarship in Electrical Engineering and won Monash, Newbigin, and Oral Presentation prizes of the Institution of Engineers Australia for two papers, one on Network Design and one on the Electrolytic Tank. After nine months on Country Installation work in Victoria Mr. Banks joined the Long Line Equipment Section at Central Office and was assigned the task of locating an intermittent fault on the Adelaide/Perth section of the Sydney Cottesloe high speed telegraph circuit. Following the successful completion of this assignment Mr. Banks spent 1955 and 1956 in England and Europe as the holder of a scholarship from the Federation of British Industries. During this time he visited and worked with Telecommunication Manufacturers and the British Post Office. On his return from England Mr. Banks took up duty as Divisional Engineer, Traffic, in the Telephone Equipment Section and later as Sectional Engineer, Network Planning. He was associated with the re-issue of Traffic Engineering Instructions as Chairman of the Traffic Engineering Committee and with the studies and work leading to the recommendation that the Department adopt Crossbar as the new standard switching system. Currently Mr. Banks is Chairman of the C.C.I.T.T. Working Party on National Automatic Telephone Networks with the responsibility for formulating guiding principles to assist new and developing countries in the development of their automatic telephone networks. Mr. Banks is an Associate Member of the Institution of Engineers Australia and an Editor of this Journal.

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W. G. SHAPLEY, co-author of the article "Sound Reinforcement for the Adelaide Festival of Arts", joined the Department as a Cadet Engineer and graduated Bachelor of Engineering at the University of Adelaide in 1952. In April 1952, Mr. Shapley was granted two years' leave during which time he worked with Siemens Bros., Woolwich, England. He resumed duty with the Department in Adelaide in the Telephone Equipment Planning Division, and since 1956 has been employed in his present position of Group Engineer, Radio Broadcast Studios.

★

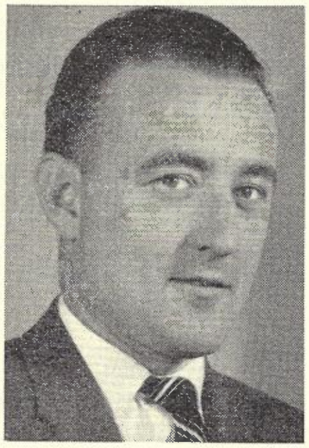
W. G. SHAPLEY

B. R. PERKINS, co-author of the article "Sound Reinforcement for the Adelaide Festival of Arts", joined the Department as a Technician-in-Training in 1947, and in 1949 was appointed Cadet Engineer. He graduated Bachelor of Science in 1955 and after experience in the South Australian Transmission Planning Division, was appointed Group Engineer, Broadcast Transmitter Installation and Maintenance. He now occupies the position of Divisional Engineer, Broadcast Studios, and is responsible for the installation, operation and maintenance of this equipment in South Australia and the Northern Territory.

★

G. MORRIS, author of the article "Line Concentrators", started his training in the Dollis Hill Research Laboratories at the B.P.O. in 1941. His eleven years' telecommunications field experience in the B.P.O., New Zealand State Hydro-Electric Department, the A.P.O. Research Laboratories and the State Electricity Commission of Victoria was followed by his obtaining Graduate Membership of the Institution of Electrical Engineers. He joined the Department in Victoria as a Grade 1 Engineer in 1952 and after experience in Country Installation and Radio Telephones was transferred as Group Engineer, Country Installation. In 1955 he was transferred to special duties concerned with the design, installation and operation of the overseas broadcasting facilities for the Olympic Games on which work he was for seven months acting Divisional Engineer. Since 1957 he has been Group Engineer in Metro Service and has recently been transferred to special investigation duties for the Supervising Engineer, Metro. Service. Mr. Morris is an Associate Member at the Institution of Engineers Australia, and an Associate Member of the Institution of Electrical Engineers.

G. MORRIS



K. V. SHARP

K. V. SHARP, author of the article "A Pentaconta Crossbar P.A.B.X.", joined the P.M.G.'s Department in 1951 as a Technicians Assistant with the Telegraph Maintenance Division. He subsequently passed the Technicians and Senior Technicians examinations and was appointed a Trainee Engineer in the initial group in 1956. He graduated in Communication Engineering at the Royal Melbourne Technicial College in 1958. Since 1959 he has been attached to the Metropolitan Service Section in the Victorian Administration. He was in charge of maintenance of Chadstone P.A.B.X. for several months following its installation, and is now engaged on Telegraph Installation.

★

A. MORTON

A. MORTON, author of the article "Subscriber Attended 5 + 20 Line P.A.B.X.", started his career in the British Post Office as a Technician-in-Training in 1942. From 1948 to 1950 he spent two years in the Royal Signals as an Instructor on the Lineman Mechanics course. He left the B.P.O. as a Technical Officer in 1951 to become an Engineer at the Signals Headquarters of the Royal Air Force. There, he was concerned with the planning and installation of V.H.F. Radio Equipment. In 1954 he was transferred on promotion to the Department of Civil Aviation, where he was employed at a very large H.F. Radio Station, dealing with overseas airline traffic. In 1955 he joined the Australian Post Office, and is at present a Group Engineer in the Metropolitan Service Section in Victoria.

Mr. Morton is a graduate of the Institution of Electrical Engineers, London and holds a full Technology Certificate in Telecommunication Engineering of the City and Guilds of London Institute.

ANSWERS TO EXAMINATIONS

Examinations Nos. 4956, 4957, 4958 and 4959
Senior Technician (Telecommunications), Telephone, Telegraphs, Radio and Research—July, 1961.

TELECOMMUNICATIONS PRINCIPLES

QUESTION 1.

(*a*) *Define the term "specific gravity".*
(*b*) *Why is the specific gravity of the electrolyte in a lead-acid secondary cell measured instead of the voltage to determine the state of charge or discharge?*
(*c*) *Why are exchange batteries earthed at the positive pole?*

ANSWER (J. DICKIE).

(a) The "specific gravity" or relative density of a substance (solid, liquid or gaseous) is the ratio of its mass to that of an equal volume of water. For example, an S.G. of 1.25 means that a given volume of the substance has a mass (or weight) 1.25 times that of an equal volume of water.

(b) During both charging and discharging cycles of secondary cells or batteries the terminal voltage rises or falls by only a small percentage. For slow charging and discharging rates the actual state of charge can vary between wide limits with hardly perceptible change in the terminal voltage which remains very close to 2 V. per cell for most of the cycle.
On the other hand, the specific gravity of the electrolyte shows a continuous and progressive change — becoming gradually lower during discharge and higher during charge. When the S.G. of the fully charged cell is known, measurement of the S.G. with a hydrometer provides a much better indication of the degree of charge than terminal voltage readings.

(c) The positive pole of telephone exchange batteries is earthed in preference to the negative pole. This ensures that all components, wires and cable sheaths which are at other than earth potential are always negative with respect to it. Where stray leakage currents to earth exist the resulting electrolytic action does not corrode the equipment because it forms the cathode electrode. In electrolysis it is always the anode which is eaten away. If the equipment were anodic with respect to earth (negative pole earthed), very small leakage currents between equipment and earthed framework could damage fine wires, etc., in a short time.
Another reason for earthing the positive pole is that partial earth faults show up more definitely on test. With the conductors positive to earth such faults tend to develop much higher fault resistance owing to oxidation and are less readily detected.

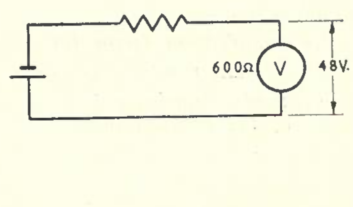
QUESTION 2.

A voltmeter of 600 ohms resistance, when connected to a battery of primary cells, reads 48 volts. When a resistance of 120 ohms is connected in parallel with the voltmeter, the reading is 40 volts.

Calculate —

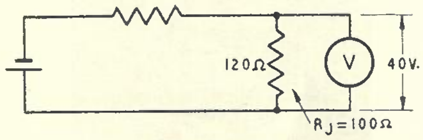
(*a*) *the e.m.f. of the battery, and*
(*b*) *its internal resistance.*

ANSWER (D. KENNER).



Condition 1.

$$\text{Circuit I} = \frac{E}{R} = \frac{48}{600} = .08\text{A}.$$



Condition 2.

$$\text{Circuit I} = \frac{E}{R} = \frac{40}{100} \text{ or } \frac{40}{600} + \frac{40}{120} = .4\text{A}.$$

There are several methods of approach:

(i) $$\text{Internal Res.} = \frac{\text{Change in Volts}}{\text{Change in Current}} = \frac{8}{.32} = 25 \text{ ohms}.$$

(ii)
$$E = I \times R$$
$$= .08\ (x + 600) \quad \text{Condition 1}$$
also $$E = .4\ (x + 100) \quad \text{Condition 2}$$
$$\therefore .4x + 40 = .08x + 48$$
$$.32x = 8$$
$$x = 25 \text{ ohms}.$$

In Condition 2

$$\text{Total resistance} = 25 + 100 = 125 \text{ ohms}.$$
$$E = I \times R = .4 \times 125 = 50 \text{ Volts}.$$

(a) E.M.F. = 50 Volts.

(b) Internal Res. = 25 ohms.

QUESTION 3.

The variations of anode current with grid and anode voltages for a triode electron tube are as follows—

Grid Voltage	Anode Current (mA) 250 Volts Anode Voltage	200 Volts Anode Voltage
0	24	16
—1	20	12
—2	16	8
—3	12	4
—4	8	0

(a) Graph the anode current/grid voltage curves, and then

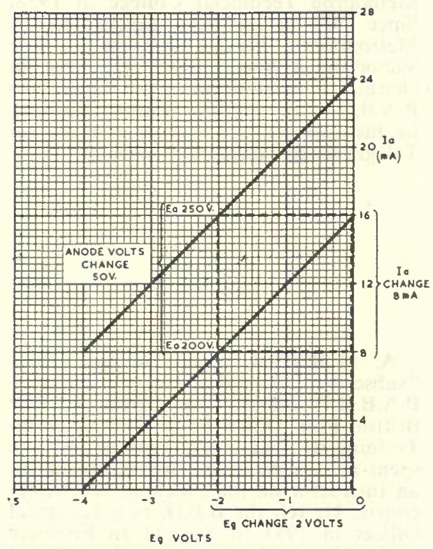
(b) Work out—

(i) amplification factor (μ),

(ii) mutual conductance (g_m),

(iii) anode impedance (r_a), of the electron tube.

ANSWER (a) (E. CULPH).



ANSWER (b).

$$\text{Amplification factor } (\mu) = \frac{\text{Small change in } E_a}{\text{Small change in } E_g} \text{ (for same change in } I_a) = \frac{50}{2} = 25.$$

$$\text{Mutual conductance } (g_m) = \frac{\text{Small change in } I_a}{\text{Small change in } E_g} \ (E_a \text{ constant}) = \frac{8 \times 10^6}{2 \times 10^3} = 4{,}000\ \mu \text{ mho or } 4\text{mA/V}.$$

$$\text{Anode impedance } (r_a) = \frac{\text{Small change in } E_a}{\text{Small change in } I_a} \ (E_g \text{ constant}) = \frac{50 \times 10^3}{8} = 6{,}250 \text{ ohms}.$$

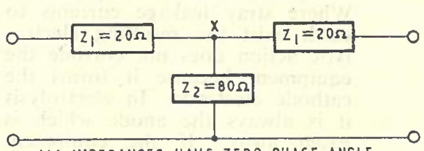
QUESTION 4.

(a) State the formula used to calculate the characteristic impedance of a telephone line when the measured values of open circuit and short circuit impedance are known.

(b) Calculate—

(i) the characteristic impedance of the attenuator shown in Fig. 1, and

(ii) the attenuation, in decibels, of the attenuator when it is terminated in its characteristic impedance.



ALL IMPEDANCES HAVE ZERO PHASE ANGLE

FIG. 1

ANSWER (S. GALE).

(a) $Zo = \sqrt{Zoc \times Zsc}$.

where Zo = characteristic impedance (ohms).

Zoc = input impedance (ohms) with open circuit at distant end.

Zsc = input impedance (ohms) with short circuit at distant end.

(b) (i)
$$Zoc = Z_1 + Z_2 = 100 \text{ ohms}$$
$$Zsc = Z_1 + \frac{Z_1 \times Z_2}{Z_1 + Z_2} = 20 + 16 = 36 \text{ ohms}$$
$$\therefore Zo = \sqrt{100 \times 36} = 60 \text{ ohms}.$$

(b) (ii)

Assume input current (I_1) of 1 ampere.

This current divides at point X, half flowing through 80 ohms (Z_2) and half through 20 ohms (Z_1) in series with 60 ohm termination.

$\therefore$ Output current (I_2) through termination = 0.5 ampere.

$$\text{Attenuation} = 20 \log \frac{I_1}{I_2} = 20 \log 2 = 20 \times 0.3 = 6 \text{ db}.$$

(Similarly, assuming any value of input voltage, it can be calculated that output voltage across termination is half the input voltage, i.e., an attenuation of 6 db.)

QUESTION 5.

(a) A moving coil milliameter having a 0-200 mA scale is to be converted into an A.C. meter by the addition of metal rectifiers. Sketch the circuits for—

(i) a meter using a single rectifier unit,

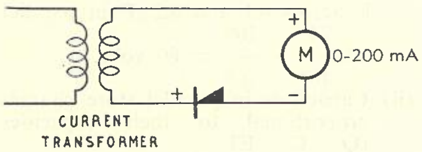
(ii) a meter using four identical rectifier units in bridge formation.

(b) When a meter using one rectifier unit is connected to a 50 c/s sinusoidal A.C. circuit it reads 50 mA.

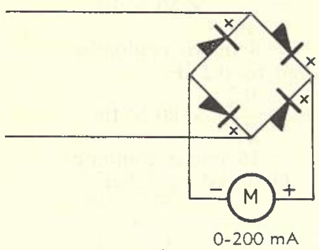
This meter is now replaced by the one using the bridge rectifier; no change is made in the external circuit conditions. What is the reading on the second meter?

ANSWER (*G. BASS*).

(a)



(i)



(ii)

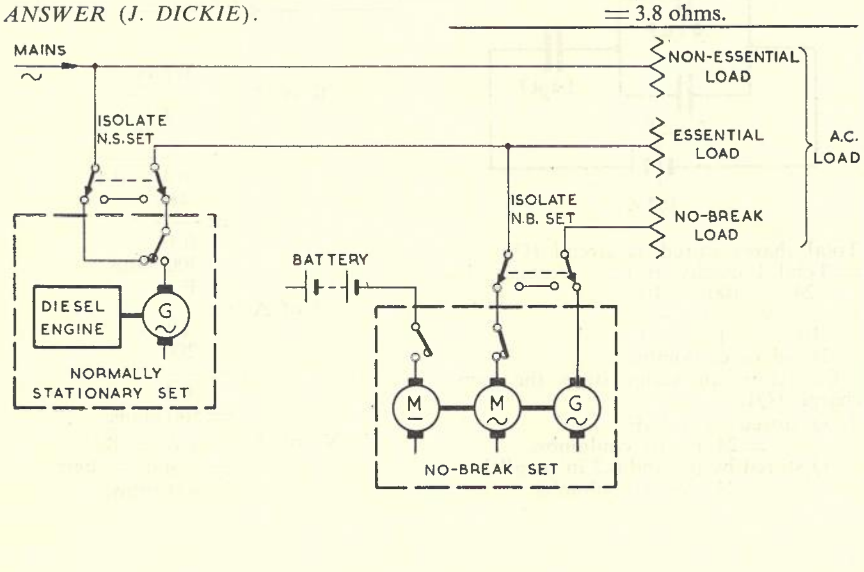
(b) Reading on the meter = 100 mA. For each cycle of A.C., two pulses of current pass through the meter with the full wave rectifier bridge (ii) but only one pulse passes through the meter in the half wave circuit (i). As the deflections on the meters are proportional to the average value of current through the meters, the reading with the full wave bridge is twice that with the single rectifier and it will be 100 mA.

QUESTION 6.

By means of a block diagram show how the three categories of A.C. load (no-break, essential and non-essential) are catered for by a standby power plant at a typical combined station where telephone, long line and telegraph equipment is installed.

Details of control sets are not required.

ANSWER (*J. DICKIE*).



QUESTION 7.

Two bays of telecommunication equipment are connected to a D.C. supply via busbars as shown in Fig. 2. One bay of equipment requires 2,500 watts at 250 volts and the other 2,000 watts at 200 volts. The resistance of each busbar is 0.2 ohms per 100 feet.

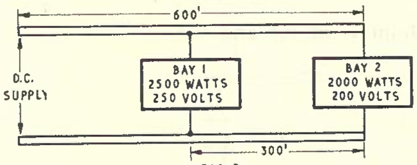
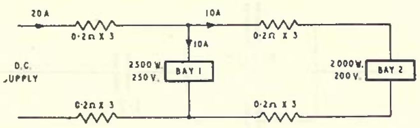


FIG. 2

(*a*) *What value of resistance must be connected in series with one of the bays to give correct voltage conditions at both bays? and*

(*b*) *What D.C. supply voltage is necessary?*

ANSWER (*D. KENNER*).



Current in Bay 1.

$$I = \frac{W}{E} = \frac{2500}{250} = 10A.$$

Current in Bay 2.

$$I = \frac{W}{E} = \frac{2000}{200} = 10A.$$

(a) Voltage dropped between Bay 1 and Bay 2 = 250-200
= 50 V.

P.D. across Busbar Res. from Bay 1 and Bay 2 = .2 × 6 × 10
= 12 V.

P.D. across Extra Res. necessary in series with Bay 2 = 50 − 12
= 38 V.

$$\text{Extra Res.} = \frac{E}{I} = \frac{38}{10} = 3.8 \text{ ohms.}$$

(b) Busbar Resistance to Bay 1
= .2 × 6 (both + and −).
P.D. Busbar Res. = .2 × 6 × 20
= 24 V.
Total E.M.F. (D.C. Supply)
= 250 + 24
= 274 Volts.
(a) 3.8 ohms. (b) 274 volts.

QUESTION 8 (*a*).

An amplifier has an input impedance of 250 ohms and an output impedance of 600 ohms. The output of the amplifier is fed into a 600 ohm line which is terminated in a 600 ohm load as shown in Fig. 3. All impedances have zero phase angle.

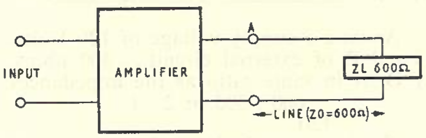


Fig. 3.

When a signal level of 1 volt is applied to the input of the amplifier, the output power in the load is 4 Watts. Calculate the overall gain of the circuit in decibels.

(*b*) *Calculate the error, in decibles, if a 600 ohm terminated decibelmeter is used to measure the signal level at point "A" in the circuit with the line and the load still connected.*

ANSWER (*E. CULPH*).

(a) NOTE: As the input and output impedances are unequal, power ratios must be used.

$$Db = 10 \log \frac{P1}{P2}$$

(i) Calculate input power (P2).

$$\text{Power} = \frac{E^2}{R} = \frac{1 \times 1}{250} \times \frac{1000}{1}$$

= 4 Milliwatts.

(ii) Output power (P1) = 4 Watts.

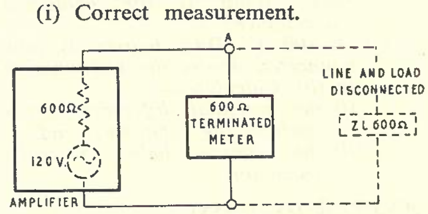
$$\text{(iii) Gain} = 10 \log \frac{4}{4} \times \frac{1000}{1}$$

= 10 log. 1000
= 30. db.

ANSWER: OVERALL GAIN = 30 db.

(b) For correct measurement of level at point "A" the 600 ohm load is disconnected or alternatively the measurement taken with an unterminated meter.

(i) Correct measurement.

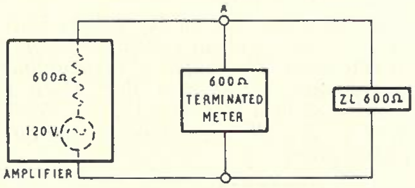


Assume any convenient supply voltage from the Amplifier, for example, 120 Volts.

E across Meter = Supply Voltage — P.D. across internal impedance of Amplifier. As meter and internal impedance of Amplifier are both 600Ω, 60 volts will be dropped across each.

$$\text{Power in Meter} = \frac{E^2}{R}$$
$$= \frac{60 \times 60}{600}$$
$$= 6 \text{ Watts.}$$

(ii) Incorrect measurement.



Assume a supply voltage of 120 Volts. Total Z of external circuit = 300 ohms. P.D. is in same ratio as the impedances 600 : 300 or 2 : 1

$\therefore \frac{2}{3}$ of $\frac{120}{1} = 80$ V. is dropped across the internal impedance of the Amplifier.

$\frac{1}{3}$ of $\frac{120}{1} = 40$ V. is dropped across the meter and the load in parallel.

$$\text{Power in meter} = \frac{E^2}{R}$$
$$= \frac{40 \times 40}{600} = \frac{16}{6}$$
$$= 2\tfrac{2}{3} \text{ Watts.}$$

(iii) Error in db

$$= 10 \log \frac{\text{Correct Power}}{\text{Incorrect Power}}$$
$$= 10 \log \frac{6 \times 6}{16}$$
$$= 10 \log 2.25$$
$$= 3.52. \text{ db.}$$

ANSWER: ERROR = 3.52 db.

QUESTION 9.

(a) A capacitance of 0.8 μF is made of three separate capacitors. If two of these are 0.1 μF and 0.2 μF, what value is the third capacitor? How are the capacitors connected?

(b) The third capacitor is now removed. The 0.1 μF and 0.2 μF capacitors are connected in parallel and a capacitor of 1.2 μF is connected in series with them. What is the combined capacitance?

(c) A 100 V. D.C. battery is now connected across the combination in (b). Calculate —

(i) the potential difference across each of the capacitors, and

(ii) the charge held by each capacitor.

ANSWER (G. BASS).

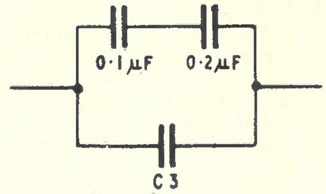
(a) When all capacitors are connected in parallel

Total C = C1 + C2 + C3

∴ The third capacitor is 0.5 microfarads.

Alternative Answer.

When 0.1 and 0.2 μF capacitors are connected in series and the third capacitor in parallel.

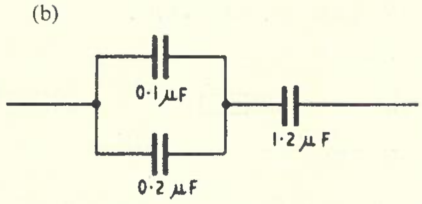


Joint C of 0.1 and 0.2

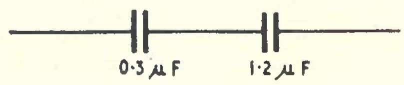
$$= \frac{1}{\frac{1}{C1} + \frac{1}{C2}}$$
$$= \frac{1}{\frac{1}{0.1} + \frac{1}{0.2}}$$
$$= .066\ \mu F.$$

$$\text{Total C } (0.8) = 0.066 + C3$$
$$= 0.8 - 0.066$$
$$= 0.734\ \mu F.$$

(b)

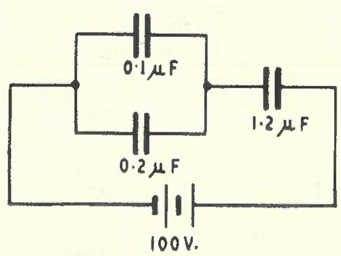


Joint C of 0.1 and 0.2 = 0.3 μF. Equivalent Cct.



$$\text{Total Capacity} = \frac{1}{\frac{1}{.3} + \frac{1}{1.2}}$$
$$= \frac{1}{5/1.2}$$
$$= \frac{1.2}{5} = 0.24\ \mu F.$$

(c)



Total charge stored by circuit (Q) = Total Capacity (C) × Voltage (E)

$$= \frac{.24}{10^6} \times \frac{100}{1} \times \frac{10^6}{1}$$

= 24 micro coulombs.

Capacitors in series store the same charge (Q).

∴ Q stored by 1.2 μF

= 24 micro coulombs.

Q stored by 0.1 and 0.2 in parallel

= 24 micro coulombs.

(i) Voltage across each section of the circuit can be calculated from $E = \frac{Q}{C}$.

$$\text{E across } 1.2\ \mu F = \frac{24}{10^6} \times \frac{10^6}{1.2}$$

= 20 volts.

E across 0.1 and 0.2 μF in parallel

$$= \frac{24}{10^6} \times \frac{10^6}{0.3} = 80 \text{ volts.}$$

(ii) Capacitors in parallel store charges proportional to their capacities (Q = C × E).

∴ Q stored by 0.1 μF

$$= \frac{0.1}{10^6} \times 80 \times 10^6$$

= 8 micro coulombs

Q stored by 0.2 μF.

$$= \frac{0.2}{10^6} \times 80 \times 10^6$$

= 16 micro coulombs

Q stored by 1.2 μF

$$= \frac{1.2}{10^6} \times \frac{20}{1} \times \frac{10^6}{1}$$

= 24 micro coulombs.

QUESTION 10.

Two coils, "A" and "B", are connected in parallel across a 200 V. A.C. supply. The current in each coil is 400 mA, coil "A" dissipates 48 watts, and coil "B" dissipates 64 watts.

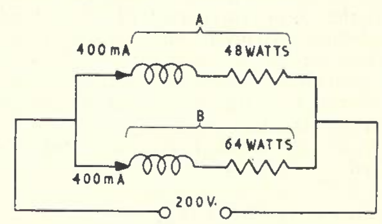
If the two coils are now connected in series across the 200 V. A.C. supply, calculate —

(a) the current through the coils, and

(b) the total power dissipated.

ANSWER (E. CULPH).

(i) As coil "A" dissipates 48 watts and "B" 64 watts, each coil must have different value of resistance.

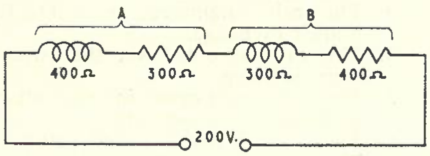


$$\text{R of A} = \frac{\text{Watts}}{I^2}$$
$$= \frac{48}{0.4 \times 0.4}$$
$$= \frac{48}{0.16}$$
$$= 300 \text{ ohms.}$$

$$\text{Z of A} = \frac{E}{I}$$
$$= \frac{200}{0.4}$$
$$= 500 \text{ ohms.}$$

$$X_L \text{ of A} = \sqrt{Z^2 - R^2}$$
$$= \sqrt{500^2 - 300^2}$$
$$= 400 \text{ ohms.}$$

$$\text{R of B} = \frac{\text{Watts}}{I^2}$$
$$= \frac{64}{0.4 \times 0.4}$$
$$= \frac{64}{0.16}$$
$$= 400 \text{ ohms.}$$
$$\text{Z of B} = \frac{E}{I}$$
$$= \frac{200}{0.4}$$
$$= 500 \text{ ohms.}$$
$$X_L \text{ of B} = \sqrt{Z^2 - R^2}$$
$$= \sqrt{500^2 - 400^2}$$
$$= 300 \text{ ohms.}$$



$$\text{Total } X_L = X_{LA} + X_{LB}$$
$$= 400 + 300$$
$$= 700 \text{ ohms.}$$
$$\text{Total R} = R_A + R_B$$
$$= 300 + 400$$
$$= 700 \text{ ohms.}$$
$$Z = \sqrt{R^2 + X_L^2}$$
$$= \sqrt{700^2 + 700^2}$$
$$= 990 \text{ approx.}$$
$$I = \frac{E}{R}$$
$$= \frac{200}{990} \times \frac{1{,}000}{1}$$
$$= 202 \text{ mA (approx.)}$$

$$\text{Total Power} = I^2R$$
$$= \frac{202}{1{,}000} \times \frac{202}{1{,}000} \times \frac{700}{1}$$

or can be shown as

$$\frac{202 \times 202 \times 700}{1000 \times 1000}$$
$$= \frac{285{,}628}{10{,}000}$$
$$= 28.56 \text{ Watts (approx.)}$$

Examination No. 4956, Senior Technician Telephones, July, 1961 TELEPHONY AND LONG LINE EQUIPMENT — PART I

A. C. WISE

QUESTION 1.

You are instructing a trainee in the techniques of locating intermittent and obscure service fault conditions on bimotional switching equipment —

(a) List the causes of intermittent and obscure service faults you would describe to the trainee. Actual service faults such as stop-on-busy and drop-out are not required in your answer, only the types of defects on wiring and parts which cause service faults.

(b) List the various methods the trainee could use to help locate intermittent and obscure faults.

Comment.—The question calls for intermittent and obscure service fault conditions. An intermittent condition is one which does not persist but reoccurs at odd occasions. An obscure condition is one the cause of which is not easily understood. The answer is to be limited to bimotional switching equipment as distinct from manual, rotary or electronic switching equipment and the question appears to infer that conditions which may occur in the bimotional switch and its jack and bank would be preferred. No limit is set to the lists in each part, so answering time would be the important factor. Good marks would be obtained by lists comprising 6 or 7 in part (a) and 3 or 4 in part (b) of the following answer points, depending upon the grouping.

ANSWER 1.

(a)
1. Dry joints and terminations causing high resistance.
2. Dirty or tarnished contacts on relay and mechanical springsets.
3. Light contact pressure on relay and mechanical springsets.
4. Damaged or defective insulation on wiring or wires touching at terminating points.
5. Dirty, tarnished or worn banks or wipers.
6. Incorrect wiper to bank adjustment.
7. Breaking up wiper cord.
8. Condensers or rectifiers breaking down.
9. Incorrect mechanical adjustments.
10. Loose screws or nuts.
11. Short circuit turns in coils of relays or switch electromagnets.
12. Marginal adjustment faults on relays.

(b)
1. Visual inspection for dry joints, damaged insulation or pitted contacts.
2. Visual inspection and check of the adjustments of mechanism, relays and springsets.
3. Continuous tests with automatic routiner.
4. Visual observation of equipment in action for abnormal conditions such as contact arcing.
5. Marginal tests of relays and switch performance.
6. Electrical current, voltage and resistance tests of circuits and components.
7. Any form of vibration or movement test to highlight dry joints, loose parts, etc.

QUESTION 2.

(a) What precautions would you take to ensure satisfactory soldering of wires on tag blocks on an installation being carried out under your direction?

(b) List three safety precautions you would take to prevent fire damage during the installation of a telephone exchange for which you are responsible.

(c) What features would you check when inspecting the jumpering on a new M.D.F.?

Comments —

(a) An unlimited list is required of the preventive measures necessary to ensure that satisfactory soldering of wires on tag blocks is carried out by workmen under the supervision of the answerer. About five of the points from the model answer should have earned good marks.

(b) A definite list is required of only three of the many measures that should be taken by an exchange installation supervisor to prevent the outbreak or limit the extent of fire. A list of more than three would not earn more marks but could be insurance against any one being considered unimportant by the examiner.

(c) This requires a list of the points which a supervisor would check to determine the quality of jumpering recently performed on an M.D.F. About four main points should obtain good marks.

ANSWER 2.

(a)
1. The staff to perform the work should be adequately trained and instructed in soldering wires on tags.
2. Provision should be made for adequate lighting of the tag blocks.
3. The terminal tags of the blocks should be checked to ensure that they are clean and tinned before terminating any wires.
4. The wires should be clean and correctly wrapped on the tags. If the wires are not tinned they should be soldered as soon as possible after terminating, before they tarnish.
5. The correct resin cored solder of 65% tin, 35% lead, should be the only solder available. Other fluxes should not be available and a check should be made to ensure that they are not used.
6. Only soldering irons in good condition and of adequate heating capacity should be used.
7. The completed job should be checked for unsoldered and poorly soldered terminations preferably by someone other than the solderer.

(b)
1. Adequate fire extinguishers in working order should be provided in good locations.
2. A check should be made each day to ensure that personnel are not smoking in the last hour before ceasing duty.
3. All electrical fuses in use should be of the correct rating for the circuit concerned.
4. A check should be made each day before ceasing duty to ensure that all electrical appliances, such as soldering irons, radiators and lamps are disconnected.
5. The use of inflammable liquids should be carefully controlled and they should be stored clear of the installation.

6. An adequate sign indicating the precautions necessary to prevent explosions in the battery room should be displayed there and the precautions should be supervised.
7. All equipment alarms which indicate conditions which might result in fire, such as the release alarm, should be checked immediately after power is connected to the equipment and thereafter at reasonable intervals.
8. Heaps of rubbish should be avoided as they may be ignited by the careless disposal of matches and cigarettes or by spontaneous combustion.

(c) 1. Each jumper should have slight slack and the terminations should not be under tension.
2. Each termination should be correctly wrapped and soldered.
3. The insulation on each wire should terminate close to the wire terminal tag.
4. The jumpers should be evenly distributed in jumper rings in such a way they are not unnecessarily bunched at any point.
5. The route of each jumper should be in its correct horizontal and vertical position on the frame.

QUESTION 3.

(a) Show by means of separate block schematic diagrams the routing of the following types of call in a C type P.A.B.X.:—
(i) Extension to extension call.
(ii) Incoming exchange call to
(1) the switchboard,
(2) an extension.
(iii) Switchboard to extension.

(b) What is the purpose of the A.C. clearing feature on the exchange line circuit?

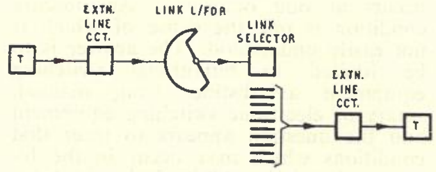
Comment—

(a) The question calls for four separate block schematic diagrams of call routes through a C type P.A.B.X. No explanation is required but it might be advisable for clarity to arrange each diagram from left to right. Some labelling of the diagrams and individual blocks would probably be essential.

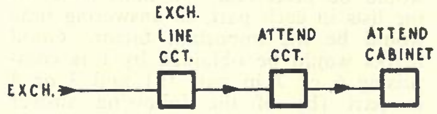
(b) A short explanation of the function of the A.C. clearing feature on the exchange line circuit, presumably of the C type P.A.B.X. is required.

ANSWER 3.

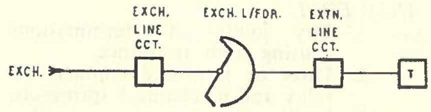
(a) Type "C" P.A.B.X.



3 (i)



3 (ii) 1



3 (ii) 2

3 (iii)

(b) A.C. clearing enables an exchange line circuit to detect when, upon the completion of an incoming call, the exchange final selector has released off the P.A.B.X. line and the line is free for outgoing calls from the P.A.B.X. Until the exchange final selector releases, the particular P.A.B.X. exchange line is marked busy at its link circuit outlet appearances.

QUESTION 4.

Show by diagram the circuit conditions on the speech and private wires on a typical call from a 2,000 type D.S.R. branch exchange to another 2,000 type exchange via the parent main exchange in a five-digit network. Designate switches and relay sets in the train and show the wipers, relays, retards, transmission condensers and rectifiers in the speech path in the "call answered" condition. Contacts in the speech path need not be shown.

Show sufficient detail in the private wire circuit to indicate how the call is held.

Comment.—This question requires particularly careful reading to extract its aim and relevant information. Superfluous time consuming information must be omitted from the answer. In reading, the following points are noted:—

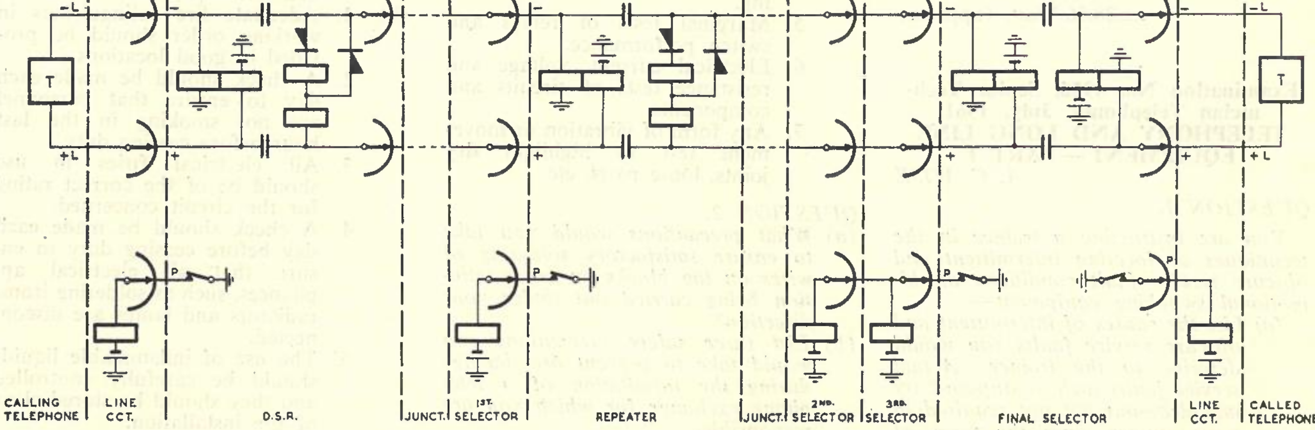
1. A diagram of circuit conditions is required.
2. The negative, positive and private wires are relevant.
3. The call originated in a D.S.R. branch exchange.
4. The call is routed via the parent main exchange.
5. The call terminates in any other exchange in the network.
6. The network is a five digit network.
7. The only equipment mentioned is that for originating and terminating exchanges and that is 2,000 type.
8. In the negative and positive wire paths the following are required:— (a) wipers, (b) relays, (c) retards, (d) transmission condensers, (e) rectifiers.
9. In the private wire circuit the elements responsible for holding the call are required.
10. The call is established.
11. Contacts in the negative and positive wire paths are not required.
12. The diagram has to be arranged in switches and relay sets so they can be designated.

In answering, as the called exchange may be another branch or main exchange, it should not matter if the repeater is located after the first, second or third selectors.

QUESTION 5.

(a) State briefly what you understand by the following terms:—
(i) Corrective Maintenance.
(ii) Preventive Maintenance.
(iii) Qualitative Maintenance.

ANSWER 4.



(*b*) *List seven precautions you would ensure are taken to reduce the dust hazard in a switching equipment room.*

Comments —

(a) Three precise definitions are required.

(b) A definite list is required of seven measures which should be taken to reduce the entrance of dust into a switchroom or to ensure its removal. More than seven will not gain extra marks but it may ensure that the examiner does not detract marks for points of doubtful value.

ANSWER 5.

(a) (i) Corrective maintenance is attention to equipment defects after they cause trouble in service.
(ii) Preventive maintenance is attention to equipment defects before they cause trouble in service.
(iii) Qualitative maintenance is a combination of the practices of corrective and preventive maintenance aimed at giving satisfactory service at reasonable cost.

(b) (i) Keep windows and doors normally closed.
(ii) Reduce personnel traffic through the switchroom to a minimum.
(iii) Remove unnecessary activities from the switchroom.
(iv) Do not use the switchroom as a storage area.
(v) Door mats and "wipe your feet" notices should be provided at all entrances to the switchroom.
(vi) Staff should wear clothing and shoes which do not readily shed lint, dirt and fluff.
(vii) Smoking should not be permitted in the switchroom.
(viii) All waste should be cleaned up after any job.
(ix) Only remove switch covers or rack dust covers when absolutely necessary.
(x) Floors and racks should be cleaned with a minimum amount of dust disturbance.
(xi) Air-conditioning filters should be kept in good condition.

QUESTION 6.

(*a*) *List the frequency (c.p.s.) and duration of each of the following signals in the 2VF signalling system:—*
(*i*) *answer,*
(*ii*) *answer acknowledge,*
(*iii*) *release.*

(*b*) *Draw the trunking diagram of a typical transit switching exchange associated with a sleeve control trunk suite, a local automatic exchange, and bothway trunks employing 2VF, loop and generator signalling.*

Comments —

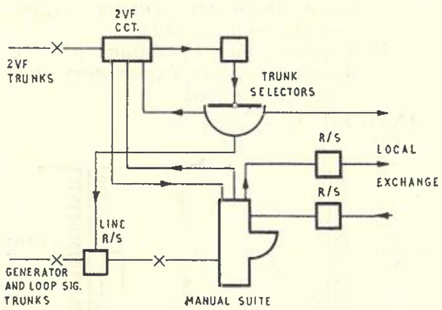
(a) Straightforward question requiring only three frequency and duration statements.

(b) A trunking diagram in block form showing the traffic routes through a transit switching exchange is required. Switching will be by a sleeve control manual suite and obviously trunk selectors. Connection must be able to be established between a local automatic exchange and 2VF and loop and generator signalling trunks and vice versa. As no other information is given in the question, incoming calls on the 2VF trunks to the manual suite may be trunked direct from the 2VF circuits or via the trunk selectors.

ANSWER 6.

(a) (i) Answer signal
600 c.p.s., 350-400ms on and off until answer acknowledge signal is received.
(ii) Answer acknowledge signal
600 c.p.s., single pulse of 250-350ms.
(iii) Release signal
600 c.p.s., 450ms minimum and maintained until clear forward signal is received.

(b)



QUESTION 7.

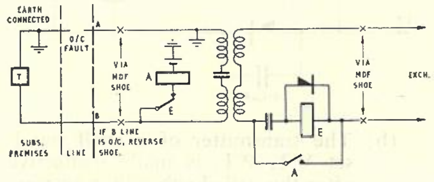
"Special Service on Faulty Line" (hospital) circuits are provided in automatic exchanges to give service on subscribers' lines having certain fault conditions. Briefly describe, with the aid of suitably designated diagrams, how the hospital circuit is used to give service on lines under each of the fault conditions (*a*), (*b*) *and* (*c*). *A detailed description of the hospital circuit is not required.*
(*a*) *Line open one side.*
(*b*) *Line earthed one side.*
(*c*) *Line looped or short-circuited.*

Comment.—This question concerns the Special Service on Faulty Lines Circuit and calls for a brief description of how this circuit is used to give service for three particular types of line fault condition. The question states that a detailed description is not required but that the brief descriptions should be with the aid of suitably designated diagrams. These diagrams will obviously be required to be simplified schematic sketches of the relevant circuit elements and if efficiently done little additional written description will be required to gain good marks. For completeness in part (c), a separate short circuit should be provided across the A and B legs of the line either at the exchange or subs. premises to eliminate the possibility of the temporary service being made via the short circuit fault.

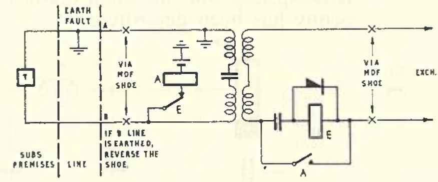
ANSWER 7.

Service is provided by the hospital circuit by correctly connecting it between the subscriber's line and the normal exchange line circuit. The connection is made at the exchange M.D.F. protector unit by cord and plug. In some cases various arrangements are also necessary at the subscriber's premises.

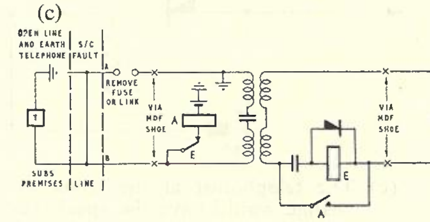
(a)



(b)



(c)



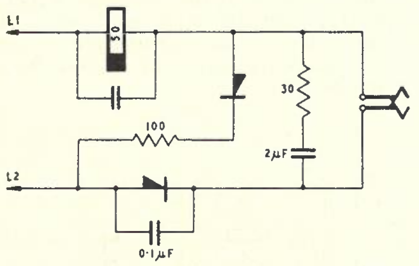
QUESTION 8.

Briefly explain, with the aid of a simple schematic diagram, showing only the elements actually in circuit, the following:—
(*a*) *The dialling circuit on a variable tariff public telephone.*
(*b*) *The method of making the transmitter ineffective to the caller before payment of the call fee on a variable tariff public telephone.*
(*c*) *How the telephonist at the trunk exchange supervises the payment of a trunk call fee from a multi-coin public telephone.*
(*d*) *How a standard lamp signalling P.B.X. extension fitted with a call-back button can attract the attention of the P.B.X. operator during an extension to exchange call.*

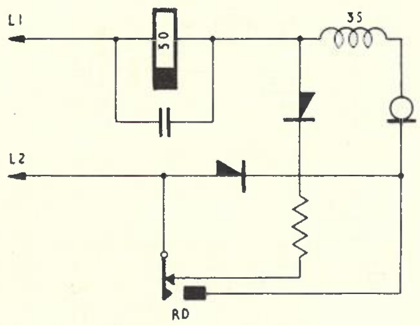
Comment.—An explanation of various circuits of substation equipment is required. A simple diagram of only the relevant elements is called for in each case, and good marks should be obtained with only limited written explanations. In parts (a) and (b) the variable tariff P.T. could be a table handset or wall type and in (c) the multi-coin could be any type (i.e., Auto, R.A.X. or Magneto). In part (c) the standard lamp signalling P.B.X. obviously means a C.B. P.B.X. to drawing CE250.

ANSWER 8.

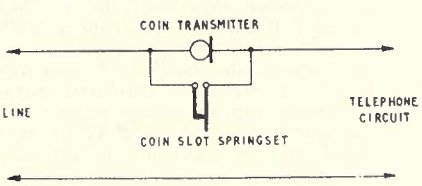
(a) During dialling the off normal contacts of the dial will arrange the circuit of the shelf handset V.T. P.T. as follows:



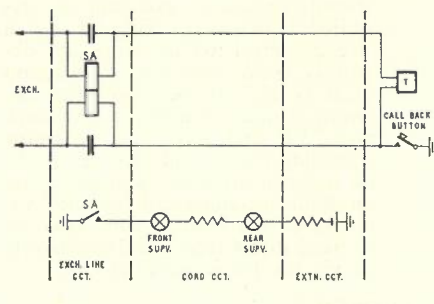
(b) The transmitter of a shelf handset V.T. P.T. is made ineffective after the called subscriber answers by a reversal on the line. It becomes effective again after the R.D. springs operate when the last penny has been deposited.



(c) The telephonist at the trunk exchange would have the speak key operated and would request multi-coin P.T. user to deposit coins. As the coins are deposited the first will operate the coin slot springs, if they are not already operated, then as they pass down the chute they strike gongs and a coin transmitter picks up the tones and transmits them to the listening telephonist. A penny strikes a wire gong once, a sixpence strikes the bell gong once, and a shilling strikes the bell gong twice.



(d) A series differential relay S.A. in the exchange line circuit will operate and cause both cord circuit supervisory lamps to glow if the current in each of the exchange lines become unbalanced. When operated the call back button fitted to extension telephones connects earth to one side of the extension line to allow the S.A. relay to operate on extension to exchange calls.



Examination No. 4956 for Promotion or Transfer of Senior Technician (Telecommunications) Telephone

TELEPHONY AND LONG LINE EQUIPMENT — PART II

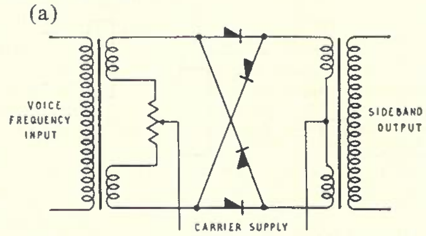
QUESTION 9.

(*a*) *Draw a simplified schematic circuit of a carrier telephone system channel modulator.*
Show all essential elements, including those used for carrier leak control if any.
Show the points of connection to voice frequency, carrier supply and sideband circuits.

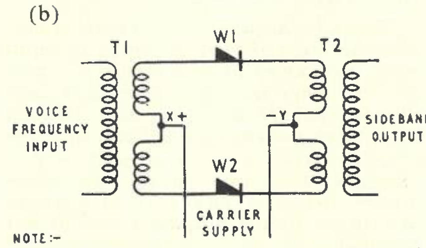
(*b*) *Explain the operation of the modulator. Use explanatory diagrams if desired.*

ANSWER 9.

(a)



(b)



NOTE:-
THE RECTIFIERS WITH A BACKWARD BIAS (HIGH IMPEDANCE) HAVE BEEN OMITTED FOR CLARITY ON FIGS 1 & 2.

Fig. 1.

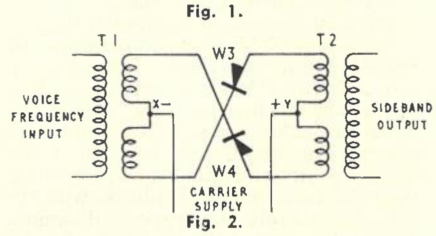
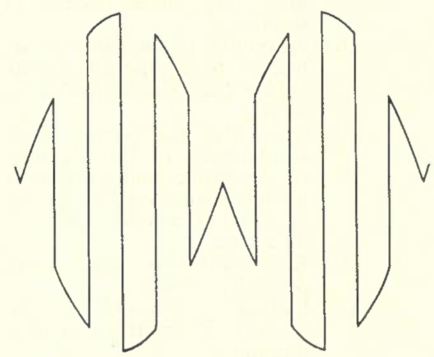


Fig. 2.

The carrier supply input voltage, which is approximately ten times greater than the greatest voice frequency signal input, is applied to the mid-points of transformers T1 and T2. On half cycles of the carrier, which make point X positive and Y negative, rectifiers W1 and 2 will have a forward bias and consequently a low impedance, while rectifiers W3 and 4 will have a backward bias and consequently a high impedance and the voice frequency signal will flow in the local circuit W1, primary of T2, W2 and secondary of T1. On the other half cycle of the carrier the bias will be interchanged and the voice frequency signal will flow in the local circuit W3, primary of T2, W4 and the secondary of T1. Thus the voice signal will be reversed in the local circuit at the carrier frequency rate. The output waveform in T2 with a sine-wave input is as shown in the figure. It can be analysed to show that it contains a frequency carrier plus voice (upper side band), a frequency carrier minus voice (lower side band), plus odd harmonics of the carrier and sidebands. The original carrier frequency and the voice frequency will not appear in the output.



With perfect balance the carrier current will divide equally at the point X into two parts and re-unite at the point Y so that the resultant flux in T1 and T2 due to this current will be zero.

This modulator is known as the double balanced type because both the carrier and voice frequency are suppressed.

QUESTION 10.

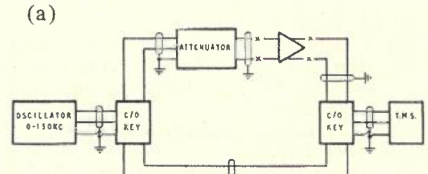
You are required to measure the gain versus frequency response characteristic of a carrier amplifier designed to cover the frequency range from 30 Kc/s to 150 Kc/s.

(*a*) *Show by a block diagram the test equipment which would be required and the interconnections between the various items.*

(*b*) *Describe the method of carrying out the tests with special mention of any precautions necessary to ensure accurate results.*

ANSWER 10.

(a)



NOTE:-
THE INPUT AND OUTPUT IMPEDANCES OF THE AMPLIFIER AND ALL TEST EQUIPMENT IS ASSUMED TO BE 135 OHMS.

(b) The various components of the testing circuit, including the amplifier, should be set up as indicated in the diagram 10 (a). This is known as the test and compare method of gain testing. All patch cords connecting the various items are of the balanced shielded variety. An earth connection should be made to each of the items of test equipment.

For the purposes of the answer it is assumed that the amplifier is of fixed gain and has input and output impedances of 135 ohms. The test oscillator and transmission measuring set are also of this nominal impedance.

The following steps would be taken to carry out the tests:—

1. Set the variable attenuator preceding the amplifier to maximum setting (at least 60 db).
2. Switch on the oscillator, amplifier and T.M.S. and allow to warm up and stabilise. Calibrate the oscillator and T.M.S. as required for the particular type in use.
3. Operate the change-over key to the compare position.
4. Adjust the oscillator frequency to the value of 100 K/cs.
5. Adjust the amplifier output control to obtain a suitable reading on the T.M.S. This reading will be determined by the value of output power at which it is desired to test the amplifier response. Assume for the purpose of the answer that it is 0 dbm.
6. Operate the change-over key to the test position and reduce the attenuator setting until the output from the amplifier gives the same reading on the T.M.S. as previously obtained. The setting of the attenuator is then equal to the gain of the amplifier at this frequency. Record the value.
7. Set the oscillator at 30 Kc/s and repeat the procedure.
8. Repeat at intervals of 1 Kc/s to 35 Kc/s, then at 5 Kc/s intervals to 50 Kc/s, then at suitable intervals to 150 Kc/s as indicated by the nature of the results obtained.
9. Plot the gain versus frequency response characteristic so obtained.

QUESTION 11.

Describe the procedure for complete readjustment of a receive relay of a voice frequency telegraph system.

State the type of relay covered by your answer.

ANSWER 11.

The relay to be adjusted is the carpenter type 3H10.

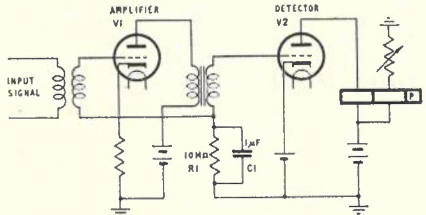
(a) The relay is withdrawn from the working socket and inserted in the test socket.
(b) The cover is removed and the bias magnet set in the mid position.
(c) The contact lock screws are loosened and the contacts withdrawn away from the armature.
(d) The contacts of the armature and the fixed contacts are carefully examined and if necessary dressed and burnished.
(e) The magnetic gap between the pole piece and armature is carefully inspected and any foreign particles are removed with a piece of paper or a strong air blast.
(f) The armature is operated by hand to ensure that it will remain on either side.
(g) Operate the appropriate test set key to connect 50 cps to the relay and adjust the current indication to about 10 mA. Screw up the contact on which the armature is resting until it just falls over to the other contact. Screw up this contact until the armature vibrates and the armature meter indicates no bias.
(h) Reduce the operate current to 2 mA and adjust both contacts until the contact time meter indicates 88% and there is less than 4% bias. Lock the contact screws.
(i) Replace the cover and adjust the bias screw at the back of the relay to get zero bias.

QUESTION 12.

Draw a simplified schematic diagram of the amplifier detector of an amplitude modulated voice frequency telegraph system.

Describe the action of the automatic gain control circuit.

ANSWER 12.



The automatic gain control circuit consists of the 10 megohm resistor and the 1 μF condenser. A normal signal amplified by the first valve makes the grid of the detector valve slightly positive, with the result that grid current flows and the condenser C1 is charged up owing to the voltage impressed on it by the flow of current through the resistance R1. In this way the amplification of valve V1 is reduced. The grid bias on valve V1 will be reduced as the condenser C1 discharges through resistance R1, but this is made sufficiently large to enable the condenser C1 to hold its charge for a time equal to or greater than the time-length of the maximum spacing signal. Although the grid bias of valve V2 is also affected by the flow of grid current through resistance R1 the change in grid bias from its normal value is not large enough to affect appreciably its operating point and thus no appreciable effect is obtained on the output signals due to this change.

If the attenuation of the circuit decreases, the grid bias of the amplifier valve is further increased and the gain is reduced accordingly. On the other hand, if the attenuation of the circuit increases, the grid current through R1 is reduced, the condenser C1 discharges slightly and the gain of the valve V1 is increased. By this means a constant output is obtained from valve V1 over a given working range, which ensures a constant plate current in valve V2.

QUESTION 13.

All channels of a 12-channel open wire carrier telephone system have been reported faulty as "no transmission in the A-B direction".

Investigation shows that the pilots have failed at the B terminal but are normal at the preceding repeater.

List the possible items of equipment or line which could be the cause of the trouble.

ANSWER 13.

The following conclusions are drawn from the information given:—

(a) There is no line trouble as this would cause failure in the B to A direction also.
(b) No equipment common to the two-wire path (such as line filters) is involved for the same reason as given in A.
(c) As the pilots have failed at the B terminal, but are normal at the preceding repeater, the trouble must be between the point at the repeater where the pilots are measured and the output of the B terminal.
(d) As all channels are faulty the trouble is most probably in the equipment common to all channels.

Possible items of faulty equipment are:—

1. The A to B out directional filter or associated wiring at the repeater
2. At the B terminal.
   (a) the receive directional filter;
   (b) the regulating amplifiers or network;
   (c) the first group demodulator or its associated carrier supply;
   (d) the intermediate frequency filter;
   (e) the second group demodulator but not its carrier supply which is common to the first group modulator of the other direction of transmission;
   (f) the auxiliary receive amplifier;
   (g) interconnecting wiring or other items of equipment in the receive path such as transformers. It is unlikely that there will be any trouble in the pilot detection circuits at the B terminal as both pilots have failed.

QUESTION 14.

On an open wire trunk route between two stations two physical circuits are reported "off crossed".

With the aid of explanatory sketches, list in correct sequence the tests which would be made from a standard trunk test board, using the voltmeter circuit, to determine the nature of the fault as a preliminary to making an accurate location by bridge means.

ANSWER 14.

The proper sequence of tests is as follows:—

1. Examine the trunk circuit maps for the two circuits concerned to determine their make-up.
2. Contact the distant end station and confirm by speaking tests that the report is accurate.
3. Assuming that the fault is confirmed and that circuit maps show no equipment at the intermediate stations or on poles then have the distant end technician open circuit the two physicals.
4. Test each physical pair for foreign battery between the wires and from each wire to ground . (See Fig. 1.)

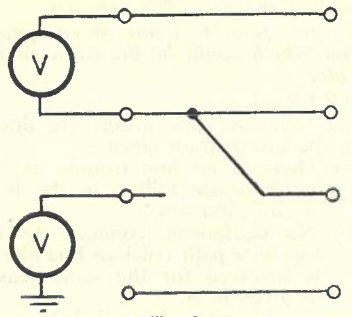


Fig. 1.

5. Assuming no foreign battery then test each pair for insulation resistance and each wire for low resistance to ground. (See Fig. 2.)

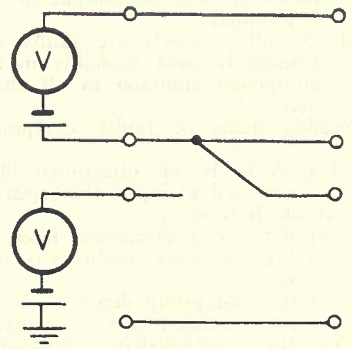


Fig. 2.

6: Assuming no trouble then have the distant end technician short circuit each pair and test for loop resistance. (See Fig. 3.)

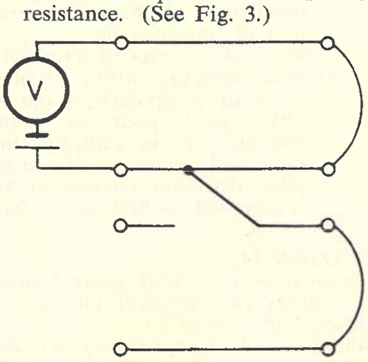


Fig. 3.

7. Assume pair 2 tests open circuit, then have the distant end technician short circuit and earth each pair and test each wire for ground. (See Fig. 4.)

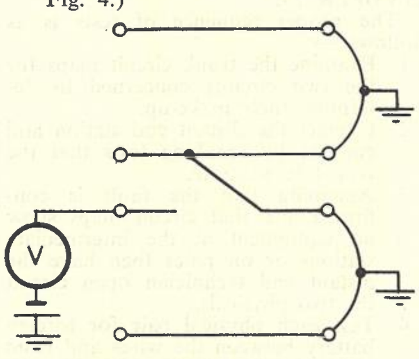


Fig. 4.

8. Assume the A wire of pair 2 tests open circuit, then have the distant end technician earth that wire only at his end and test each of the wires of pair 1 for earth. (See Fig. 5.)

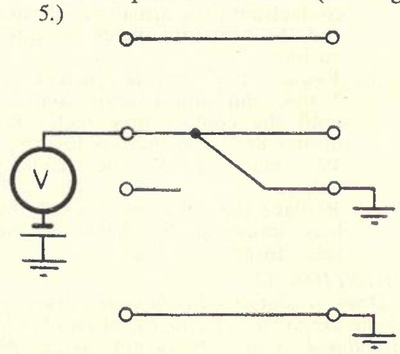


Fig. 5

9. Assume that a cross is found between the A wire of pair 2 and B wire of pair 1, then carry out varley test to determine the location. Conditions other than those assumed may be found by extension of the procedures outlined.

QUESTION 15.

You are required to carry out the initial line up of a three channel carrier telephone system prior to it being placed in service. The system has no repeater and all line measurements have been completed satisfactorily.

(*a*) *List the sequence of tests and adjustments required to achieve correct high frequency path line up and correct channel levels.*

(*b*) *What test levels would be measured at:—*
(i) channel mod in, (ii) demod out, (iii) trans amp out, and (iv) rec amp out jacks, with the system properly aligned.

ANSWER 15.

(a) 1. Send 800 cps tone, at the level determined by the controlling engineer, at the hybrid line of one channel at the A terminal with the other channels terminated and with the opposite direction of transmission interrupted and terminated.
2. Measure the level at hybrid out of the channel under test and adjust the transmit pads to give −13 dbm.
3. Measure the level at TA out and adjust the amplifier to give, as closely as possible, the correct planning level, usually +18 dbm.
4. Repeat this measurement with the other channels. The values obtained should not be significantly different from the first channel
5. Send tone on the low frequency channel and have the distant end read the level at the HP drop of the line filter group, at RDF out and at RA out. Record these readings.
6. Send on the other channels in turn and read and record the levels at the same points.
7. From the readings obtained at RA out for the low and high frequency channels, compute the slope of equalisation needed in addition to the basic equaliser and adjust the variable receive equaliser accordingly.
8. Repeat the measurements at TA out to confirm correct adjustment, then send on the mid frequency channel and adjust RA gain to get the correct output level for the system (generally +6 to +18 dbm).
9. Record the levels on other channels at this point and record the RA setting.
10. With tone on each channel in turn measure at demod out and adjust to +4 dbm.
11. With tone on each channel in turn measure at hybrid line and adjust the receive pad to give the correct planning level.
12. Repeat the whole sequence in the opposite direction.

(b) −13 dbm
+ 4 dbm
+18 dbm
+ 6 dbm
} for a typical system.

QUESTION 16.

You are required to carry out a line up of a physical programme channel between two capital cities.

(*a*) *List the tests which are required to ensure that the channel gives satisfactory performance.*

(*b*) *What is the frequency and level of tone used to line up programme channels?*

(*c*) *What are the usual limits of the frequency band of a physical programme channel?*

(*d*) *What limits the upper end of the frequency range?*

ANSWER 16.

(a) (i) The programme circuit is adjusted for zero equivalent. A frequency of 1000 c/s at a level of +8 dbm is applied to line at the transmitting terminal and commencing with the repeater nearest to the terminal each repeater adjusts in turn to give a programme amplifier output of +8 dbm.
(ii) The frequency response of the bearer is measured by sending frequencies of 35, 50, 100, 3000 and 5000 c/s at a level of +8 dbm to line.
(iii) The harmonic distortion is measured using a frequency of 400 cycles at a level of 6 db above line up level (viz., +14 dbm).
(iv) The line is terminated at the sending terminal and the noise level both unweighted and weighted is measured at the receive end.
(v) A programme is then sent from the originating station at zero reference level and monitored to ensure satisfactory reception.

(b) 1000 c/s at +8 dbm.

(c) 35 to 5000 c/s.

(d) The 5.6 Kc/s line filter group which is used to enable a 3-channel carrier telephone system to operate on the same open wire bearer.

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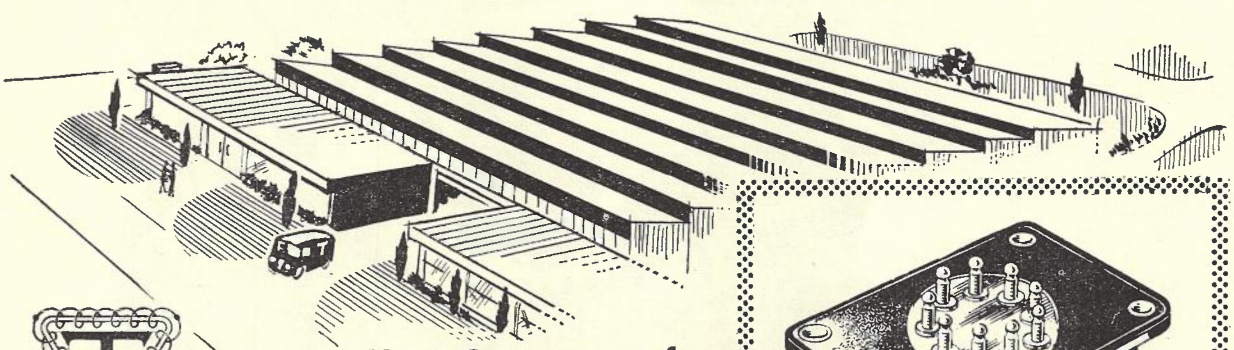

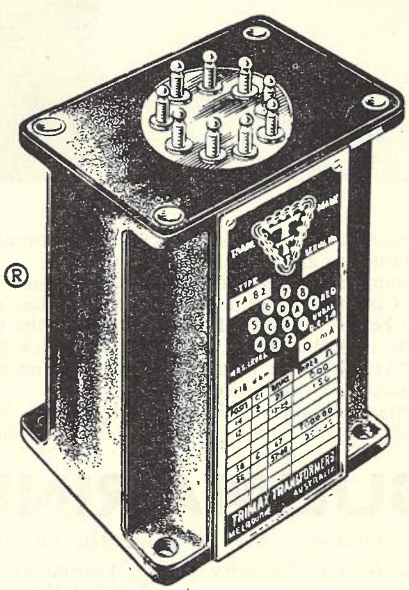

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