The Telecommunication Journal of Australia

VOL. 11, No. 5 Registered at the General Post Office, Melbourne, for transmission by post as a periodical. OCTOBER, 1958

CONTENTS

POLICY

THE object of the Postal Electrical Society of Victoria is to promote diffusion of knowledge in the communication services of the Post Office.

In advancing this object by the publication of this Journal the Board of Editors is not responsible for the statements made or the opinions expressed in any of the articles in this Journal, unless such statement is made specifically by the Board.

Editors are welcome to use not more than one-third of any article provided credit is given at the beginning or end, thus:—From "The Telecommunication Journal of Australia."

BACK COPIES:

The Society has available, in quantity, the following back copies of the Journal:—

Volume	6	Numbers	1 - 6	published	1946-48
„	7	„	1 - 6	„	1948-50
„	8	„	1, 2 & 4	„	1950-52
„	9	„	1 - 6	„	1952-54
„	10	„	1 - 6	„	1954-57
„	11	„	1 - 4	„	1957-59

These Journals may be supplied, on demand, at 10/- per set of three or at 4/- per single copy. Back copies of some earlier numbers are available but it is recommended that inquiry first be made to the Secretary, as to the availability of any particular number. In the event of the Society being unable to supply any number, it wall act as an agent to assist subscribers in obtaining a copy. The Society does not repurchase Journals but readers having copies which are no longer required should give details to the Secretary, who may thus be able to advise other readers where the back copies may be obtained.

DISTRIBUTION:

This Journal is available to members of the Postal Electrical Society of Victoria without charge. Non-members may obtain copies of all publications of the Society on the payment of 10/- p.a. Single copies of this Journal are available at 4/- each.

COMMUNICATIONS:

All communications should be addressed to:—

Hon. Secretary,
Postal Electrical Society of Victoria,
G.P.O., Box 4050, Melbourne.

All remittances should be made payable to "The Postal Electrical Society of Victoria," and endorsed "Not negotiable."

The

Telecommunication Journal of Australia

VOL. 11, No. 5 OCTOBER, 1958

MR. R. D. KERR

It is with considerable regret that the Postal Electrical Society records the retirement of Mr. R. D. Kerr from the position of Hon. Secretary, which position he has held since 1951.

In the past eight years the Society has had fluctuating fortunes and during this period has experienced many difficulties, particularly as far as its publishing activities have been concerned. Some of these difficulties have arisen due to the steep increases in publishing costs which have occurred.

The fact that we have now arrived at a satisfactory financial condition, as far as publishing activities are concerned, is due, in no small measure to the attention which Mr. Kerr has given to this problem. In addition to his secretarial activities Mr. Kerr has also found time to prepare several articles appearing in the Telecommunication Journal and to present lectures to the Society. The last of these lectures was given in February, 1957, and in this lecture Mr. Kerr gave a very interesting description of many overseas developments which he saw at firsthand during a visit upon which he had been sent by the Department during 1956.

Mr. Kerr's resignation, after a period of eight years as Secretary, was accepted with regret by the Committee and a resolution was adopted placing on record the appreciation of all members for the work he has carried out during this period. At a subsequent Committee meeting Mr. Kerr was unanimously elected a life member of the Society, a distinction which is held by only a few members. All readers of the Journal will join in expressing appreciation of Mr. Kerr's service and in wishing every success to Mr. R. G. Kitchenn, B.Sc.(Eng.), A.M.I.E.E., A.M.Brit.I.R.E., who has taken over the position of Secretary.

NATION-WIDE DIALLING SYSTEM FOR AUSTRALIA

*R. W. TURNBULL, A.S.T.C. (Elec. Eng.)**
B. F. MARROWS, M.Sc., B.A.
W. J. B. POLLOCK, B.Com.

An announcement of far reaching importance to the development of the telephone system of Australia was made by the Postmaster-General, the Honourable C. W. Davidson, on the 2nd November, 1958. The announcement followed approval of the principles on which the long term plans being prepared by the Australian Post Office are based, and the statement is given in full hereunder:—

"LOOKING AHEAD ON TELEPHONE POLICY

The Australian Post Office is making plans for a Nation-wide dialling system whereby telephone subscribers will be able to dial their own calls to any other subscriber in Australia without the aid of telephonists.

Although the plans are yet in the preliminary stages, several steps towards the adoption of a subscriber to subscriber dialling scheme have already been taken. All-figure telephone numbers are being introduced progressively to facilitate long distance dialling using national numbers which will consist of an area code and the subscriber's local number. The numbering plan for the whole of Australia is being designed to meet development for a long period ahead and a good deal of automatic trunk switching equipment has been installed and some automatic signalling and metering equipment provided. In some areas subscribers can already dial their own trunk line calls over limited distances.

Telephones in Australia have doubled in the last ten years and there are now nearly 2 million connected. As one of the first countries to realise its advantages, Australia has provided automatic service for practically all metropolitan users and for almost 25 % of country subscribers. 71% of the total services are automatic.

Of the 1,200 million local calls made annually, 80% are connected automatically, but in country districts 200 million calls a year are still handled by telephonists. It is largely in the country therefore, that the expansion of the automatic service must be pressed on with if it is to keep abreast of metropolitan development, and establish the basis necessary for the progressive automatisation of the nation's telephone system and achieve a worthwhile reduction in costs within the next few years.

The service on almost all the 15,000 trunk line channels in use is in keeping with world standards and nearly 80% of the 113 million calls over these channels are connected without the subscriber leaving his telephone.

Obviously, to keep pace with a rapidly increasing tempo and outstanding progress in the telecommunications field, the service of the future must be faster and cost less to provide. It must permit automatic charging and accounting, and incorporate the features necessary to ensure that ultimately this country can become more closely integrated with the world telephone network.

Our short term objectives in their order of priority are—

(i) More automatic telephone facilities in country districts so that rural centres can be given the benefits of a 24-hour service and become more closely knit in the national network.

(ii) Development of the long distance telephone system in such a way as will ensure that the full advantages of automatic working can be applied progressively and uniformly to local and trunk line calls.

One fundamental objective is that people should be able to make local calls over greater distances and to more subscribers than at present. To achieve this, telephone exchanges will be grouped in charging zones based on community of interest and economic factors, so that calls within a zone and to adjacent zones can be treated as local untimed calls. On trunk line calls dialled automatically by subscribers, the minimum charge based on a 3-minute call may need to be abolished. Under the proposed new scheme, the charge will be related more closely to the duration of the call. If it is sufficiently short, the charge could be only one unit fee of 3d.; the fee will be recorded automatically on the meter of the calling subscriber as is done at present for local calls.

By grouping exchanges for local call charging, reducing the number of categories in the rental scale and the number of mileage categories in the long distance tariff scale, the Post Office will be able to lower its equipment, operating, accounting and administrative costs considerably and provide better, faster and more economic service for the public. This is the overall objective. Its realization will benefit subscribers in country districts by extending their local call range and also those subscribers at present just outside metropolitan unit fee areas who will be brought within local call distances of the capital cities and subscribers in adjoining zones.

Although the project is a long range one, much will need to be accomplished progressively over the next few years. In developing its plans in detail, the Post Office will keep well abreast of the latest techniques in telecommunications throughout the world and ensure that they are applied as quickly and smoothly as possible.

Finally, I must emphasise that Post Office planning is paying, and will continue to pay, full regard to the need for distributing available resources wisely and prudently throughout Australia, and to the need to build up dependable communication services in every settled area of our country."

THE TASK AHEAD

The telecommunications system of Australia, of which the telephone service is the major part, represents a national asset valued at approximately £400 million. Expansion of the system, which is continuing at a rate sufficient to double the present capacity within the next 12 years, is a large task and will require considerable capital investment. The present level of capital expansion in the telephone service is of the order of £30 million a year. Provision of instruments and subscribers' lines necessitates the installation of additional exchange equipment with adequate connecting circuits and new trunk lines to cater for the increase in calls to and from the new services.

As well as meeting expansion, however, there is the need for continuing improvements in the interests of efficiency. The rapidly advancing fields of science and communication technology are constantly producing new and improved techniques. Notable progress has been made in electronics, automatic switching, radio and cable transmission systems.

In order that technical developments may be incorporated in the system in such a way as to keep complications to a minimum, it is necessary to consider the policy and technical aspects of development plans concurrently. Some of the major problems now confronting the Post Office and requiring the adoption of revised telephone policy are:—

(i) During the next 12 years the number of subscribers is expected to double.

(ii) The Sydney and Melbourne telephone networks have reached the limit of their planned capacity. Extensive development of 7 digit numbers and major re-planning within the framework of a national plan are required.

(iii) Integration of existing and new plant into one national system with facilities for subscriber trunk dialling, co-ordinated with operator con-

* The authors of this article are the members of the Headquarters A.N.S.O. Committee. Mr. Turnbull, the Chairman of the Committee, is a Superintending Engineer attached to Headquarters, Mr. Marrows the other Engineering representative is now a Branch Controller in the Telecommunications Division at Headquarters and Mr. Pollock, who represents the Telecommunications Division, is an Assistant Controller at Headquarters.

trolled services, is essential to ensure more expeditious and economic handling of traffic.

(iv) Technical standards for a subscriber trunk dialling system and for inter-working with international telephone systems must be determined. These features will be incorporated concurrently with major capacity extensions in existing city networks and in country areas where rural networks must be established for economic operation.

THE A.N.S.O. COMMITTEE

The solution of these problems requires the adoption of a long term plan for the development of the Australian telephone network. The Department established a special Committee to study and recommend basic policies and fundamental plans. Known as the A.N.S.O. (Automatic Network and Switching Objectives) Committee, its members included the Chairman and one other representative from the Engineering Division and a representative of the Telecommunications Division from the Headquarters staff. State Committees were also established in New South Wales and Victoria because of the particular requirements of the Sydney and Melbourne networks and their importance in the national scheme.

The Committee studied policies, practices and developmental trends of other administrations in order to recommend the principles and methods best suited for application to Australian conditions. It was empowered to schedule and co-ordinate all the investigations and development work necessary in Headquarters and States. The full weight of Departmental resources was thus employed as required. Leading overseas telecommunications manufacturing organisations also contributed valuable studies and data. From the outset the Committee received the utmost co-operation from all concerned and this has contributed greatly towards the progress made.

OBJECTIVES

The long term objective of the national plan is the provision of a fully automatic service so that subscribers may dial their own calls to any part of the nation. Such an objective can only be reached progressively over the years and hence there is a need for the short term objectives mentioned in the Postmaster-General's statement.

It is important that all new works be directed towards the achievement of the objectives. This, of course, will reduce costs and complexity and yield greater efficiency. Experience of overseas administrations has demonstrated the value of taking essential steps as opportunity offers; much can be lost in time and money if action is deferred until it becomes more complex and more difficult This is the optimum time for the adoption of a new plan for Australia and for the introduction of essential preliminary measures for its implementation.

ELEMENTS OF THE NATIONAL PLAN

The specification of fundamental plans which will influence the growth of the telephone system for several decades ahead is an extremely complex undertaking. Plans must provide a framework for predicted growth with a flexible reserve for unforeseen demands. It must also permit tariff and administrative policies to be developed in accordance with financial conditions and advancing business and accounting practices. Technical specifications must be sufficiently rigid to ensure satisfactory standards of performance and compatibility with existing plant, yet adjustable in detail to permit the absorption into the system of rapidly advancing technology and operational techniques. The specifications must ensure that the Australian system is kept abreast of international practices so that new services and facilities may be provided in the future.

The most important elements of the national plan are:—

1. National numbering.
2. Call charging system and tariffs.
3. Automatic switching and signalling system.
4. Line and transmission networks.
5. Telephone facilities and services.

Most of these are inter-related and technical considerations are also closely linked with matters of policy and administration, including the Telephone Regulations under the Post & Telegraph Act. Much work remains to be done to translate the broad principles on which the plan will be based into detailed plans and specifications and this is proceeding. Brief reference is made in the following paragraphs to the numbering and call charging plans to amplify the information given in the Ministerial statement.

National Numbering: A numbering plan is necessary so that each telephone whether it is in a capital city, provincial town or a country area may be distinguished from any other telephone. The general features of the numbering plan were outlined in an article in the June, 1958, issue of this Journal, explaining why Australian telephone numbers will be expressed in figures only. Briefly, the national number for an Australian subscriber will be made up of an area code and a local number.

The area code will designate a particular closed numbering area, which will cater for all the exchanges in that area. The policy will be to establish these closed numbering areas, based on community of interest, throughout the country as has already been done in metropolitan areas. For calls within a closed numbering area, subscribers will dial only the local number shown in the directory. On other calls, it will be necessary to dial the area code before dialling the local number. Area codes will always commence with "O".

Detailed investigation has shown that a national numbering scheme designed on these principles, will involve only nine digits, including the initial "O", to cater for the likely telephone needs of the Commonwealth for 40 or 50 years.

Call Charging: For a subscriber trunk dialling scheme, the present tariff system which was designed predominantly for manual operation, requires revision. Metropolitan and provincial communities of interest have extended beyond the limits of existing local call boundaries and the present call charge system has too many different rates.

The main principles of the new call charging arrangements announced are:—

(i) The adoption of multimetering, that is, recording of trunk call charges automatically on the calling subscriber's meter.

(ii) The grouping of exchanges for call charging with extension of the local call range; and

(iii) The reduction of the number of mileage categories in the long distance tariff scale.

These features will ensure that the system is kept as simple as possible and help to keep down equipment costs.

All automatic services are already provided with meters. Most are suitable or can readily be adapted for multimetering. The grouping of exchanges enables charging equipment for small exchanges to be centralised. This, together with the reduction in the number of mileage categories in the tariff scale, also reduces the cost and complexity of the charging equipment which is closely related to the number of digits it is necessary to examine to establish the charge rate for a call and the number of different charging rates from which the equipment must make a selection.

CONCLUSION

The principles which have been publicised represent approved policy for the development of the Australian telephone system and establish the basis on which future planning will take place. Each of the important elements of the national plan has already received considerable attention and as the firm plans are completed, they will be described in subsequent articles.

FEATURES OF THE CROSSBAR EXCHANGE AT TEMPLESTOWE, VICTORIA

*L. C. HAIG

INTRODUCTION

The standard automatic switching system used in Australia for subscribers' services is based on the use of bi-motional switches of the SE.50 type now being manufactured in this country and described in the June 1956 issue of the Journal. The system used for trunk switching, including automatic trunk exchanges, is based on the use of the Siemens motor driven uniselector which has been described in Postal Electrical Society Paper No. 25. In the light of favourable experience with the motor uniselector switch in trunk switching work, including its use in the City West trunk exchange and described in the June 1939, October 1939, February 1940, June 1941, October 1941, and June 1942 issues of the Journal, a trial installation of a subscribers' exchange using motor uniselectors was made at North Essendon. The exchange was cut into service in December 1954. A description of this system was given in the October 1951 issue of the Journal.

Service results with this equipment have indicated that a higher grade of service is now being given to the subscribers at North Essendon that at comparable exchanges using bi-motional switches. This is due, no doubt, in a large measure to the fact that in the motor uniselector switching system there are no wiper cords and that twin contacts are in use throughout the exchange, including wiper to bank contacts. The combination of these factors results in a reduction of the electrical noise in the talking parts of the system as well as improving the testing reliability. In addition, the simpler mechanical system of the motor uniselector involves less possibility of troubles due to maladjustments. After a period of four years in service it has been found that the faults are only approximately one-fifth of those experienced with exchanges working on the bi-motional switching system. In addition, only approximately half the staff are required to maintain the same amount of equipment.

Particularly having in mind the results obtained with the abovementioned equipment and also having in mind the claims made by makers of crossbar switching equipment that the crossbar system is a quiet switching system with a high reliability, it was decided to make trial installations of Swedish Ericsson crossbar equipment in this country. In this article a brief description is given of the main features of the crossbar exchange supplied by L. M. Ericsson, Sweden, which was cut into service at Templestowe, Victoria, in December 1957.

The Exchange comprises equipment for 600 subscribers' lines, with associated group selectors, relay sets, etc., with provision for extension to an ultimate capacity of 1,000 lines. The equipment was installed in a standard portable building approximately 19′ 6″ by 13′, the power plant (batteries and rectifier) being installed in the annexe.

*Mr. Haig is a Group Engineer, Exchange Installation, Metropolitan Branch, Melbourne.

PRINCIPLES OF CROSSBAR WORKING

Crossbar Switch: The crossbar switch as shown in Figs. 1A and 1B consists of a welded frame, inside which is fitted a number of multi-contact arrangements called "verticals". The vertical, which is the basic selector of any crossbar system, consists of a multi-contact arrangement whereby the single inlet circuit can be connected to any one of the twenty outlet circuits by the operation of appropriate selecting magnets. Ten of these verticals are mounted in a single frame enclosed by a glass fronted cover, to make up a normal crossbar switch, although the multiple of the vertical outlets may be extended over any desired number of verticals. There are six selecting bars called "horizontals" associated with each ten verticals which are used to select the required outlet, five bars designated H1 and H0 being used to select the particular outlet, and the sixth bar being used to increase the number of outlets from ten to twenty; thus to select a particular outlet two horizontal bars must be operated, that is HA or HB (the level switching bar) and one of the other five selecting bars. After selection of the required outlet, the selecting fingers are held in the operated position by the vertical magnet, and the horizontal operating magnets are then released. It should be noted that the crossbar selector is only a connecting device between two points, all functions such as selecting a free path, testing, ringing, etc., being done by other apparatus. Hence the amount of equipment held operated during a call is reduced to a minimum, the vertical magnet only being operated in the selector to hold the circuit path.

By-path Trunking: Since the time occupied in setting the individual selector

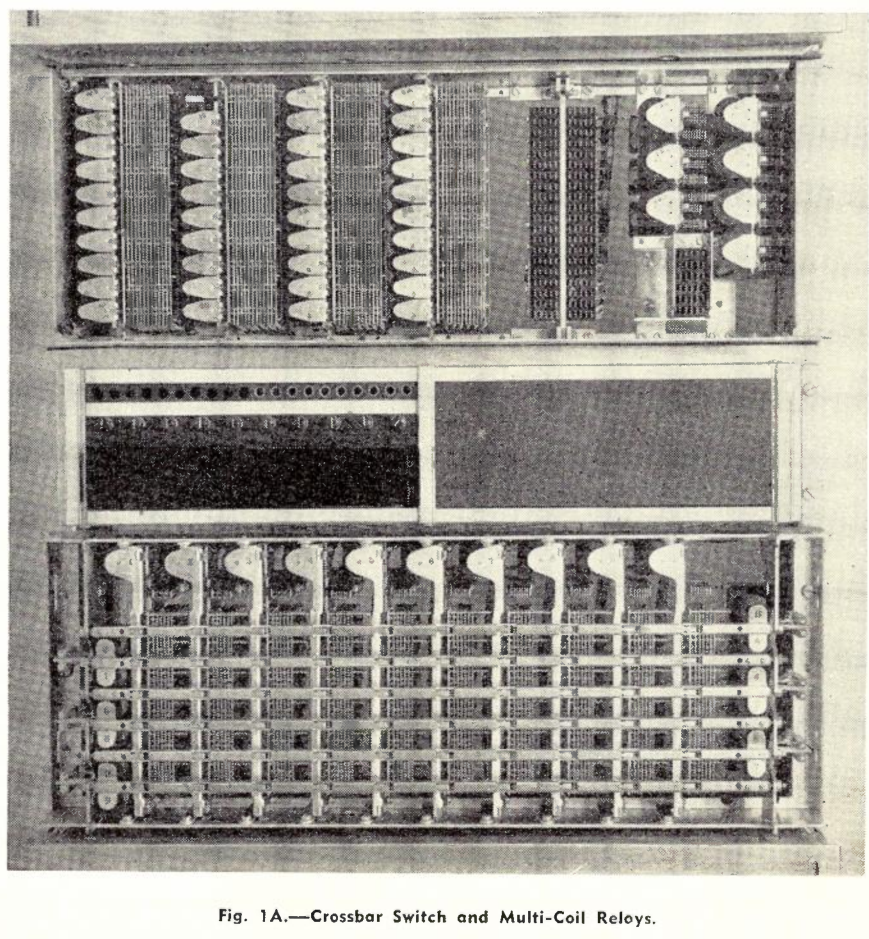


Fig. 1A.—Crossbar Switch and Multi-Coil Relays.

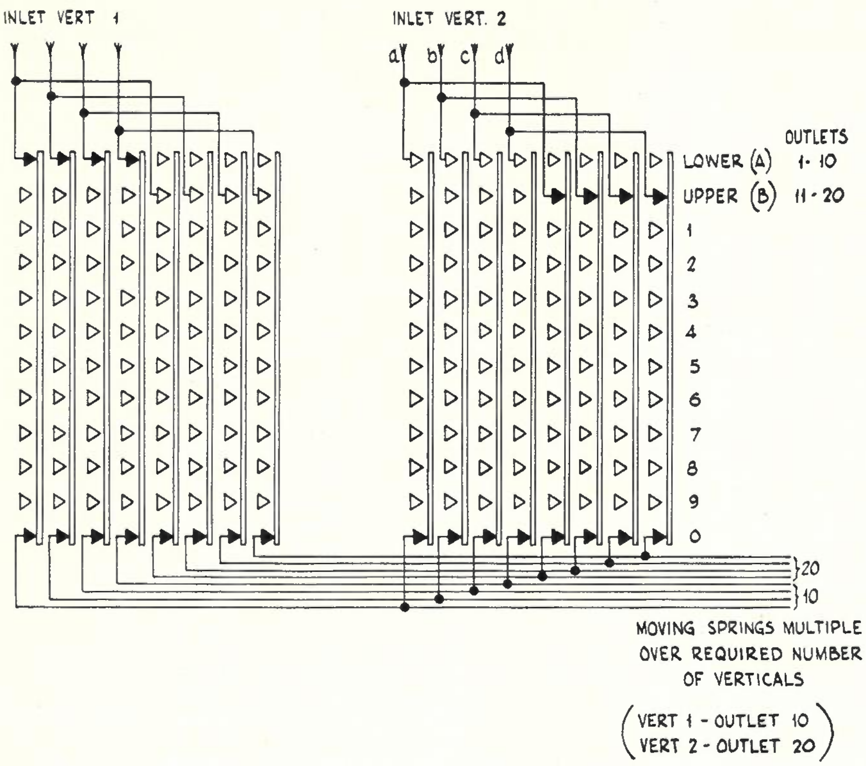


Fig. 1B—Connection through Verticals.

is very short compared with the time during which it is occupied by calls, the most economical arrangement will be to free the selectors as far as possible from individual setting devices which are in action for brief intervals only. Thus, a reduced number of control devices need only be temporarily connected to the selectors during the setting period. This system is referred to either as a "common control" or "by-path" system. It is a common control system in the sense that the setting of switches is controlled by units common to a number of switches. At the same time, however, it is a by-path system as the controlling and directing of the switching units are performed over a "by-path" separate from the speaking path. The holding time of the common relay equipment is very short so that only a small number of control devices is required. Consequently the cost of the control devices represents only a small fraction of the total cost.

Link Connection: The selector stages in this system are divided into two or more partial stages in tandem which are interconnected by means of links. (Fig. 2.) From this the name "link connection" is derived.

The links between switches of the different partial stages are arranged so that a particular switch in one partial stage may reach all or the majority of the switches in the associated partial stage. In this way the capacity of the selector stage as a whole is increased beyond the capacity of the basic unit, that is the vertical of the cross-bar switch. The name "link connection" also implies that a particular switch in a subsequent partial stage of the switching path is chosen only on condition that it has access to a free outlet on the wanted route. This feature is referred to as "conditional selection".

When a selector stage is divided into two or more partial stages, congestion may arise as a result of a lack of suitable links, known as internal congestion. Conditional selection keeps internal congestion within acceptable limits.

TRUNKING PRINCIPLES

Fig. 3A shows a simplified trunking diagram for connection between two subscribers, A and B. Fig 3B shows the Templestowe trunking diagram. The basic unit of the crossbar stage (a vertical) is symbolised by the usual designation for a uni-selector. Each of the selector stages S, GV, and L consist of two to four partial stages, and is connected by means of markers SLM and GVM. Selector stage S corresponds to the conventional line-finder stage, GV to the group selector stage, and L to the final selector or connector stage.

Fig. 4 shows the trunking diagram for Templestowe, using vertical and horizontal lines to symbolise the connection paths through the crossbar switches. Note that the two switching stages S and L of Fig. 3 are actually combined into one unit with a common marker unit SLM, two partial stages SLA/B being used for outgoing traffic and four partial stages SLA, B, C and D for incoming traffic.

The selector stage GV and its associated marker GVM perform the same function as the discriminating selector stage as used in a step-by-step system. Larger exchange units, that is, multiples of the basic 1,000 line unit differ only in the number of selector stages (GV) provided; thus all units are made up of only two different types of switching stage, namely subscribers' stages SL and group selector stages GV.

When the calling party (Fig. 3B) lifts his hand-set, his line relay operates and calls a marker SLM. The marker then identifies which particular subscriber in the 1000 line group is calling, selects a free relay set SFR with associated register, and finds a free path through stages SLA and SLB between the calling subscriber's line and the idle SFR and register. When the connection has been effected the marker is released and made available for other calls, this connection usually being attained within half a second.

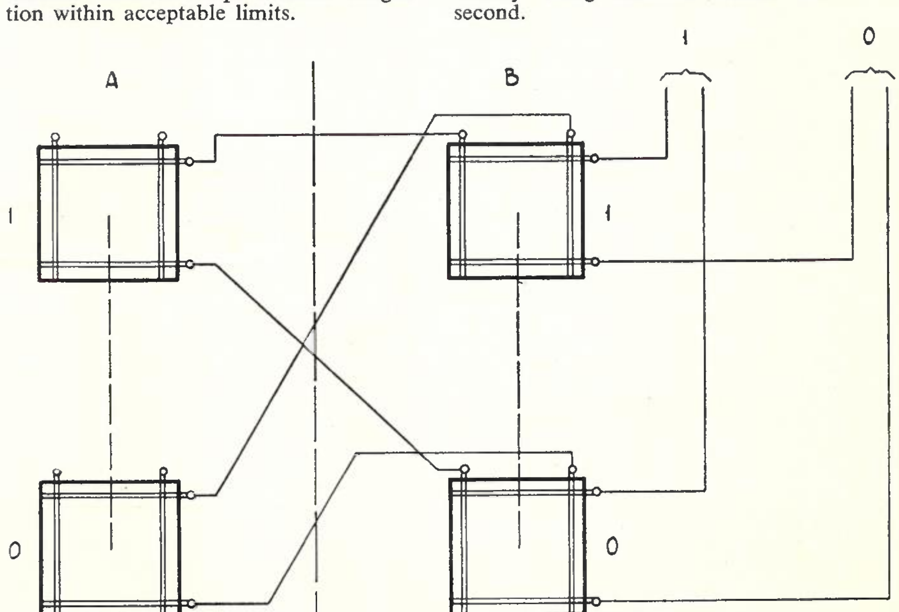


Fig. 2.—Link Connection of Two Partial Stages A and B Group Selector.

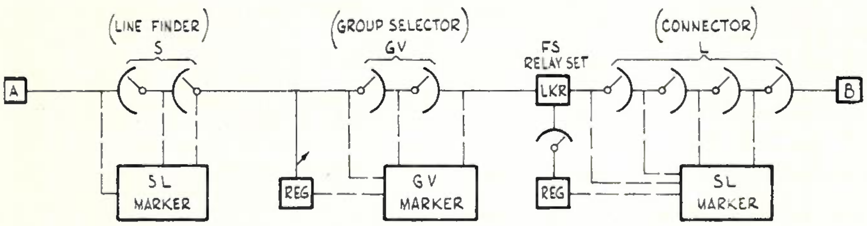


Fig. 3A—Simplified Trunking Diagram.

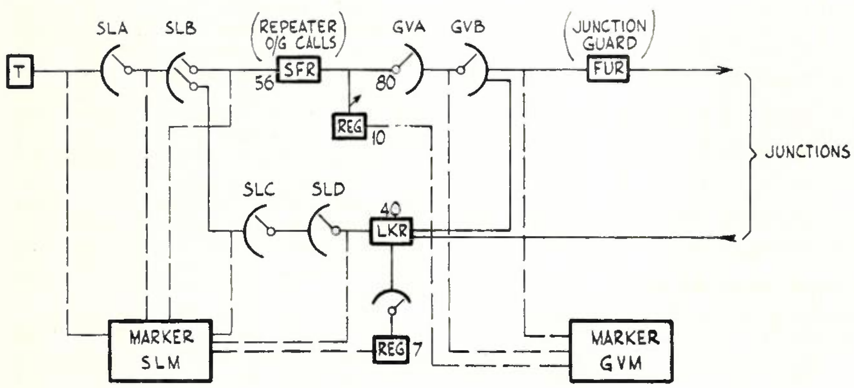


Fig. 3B—Templestowe Trunking Diagram.

When the register is connected to the subscriber's line a group selector marker GVM is called, and this marker selects an idle junction to the main exchange, and a free path through selectors GVA and GVB to connect the idle main exchange junction to the relay set SFR. When this connection has been completed, group selector marker GVM releases, and dial-tone is returned to the calling subscriber. The subscriber then dials the first digit of the wanted number, the impulses being repeated by the relay set SFR to both the register and the equipment at the main exchange. When sufficient digits have been received for the register to decide whether the call is to be a local subscriber or to a subscriber in another exchange, discrimination takes place. In the case of a local call, after receipt of the third digit, the group selector marker GVM is called, and selects an idle relay set LKR and connects this relay set through stages GVA and GVB to the SFR, and the main exchange junction is then released. The register associated with the SFR will then release and the SFR switches through to connect the calling subscriber directly to the idle LKR. When the subscriber is connected to the LKR a register-finder is brought into operation to connect an idle register to accept the remaining three digits of the wanted subscriber's number.

When the register has received the last three digits, the PBX equipment is called and a test is made to ascertain whether the call is to a PBX or a normal subscriber. If the call is to a normal subscriber the digits are transferred to the marker, and the connection proceeds. If the call is to a PBX subscriber, the PBX equipment then tests all auxiliary lines and the digits of a free auxiliary line are transferred to the marker and used to connect the call. Thus the line associated with the directory number of a PBX subscriber will only be used if all auxiliary lines are in use.

When this information is passed to the subscriber's stage marker SLM, the marker then selects a free path through stages SLA, SLB, SLC, and SLD to connect the relay set LKR to the called subscriber, tests the called subscriber for "busy" conditions, and connects the LKR to the called subscriber. The marker, register finder and register then release.

If the called subscriber is engaged, "busy tone" is fed from the final selector relay set LKR. If the called subscriber is free, then ringing current is fed to the called subscriber and "ring-tone" returned to the calling subscriber from the LKR.

If the outgoing call is to another exchange, immediately after receipt of the discriminating digits, the register will be released, and further impulses will be repeated to the distant exchange by the impulsing relay in the SFR.

If at any stage during the call there are no free outlets, that is congestion occurs, then all common equipment, markers, register, etc., and crossbar selectors are released, "busy tone" being fed to the calling subscriber from his own line relay circuit.

DETAILS OF SUBSCRIBER'S STAGE (SL)

The subscribers' lines are assembled into groups of 1,000 lines. The traffic to and from such a group is handled by a subscribers' stage SL which is built up of four partial stages SLA, SLB, SLC and SLD. Each 1,000 group is provided with its own SL marker unit. As can

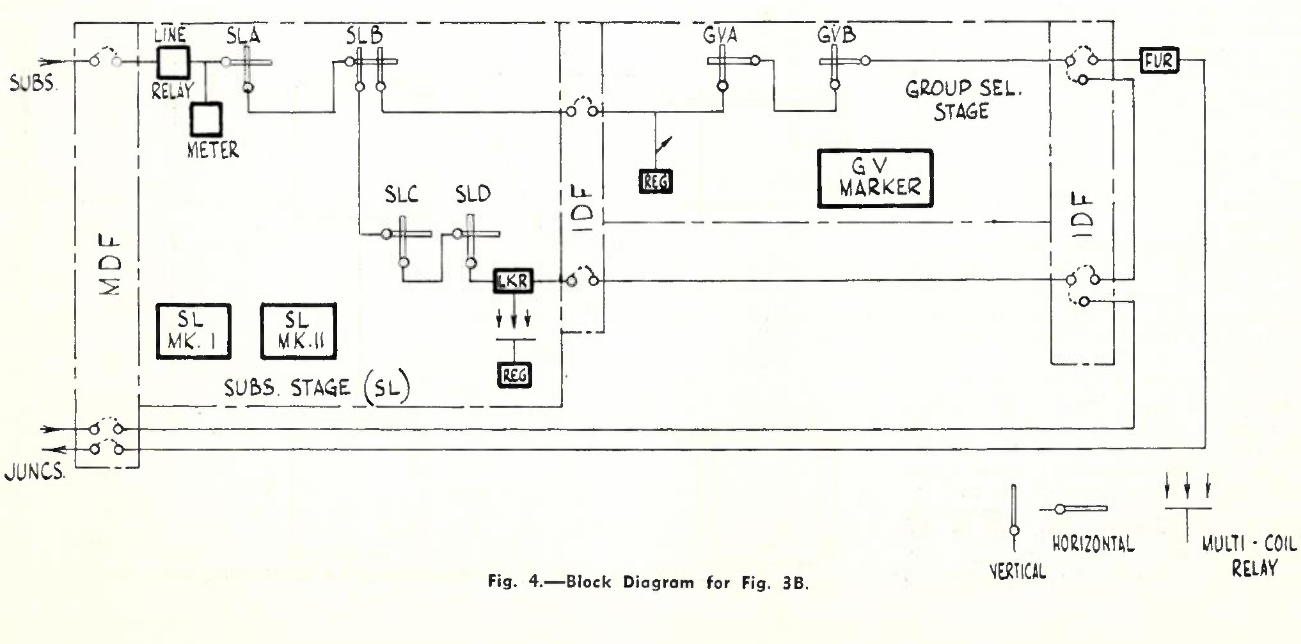


Fig. 4.—Block Diagram for Fig. 3B.

be seen from Fig. 5 there is one call indicator per 200 lines, two markers working in parallel, one digit receiver per 40 LKR and equipment for PBX services.

The SL stages in this type of exchange are manufactured in seven different sizes as regards traffic capacity, and the number of verticals in the various partial stages for different traffic capacities are shown in Table I.

The SL stages are made in different sizes with regard to the number of SLA verticals per 20 subscribers, a number usually denoted by "m". The maximum total traffic originating and terminated, and the maximum originating traffic at the full load for a full 1,000 line SL group, are shown for the three groups with "m" values 6, 8 and 10 in Table II.

The routes from a group selector stage may be arranged to have an availability ranging from 10 to 60 or more, the most common values being 20 and 40. Partial stages SLA and SLB are used for incoming as well as outgoing traffic, while partial stages SLC and SLD are used for incoming traffic only. The SLD verticals are cabled to the jacks of the final selector relay sets LKR.

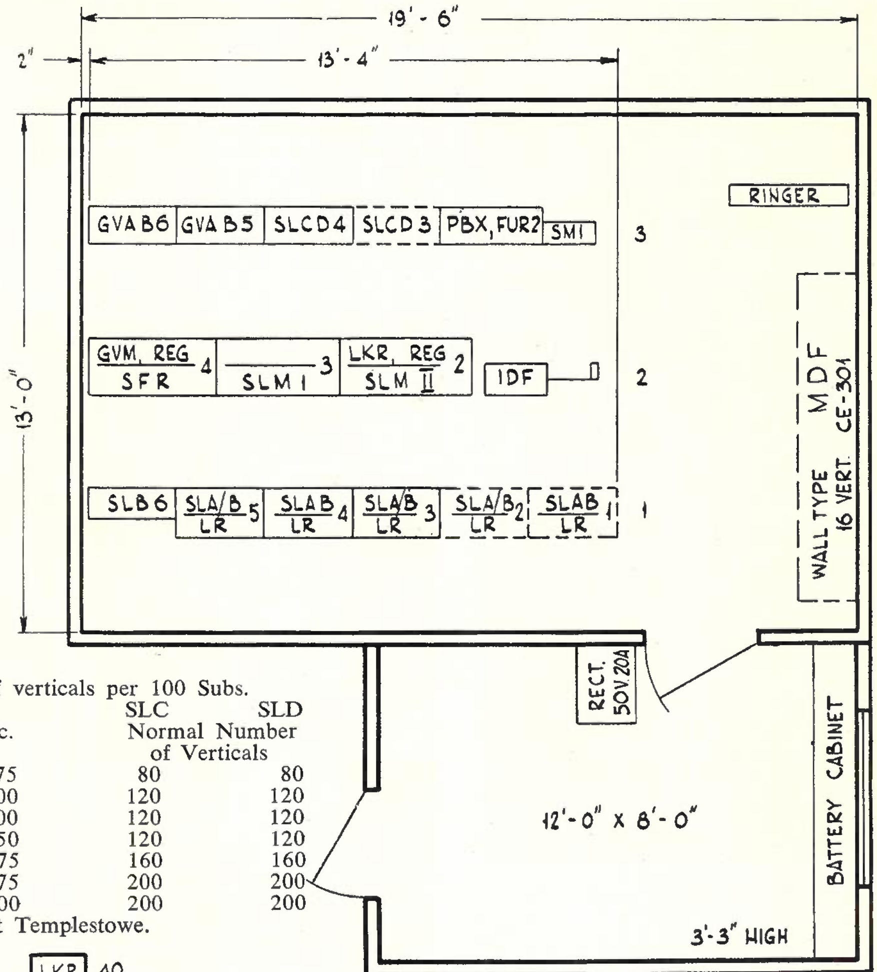


Fig. 6.—Floor Plan Layout.

TABLE I

Size	SLA per 20 Subs.	SLB Outg.	SLB Inc.	SLC Normal Number of Verticals	SLD
ARF 510/6A	6	75	75	80	80
ARF 510/6B	6	100	100	120	120
*ARF 510/8A	8	100	100	120	120
ARF 510/8B	8	100	150	120	120
ARF 510/8C	8	125	175	160	160
ARF 510/10A	10	125	175	200	200
ARF 510/10B	10	150	200	200	200

(Number of verticals per 100 Subs.)

*Number of Verticals provided at Templestowe.

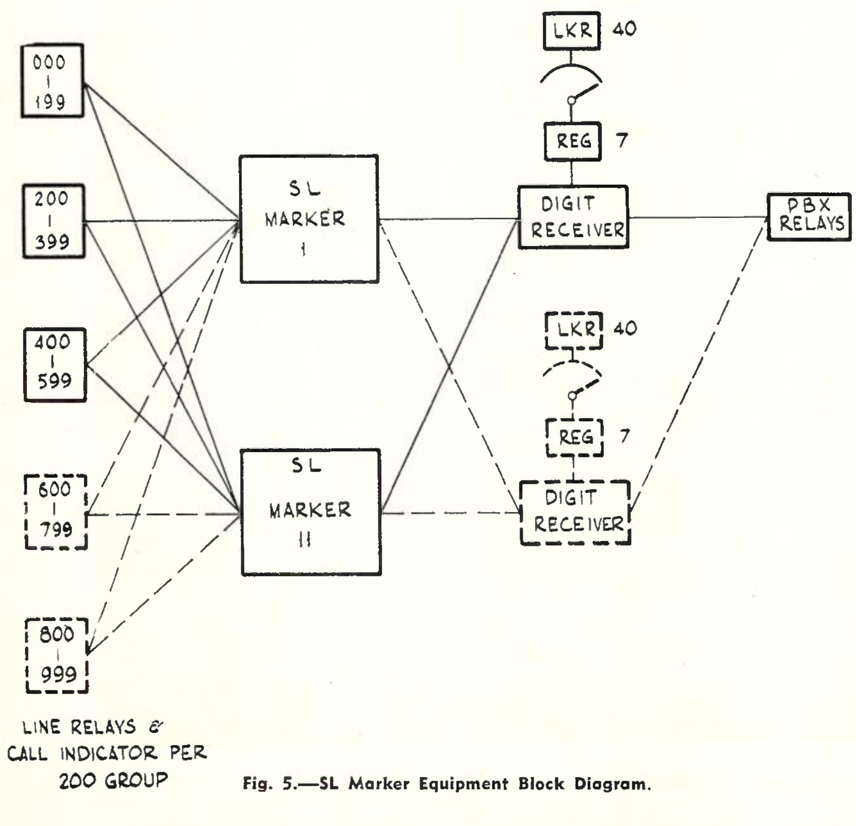


Fig. 5.—SL Marker Equipment Block Diagram.

TABLE II

Size	m	Traffic Orig.	Traffic Total
ARF 510/6A	6	46E	88E
ARF 510/6B	6	58	105
ARF 510/8A	8	67	134
ARF 510/8B	8	66	145
ARF 510/8C	8	82	174
ARF 510/10A	10	87	204
ARF 510/10B	10	106	228

The verticals have a capacity of 20 lines each, and thus the 1,000 subscribers' lines are split up into primary groups of 20 lines each. Ten such groups form a 200 line sub-group referred to later. The twenty line primary groups are connected to a number of verticals in parallel, the number of which depends on the traffic. The SLA verticals are connected to the multiple of the SLB verticals. The SLB verticals are divided into two groups, one for outgoing traffic, and one for incoming. The SLB verticals for incoming traffic are connected to the multiples of SLC verticals, which in turn are multipled over SLD verticals.

The final selector relay sets LKR are connected by means of plug and jack, their number being determined by the traffic to be catered for. They contain the battery feed relays for both called and calling subscribers, and relays for

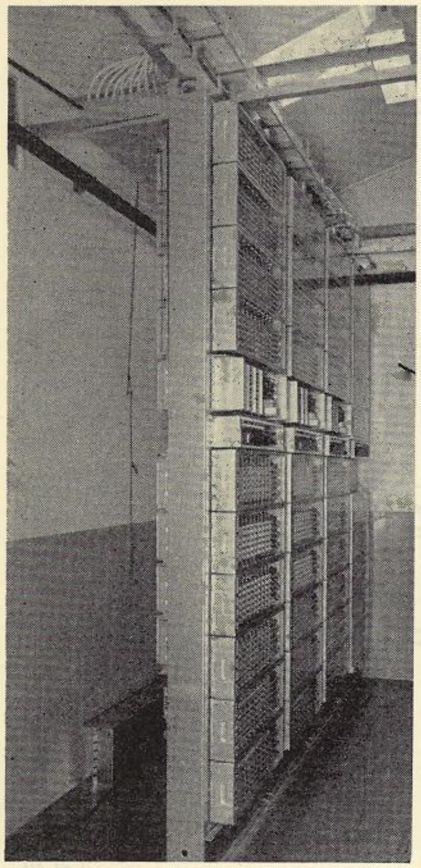


Fig. 6A—S.L.A.B. Selector Racks, 1st Suite.

connection of SL marker, signalling and ringing relays. The registers of the SL groups are connected to the relay sets LKR over register finders composed of multi-coil relays. The number of registers depends on the register traffic, but seven registers usually serve a group of forty relay sets LKR. The SL marker unit directs and controls the traffic in the subscribers' stage SL. An SL marker unit comprises two separate markers working in parallel. Each of the markers can handle one call at a time, and as a rule therefore they can together handle two simultaneous calls. If necessary, each of the markers can handle the total traffic, although short delay times may be experienced.

A marker is connected for outgoing as well as incoming calls. For outgoing calls parts of the SL marker are used for identification of the calling subscriber, and parts for connecting the subscriber to a free SFR relay set that has access to a free register. For incoming calls parts of the marker are equipped for marking the called subscriber, and parts for effecting the connection from the calling final selector relay set LKR, to the called subscriber. Some of the marker equipment is decentralised. Thus digit receivers for terminating traffic are placed in the SLC/D racks. Other equipment under this heading is the call indicators, marking that a call is being made from a 200 line group, and the PBX equipment.

GROUP SELECTOR STAGE GV

Group selector stage GV consists of two partial stages GVA and GVB, and is built up in units of 80 GVA verticals (8 crossbar switches) and 120 GVB verticals (12 crossbar switches). The 80 inlets of a group selector unit all have access to the same 400 outlets. The outlets can be arranged into routes with varying numbers of outlets, thus it is possible to form 20 routes with 20 outlets each, or 10 routes with 40 outlets each. Under certain conditions it is possible to divide a route with 20 outlets into two smaller groups. It is also possible to use routes with different numbers of outlets in the same group selector stage.

The group selector marker GVM receives the digit or digits instantaneously transmitted from the register, and uses this information for marking the wanted route. The marker thereafter tests for a free outlet in the route, simultaneously checking the free switching paths through the stage, and finally sets the switches of the A and B stages. The registers of the

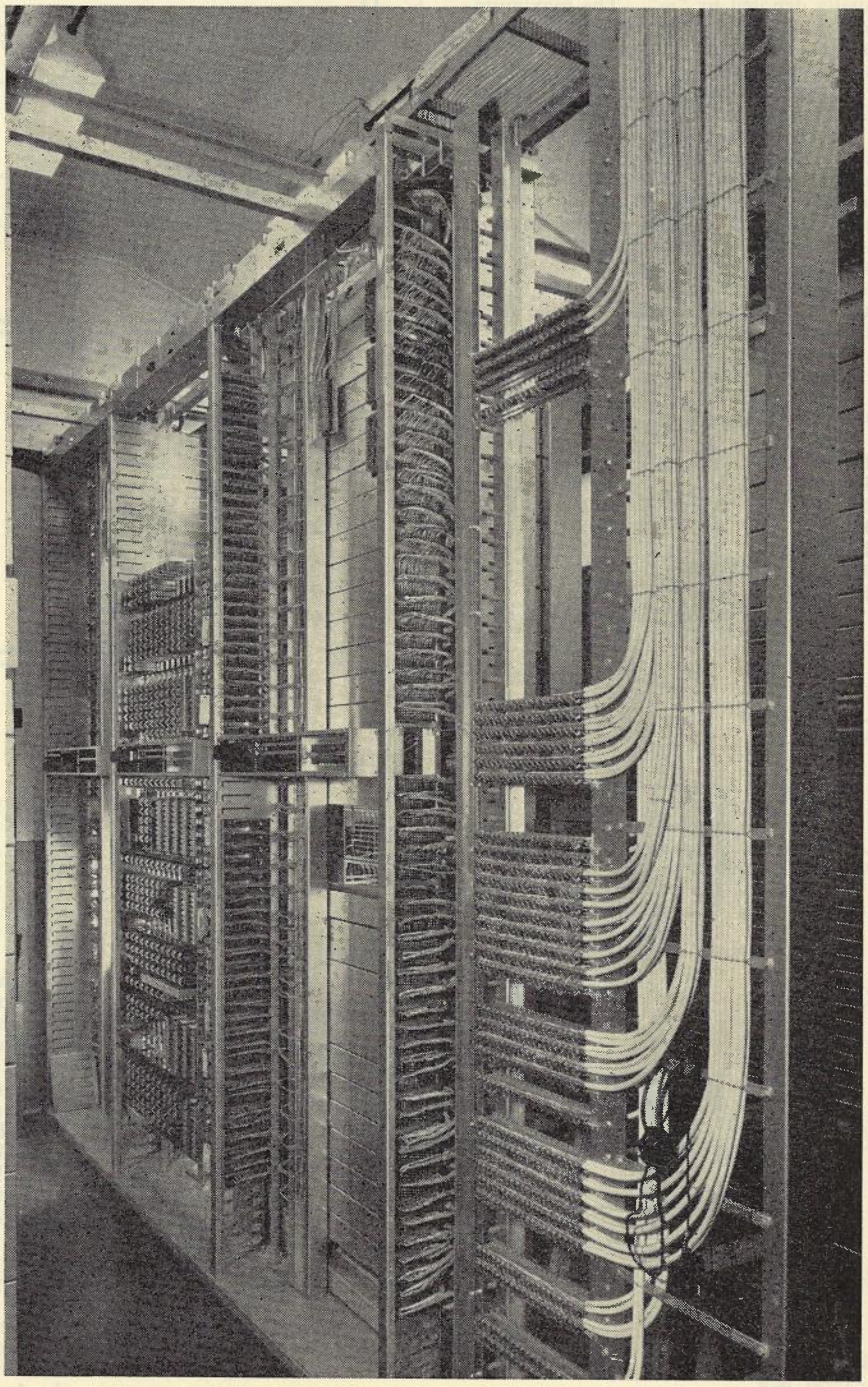


Fig. 6B—2nd Suite of Equipment.

group selector stage are connected to the SFR relay sets in the proportion of one register per six working relay sets. The number of registers depends on the register traffic, but six registers usually serve a group of 40 relay sets SFR. All Registers may be equipped to receive one or more digits dialled by the calling subscriber, and to send them instantaneously to the marker GVM. The group selector registers at Templestowe are equipped to receive three digits, discriminating on any of the three, as required.

The design of these registers is such that as soon as they are seized they in their turn seize a junction to a main exchange to which the dialled digits are also transmitted. If the call should be routed to or through the main exchange, it passes via the junction originally seized. If it is a local call, however, or destined for an exchange reached by an alternative route, the path from GV to the main exchange is disconnected and the call is routed as if GV had been an ordinary group selector, (thus performing the function of the discriminating selector repeater in the step-by-step system). Up to 19 local or interaccess routes may be connected.

LAYOUT AND MECHANICAL CONSTRUCTION OF EQUIPMENT

Layout: Two main types of racks are used, the racks for crossbar selectors (Type BDD) being 26⅜" in width and 11" in depth. Racks for marker and register relay sets, and relay sets LKR and SFR, (Type BDH) are 37⅞" in width and when placed in a double-sided suite occupy a depth of 16¾". The SLAB racks have provision for mounting subscribers' line relays LR, at the rear of the rack, the total depth of the rack then being 16¾". The overall height is 9' 7" for all racks and a minimum free ceiling height of 10' 10" is required.

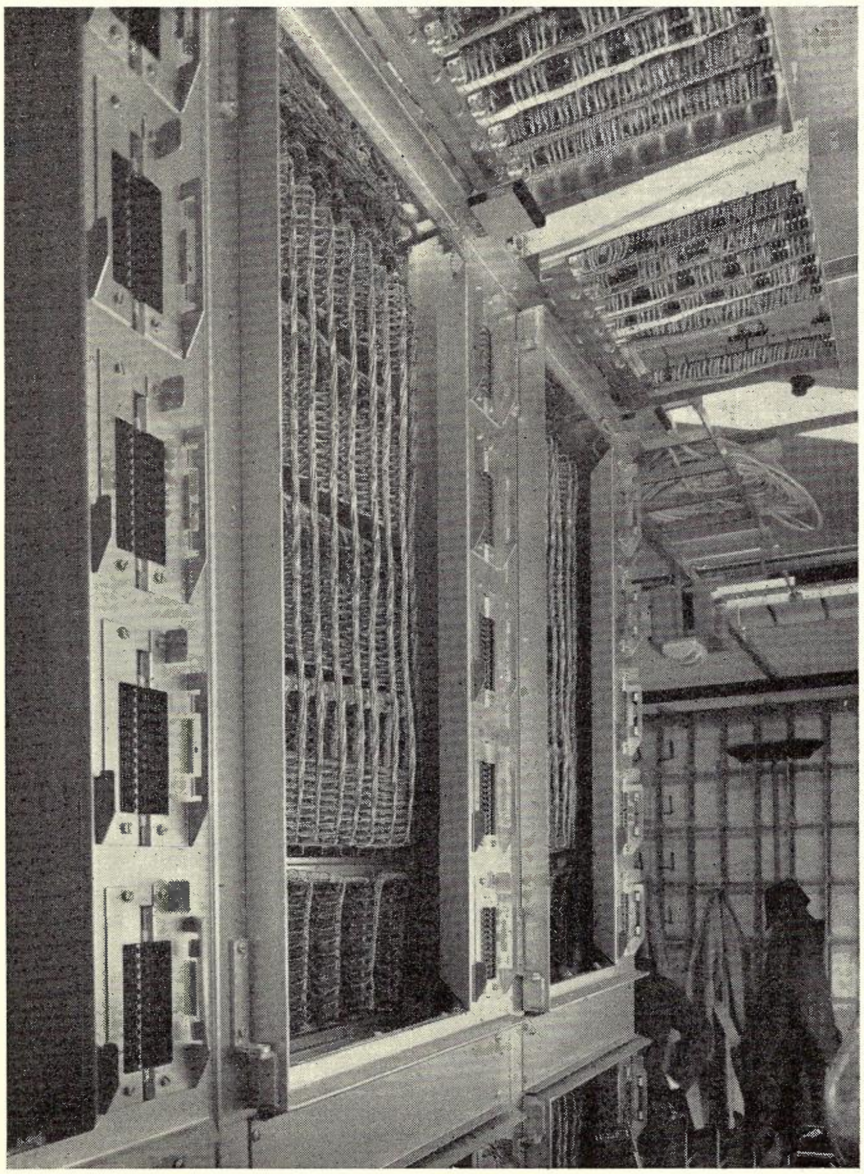


Fig. 7—Rear view SLAB jack fields mounted for cabling.

The layout of the equipment is shown in Fig. 6. The subscribers' stage in Suite 1 consists of five SLAB racks comprising 8 SLA and 2 SLB selectors, together with line relays for 200 subscribers, and one rack of 10 SLB selectors. Group selectors GVA/B, SLC/D selectors, together with PBX and FUR (outgoing junction) relay sets, and subscribers' meters, are placed in Suite 3. Marker, register, LKR and SFR relay sets are installed in the centre suite with the centralised I.D.F. The SLAB racks of selectors are shown in Fig. 6A and the IDF, etc., in Fig. 6B.

Cabling: The wiring of selectors is terminated on a jack field mounted on the top of the selector rack, (Figs. 7, 8 and 9), and connection between racks is done with cables terminated on 40 point plugs. This method of connection is used to facilitate the alteration of internal cabling for the provision of additional selectors as the capacity of the exchange is increased. Connection of junction line relay sets (FUR), final selector relay sets (LKR) and repeaters (SFR) to the appropriate selector stages is done by jumpering on the I.D.F.

All relay sets in BDH type racks are connected to the rack wiring with a multi-point plug and jack, in such a way that the connection between the relay set and the rack wiring may be broken without removing the relay set from the rack. Only one size of cable (42 wire) is used throughout the exchange, and the cable used is cream coloured PVC insulated and sheathed. A colour code is not used, but a marker and reference pair is provided in each layer and final indentification is done by inserting the previously terminated 40 point plug into a jack connected to a bank of 40 lamps, thus testing for short circuits, cross connections between pairs, and continuity of each wire as the unterminated end of the cable is fanned out.

Power Distribution: In this exchange the power distribution is done using 19/.064 cable, run in the channel irons used to support the racks and superstructure, a 15 amp. alarm-type fuse being provided at the top of each rack. The cable is run in a closed loop, commencing from the main discharge panel, running the length of each suite in turn, and returning to the discharge panel, the object being to reduce the impedance of the distribution and hence reduce any noise which may be caused by the fast operating relays in the markers. Tests are to be performed to check the effectiveness of the latter feature. Alarm and tone distribution is wired through a bay control unit associated with each suite (Fig. 10). This unit contains alarm relays and provision for opening the alarm or tone leads to any individual rack for fault tracing purposes, together with a lamp display to indicate the nature of an alarm within the bay.

Superstructure: Details of the runway fittings are shown in Fig. 11. The runway side members are of 1½" x ¼" mild steel, and the slats are made from approximately 18 gauge steel, cold pressed into a U cross-section. Normal slat

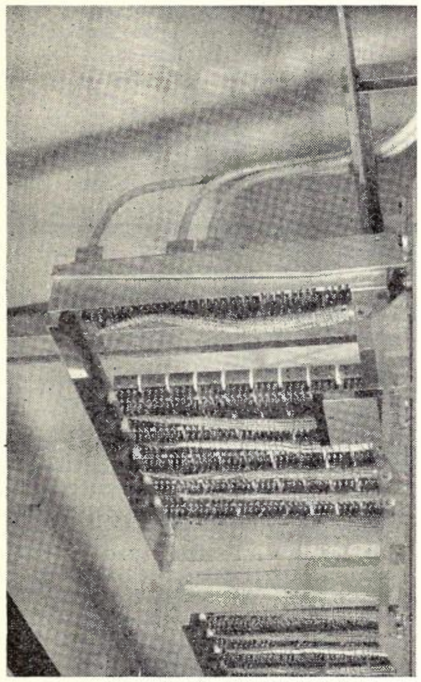


Fig. 8.—Jack fields with 3 cable plugs in position.

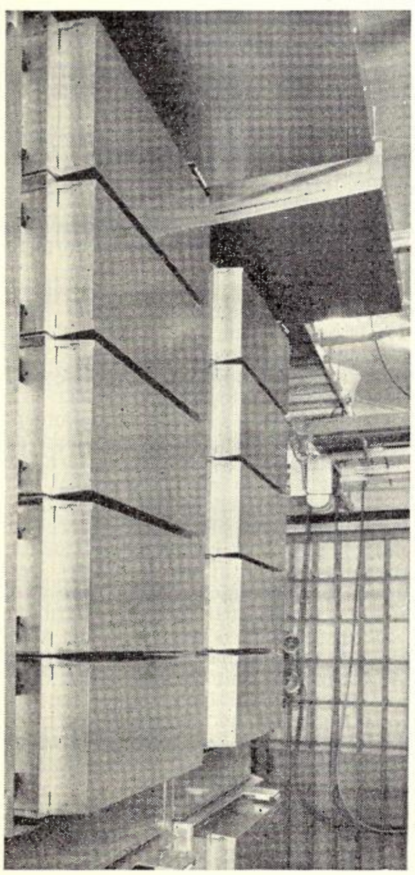


Fig. 9.—Showing Jack Fields (Enclosed) and LR sets.

spacing is 7" but as the slats are only pushed on to the side members the spacing may be adjusted as required. Also shown in Fig. 11 are the cable supports which clamp to the runway slats and reduce the need for lacing of cables. In places where the support of small packs of cables is difficult a PVC cement is used to glue the cable together in the form required.

SPECIAL FACILITIES

Line Lockout: To avoid unnecessary occupation of the switching circuits, a calling subscriber is not permitted to hold an unsuccessful connection (whether due to congestion, called subscriber busy or not answering) or a connection which has been released by the called subscriber for longer than a pre-determined time, usually two to four minutes. After that period a time control in the LKR relay set causes the connection to restore, and "busy-tone" is fed from the line relay set. Short circuited subscribers' lines are also cut off from the switching equipment after the above pre-determined time. A register that is held unnecessarily will be released after a short period which can be adjusted usually between 20 to 40 seconds.

PBX Subscribers: Any subscriber's number can be made a PBX line by the addition of a PBX relay for each four lines to the PBX, this relay being connected to the line whose number is given in the directory. Hunting over the auxiliary lines is done when a call is received to the directory number, but a call direct to an auxiliary line proceeds as for a call to a straight line number, thus allowing for direct connection to night switched lines. Although any number can be connected to the PBX facility, connection of the PBX relay is simplified if the directory number chosen has the last two digits the same, that is WJ7288, 7177, 7122, etc. Auxiliary lines can be chosen from anywhere within the 1,000 group, the only restriction being that the auxiliary lines serving one subscriber cannot have more than two lines with the same last digit.

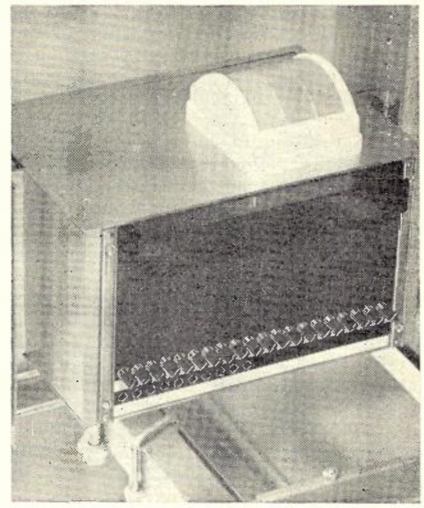


Fig. 10.—Bay Control Unit.

Extended Alarm and Test Facilities: Relay sets are provided so that all alarms are extended to a parent exchange, and a special test distributor circuit is provided so that tests on any subscriber's line can be done from the one exchange. For testing the equipment one subscriber's number is reserved in each 200 group.

Line Test Facilities: A portable test desk is provided for testing subscribers' services which is connected to the required subscribers' lines with cords. Services may be tested for continuity,

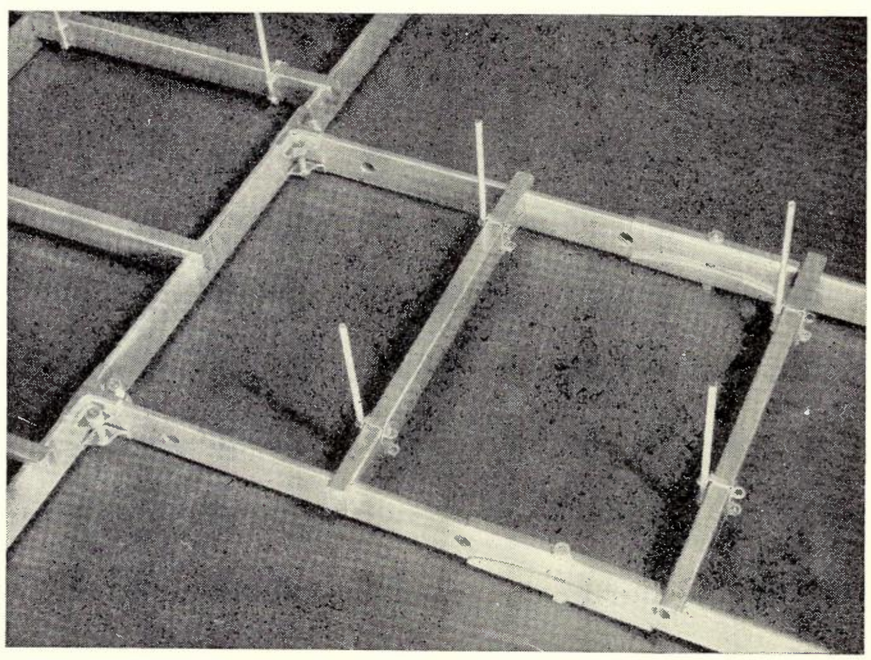


Fig. 11.—Runway fittings and Cable Support Details.

insulation resistance, foreign earth or battery, and impulse ratio, speed and count.

Junction Relay Set (FUR): A relay set consisting of three relays is associated with each outgoing junction to provide protection against short circuit or open circuit junctions. A high resistance relay (15,000 ohms) is normally held operated to the battery and earth being fed from the distant exchange. If the junction line is open or short-circuited, this relay will release and prevent the seizure of the faulty junction by the marker equipment. The other two relays prevent the junction being seized after the conclusion of the call before the switches in the distant exchange have released.

Testing Circuits: In the testing circuits of the group selector marker provision is made for either battery or earth testing. Battery testing is used throughout the crossbar equipment, but the earth test facility is provided for where direct inter-working between crossbar and step-by-step equipment is required.

ACKNOWLEDGMENT

I wish to acknowledge the assistance of Mr. L. Estberger of L. M. Ericsson, Sweden in the preparation and checking of this article.

REFERENCE

Automatic Telephone Exchanges with Crossbar Switches, System ARF 51. Published by L. M. Ericsson, Sweden.

OPEN WIRE TRANSMISSION LINE SWITCH FOR USE AT HIGH FREQUENCIES

*S. S. MINZ, B.E.E., A.M.I.E.Aust.**
F. J. NORMAN, B.E.E.(Hons.), D.I.C., Grad. I.E.E.

SUMMARY

In October, 1952, "The Engineer" (1), (2) published general details of a transmission line switch which had been devised by the British Admiralty and engineered commercially in Great Britain. The switch, which was a new application of the crossbar principle, represented probably the first satisfactory solution of the difficult problem of switching open wire, radio frequency transmission lines.

The general requirements of such a switch are examined below together with details of some earlier systems employed by the Australian Post Office. The adaptation of the Admiralty type switch for use at the Lyndhurst Transmitting Station, Victoria, is discussed, particularly with respect to its modification for outdoor use and its performance in service. The Lyndhurst Station is used mainly to provide a high frequency broadcasting service to remote areas in Central and Northern Australia.

INTRODUCTION

A high frequency transmitting station basically comprises a number of transmitters feeding directional aerials which are orientated in such a manner as to give maximum signal strength at the distant receiving point. From a purely operational viewpoint, it would be desirable to have a transmitter permanently feeding the aerial associated with each circuit. However, permanent connections are extravagant in terms of transmitters when the number of directions of fire is in excess of the number of simultaneous transmissions. Further, when transmitting over a particular circuit, different frequencies have to be used depending on the time of day, season and the year, making it generally necessary to switch to different aerials with each frequency change. It may therefore be seen that the number of aerials could be considerably greater than the number of transmitters. The use of wide frequency band aerials, such as the rhombic, reduces the number of aerial changes required, but does not eliminate them, since these aerials cannot work efficiently over the whole of the high frequency broadcasting band. In practice then, a number of transmitters are fed through a switching system enabling any one transmitter to select any one aerial. With such a switching system the number of transmitters to be provided is thus reduced to only those required to meet the number of simultaneous transmissions, plus a small margin for emergency use. In addition to the saving in capital cost of transmitters, the provision of the switching system enables rapid replacement of a unit developing a fault and restoration of service with a minimum of delay.

BASIC DESIGN REQUIREMENTS

Superficially such a switching system does not present a difficult problem, but as the station grows, the complexity increases rapidly even with a small increase in the number of transmitters or aerials. This is shown strikingly upon examination of the number of possible switching combinations for two typical examples:—

Transmitters	Aerials	Number of Possible Combinations
2	6	30
10	26	20×10^{12}

A large switching system may constitute a significant proportion of the cost of a transmitting station installation and for this reason the designer is frequently tempted to eliminate the access of some transmitters to some aerials to reduce costs. Any limitation of access is particularly inconvenient for overseas broadcasting purposes where a greater number of programme changes are made in order to reach different countries at their preferred listening times. In practice this limitation affects the allocation of programmes to transmitters and aerials and may prevent a programme from being broadcast even though both the

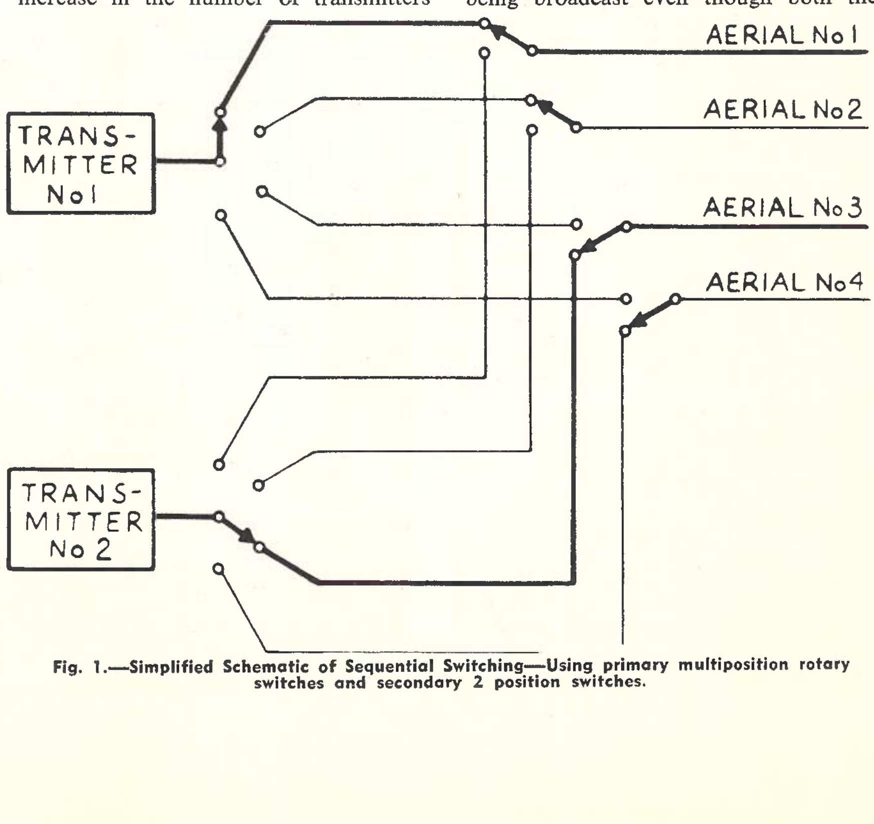


Fig. 1.—Simplified Schematic of Sequential Switching—Using primary multiposition rotary switches and secondary 2 position switches.

*Mr. Minz is a Group Engineer in the Services Branch, Engineering Division, Victoria and Mr. Norman a Divisional Engineer in the Radio Section, Central Office.

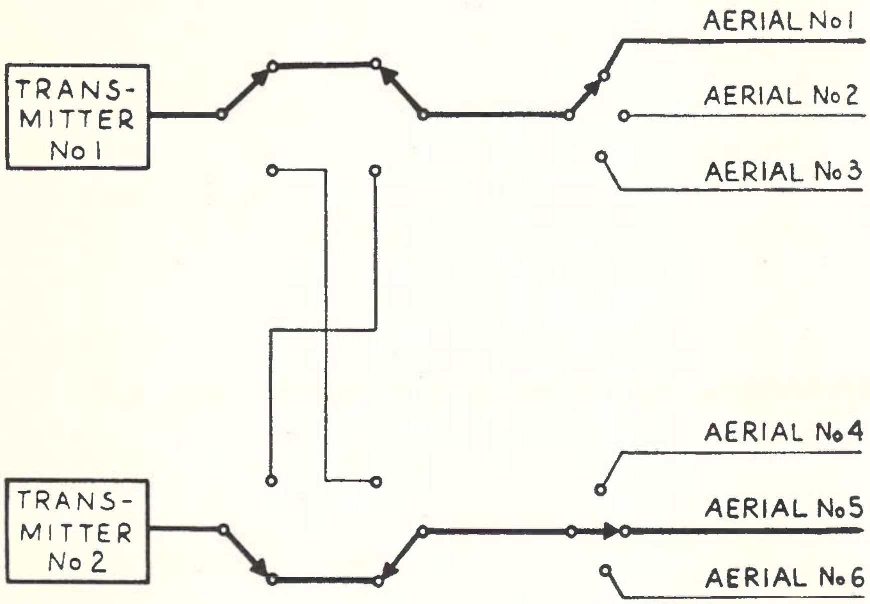


Fig. 2.—Simplified Schematic of Sequential Switching—Using small 2 and 3 position switches.

aerial and transmitter may be free, but not available to each other. It is therefore considered essential to provide 100% access, or in other words every transmitter should be capable of being switched to any aerial irrespective of interconnection of the other transmitters with other aerials.

A number of other unique problems arise in such a switching system, of which perhaps the most important is the avoidance of impedance variations in the transmission lines which may be introduced by the switch itself. As a measure of this, it is normal practice to reduce any unavoidable individual discontinuity so as not to introduce into the transmission line a voltage standing wave ratio in excess of 1.1 to 1.

It is therefore not possible to leave stub lines in parallel with the main line as would appear if the switch contacts were multipled; for example, a stub line of 8 inches in length would introduce a voltage standing wave ratio of approximately 1.1 to 1 at 21 Mc/s when paralleled across a 600 ohm transmission line. To avoid having to multiple contacts it is therefore necessary to have some means of switching both the aerial and the transmitter.

Other discontinuities may be introduced by the physical construction of the switch and for this reason switch arms must be so proportioned as to maintain the characteristic impedance of the line, whilst the switch contacts, insulator end caps and similar irregularities must be kept as small as practicable, so as not to appear as a lumped impedance across the line.

It is essential that the switch be operated "off load". The capacitive reactance at these frequencies which would appear across the switch contacts as they open, is so small that under load conditions an arc would most certainly be maintained for some time and serious burning of the contacts would result. For this reason also protective means must be introduced to prevent accidental operation under load conditions.

The switch must be capable of withstanding peak voltages associated with high power transmitters and for the calculation of insulator dimensions a rating of 1 inch per 1,000 volts R.M.S. unmodulated carrier voltage has been adopted. Corona is not generally a problem when operating with powers of 10kW as is the case at Lyndhurst, and no particular care has to be taken to provide corona rings or rounding off of projections or sharp edges. The peak voltage expected on the line assuming 100% modulation and a voltage standing wave ratio of 1.5 to 1 is 6kV which is well below the corona limit of about 25kV peak found with the particular type of line construction in use.

Cross-talk between two circuits may be aggravated by the proximity of the lines near the switch and sufficient spacing must be maintained so that its value is kept at least 30 db below the wanted signal.

From an operational viewpoint the switch must be simple and unambiguous to use, particularly as the time available to perform the switching operation is generally limited by programme commitments.

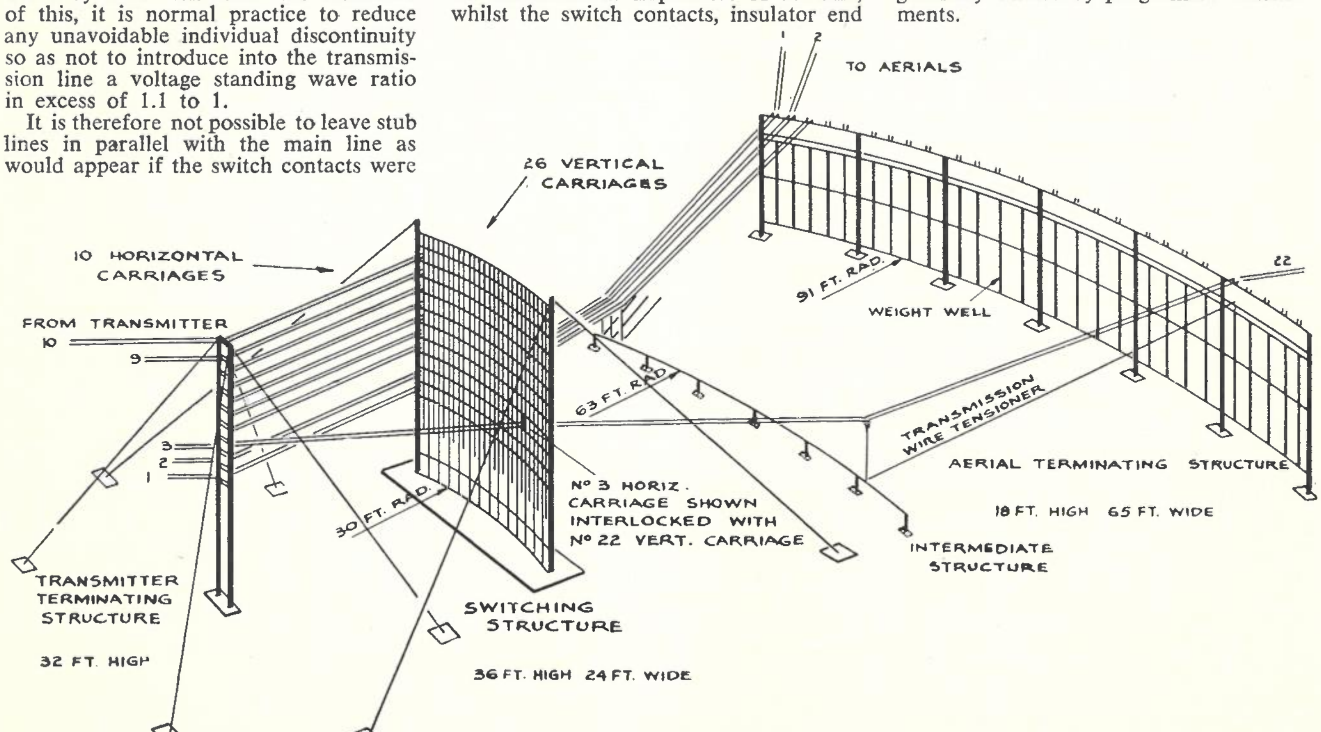


Fig. 3.—Crossbar Switch.

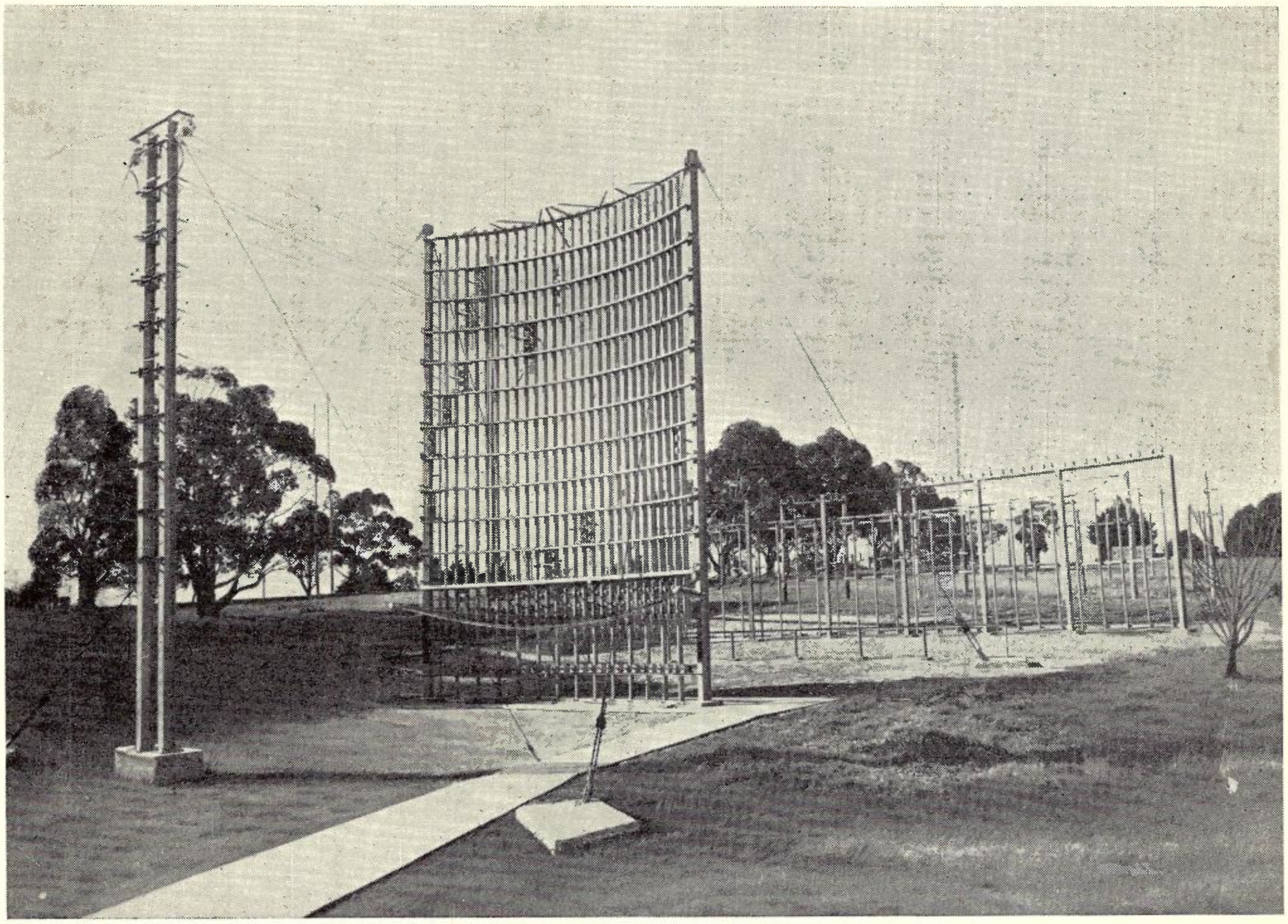


Fig. 4.—Crossbar Switch installed at Lyndhurst Transmitting Station.

TYPES OF SWITCHING

Types of switches developed in the past are examined in the following paragraphs particularly with respect to their compliance with the basic design requirements discussed above.

It is not proposed to examine in detail the merits of coaxial line switching, since at an established station using 600 ohm transmission lines, the transformation to practical coaxial line impedances (below 150 ohms) becomes uneconomical. This is not necessarily valid for a new installation and in fact a coaxial switching system has been employed by the British Post Office at their new station at Rugby.

During the early development of Lyndhurst Transmitting Station, the rotary multi-position sequential type of switch shown in a simplified schematic in Fig. 1 was used for interconnection of two transmitters to any of 10 aerials. Since it was mounted indoors the physical size was small and the stub lines associated with the contact multiples could be switched out of circuit by means of simple auxiliary mercury tilt switches. The addition of further aerial positions on the switch was not possible and the system suffered severe limitations in access with the introduction of new

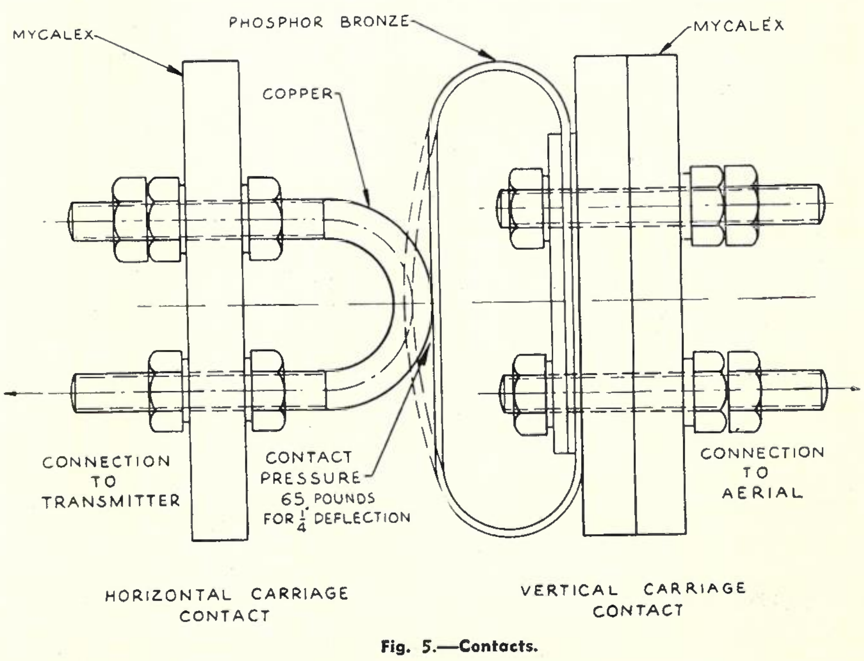


Fig. 5.—Contacts.

transmitters and aerials and for this reason it was replaced.

The problem of the multipling of switch contacts was overcome by the British Broadcasting Corporation (3), (4) in their switching system at Skelton where they introduced a number of bifurcating switches on the aerial side of the main switch tower. The bifurcating switches enabled switching of each aerial to either of two transmitter levels of the main switching tower, each level of which gave access from a transmitter through a horizontal rotary switch to seven of the bifurcating switches. The restriction in this design was that to achieve 100% access, manual jumpering had to be performed.

Sequential switching is shown in the simplified schematic in Fig. 2 and as used at Radio Australia, Shepparton, Victoria, employs a number of small switches of the 2 and 3 position type. It is an extension of the rotary switching principle. The system involves a large number of automatic operations to complete a transmitter to aerial connection, and to ensure correct operation a complex system of supervision is necessary. While the switches themselves are comparatively small, the interconnection of the transmission lines is awkward without spreading the system over a large portion of the site. As the number of transmitters and aerials increases it becomes difficult to arrange 100% access and a reduction had to be accepted at Shepparton to the extent that each aerial had access to only half the transmitters.

The crossbar system described below overcomes most of the limitations found in these earlier systems. Physically it is a large framework along which sets of carriage mounted switch contacts, each one connected to a transmitter, move horizontally so as to select complementary carriages moving in a vertical plane and which are connected to the aerials. The main advantages of this system are, firstly, it has 100% accessibility and, secondly, there is only one set of switch contacts associated with each connection, thus considerably reducing impedance discontinuities and improving the reliability.

In the form developed by the Admiralty the switch was mounted indoors and partly power operated. Local conditions precluded provision of a special switching building and in order to mount the unit externally, component parts were redesigned to be suitable for outdoor operation. At the same time conversion to fully manual operation was undertaken as the number of switching operations did not warrant the complication of motor driven carriages with the attendant problems of control and supervision.

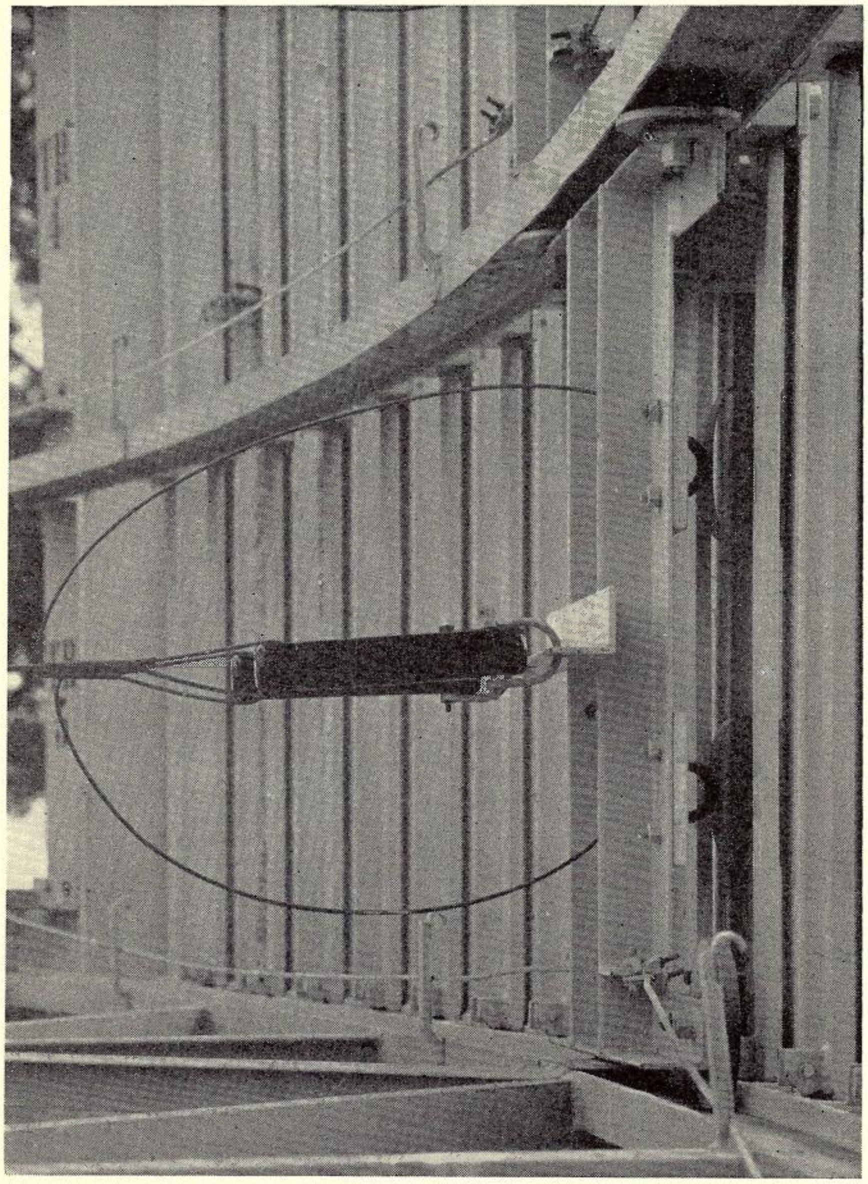


Fig. 6.—Horizontal Transmitter Carriage—Showing the contacts mating.

SWITCH CONSTRUCTION

The switching system installed at Lyndhurst Transmitting Station provides for the interconnection of any of 10 transmitters to 26 aerials fed through two wire balanced transmission lines of 600 ohms characteristic impedance. Structurally the switching system consists of three frameworks which are shown in Figs. 3 and 4 and comprise a transmitter terminating structure, a switch and an aerial terminating structure.

The output lines from the transmitter building converge to the transmitter terminating structure from where they are extended radially to the switch contacts which are carried on horizontal moving carriages supported by the switch structure. Complementary to these are vertically moving carriages on the reverse side of the switch which are connected to the aerial transmission lines through an intermediate aerial terminating structure. The whole system occupies a sector of a circle of radius 91 feet, and the included angle is 41 degrees.

Transmitter Terminating Structure: The transmitter terminating structure is a 32 feet high double beam pole guyed in four directions and is located at the centre point of the sector. The 10 transmission lines from the transmitter building are terminated on the near side one above the other, and are jumpered across to the section of the line between the transmitter terminating structure and the switch. To enable the lines to rotate as the switch carriages move around the arc of the circle formed by the switch, the outgoing lines are terminated on yokes which are free to swivel about a vertical pivot so as to maintain correct spacing and not disturb the line characteristics. As the transmission lines hold the carriages vertically in position against the tracks, the tension in the line between the transmitter terminating structure and the switch affects the ease of travel of the carriage, and it was found necessary to adjust this load to a value of 125 pounds for satisfactory operation.

Switch Structure: The switch consists of a grid of "I" beams forming a part of a vertical cylinder 36 feet high and 24 feet arc with a radius of 30 feet and a centre at the transmitter terminating structure. The beams are arranged in such a way that they provide tracks on either side, the concave side having 10 horizontal tracks, each one associated with a transmitter, and 26 vertical tracks on the reverse side for the aerial carriages. The grid is supported by two main guyed columns at the ends of the arc and at intermediate points by the vertical track beams which have been extended down to the foundation level.

Switch Carriages: The switch carriages, of welded angle iron framework, run on four cast iron wheels, and are moved manually by means of stranded steel hauling cables. The 10 horizontal carriages (Fig. 6) are attached to individual continuous cables looped down to head height below the frame so that each carriage may be positioned by pulling it horizontally across the switch structure by means of a handle attached to the cable. The vertical carriages may be raised and lowered by small hand winches (Fig. 7) attached to the bottom of each aerial track. Free movement of the vertical carriage is prevented by means of a clutch, arranged so that positive rotation of the winch handle is required to move the carriage up or down. In the event of failure of the hauling cable a spring loaded safety brake, normally kept free by the cable tension, exerts a braking action through two shoes on the web of the tracks, thus bringing the carriage to rest within a few inches. The transmission lines are terminated by strain insulators on the carriages and are then jumpered across to pairs of contacts mounted on "Mycalex" insulating panels. The contacts on the transmitter carriage consist of two copper "U" bolts which make point contact with phosphor bronze loops attached to the aerial carriage, (Fig. 5) and which in the closed position compress the loop contacts by about ¼ of an inch, the pressure on the contacts then being 65 pounds. The mating of the contacts is arranged to be independent of the switch structure itself in the longitudinal and vertical planes where tight mechanical tolerances are difficult to maintain, particularly during periods of high wind velocity when the manufacturing tolerance of ± ⅛ of an inch is expected to be exceeded. For this reason the mating of the contacts in these planes is arranged to be governed by an inverted V slot on the vertical carriage which is self locating on a bar projecting out from the horizontal carriage, while the large area available for contact (1 square inch) ensures good contact at all times. In the plane normal to the contacts the location is dependent upon the structure itself; however, in this plane, the effect of the wind is less serious and tolerances considerably less than the latitude in the switch contacts (¼ inch) are maintained.

For interconnection it is necessary to bring the horizontal carriage approximately into line of the vertical carriage and yet allow sufficient free movement for the location to be controlled by the inverted V bar. This is achieved by means of 26 control rods mounted up the side of each track and which, when lifted, trip a latch on the horizontal carriage stopping it at the nominated aerial position. The vertical carriage is lowered into position and the location is then fixed mutually between the carriages after which the latch is cleared by lowering the control rod. Simple protection is provided by means of winch locks, the keys of which are interlocked to the high tension circuit of the transmitter thus ensuring that the circuit may not be broken while on load. (Fig. 7).

Aerial Terminating Structure: The third section of the switch is the aerial terminating structure located at the periphery of the switching area and which is in effect a distributing frame for the outgoing lines to the aerials. The lines fan out horizontally from the switch to the aerial terminating structure and from there, are routed directly to the aerials. A considerable amount of slack appears in the lines between the switch and the aerial terminating structure when the aerial carriage is at its lowest position. Means have to be provided to take up this slack, firstly so as to maintain adequate clearance between the lines, and secondly to ensure that a positive tension is exerted on each carriage to hold it against the track at all levels. This is achieved by a pulley and weight system so arranged that a downward tension varying between 35 to 65 pounds is exerted on the transmission line mid span between the aerial terminating structure and the switch.

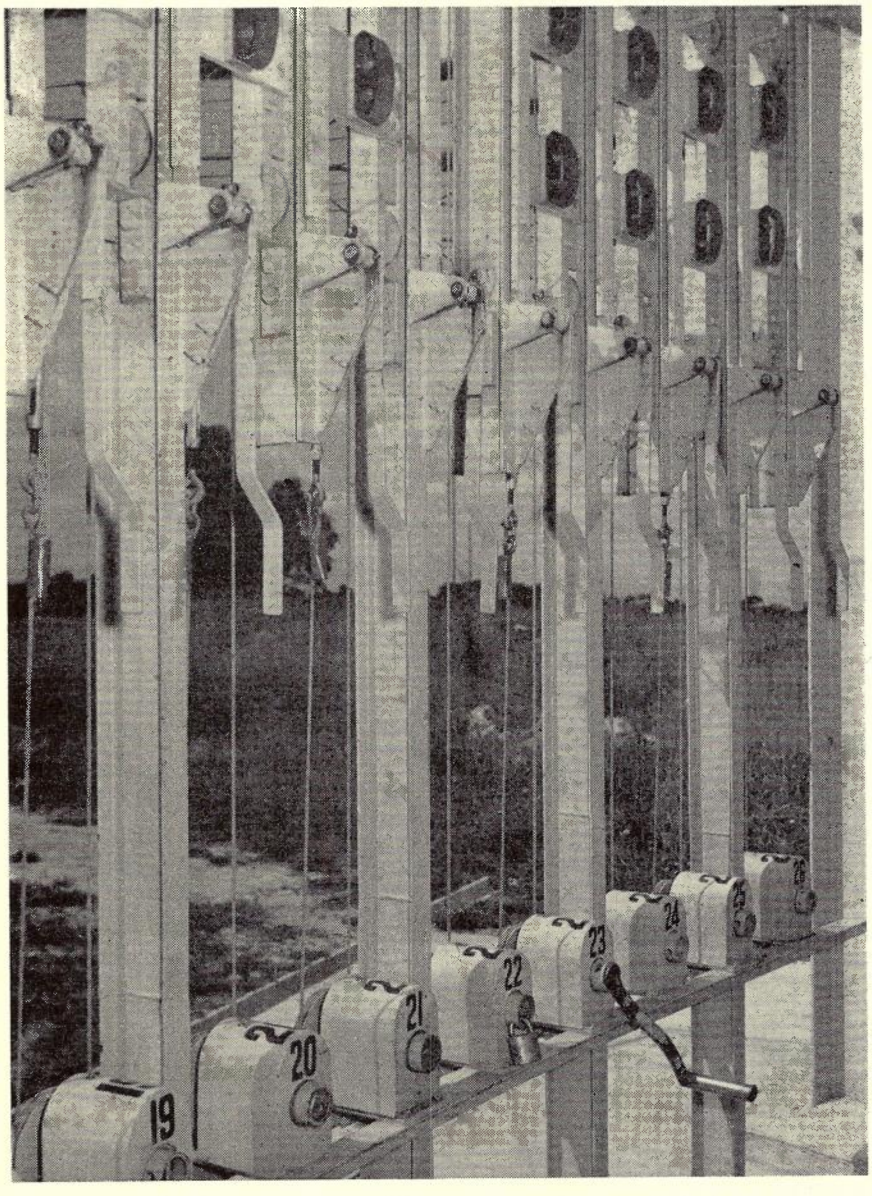


Fig. 7.—View of Winches, Control Rods, Levers and Vertical Carriages.
(**Note.**—No. 22 aerial is in service and the winch is locked.)

OPERATION

The procedure in making a switching operation is as follows:—

(a) The aerial carriage is lifted by means of the winch up above the horizontal level which carries the required transmitter carriage. (This is necessary to clear the inverted V and bar locating device).

(b) The control rod associated with the required aerial is raised by means of a lever and the horizontal carriage is pulled along until its latch is tripped.

(c) The aerial carriage is lowered to engage with the transmitter carriage on to which it locks itself.

(d) The control rod is returned to its normal position.

(e) The winch is locked to prevent accidental release.

The average time to perform these operations is 4 minutes.

CONCLUSION

A requirement for a simple reliable type of manually operated outdoor switch capable of giving 100% access to 26 aerials for 10 transmitters has been met by the construction of a crossbar switching system. Simplicity and reliability are achieved by the need for only one switch operation for each interconnection. Since putting the switch into service late in 1956, no evidence of overheating or arcing of the contacts has been observed, such as might be expected with the intermittent use which the switches receive. Electrical measurements on the switch show that the crosstalk between the lines in their worst position is better than 30db while impedance discontinuity in the switch introduces a voltage standing wave ratio of less than 1.5 to 1.

REFERENCES

1. A Radio Transmission Line Exchange; The Engineer, October 1952, Page 451.

2. Aerial Exchange; Wireless World, November 1952, Page 444.

3. McLean, F. C. & Bolt, F. D., "The Design and Use of Radio Frequency Open Wire Transmission Lines and Switchgear for Broadcasting System"; Proceedings I.E.E., Part 3, May 1946, Page 191.

4. Gillam, C., "High Power Aerial Switching"; Electronic Engineer, June 1954, Page 274.

AUSTRALIAN POST OFFICE REPRESENTATION IN LONDON

*A. W. McPHERSON, A.M.I.E.Aust., S.M.I.R.E.Aust.**

INTRODUCTION

The needs of a modern telecommunication system with its ever-increasing complexities demand visits by the engineering personnel of any Telecommunication Administration from time to time to other parts of the world to study the methods and practices of other Telecommunication Authorities and to exchange ideas on problems of mutual interest.

We have always been very closely interested in developments of the British Post Office (B.P.O.) and those of the telephone industry in the United Kingdom and our present standard automatic telephone switching equipment is very close to that used by the B.P.O. Soon after World War II, with an accelerated demand for service resulting in unprecedented requirements for equipment and materials, it became increasingly apparent that some form of technical liaison was required in the U.K. and therefore, it was not surprising that a move was made to establish an office in London. The history of our permanent London representation really begins early in 1948 when Mr. F. Bradley, ex-Director, New South Wales, was appointed as Australian Member of the Commonwealth Communications Council, which, in 1949, was constituted as the Comomnwealth Telecommunications Board (C.T.B.). He took up duty on 19th April, 1948, and became the A.P.O. Representative in London as well as Australian Member of the C.C.C. and later the C.T.B. At about this time an engineer from Victoria, Dr. J. F. Ward, was in the U.K. completing post-graduate studies and, owing to the number of technical matters which required some discussion on the spot with manufacturers and the B.P.O., Dr. Ward was called in by the Department in a liaison capacity and it was not long before he became officially known as Liaison Engineer. The position of Liaison Engineer actually dated from 1st March, 1948, but at that stage it was on a temporary basis. In July 1949 Mr. Bradley recommended to the Department that a position of Liaison Engineer should be part of the establishment of Australia House and the result was that Mr. K. B. Smith, then Divisional Engineer, Telephone Equipment Section, Headquarters, was selected for the position and took up duty on 3rd January, 1950. On 3rd March, 1950, Mr. Bradley was succeeded by Mr. R. V. McKay, Engineer-in-Chief.

Readers may be interested in learning something of the activities of the London staff of the A.P.O., and the purpose of this article is to cover briefly what is involved in A.P.O. Representation in London.

AUSTRALIA HOUSE STAFF

The office of the A.P.O. Representative is at Australia House, Strand, London, W.C.2. Australia House is situated on the corner of Aldwych and Strand and is handy to B.P.O. Headquarters at St. Martins Le. Grand, the Institution of Electrical Engineers, Thames Embankment, and Her Majesty's Stationery Office Kingsway. Fig. 1 refers. The building, shown in Fig. 2, is constructed in Doric classical style and was erected by the Commonwealth of Australia to serve as offices for the staffs of the various Government Departments. The foundation stone was laid in 1913 and the formal opening took place in 1918, both ceremonies being performed by King George V. The colonnaded building is so well proportioned that at first glance its size is scarcely apparent. Much of the stone and woodwork is Australian as also are the marble pillars. The site cost nearly £S400,000 and the total cost amounted to nearly £S1,000,000. By any standards it is indeed a landmark worthy of the country it represents, and this is

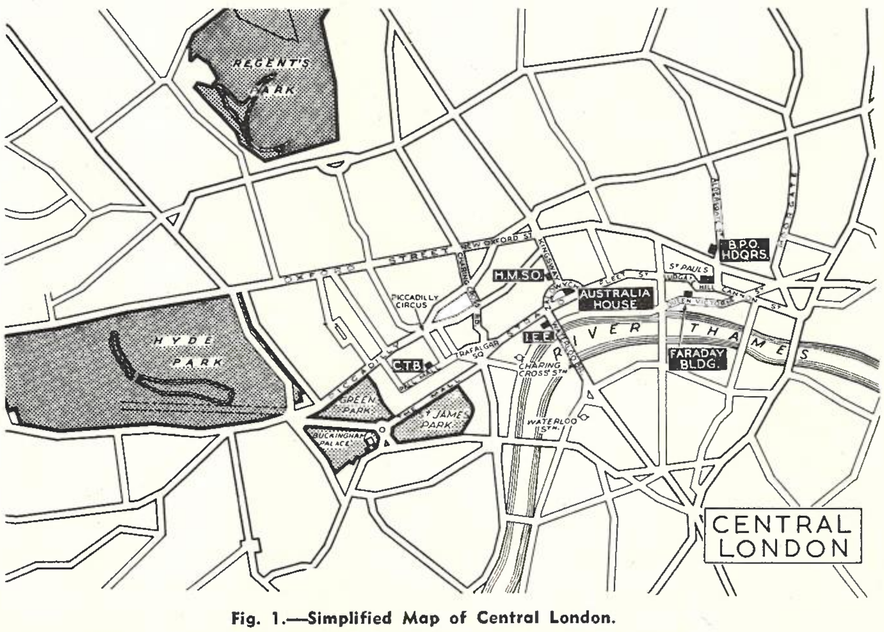


Fig. 1.—Simplified Map of Central London.

*Mr. McPherson is Acting Supervising Engineer, Supplies, Central Office.

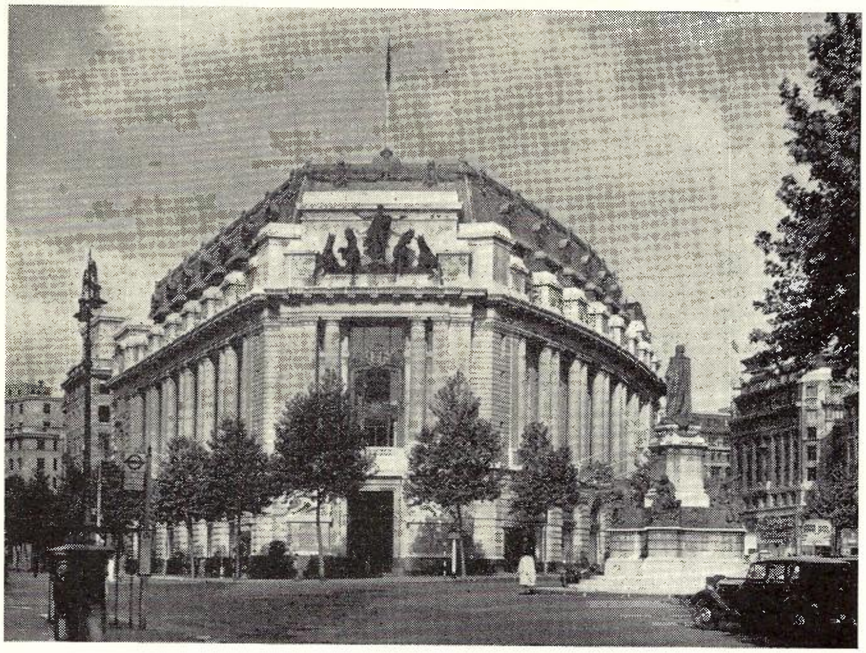


Fig. 2.—Australia House.

probably best exemplified by the fact that even in a city so vast as London one merely has to say to a taxi driver "Australia House" and he will do the rest.

The total staff at Australia House is of the order of 700 to 800 and, of these, about 150 to 200 are representatives of Commonwealth Departments doing a tour of duty for a specific period, usually two or three years. The remainder, that is, the majority, are permanently employed at Australia House on what is known as the High Commissioner's staff. The High Commissioner's staff are employed under the same general conditions as public servants in Australia but their salaries are based on English rather than Australian standards. The Chief Administrative Officer for the High Commissioner is the Official Secretary who is usually an Australian especially selected for the post for a chosen period. The latter applies also to the post of Assistant Secretaries of which there are two at the present time.

The main Departments and Sections at Australia House are shown in the organisation chart in Fig. 3, with some explanatory comments as follows:—

Administrative Branch—The Administrative heads are the High Commissioner, Deputy High Commissioner, Official Secretary and Assistant Secretaries.

Procurement Branch — This Branch handles all commercial matters relating to the invitation of tenders and the placing of contracts in U.K. and Europe for the procurement of material on behalf of all Commonwealth Government Departments in Australia.

Health Branch—This Branch is headed by the Chief Medical Officer and its function includes the general medical oversight of migrants and personnel recruited for positions in the Commonwealth Public Service.

Migration Branch—As would be expected, this Branch has a very large administrative section and is responsible for the processing of all British migrants. The Chief Migration Officer and some 12 or more Administrative and Selection Officers are Australian officials.

News and Information Bureau—Apart from its normal publicity function, this Department has an excellent library of several hundred Australian films in 16mm and 35mm black and white, and colour. These films are issued out on loan at a nominal fee to any reputable organisation making the application. The Director is an Australian official.

Postmaster - General's Department—The Senior Representative and Engineering Representative (liaison engineer) are A.P.O. officials. The present occupants of these two positions are Messrs. J. A. Kline and F. L. C. Taylor respectively.

Scientific Liaison Office — This is headed by the Chief Scientific Liaison Officer assisted by a Senior Research Officer and an Assistant Liaison Officer, all of whom are Australian officials. The offices are at South Africa House, Kingsway, because there is insufficient accommodation at Australia House.

COMMONWEALTH OF AUSTRALIA

HIGH COMMISSIONER'S OFFICE, LONDON

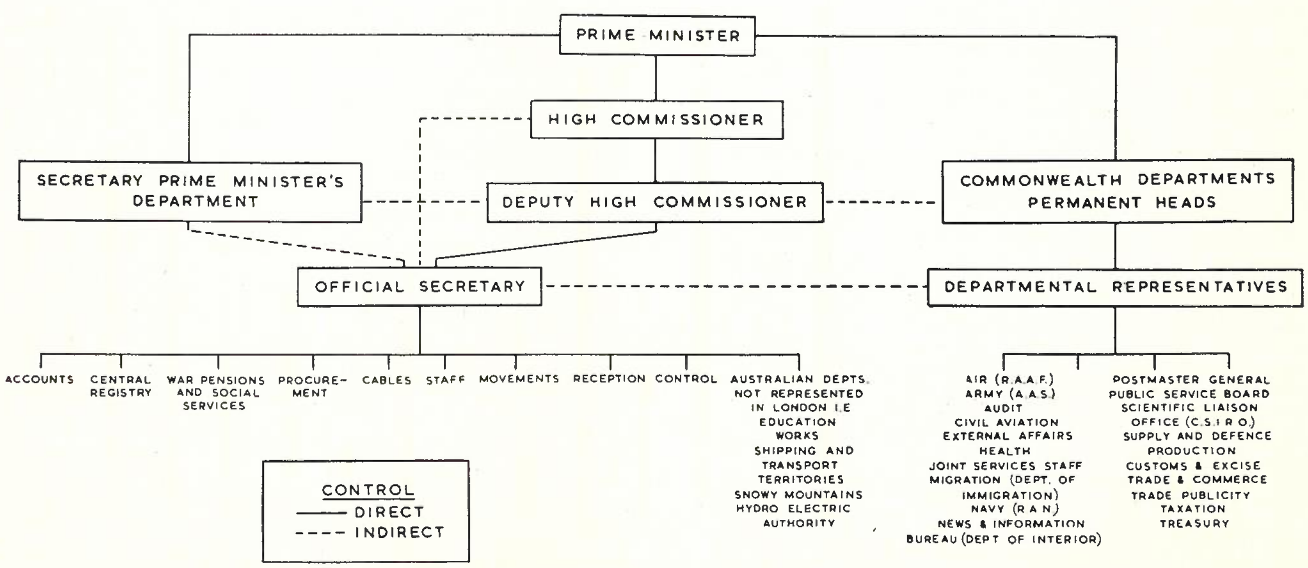


Fig. 3.—Organisation Chart—Australia House.

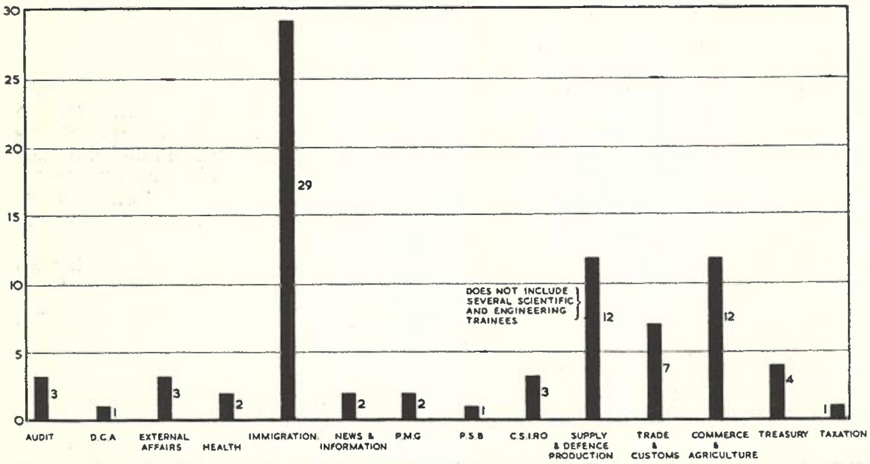


Fig. 4.—London Representatives of Commonwealth Government Civil Departments as at 31/5/56

Supply Branch—The Department of Supply has a very strong technical representation in London which includes specialists in various fields, and these include an aircraft representative, chemical representative, mechanical engineering representative, physicist, senior scientific officer and senior engineer, all of whom are Australian officials.

Department of Defence Production—Representatives of this Department, which include a mechanical engineering representative, senior scientific officer and engineer, all from Australia, operate under the direction of the Senior Representative, Supply Branch.

Trade and Customs Branch — The Senior Representative plus several investigation officers are all from the Department of Trade and Customs, Australia.

Trade Commissioner's Office — The Senior Trade Commissioner plus about eight senior officers are Australian officers.

Department of Army, Department of Navy, Department of Air—These three Departments have strong numerical representation and work in liaison with the War Office, Admiralty and Ministry of Air, respectively.

The actual numbers of Australian officials in London on a tour of duty for their respective Departments as at 31/3/56 are shown in Fig. 4. Numerically, the Postmaster-General's Department has a very small representation in London considering its size, importance and extent of its overseas interests as compared with other Departments, and this is illustrated better in Fig. 5 which shows the equivalent number of representatives per 1,000 of staff in Australia. Statistics published in the 32nd Annual Report of the Public Service Board showed that, of a total of 85,260 permanent staff for all Departments as at 30/6/56, 50,397 or 59% were in the Postmaster-General's Department. The proportion of P.M.G. personnel in the total number of London representatives in Fig. 4 is 2.4%.

COMMONWEALTH TELECOMMUNICATIONS BOARD (C.T.B.)

For approximately seven years, Mr. R. V. McKay occupied the dual post of the Australian Post Office Representative and Australian Member of the C.T.B. The Liaison Engineer was the alternate Australian member of the C.T.B. Representation on the C.T.B. was separated from A.P.O. representation as from 31st March, 1957, consequential upon Mr. McKay's retirement as Engineer-in-Chief of the A.P.O. He continues in the position of Australian member of the C.T.B. The Alternate Membership has lapsed.

Information on the responsibilities, functions and activities of the C.T.B. has been published in detail elsewhere but the position is summed up in the following extract from the Commonwealth Telegraphs Agreement of 1948:—

"For the purposes of promoting the efficiency and development of the external telecommunications service of the British Commonwealth and Empire, the Partner Governments agree to the establishment of a body which shall be known as the Commonwealth Telecommunications Board."

The "Partner Governments" were originally those of the United Kingdom (which includes the colonies), Canada, Australia, New Zealand, South Africa, India and Southern Rhodesia. Pakistan and Ceylon were not in the Agreement; India had not then been partitioned and Ceylon had not attained Dominion status. The Agreement provides for the admission of new members. Ceylon was subsequently admitted on 1st June, 1951. The door stands open for Pakistan.

The Board was incorporated by an Act of the United Kingdom Parliament in 1949 with all Partner Governments consenting parties, and the net result was full Government ownership and operation of the cable and radio services forming the external communications of all the Partner Governments. With the exception of Australia and Canada, the operating bodies are the Government Posts and Telegraphs Departments but, irrespective of their particular local form, they are known as the "National Bodies". In Australia the National Body is the Overseas Telecommunication Commission with cable terminals at Sydney and Cottesloe (Western Australia) and cable repeater stations at Southport (Queensland), Norfolk Island and Cocos Islands, also international Radio Stations at Doonside and Bringelly (New South Wales); Fiskville and Rockbank in Victoria, and Applecross and Bassendean in Western Australia. The Board is mainly an advisory rather than an executive body but it exercises an overall supervision over the operations of the British Commonwealth external communications system. The respective National Bodies are "common users" of this system, each National Body being responsible for operating and maintaining its component part thereof. An agreed basis is used for determining the financial arrangements as between the respective National Bodies.

Fig. 6 shows the composition of the Board and the functional organisation. The Board comprising members representing their respective National Bodies, is presided over by an independent Chairman appointed jointly by the Partner Governments. The first Chairman was Right Honourable Lord Reith, P.C.,

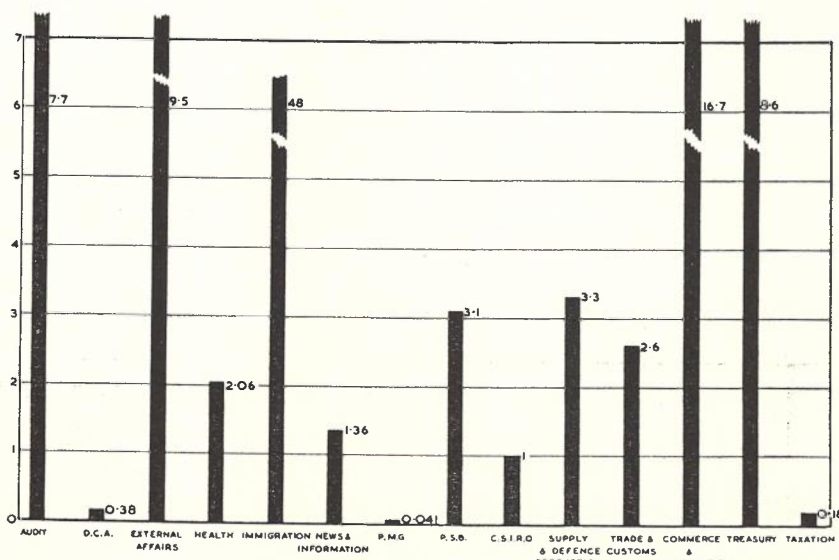


Fig. 5.—Equivalent Number of Representatives per 1000 of Staff in Australia as at 31/3/56.

G.C.V.O., G.B.E., C.B., T.D., who was succeeded by Col. Sir Stanley Angwin, K.B.E., D.S.O., M.C., T.D., the latter having previously been Chairman of Cable and Wireless Ltd., London, following his retirement as Engineer-in-Chief of the British Post Office. In 1956 Sir Stanley Angwin was succeeded by Sir Ben. L. Barnett, K.B.E., C.B., M.C., who retired from the position of Deputy Director-General of the British Post Office to take the Chairmanship of the Board. The National Bodies are represented by men with long and wide experience in telecommunications and some of them have held the highest executive positions in their own countries. Therefore the Board itself has permanent access, through its members, to a pool of extensive knowledge which enables it to initiate studies and to give balanced judgment on the many matters submitted for consideration by the National Bodies.

The Secretariat consisting of some 30 officers is headed by the Secretary-General of the Board, Col. W. W. Shaw-Zambra, C.B.E., T.D. The three study groups, viz., Technical, Traffic, and Finance and Rates, consist of a number of Board members, experts from the U.K. National Body and the Engineer, Traffic and Fnancial Officers respectively of the Secretariat. In order to provide for direct consultation between National Bodies and for the discussion of mutual problems around the table, special meetings are held from time to time in London and representatives from the National Bodies are invited to attend. So far there have been Technical and Traffic meetings in 1950 and 1955 and a Finance and Rates meeting in 1952. The Board has also visited Canada, Australia, New Zealand, India and Ceylon for on-the-spot discussions with National Bodies. During the writer's association with the C.T.B. discussions were held on what is probably the most spectacular if not the greatest achievement in the history of modern international telecommunications, that is the Trans-Atlantic Telephone (T.A.T.) Cable project. It involved approximately 4,500 miles of cable, cost about £15,000,000 sterling and was laid during the Northern Hemisphere summers of 1955 and 1956. The long span between Oban, Scotland, and Clarenville, Newfoundland, is approximately 1,950 nautical miles, and is served by two one-way cables each of which has 51 under-water repeaters to compensate for an attenuation of 3,200 db at 164 kc/s. The present capacity of the cable is 36 telephone channels, plus maintenance circuits. The connection beyond Clarenville to the cable terminal at Sydney Mines, Nova Scotia, is partly land, partly coastal waters for distances of 63 statute miles and 270 nautical miles respectively. This is a single cable containing sixteen two-way repeaters providing close to 1,000 db gain at 552 kc/s. This portion of the system provides for 60 two-way telephone circuits, 36 of which are required for the trans-atlantic service, and the remainder for service between Newfoundland and the mainland. Additional maintenance circuits are also provided. The valves used in the Clarenville-Sydney Mines Section of the T.A.T. cable were designed and manufactured at the Post Office Research Station, Dollis Hill, where extensive studies and experiments have been carried out for some years in the design of long life valves.

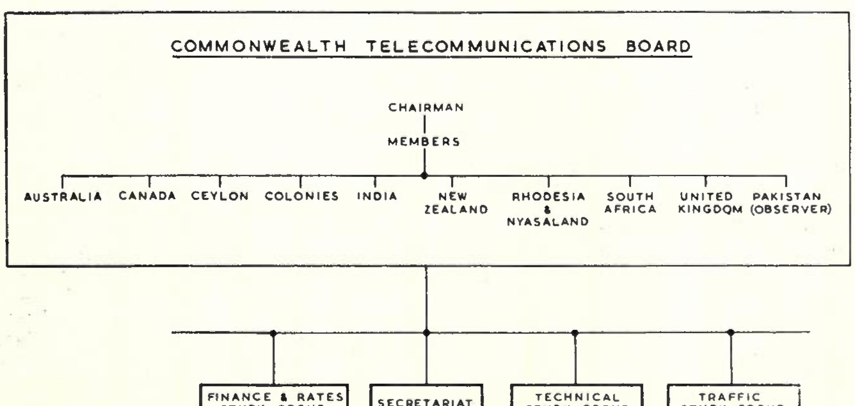


Fig. 6.—Commonwealth Telecommunications Board—Composition and Organisation.

BRITISH TELEPHONE TECHNICAL DEVELOPMENT COMMITTEE (B.T.T.D.C.)

A very important function of the London office is that of participation in the activities of the B.T.T.D.C., and the history and constitution of that body is given in the following extract from the P.O.E.E. Journal, Vol. 41, Part 4, January 1949:

"In 1923, when the wholesale conversion of the telephone system in London to automatic working was seriously considered by the Post Office, and the step-by-step system was to be standardised, it was obvious that there would be grave disadvantages in the competitive system, so the Post Office called together the four manufacturers then in the automatic field and made an agreement with them to co-ordinate the supply of equipment at a satisfactory price level for the standard components. By 1928, a fifth manufacturer was available and a fresh agreement was drawn up for a period of five years based on the competitive quotations submitted by each of the five parties. The administration of this agreement, and those which have succeeded it, necessitated the formation of the manufacturers' Bulk Contract Committee (B.C.C.) to decide production policy and distribution of contracts, and to negotiate prices. The five firms represented are:—

Automatic Telephone & Electric Co. Ltd., Liverpool.
Ericsson Telephones Ltd., Beeston.
General Electric Co. Ltd., Coventry.
Siemens Bros. & Co. Ltd., Woolwich.
Standard Telephone & Cables Ltd., New Southgate.

"This rational sharing of contracts of responsibility made possible the establishment of a highly technical organisation which, under the auspices of the British Post Office, could influence telephone technical development in this country to a degree hitherto not attempted, and promote standardisation on sound practical lines. A joint technical committee was therefore formed in 1933 under the chairmanship of an Assistant Engineer-in-Chief to the Post Office, and this was named the "British Telephone Technical Development Committee" (B.T.T.D.C.). The manufacturers' complement of this committee is known as the Manufacturers' Technical Development Committee (M.T.D.C.) which meets under the chairmanship of the Manufacturers' Secretary to exercise control on technical policy, development and technical routine so far as the manufacturers are concerned. Devolution of work to specialist committees was also necessary to cover the detail of apparatus, circuit, equipment, etc., as the range and complexity of automatic telephony expanded.

"Subscribers' telephone instruments and the many common components of telephone plant such as switchboard jacks, tag blocks and the like were also made the subject of a supply agreement in 1936, but in this case three additional manufacturers (making eight in all) were parties to the 'Telephone Apparatus Agreement' (T.A.A.):—

Phoenix Telephone & Electric Works Ltd., London, N.W.
Plessey Co. Ltd., Ilford.
Telephone Manufacturing Co. Ltd., London, S.E.

"A corresponding joint technical committee for this class of plant was formed and for convenience was linked with the B.T.T.D.C. so far as general direction is concerned."

The terms of reference of the B.T.T.D.C. are:—

"To co-ordinate development work between the Post Office and the five principal telephone manufacturers in respect of items for exchange equipments under the "Bulk Supply Agreement" and to direct the co-ordination of development work between the Post Office and the eight manufacturers in respect of items purchased under the 'Telephone Apparatus Agreement'."

It has also been laid down that the Chairman shall be an Assistant Engineer-in-Chief of the Post Office. The committee members from the Post Office side consist of Staff Engineers (1) from the various plant sections, including the Controller of Research. Also there are a number of Assistant Staff Engineers (2). On the manufacturers' side there are two representatives from each of the five companies mentioned. The chairman of the B.T.T.D.C. and Chairman of the M.T.D.C. may invite additional representatives for discussion on particular items as necessary.

By courtesy of the B.P.O., and with the agreement of the manufacturers, an A.P.O. representative is permitted to attend B.T.T.D.C. meetings. The first Australian representative was Mr. W. Reid, who was on the High Commissioner's staff at Australia House performing the duties of Chief Supply Officer. The first meeting attended by him was Meeting No. 61 on 18th July, 1946. At Meeting No. 69 on 15th July, 1948, Dr. Ward took over from Mr. Reid and continued until Meeting No. 74 on 20th October, 1949. Mr. K. B. Smith joined the Committee at Meeting No. 75 on 19th January, 1950, and remained the A.P.O. member until Meeting No. 89 held on 23rd July, 1953. The writer took over from Mr. K. B. Smith and was succeeded by Mr. F. L. C. Taylor after Meeting No. 102 on 25th October, 1956.

Briefly, the procedure for all major developments is to table a Committee Paper clearly setting out the intentions of the new development, and the case is then known by a C.P. number until it has been discharged by the committee. The next stage is to allocate the work to a manufacturer or a Post Office Branch, and one liaison officer is named from the Post Office and one from the manufacturer. The development proceeds in accordance with a planned programme and the quarterly meetings of the B.T.T.D.C. enable progress to be directed by reports from liaison officers.

Fig. 7 shows the organisation of the B.T.T.D.C. and it will be seen that the group on the left-hand side are joint committees whilst those on the right are the manufacturers' counterparts. The B.T.T.D.C. is shown at the top and, apart from its function of co-ordinating and directing developmental projects, it is a valuable clearing house from the dissemination of technical information. The manufacturers' counterpart of the joint committee is the M.T.D.C., the chairman of which is the permanent secretary of the B.C.C. or M.T.D.C. Each of these committees has a number of sub-committees as shown, and these sub-committees are responsible to the main committees.

The Subscribers' Apparatus Sub-Committe is rather different from the other sub-committees in that it has the distinction of representing the eight manufacturers under the Telephone Apparatus Agreement and, therefore, is to some extent autonomous.

(1) The A.P.O. equivalent position is Supervising Engineer, Central Office.
(2) A.P.O. equivalent is Sectional Engineer, Central Office.

The B.P.O. and the five manufacturers are pressing on rapidly with electronic switching and electronic control of mechanical switching, and, about the middle of 1956, a new committee, constituted broadly on B.T.T.D.C. lines, was established with the Engineer-in-Chief as the chairman, and this is known as J.E.R.C. (Joint Electronic Research Committee).

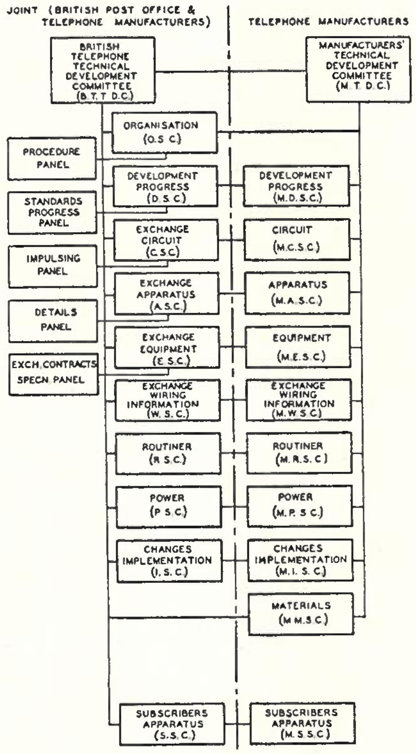


Fig. 7.—B.T.T.D.C. Organisation.

MISCELLANEOUS MATTERS

So far, the activities associated with the C.T.B. and B.T.T.D.C. have been covered in broad outline. Between meetings, of course, there is continuous consultation and correspondence on detailed matters arising from the affairs of these bodies. So far as the B.T.T.D.C. is concerned, there is a continuous stream of correspondence with the Telephone Equipment Section, Central Office, because the London Office is the point of contact between the A.P.O. and B.T.T.D.C.

The position of Liaison Engineer in London was established primarily for the purpose of providing a much needed engineering liaison on telephone equipment matters, and also to provide an A.P.O. representative at B.T.T.D.C. meetings. This consideration still stands but the scope of activities of the London office has increased out of all proportion to that originally envisaged. Probably the main reason for this is an increasing awareness at the Australian end of the valuable technical and other services which can be rendered by an overseas position situated in the centre of world communications. The net result has been that the London office is being used more and more by other sections of the Engineering Division as well as by other Divisions of the Department.

The A.P.O. representatives in London are also in a key position to obtain first-hand information on developments in the continent of Europe. Indeed, part of the function of the London office is to provide delegates as necessary for international conferences here under the auspices of the International Telecommunication Union (I.T.U.). These include regular Plenary Sessions and study group meetings of the C.C.I.R. (International Radio Consultative Committee) and C.C.I.T.T. (International Telegraph and Telephone Consultative Committee).

Apart from the presence in the U.K. from time to time of officers on short term official visits and the regular scholarship students there is a fairly continuous flow through the London office of personnel requiring introductions to the B.P.O. and other establishments. In recent years the number of people in the U.K. visiting Australia House in search of information on conditions and prospects of employment in the Postmaster-General's Department, especially in the non-professional grades, has been increasing rapidly. There is also a steady flow of enquiries on postal and other miscellaneous matters. The London office is concerned as well, in conjunction with the P.S.B. Representative at Australia House, in the recruitment of engineers from the U.K. and Europe.

It would not be practicable to cover in detail the wide variety of technical and other details handled in the London office because they cover the whole range of activities of the Postmaster-General's Department. However, a number of items which it is thought may be of particular interest to readers are given as follows:—

Recorded Information Services

This offers a most fascinating and attractive line of investigation particularly on the continent of Europe where recorded information services are provided on a liberal basis in some countries. The writer's experience of using these services on the Continent was confined to Switzerland and Germany where the following recorded services are available:—

Switzerland:

Call Number	Service
161	Speaking Clock
162	Weather Forecast
164	"Toto" or football pool results.
167	News (In German)
168	News (In French)
169	News (In Italian)

The time service is completely automatic and needs no special day-to-day recordings. The news service is recorded six times a day as a general rule but the frequency may be increased as necessary. The weather service is recorded about three or four times a day. The "Toto" service is used in the main on Mondays only because the pools are weekly events.

The recording machines and procedure are of interest. The machines are provided on the basis of two per standard carrier type equipment rack. Tape recorders are used and each machine has two sets of two spools each with recordings and erasing heads. Since the weather and news and "Toto" services are given in German, French and Italian, a minimum of 9 recording machines is used at Berne. There were 15 installed in 1956 which provided adequate margin for spares and maintenance. The information is transmitted via trunk channels to all main exchanges throughout the country and is, therefore, accessible to practically all subscribers in Switzerland.

All duties relating to recordings and changeover of equipment from one to another and allocation to outgoing channels, are done by female operators in the recording room. Normally, no technical aid is required. In fact, there is no technical staff on duty after 6 p.m. on weekdays or on Sundays and holidays. In the recording room there is a control panel of the console type on which the female operators can see at a glance the disposition of the 15 recorders. Information for the recordings is received from the Weather Office and Information Bureau, by means of page printing teleprinters, situated in the recording control room.

When it is time for a new record to be made, a spare recorder is selected and the announcer retires to a small sound-proof annexe off the recording control room. The maximum time of each recording is three minutes. After making the recording, the operator plays it back to check accuracy and also to insert a "stop" signal. The reason for the "stop" signal may be of interest. As mentioned earlier, each recording machine has two pairs of spools using two separate tapes, each of which contains the same recorded information. Whilst one tape is starting to run in the forward direction and playing back, the other is rewinding at a higher speed. Therefore, when the information on the forward tape is completed, the "stop" signal automatically stops the tape and commences to rewind it. Simultaneously, the other tape commences to move in the forward direction and play back the information. The cycle of winding and rewinding continues until the recorder is removed from service, erased and made ready for the next broadcast. The units cater for recordings of any length of time up to three minutes.

Germany:

Call Number	Service
1161	Football "Toto".
1162	Football "Toto".
1163	Horse "Toto" racing results, lottery by numbers.
1164	Weather information.
1165	News service.
1167	Cooking information, e.g., recipes.
1168	Stock Market quotations.
1169	Condition of highways.
1170	Tourists' weather information, and seaside resort information.
1151	Cinema schedules.
1152	Sporting events, forecast and results.
1153	Last train, bus and tramway connections.
1154	Travel service and suggestions, excursions and special tours.
1155	Water level reports, storm tide warnings.
1156	Theatre and concert schedules, cabarets, variety shows and similar entertainments.
1158	Special events, exhibitions, fairs, etc.
1160	Physicians and chemists' shops on duty.

In large local networks and areas where, because of the great number of cinemas, the cinema schedules have to be announced on several numbers, a further digit must be added to 1151. The foregoing list of services and call numbers are those used generally, but variations are made as necessary to suit the peculiar requirements of any city or local network. If a particular service listed has to be obtained via a trunk line the call number is prefixed by "0" which is the trunk access digit.

The German Bundespost uses "Dimafon" machines which are about the same size as portable gramophone record players. In general the principle of operation is the same because the machine uses discs impregnated with magnetic material and the sound head fits into grooves in a manner similar to that of a conventional gramophone record. The method of operation of the "Dimafon" machines is that a female operator makes the recording on a disc and having done so, she places it on a reproducing machine which is then connected to the network via a patch jackfield. The machine remains idle until a caller dials the appropriate number in which case the disc begins rotating and the recorded service is transmitted via the sound head to the subscriber. At the completion of the recording a simple mechanical latch trips a mechanism which lifts the head and returns it to the start position. The latch is adjustable and can be set for each recording. The circuitry is so arranged that if there are no subscribers connected to the service after the completion of a playing cycle, the recorder remains at rest in the start position and is not re-energised until the next call is made. However, it cannot stop in the middle, but must return to normal to complete a full cycle before it is re-energised.

When a recorder is withdrawn from service to have the information changed, the disc is removed and taken to a control booth for erasure which takes only a few seconds, and subsequent re-recording with the fresh information. The disc is replaced on the machine and after the necessary adjustment to the mechanical latch the machine is ready for service again.

United Kingdom:

For many years the B.P.O. has provided a recorded time service whereby the dialling of "TIM" in director areas connects the subscriber to the speaking clock. A similar service is provided in Sydney and Melbourne by dialling B074 and M074 respectively. A weather service "WEA", was opened in Holborn Exchange (London) early in 1955 and this has been such a success that it is being extended throughout the U.K. During the Australia versus England test cricket series in 1956, a service was opened whereby the dialling of "WEB" connected the subscriber to an announcing machine giving the latest score, the recording of which was changed every 15 minutes. The original installation at Holborn consisted of commercial tape recorders modified for the purpose so that the information required for transmission could be stored in a tape loop. There are a number of disadvantages and difficulties associated with a tape loop system and the B.P.O. are using disc machines for extension of the service to provincial cities. The B.P.O. Research station at Dollis Hill has also developed a magnetic drum type of machine which lends itself readily to press button operation without the attendant disadvantages of complicated mechanisms. Three of these particular units have been purchased to provide the Sydney weather information service.

Readers may be interested to know that in the U.K. there is an independent telephone service owned and operated by the Corporation of the City of Hull in Yorkshire. This network consists of approximately 36,000 lines (1956 figure) and about 48,000 stations. Approximately half of the equipment is step-by-step with the remainder Bell (Antwerp) rotary equipment. Apart from the speaking clock which is a tap off the B.P.O. ring main, the Hull Corporation has been giving a recorded information service for some years. Prior to the general election in May, 1955, a service was given whereby a subscriber could obtain access to recorded political party broadcasts by dialling an appropriate number. Recorded services given by the Hull Corporation in 1956 were as follows:—

Santa Claus on the Telephone: This service provided a recorded Christmas story by dialling of an advertised number and has proved to be very popular with the people of Hull and surrounding districts.

Phondiary: (2 p.m.-8 p.m. week days). This is a recorded guide to local entertainments. Extracts from the actual trailers of films showing at cinemas are often included in the recording which is normally changed once a week.

Record of the Week: The dialling of an appropriate number will connect the subscriber to a recording similar to our hit tune of the week.

Medical Talks: A special edition giving a cancer education talk was arranged in conjunction with the Madame Curie Memorial Foundation, London. There were three talks in the series.

Birthday Greetings and Daily Horoscope: This has since been discontinued.

Telechef: A recipe service for housewives was started in March, 1955, between 8.30 a.m. and noon on week days. Subscribers calling a certain Hull number are given a recipe for the day recorded by expert cookery demonstrators of the Yorkshire Electricity Board and North-Eastern Gas Board on alternate days.

Special services are introduced from time to time by the Hull Corporation and proved to be very useful in connection with railway strike announcements. The recorded services at Hull, with the exception of "TIM" are made on a tape loop with a machine developed by engineers of the Corporation.

B.P.O. Telephone, Type 700

This is a recent development by the B.P.O. and has already been covered in an article contained in P.O.E.E. Journal, Vol. 49, Part 2, July, 1956. However, in view of its importance it would not be out of place to make brief mention here of the development, even at the risk of giving readers an over-simplified idea of a complex subject.

The assessment of the relative performance ratings of telephone instruments is difficult to express in simple terms and is incapable of absolute measurement because results vary depending upon the method of test. Tracing back the history of the modern series of British Handset Telephones, the Type 162 was the first (about 1930) and this instrument was generally equivalent in performanc to the earlier non-handset types. The next development was the inclusion of the A.S.T.I.C. (Anti Side Tone Induction Coil) and the modified version of the Type 162 which included the A.S.T.I.C. was known as the Type 232. The net result was an improvement in receiving efficiency of approximately 2 db. Both the 162 and 232 Type Telephones contained the No. 13 Transmitter and 1L Type Receiver.

The introduction of the 332 Telephone several years later brought a change in physical characteristics, but the transmission performance was about the same as that of the Type 232. The 2P Receiver was introduced about 1939 and this was incorporated in the 332 instrument. The use of the 2P Receiver resulted in an improvement in receiving efficiency of the order of 8 db, but only a portion of this was directly measurable in terms of volume efficiency, the main gain being in articulation efficiency because of the better frequency response of the 2P as compared with the 1L Receiver. Thus the 332 Telephone (13-2P-27) is regarded as being about 10 db better in receiving efficiency than the Type 162.

In recent years the introduction of the Rocking Armature Receiver (S.T.C., U.K.) which uses an armature driving a diaphragm in lieu of the previous practice of having the diaphragm perform the dual magnetic and acoustic functions, resulted in a further increase in receiving efficiency of approximately 6-8 db. Thus, over the years the receiving efficiency has been improved by 16-18 db over the 162 Type, but no improvement has been made to the sending efficiency because the No. 13 Transmitter has remained substantially the same. If a new telephone network were being established and all telephones were say of the 332 Type with Rocking Armature Receiver, the permissible loops could be extended to 1000 ohms without the need to increase the sending efficiency. However, in view of the millions of less efficient telephones already in the network, the only means by which the local line limit may be relaxed is by increasing the sending efficiency of the new telephones connected to the longer loops so that the overall transmission performance will not be degraded when such a telephone is connected over the network to a less efficient telephone. It was this requirement which dictated the need for designing a new induction coil to transfer some of the receiving efficiency achieved progressively over the years to the sending side. This has been done on the B.P.O. 700 Type Telephone. The A.P.O. equivalent is known as the "400" series.

P.V.C. Switchboard Cables and Wires

The B.P.O. and U.K. manufacturers have been actively engaged in recent years in the development of a grade of polyvinyl-chloride which will be suitable without protective textile lapping for switchboard cables and wires. As an insulant, P.V.C. is vastly superior to textile or textile-enamel, but there were a number of physical drawbacks which had to be overcome before it was safe to make a complete changeover to this type of insulant. These limitations have been overcome largely by improved manufacturing techniques but, since P.V.C. is a thermoplastic material, care will always be necessary to avoid damage to insulation from hot soldering tools, especially at terminating points such as terminal strips where there is a high concentration of wires. Another prerequisite to the universal adoption of P.V.C. was the application of colours to conform to standard colour codes. One method of providing the range of colours required and at the same time minimising the possibility of heat damage is to cover the P.V.C. insulation with a suitably coloured textile lapping. The main drawback to this arrangement is that textile lapping adds to the cost of the wire. Developmental work, therefore, has been directed towards the elimination of textile lapping and the first step towards this objective was made in the automatic switch bank wiring because the nature of the termination lends itself readily to the use of unlapped P.V.C. with wires requiring not more than one colour per conductor. There is no doubt that the most effective method of overcoming heat difficulties on congested terminal strips is to redesign the strips to avoid having the insulation of any wire touching a dissociated terminal. This redesign work is being done, but as it was not desired to delay the universal application of unlapped P.V.C. pending this rather longer term development, efforts were directed towards seeing what could be done with existing terminal strips. Therefore, pending the availability of a completely redesigned strip, unlapped P.V.C. may be safely used on existing strips provided that there are channels of insulation between rows of terminals, or alternatively an insulating sleeve over the lower portion of each tag.

In the meantime, manufacturers had been pressing on with a technique for applying identifiable and fast colours. This was achieved by a special process and the end result is not unlike the textile colours in formation but vastly superior in clarity and ease of identification.

The Swiss P.T.T. have been using unlapped P.V.C. on all telephone equipment racks for some years, but no special provision is made on the terminal strips to meet the possibility of accidental damage from soldering tools. When the writer questioned Swiss engineers about this aspect they seemed rather puzzled that there should be any possibility of skilled technicians damaging the insulation during soldering. The terminal strips used by the Swiss P.T.T. are not a great deal different from those of our own and the B.P.O., and they do not appear to encounter the difficulties mentioned. An interesting feature of the P.V.C. wire used by the Swiss P.T.T. is that the colours are injected at the same time of extrusion and the net result is a very attractive coloured wire. It was thought at one time that the excellent appearance of this wire could not be matched by a printing process, but subsequent developments have proved this contention to be wrong, because some of the printed wires manufactured in U.K. and Australia compare very favourably in appearance with those produced by the Swiss multi-extrusion processes.

Solderless Wrapped Connections

In the Bell System Technical Journal, Vol. XXXII, No. 3, of May, 1953, an article appeared on the use of a form of wrapped connection that eliminates the need for solder. In short the technique is to wrap the wire around the tag under a given pressure by means of a special tool and the net result is a gas tight joint which in every way is as good as a well soldered joint. Its application is particularly attractive with P.V.C. insulation because of the fact that it is not necessary to apply heat to the joint. However, there are a number of practical problems in introducing such a technique in equipment such as our own and that of the B.P.O., and therefore the matter has to be studied carefully to assess the gains, if any, which would accrue from its introduction. The technique is at present undergoing trial in the U.K. at Brixton and Kidderminster Exchanges on specially constructed terminal strips.

Subscriber Trunk Dialling

Probably the most important single item of development in the United Kingdom during the writer's term of service between 1953-1956 was the announcement in 1955 by Sir Gordon Radley, K.C.B., C.B.E., Ph.D.(Eng.), M.I.E.E., Director-General of the B.P.O., that subscriber trunk dialling would be introduced into the National network during 1958. Since that announcement was made the vast technical and administrative resources of the B.P.O. and the U.K. manufacturers have been directed towards this goal and the first subscriber trunk dialling installation will be placed into service in the Bristol area in December, 1958, and it is expected that by 1970 about 75% of trunk traffic in the U.K. will be subscriber dialled. The method of registering charges for trunk line calls will be on the basis of periodic time-zone metering. This is consistent with the practice used in Germany, Sweden, Switzerland, Holland and France. In order to gain access to a wanted subscriber via the trunk network, the calling subscriber will dial Y (O) to gain access to the trunk equipment in the first instance and this will be followed by a national code to reach the distant trunk centre and then the Directory number of the wanted subscriber. If trunk operator assistance is required the calling subscriber will merely dial "O" after the first trunk prefix.

GENERAL IMPRESSION OF U.K. TELEPHONE NETWORK

As a subscriber living in the London Director area for nearly four years some observations by the writer, in the form of customer reaction, may be of interest to readers. For the information of those who may not be familiar with the London network, the Director system is a system of registration and translation using a switch known as a Director which consists of a six-bank bimotional switch plus four uniselectors, control equipment, and a translation field. The Director system was introduced into the London area at the opening of the Holborn Exchange with approximately 10,000 subscribers in 1927 and subsequently this system was introduced in Birmingham, Manchester, Liverpool, Glasgow and Edinburgh. Thus a substantial portion of the seven million subscribers in the U.K. are in Director areas.

The first time of dialling a number in a Director area by one who has been used to non-Director step by step exchanges produces an interesting reaction because of the fact that the operation of the switches is not audible in the receiver. There is no sound whilst the Director registers, translates and sends impulses to operate the forward switches. The first sign that the Director has performed its function occurs when ringing tone is heard some several seconds after the dialling of the last digit. For a start one has to overcome a tendency to hang up and call again after dialling the first two or three digits and upon completion of the last digit. One of the features of the Director system is that the first three call letters represent the exchange to which the subscriber is connected. For example, Australia House is connected to the Temple Bar Exchange and the number is TEM2435. Similarly, Scotland Yard is connected to Whitehall Exchange and the number is WHI1212. The most notable advantage of this arrangement occurs not so much in subscribers' numbers, but in the service numbers, some of which are given as follows:—

Time	TIM
Directory Information	DIR
Telegrams and Cables (Phonograms)	TEL
Trunk Lines	TRU
Toll Lines	TOL
Weather Forecast	WEA
Operator	O

Apart from the convenience of being able to dial service numbers without bothering to consult the directory the "O" for operator facility is a most useful aid to a subscriber when in doubt about the procedure to be followed in the making of a call. There is also the world famous "999" service for use in an emergency and all such calls are handled by operators on a "drop everything" basis. It is more than 30 years ago since this system was conceived and in that time the world has become so much more telephone minded that the mere remembering of telephone numbers is a facility which has been fairly well cultivated by most people. Indeed, a large number of Telephone Administrations do not use letter prefixes at all, and this is an increasing tendency throughout the world. They simply rely on the numbers which are usually broken up thus: 26.14.38, for ease of remembering. The writer found the latter system very easy to handle on the continent of Europe and it was surprising how little time it took to become accustomed to memorising and using figures only. In fact this arrangement simplifies the dialling of numbers and makes for greater accuracy because the dial is not complicated with a mixture of letters and numbers and phonetic difficulties are substantially eliminated.

CONCLUSION

The presence of technical representatives in London gives the A.P.O. direct access to an extensive pool of technical information both in the U.K. and Europe and provides first hand information at a very early stage on valuable scientific and technological developments. A similar post in the U.S.A. would complete, for all practical purposes, an all-world coverage and would place Australia in a very strong position in the field of world communications.

ACKNOWLEDGMENTS

The writer would like to pay a tribute to the co-operative spirit displayed by personnel in Telephone Administrations and private companies in supplying information on technical developments. In Europe, language difficulties are overcome largely by the willingness of the organisation visited to arrange, in a most friendly way, for English speaking personnel to be continuously available for consultation or interpretation.

In particular the writer's thanks are due to personnel of all ranks in British Post Office, British Broadcasting Corporation, Commonwealth Telecommunications Board, Corporation of the City of Hull, Cable and Wireless Ltd. and members of the Telecommunication Industry in the U.K. for their never failing courtesy and willingness to help at all times.

BIBLIOGRAPHY

(1) The Transatlantic Telephone Cable, P.O.E.E. Journal, Vol. 49, Part 4, January, 1957.

(2) The British Telephone Technical Development Committee—R. W. Palmer, M.I.E.E. and W. L. Brimmer. P.O.E.E. Journal, Vol. 41, Part 4, January, 1949

(3) The New 700 Type Telephone—H. J. C. Spencer, A.M.I.E.E. and F. A. Wilson, C.G.I.A., A.M.I.E.E., A.M. Brit. I.R.E., P.O.E.E. Journal, Vol. 49, Part 2, July, 1956.

(4) Solderless Wrapped Connections—Bell System Technical Journal, Vol. XXXII, No. 3, May, 1953.

JOINTING OF PLASTIC INSULATED AND SHEATHED TELEPHONE CABLES

*V. J. WHITE, B.A. (Hons.), B.Sc.**
A.M.I.E.Aust., M.Br.Ps.Soc.

INTRODUCTION:

Plastic material first came into use in the manufacture of telephone cables as a sheathing material to offset the shortage of lead which occurred during and after World War II. This shortage stimulated the development of materials and manufacturing techniques with such success that when lead supplies returned to normal, the advantages of plastic cable namely economy, ease of handling, chemical stability, corrosion resistance and easier maintenance, were strongly established. Since then the demand for plastic cables has steadily increased. Today the plastic polyethylene, usually known as polythene is used extensively in the manufacture of outdoor telephone cables both as a sheathing material displacing lead and as an insulating material displacing paper. Another plastic material, polyvinyl chloride, is used extensively in the manufacture of indoor telephone cables where it has displaced textile and wax as sheathing materials and cotton and enamel as insulating materials. P.V.C. is also used for outdoor insulated wires.

This paper deals specifically with the jointing of outdoor polythene sheathed and insulated telephone cables. It is proposed to

(i) make a general analysis of the problem,
(ii) briefly review current methods used in England, America, Sweden and Australia,
(iii) describe a new method of sheath sealing developed in the Lines Section of the Australian Post Office, and
(iv) indicate possible future developments.

GENERAL ANALYSIS OF PROBLEM

In making a joint between two lengths of cable, the ideal condition is to leave the cable with exactly the same degree of protection as it has in a section where there is no joint, that is, where conductors and sheath remain intact.

Provision of greater protection at the joint than is provided in an unjointed section of cable would of course be wasteful overprovision. This point must be remembered when thinking about plastic cables. Three different elements must be considered, namely:—

(i) Conductors
(ii) Conductor insulation
(iii) Sheath.

Conductors: In a paper insulated lead sheathed cable system, the conductor joints are made by merely twisting the bared conductors together. Experience has proved this method entirely satisfactory for lead sheathed cables where the cable core must remain dry because of the hygroscopic nature of the paper insulation. It does not automatically follow that this method of conductor jointing will prove equally satisfactory in a plastic sheathed system where moist air (a) does not have the same effect on the conductor insulation and (b) can diffuse through the plastic sheath, causing, it is claimed (see para 3.1, Reference No. 3) an eventual (in 3 to 4 years) equalizing of humidity both inside and outside the plastic sheath.

Conductor Insulation: The continuity of the conductor insulation in a paper insulated system is maintained at a conductor joint by simply slipping a paper sleeve over the twisted joint. Because moist air will quickly reduce the insulation resistance of the paper and therefore must be kept out of the system, there is obviously no need to consider any sealing of the conductor joints. However in a plastic system moisture does not materially affect the insulation resistance of the insulating material provided it remains intact. To fully utilize this attractive moisture resistant property and because it appears that moist air will ultimately diffuse through the plastic sheath in any case, it seems desirable to investigate methods, of sealing each conductor joint. With sealed conductor joints sheath failures may occur without loss of service.

Sheath:—In the paper and lead system, the continuity of the lead sheath is maintained at a joint by plumbing on a lead sleeve. This must provide a perfect seal and any imperfections are soon detected when moist air penetrates through to the paper insulated conductors. There is no alternative in a paper cable other than a complete sheath seal at each joint. In a plastic system however the moisture resistant property of the plastic insulation does allow some easing of this very stringent requirement. With plastic it is possible to consider a system where each conductor joint is made waterproof; indeed when failures of the sheath at points remote from the joint are considered, conductor joint sealing becomes even more attractive. Sheath failures in paper systems cause failure of the conductor insulation at the point of sheath damage. In a plastic system however sheath failure will not show up until water has penetrated some distance through the cable to a break in the plastic insulation usually at a conductor joint. Thus the cause of the fault is remote from the fault itself and cannot be readily located.

This analysis leads to the conclusion that in a plastic cable system jointing should involve sealing conductor joints rather than the sheath. However another alternative is possible. This is to provide both an external sheath seal and an internal seal at all joints. This internal seal—known as a "moisture barrier"—is simply a block of sealing compound inserted on each side of the joint in much the same way as a gas seal is installed in paper cables when putting them under pressure.

B.P.O. practice is to not seal conductor joints but to instal moisture barriers whereas it appears that American practice favours conductor joint sealing. Irrespective of the method used for plastic to plastic joints moisture barriers must be used at all joints between plastic and paper cables. Even if the wire joints were sealed in this case, moisture in the plastic system either from sheath failure or long term diffusion may eventually cause failure of the paper insulation at the joint.

Summarising this analysis it can be said that conventional conductor jointing and paper sleeving methods have proved satisfactory because a paper-lead system operates on the basis of moist air being excluded by the lead sheath. Any failure of the lead sleeve or sheath is quickly detected and fairly accurately located because of the "burglar-alarm" characteristic of the paper insulation. It seems unwise to expect the same conductor jointing and sleeving techniques to work equally as well in a plastic system when (a) the plastic sheath does not keep moisture out as effectively as a lead sheath and (b) the plastic insulation is not affected by moist air so that the "burglar alarm" will not operate, and moisture can exist undetected inside the sheath.

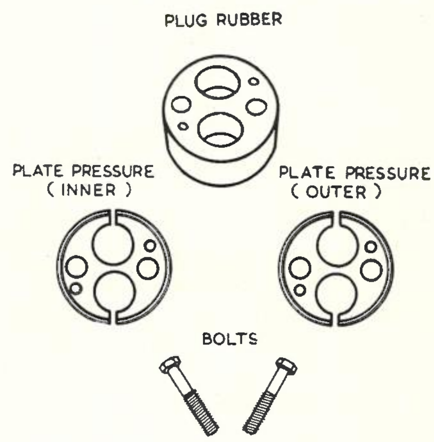


Fig. 1—Rubber Plug and Pressure Plates of B.P.O. Type Joint.

CURRENT JOINTING METHODS

Some of the methods in use in Australia and other overseas administrations will now be reviewed briefly.

Fig. 2.—Lead Sleeve with Brass Reinforcing Collar.

*Mr. White is a Sectional Engineer in the Lines Section, Central Office.

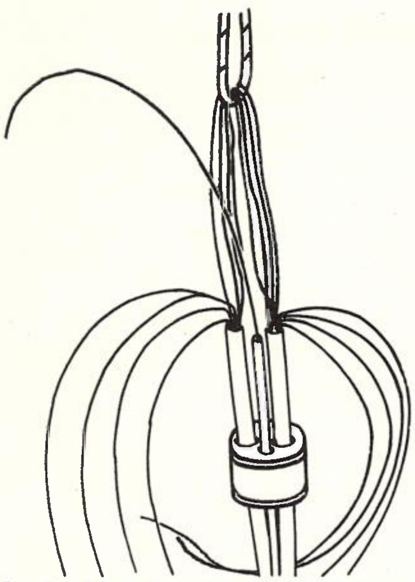


Fig. 3.—B.P.O. Type Joint Partly Complete.

Great Britain:

The method in general use in the B.P.O. is a mechanical type joint involving a rubber plug which is compressed between two brass pressure plates. The rubber plug when compressed, seals against the inside surface of a sleeve and over the cables which have previously been inserted in appropriate holes in the plug (1). Fig. 1 illustrates the rubber plug and pressure plates. Fig. 2 shows the sleeve and brass reinforcing collar used to accommodate the joints. Fig. 3 shows the rubber plug with plastic cables inserted, and a completed joint is shown in Fig. 4. Initially the B.P.O. used a lead sleeve and external reinforcing collar of brass, later developments indicate a change to a moulded plastic sleeve with a brass collar insert.

The B.P.O. system allows for single ended as well as double ended sleeves. The latter are used in cases where joints to a lead covered cable are required and the lead cable cannot be fitted into a hole in the rubber plug. Fig. 5 illustrates a joint using a double ended sleeve.

Reviewing this method in terms of the four elements, namely:—

(i) conductor jointing, (ii) conductor insulation, (iii) sheath seal and (iv) moisture barrier, the following comments are made:

The conductor joints are made using the twist method and are left unsoldered. No attempt is made to seal each conductor joint, open ended polythene sleeves being using in the same manner as paper sleeves are used in the paper lead system. Elaborate precautions are taken to effect a good sheath seal at the cost of complexity of components required. To ensure that a jointer can meet all possible combinations in making branch joints, plugs have to be supplied in various sizes with various combinations of different size holes. This makes the material cost per joint relatively high and introduces a supply problem. Moisture barriers are apparently now fitted to every joint. The barrier is made by using a rubber sleeve (Fig. 6) which is fitted over each cable sheath at the point where the conductors emerge. This water barrier sleeve is then filled with a hot (100° C) sealing compound which penetrates into the conductors and which shrinks as it cools.

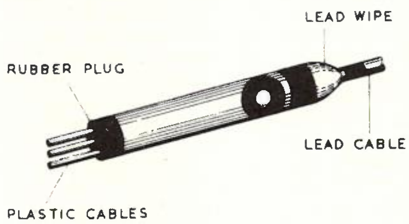
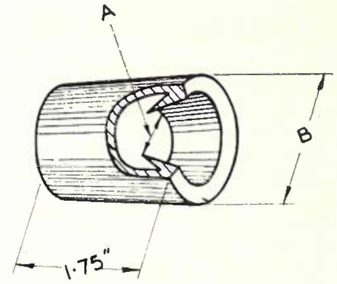


Fig. 5.—Double Ended B.P.O. Joint to Lead Covered Cable.

The B.P.O. also use a water barrier coupling unit made of bakelite as their standard method for jointing cables less than 7 pairs. This unit, illustrated in Fig. 7, is also used to apply a moisture barrier to existing plastic cables. It is fitted around the two cables by means of a P.V.C. adhesive backed tape and the whole sleeve is then filled with the hot sealing compound.



SLEEVE, WATER BARRIER, NO.	DIMENSIONS (DIA. INS.)	
	A	B
1	0·21	0·75
2	0·34	1·0
3	0·58	1·25
4	0·81	1·5

Fig. 6.—B.P.O. Type Moisture Barrier.

America:

In England plastic sheathed and insulated cables have been in general use for some years, but in America plastic has been mostly only used as a sheathing material and conductors are mainly still insulated with paper. Plastic insulated cables are widely advertised in American journals but as far as can be determined paper insulation still prevails, although recent articles indicate an increasing trend towards plastic cables and a cor-

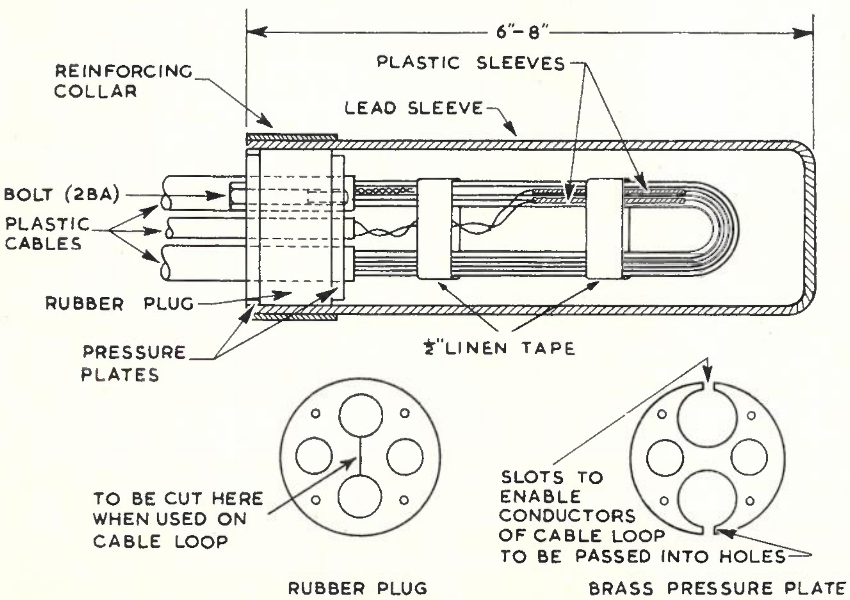
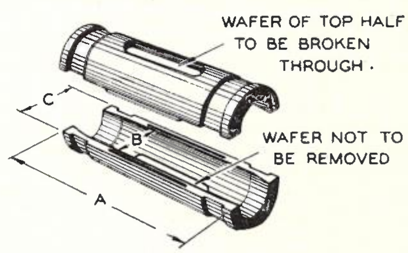


Fig. 4.—Details of Completed B.P.O. Type Joint.



COUPLING WATER BARRIER NO.	DIMENSIONS (DIA. INS.)		
	A	B	C
1	3	0·421	1·047
2	4	0·624	1·250
3	5	0·936	1·562
4	6	1·200	1·826

Fig. 7.—B.P.O. Type Moisture Barrier Coupling also used for jointing small cables.

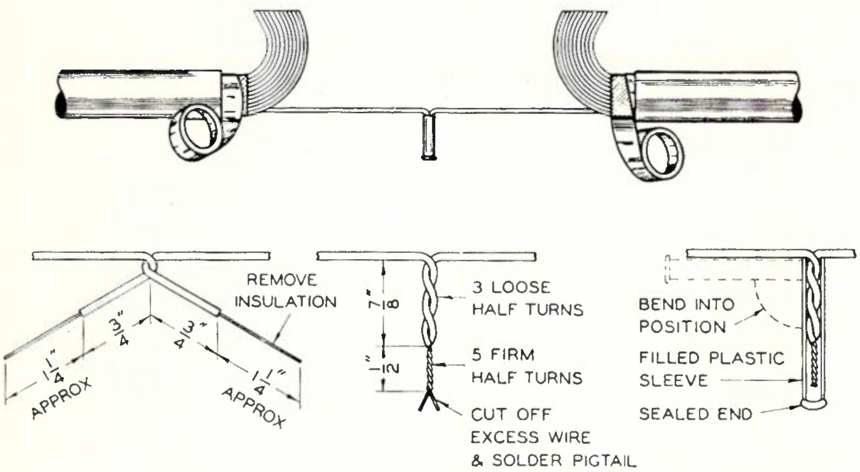


Fig. 8.—Anaconda Cable Co. Conductor Jointing Technique.

responding trend toward a totally underground system. American paper insulated plastic sheathed cables include metal tapes designed to give a moisture proof sheath as in a lead cable.

Jointing methods used in America vary considerably. Some of the methods in use are:—

Taping Method: The Rural Electrification Administration have approved a taping method as follows:—

(i) Apply a filler tape or putty like synthetic rubber to fill all voids in joint and provide a foundation surface to tape over.

(ii) Two layers of black P.V.C. tape are then applied for mechanical and electrical protection. The first layer is applied with the adhesive out, and the second with the adhesive in.

(iii) A layer of self bonding Biseal Tape is then applied.

(iv) Over this is applied pressure sensitive aluminium foil tape to act as a moisture barrier.

(v) Finally a layer of P.V.C. tape is added to provide protection against abrasion.

The Anaconda Wire and Cable Company: The conductor jointing and sleeving techniques recommended by this firm are shown in Fig. 8. The sheath is sealed using tapes in much the same way as in the REA method described above. The Branch joints are made using a specially shaped plastic grommet. This company recommend soldering of the conductor joints and also advise the use of a special sleeve to seal the conductor joints. It seems that with soldered and sealed conductor joints the elaborate taping methods recommended for sealing the sheath are unnecessary. None the less the method is interesting as an example of a departure from traditional conductor jointing and sleeving methods.

Auxiliary Lead Collar and Plumbing Method: Used for larger sized cables, this method involves an auxiliary lead collar fitted over the cable sheath and then a lead sleeve is wiped to this auxiliary collar as for a lead sheathed cable. The seal between the lead collar and the plastic sheath is effected by using wire mesh wrapped around the plastic sheath and embedded into the sheath by the application of a hot soldering iron. The lead collar is soldered to the wire mesh and the joint between lead collar and plastic sheath is sealed by use of tapes, a special cement or by heating polythene sheets and using an external mould clamped over the molten mass to exert pressure on it as it cools. Alternatively when a steel tape is provided under the plastic sheath the lead sleeve is soldered directly to it.

Bell System: In a recent article in the Bell Telephone Quarterly (2), reference is made to trials with underground plastic cable. In these trials the jointing method adopted appears to have been to make all joints above ground in pedestal type terminal unts. No details of this method have yet come to hand. In addition we have some evidence to suggest that a cast iron or cast aluminium joint case with a suitable sealing gasket is being developed to accommodate underground cable joints. No details are available yet.

Reviewing the various American techniques mentioned here it can be said that where plastic insulated and sheathed cables are used there is some evidence of

(i) soldering of conductor joints, and

(ii) sealing of conductor joints.

Sheath sealing is given elaborate attention particularly where paper insulation is still used. No mention is made of moisture barriers.

Sweden:

L. M. Ericsson advocate the use of a casting resin to seal the sheath and provide a moisture barrier. Their method is illustrated in Fig. 9 and the procedure is as follows:—

Make the conductor joints using soldered twist joints and paper or plastic sleeves. Expose the conductors at each end of the joint by removing a strip of insulation about 40 mm wide. Build up a collar on each cable sheath using a plastic putty material similar to Scotchfil at the positions shown. Position a lead sleeve over the joint so that it extends beyond the exposed conductors at each end. Beat the lead sleeve down onto the cable sheaths and on to the collars made from the plastic putty thus making a chamber at each end of the joint around the two belts of exposed conductors. Make two holes in the lead sleeve and solder a 50 mm length of lead tube to each hole. Fill the casting chamber with casting resin and after waiting for it to cure saw off the lead tubes. The joint is then completely sealed. The casting resin not only makes the seal but by penetration into the cable core at the two exposed belts also constitutes a moisture barrier.

In the L. M. Ericsson method we find a clear recognition of the possible effects of moisture diffusion through the sheath.

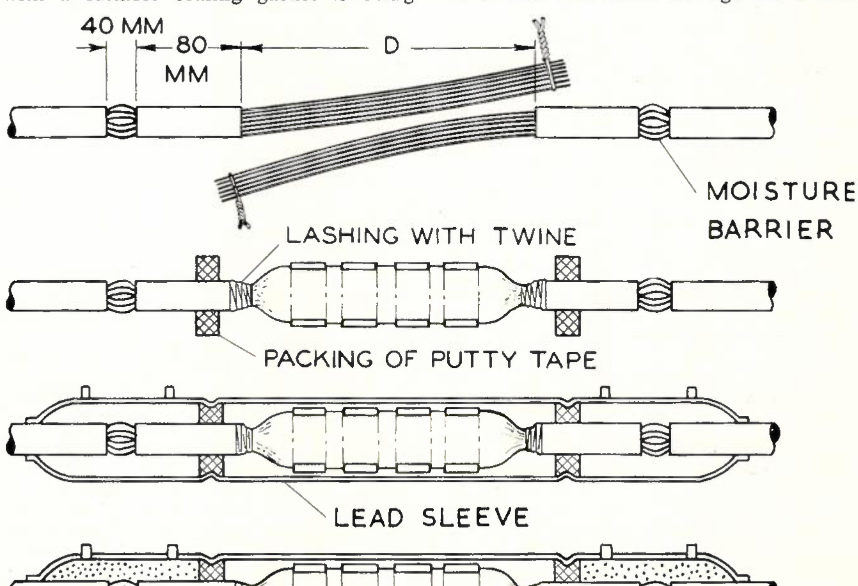


Fig. 9.—L. M. Ericsson Jointing Method Showing Stages of Making Joint.

Fig. 10.—Taped Joint for 1 and 2 Pair Cable.

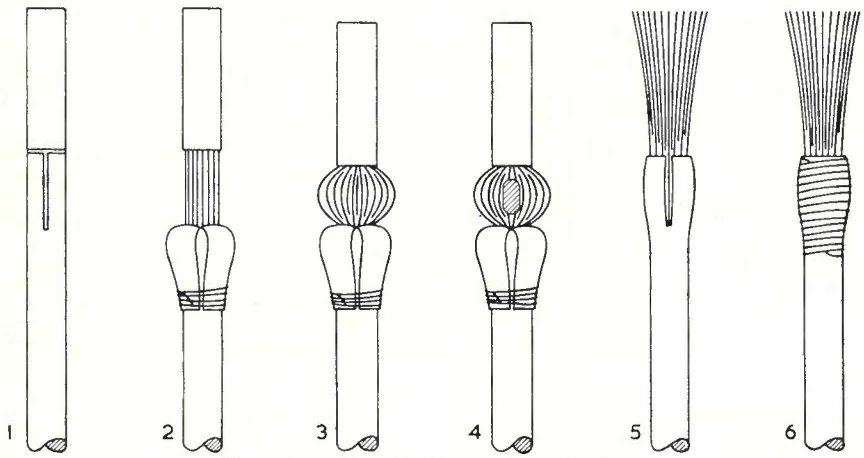


Fig. 11.—Moisture Barrier Developed in N.S.W.

(i) Circular cut in sheath and longitudinal cuts 4 inches long.
(ii) Sheath peeled back and temporarily tied.
(iii) Conductors belled out and layer tapes removed.
(iv) Caulking compound inserted.
(v) Conductors pulled tight and sheath replaced. Surplus compound removed from outside sheath and end of sheath removed.
(vi) Three layers of P.V.C. adhesive tape applied over moisture barrier.

In joints not sealed in the manner described above they recommend conductor joint soldering. However, for all underground cable joints they advise the casting resin seal and moisture barrier technique which prevents moisture penetrating through to the conductor joints and allows them to dispense with soldering.

The sheath seal method proposed by Ericssons appears to be somewhat involved and suffers the disadvantages associated with using casting resin in the field, namely, toxicity of the hardener, sensitivity to ambient conditions, waiting time for joint to set, and dependence on availability of the resin in suitable packs.

Australia:

The standard methods used in Australia are:—

(i) B.P.O. method for cables larger than 2 pair (3).

(ii) A taped lead sleeve method for 1 and 2 pair (3).

In adopting the B.P.O. method, the A.P.O. have not as yet included water barriers, and have developed an aluminium sleeve cast from a corrosion resistant alloy to replace the lead sleeve and brass reinforcing collar.

The taped lead sleeve method for 1 and 2 pair joints is shown in Fig. 10. The lead sleeve and self bonding tape are being replaced by a neoprene rubber sleeve and a butyl rubber strip as described in Section 3. The conductor joints are left unsoldered and are not sealed. Investigations are proceeding to determine whether unsoldered and unsealed conductor joints will give satisfactory service over a long period in a plastic system. The need for moisture barriers is also being investigated.

Moisture barriers are being installed in N.S.W. using a caulking compound with the trade name "Cableastic". This plastic putty-like material is inserted into the cable in such a way that all conductors are embedded in it thus forming an effective moisture block on each side of the joint. (See Fig. 11). This method was first used by Linemen Orr and Perridge at Villawood, N.S.W.

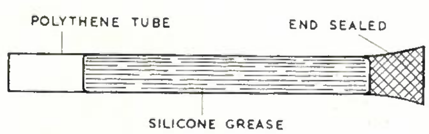


Fig. 12.—Silicone Grease Filled Sleeve.

Purchase is being considered of silicone grease filled sleeves for sealing conductor joints in plastic cables. These sleeves are illustrated in Fig. 12. Use of these sleeves will eliminate moisture barriers at plastic to plastic joints. As stated before, they will however still be required at all plastic to paper joints particularly if sheath seal requirements at plastic to plastic joints are relaxed.

A NEW METHOD OF SHEATH SEALING

Although the B.P.O. method of jointing as adopted by the A.P.O. offers advantages of minimizing conductor joints and appears to give an effective and permanent sheath seal, it suffers from being somewhat complex, and rather expensive. In addition both the A.P.O. and B.P.O. systems involve a different method for 1 and 2 pair joints. Field experience with the B.P.O. method in Australia was delayed because of difficulty in supplying all the components required for a complete jointing kit. Investigations in the Lines Section of Central Office have been aimed at developing a method which will give an adequate seal and can be used on all sizes of cables. It depends on a relatively small number of different items, is reasonably easy to make, and uses readily available materials.

A method meeting these requirements has been developed. It involves the use of three different components namely,

(i) a soft thin walled neoprene rubber sleeve supplied in approximately 6 foot lengths and cut to size in the field. Approximately four different sizes will be required to cover joints in cables ranging from 1 pr. 6½ lb. to 74 pr. 20 lb.

(ii) A butyl rubber strip 2 inches wide by ⅛ inch thick supplied in rolls approx. 10 feet per roll.

(iii) A P.V.C. adhesive backed tape.

All items are readily available in Australia.

To make a branch joint using the neoprene rubber tubing the following operations are involved:—

(i) Select the appropriate size of neoprene tubing and cut a sleeve to the required length. If one size is not available a joint can be still made by using the next larger size.

(ii) Slip the neoprene rubber sleeve over the main cable of the branching joint.

(iii) Make the conductor joints.

(iv) Position the neoprene sleeve and mark points at each end of the joint as a guide to the position required for building up the collars referred to in (v).

(v) Apply butyl rubber to build up collars and fill in crutch between branching cables. In small sized cables the compound will also provide a moisture barrier. See Fig. 13.

(vi) Tape over butyl rubber strip to contain it in an envelope of P.V.C. tape. During this operation tension should be kept on the tape in order to ensure the butyl rubber seals around the cable sheaths, and cable conductors. See Fig. 14.

(vii) Fit the ends of the rubber sleeve over the two collars so formed, and seal down with stretched butyl rubber.

(viii) Apply two layers of P.V.C. adhesive backed tape over the rubber sleeve and butyl rubber and continue the taping at 50% overlap down to the cable sheaths. See Fig. 15.

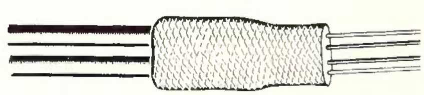


Fig. 13.—Butyl Rubber Collar applied to Cable.

Joints made in this way will withstand air pressure to the limit of the neoprene rubber sleeve, approximately 10 lbs. per square inch. Although neoprene rubber will deteriorate when exposed to light and heat, it is a high grade, oil resistant rubber with adequate life in an underground situation. It is preferred to polythene or P.V.C. which, though possibly more durable, will not stretch as much as rubber, making it more difficult to fit the collars and make the seal.

In cables up to 6 pair the butyl rubber strip pushed in between the conductors at the end of the cable sheath as shown in Fig. 12 gives an effective moisture barrier.

In cables larger than 6 pair the butyl rubber collars are built up entirely on the sheaths of the cables and moisture barriers are provided using a separate sealing compound.

FUTURE DEVELOPMENTS

There appear to be two definite trends in research activity on jointing plastic cables:—

(i) Improved methods of conductor joint sealing.
(ii) Improved methods of effecting an internal moisture barrier and an external sheath seal.

In a system where paper lead cables are mixed with plastic cables both lines of development are important. But in a pure plastic cable system the two trends tend to be mutually exclusive; a simply made effectively sealed conductor joint eliminates the need in a pure plastic system for moisture barriers and complete sheath seals.

Conductor Joint Sealing:

The Bell System are working on a device which will mechanically strip, joint and seal the conductors. One such device is described by E. Bollmier (6) and involves a plastic covered metal sleeve known as "Scotchlok Type T". This is illustrated in Fig. 16. A pneumatically operated pressing tool is required to crimp this connector. The price of this system is likely to be high.

Pending availability of other sealing connectors, wire joints may be sealed using the silicone grease filled sleeves referred to previously (Fig. 12). Experience with these filled sleeves is limited, points of doubt being:—

(i) long term effects on copper and polythene.
(ii) Need for soldering twisted wire joint.

Laboratory and field tests to resolve these points are in progress and so far the results are promising. If experience indicates that there is no need to solder and that the silicone grease does not affect copper or polythene then, the filled sleeve may well prove the best method of sealing conductor joints.

Sheath Sealing and Moisture Barriers

The B.P.O. method of jointing plastic cables suffers from these disadvantages:—

(i) It is inflexible in that a fairly large number of components are required to cover all cable sizes.
(ii) It appears limited to cables of approximately 1 inch in diameter or less.
(iii) Special arrangements must be made to instal moisture barriers.

It is probable that plastic cables at least of equal diameter to the equivalent paper lead cable will be produced soon. This means that large size plastic cables are a definite possibility. It is known that the B.P.O. are trying a 408 pair 6½ lb. plastic cable (outside diameter 1.35 inch) and it would appear that unit twin

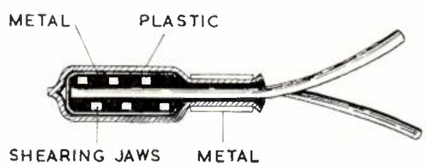


Fig. 16.—Cross section of "Scotchlok Type T" Sealing Connector before Crimping.

4 lb. plastic cables up to 1800 pairs are not unlikely. Jointing of these larger cables will probably be beyond the scope of the expanding plug type joint. Because of the limitation of existing methods epoxide resin methods of jointing plastic cables will soon be field tested in Australia. The epoxide resins have been used to joint underground plastic power cables by some Administrations. So far as is known Ericssons in Sweden are the only telephone people using this material for jointing cables. Epoxide resin packs are commercially available for jointing telephone cables from an American source. However, use of packs from this source would increase the cost of plastic jointing excessively.

The properties of epoxide resin which make them attractive for this purpose are:—

(i) Initial liquid state ensuring complete penetration of the conductors and forming a perfect internal seal when set.
(ii) Hard stable compound in the cured state.
(iii) Cured state unaffected by most corrosive agents.
(iv) Once cured little or no change in properties with age.
(v) Cured resin maintains hardness over wide range of temperature.

The cured resin adheres strongly to copper and lead but not to polythene. It gives an effective seal on polythene because it shrinks slightly on curing thus ensuring a tight fit of the hard resin around the sheath and insulated conductors. The difficulties associated with field use of these resins were briefly stated previously. In more detail these difficulties are:—

(i) **Toxicity:** Use of epoxide resins involves handling two components, the base resin and the curing agent or hardener. Once the resin and curing agent are mixed the activated resin commences to change from a liquid to a hard solid. Thus the two liquid components must be handled separately in the field. The hardener is usually fairly toxic and may cause allergic skin troubles in some cases. Special care is therefore required to handle this material. A non-toxic hardener is now available. This together with the use of a method of packing which reduces exposure of the hardener to the operator, allows the use of these materials in the field to be seriously considered.
(ii) **Sensitivity to Ambient Conditions:** Proportions of resin and hardener selected to give a specified curing time at certain ambient conditions will give quite different curing times when the ambient conditions change. Also an activated resin mix will have a certain viscosity at one temperature and a different viscosity at another. It is possible that if ambient conditions are extreme the resin will either not cure properly or be too viscous after activation for proper penetration and sealing of the joint. This sensitivity to ambient conditions is a problem in considering field use of epoxide resins. One method being considered to reduce this difficulty is to pre-heat the resin and hardener pack before mixing.
(iii) **Waiting Time for Joint to Set:** The fact that the resin may not cure sufficiently to allow movement of the joint for half an hour or more represents a problem which it is proposed to overcome by arranging for the pouring of the joint to be done with the cables in their final position. Thus the joint is poured just before the lid of the pit is replaced.
(iv) **Accurate Mixing of Hardener and Resin in Correct Proportions**: The proportions of hardener to resin are critical, making it unwise to leave the proportioning to field staff. This is overcome by pre-packing at the factory, resin and hardener in the correct proportions using two compartment packs.
(v) **Non-Reopenable Joints:** The epoxide resin sets into a hard mass so that a completely impregnated joint cannot be re-opened for re-arrangements or taps, etc. It is proposed to overcome this problem by:
  (a) Underground sealed terminal units permanently stubbed into the street cables.
  or (b) Keeping the resin out of the actual joint area and using it only to

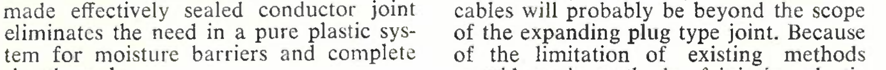


Fig. 14.—P.V.C. Tape applied over Butyl Rubber Collar.

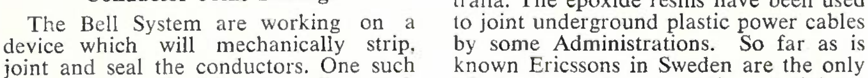


Fig. 15.—Completed Joint with Neoprene Rubber Sleeve in Place.

provide a moisture block at each end and to give a shell of resin around the joint.

or (c) Using stubs permanently cast into the main joints to provide subscribers' lead-ins. Connections to these stubs would be sealed by silicone grease filled sleeves.

The Australian field trials will test a joint made up from epoxide resin supplied in two compartment plastic bags. When the joint is to be sealed an internal seal between resin and curing agent is broken and mixing of the resin occurs before the outer seal is broken. The joint will be contained in a paper pulp mould into which the activated resin is poured. If initial tests indicate difficulty in sealing the joint without totally impregnating the joint with resin, a cable stub or an underground terminal will be permanently stubbed into the epoxide resin joint. The terminal would allow subsequent connection of leads into subscribers' premises from sealed screw terminals.

CONCLUSION

In analysing plastic cable jointing problems, attention has been drawn to the fact that plastic cables are basically different to paper lead cables and hence traditional jointing techniques must be critically examined before applying them in a plastic cable system.

Two basic approaches are being used. One follows traditional techniques in providing a sealed area for conductor joints. Because plastic insulation is unaffected by moisture this approach requires additional internal seals or moisture barriers to be completely effective. The other approach abandons the traditional concept of hermetic sealing of the whole joint area and takes advantage of the plastic insulation by emphasizing conductor joint sealing in preference to sheath sealing and moisture barriers. Current investigations in Australia seek to test developments in both areas.

REFERENCES:

1. B.P.O. Engineering Instructions, Lines Underground F3230 and F3233.
2. "Putting Cables Underground in Urban Areas", Elder & Buch; Bell Telephone Quarterly, Winter 1956.
3. L. M. Ericsson Instruction N.1531-019e, "Jointing of Plastic Cable".
4. A.P.O. Engineering Instruction, Lines Cables J3822.
5. A.P.O. Engineering Instruction, Lines, Cables J3821.
6. "A Sealing Connector for Small Insulated Conductors", E. W. Bollmier; A Paper Presented to the 1956 Signal Corps Wire and Cable Symposium.
7. A.P.O. External Plant Information Bulletin No. 4.

RECENT DEVELOPMENTS IN P.A.B.X.s IN THE A.P.O.

*E. J. ANGEL, A.M.I.E. Aust.

INTRODUCTION

The Private Automatic Branch Exchange or P.A.B.X. as it is generally referred to, has become an essential component in the communications of business, industrial and governmental institutions in this country. The increasing complexity of these organisations creates a need within themselves for additional co-operation and co-ordination resulting in the P.A.B.X. being a necessity for both small and large organisations.

The remarkable growth of the P.A.B.X. in the post war period can be gauged from the following statistics, which also reflect the vast expansion of Australia as an industrial nation in the same period.

Year	Total Working P.A.B.X. Ends	Rate of Growth
1939	19,060	5,204/year
1945	51,488	2,921/year
1950	66,094	3,633/year
1953	76,992	10,037/year
1957	117,141	

The large requirement for P.A.B.Xs. to assist the war effort over the period 1939-45 can be clearly seen as can also the lag in the early post war years when difficulty was experienced in obtaining equipment. However, with the gradual increase of production in later years, expansion has continued to such an extent that at the present time the amount of P.A.B.X. equipment in situ is more than six times that of 1939.

*Mr. Angel is a Divisional Engineer, Metropolitan Installation Section, Melbourne.

MAIN FUNCTIONS OF P.A.B.X's.

The general functions of the P.A.B.X. are:

(a) To provide automatic internal communication within an organisation.

(b) To provide automatic access to outgoing exchange lines to enable extensions to dial their own outside numbers. Where specified, an extension may obtain exchange access only via the manual operator.

(c) To provide a common answering point for all incoming exchanges calls with means for rapid extension to the person or section required. In certain larger P.A.B.X's. facilities for direct "In Dialling" of extensions may be provided.

(d) To provide facilities for information calls, revertive calls and special facilities such as conference facilities, automatic hold and call facilities, etc.

TYPES OF P.A.B.X's.

These functions are provided by medium of three main types of P.A.B.X. equipment which constitute almost the entire installations in Australia.

The three types of P.A.B.X. are as follows:—

(i) Unit type P.A.B.X. consisting of C and CA units which have a capacity of 4 exchange lines, 25 extensions and 8 exchange lines, 50 extensions respectively.

(ii) Linefinder type P.A.B.X. ranging from 50 extensions to approximately 300 extensions.

(iii) Uniselector type P.A.B.X. for those cases where the calling rate is in excess of .12 Erlang and for P.A.B.X's. above an initial capacity of 300 extensions.

The C and CA unit type (reference 1) has been a standardised unit since its introduction about 1938, and with the exception of a number of circuit improvements which were necessary to overcome operating weaknesses, has not altered greatly. Because of this, it is not proposed to deal with this type in this article but rather to consider the linefinder and uniselector types where development and recent standardisation has occurred.

In the case of these latter types, apart from several linefinder racks and a number of relay sets, the overall design has varied considerably throughout the Commonwealth, each State providing the complete P.A.B.X. with the same facilities to somewhat different designs. The difficulties of manufacture and supply of the various components were undoubtedly increased under these arrangements and when a decision was reached in 1957 to undertake the installation of P.A.B.X's. conjointly by private contractors and the Department, it became essential to standardise the design of the various types throughout Australia.

It must be appreciated that P.A.B.X. equipment, unlike exchange equipment, is installed in commercial and various other types of buildings, which are primarily designed for purposes other than the installation of such equipment. Difficulties are met with the delivery of equipment to the buildings, the ceiling height between floors and the load which

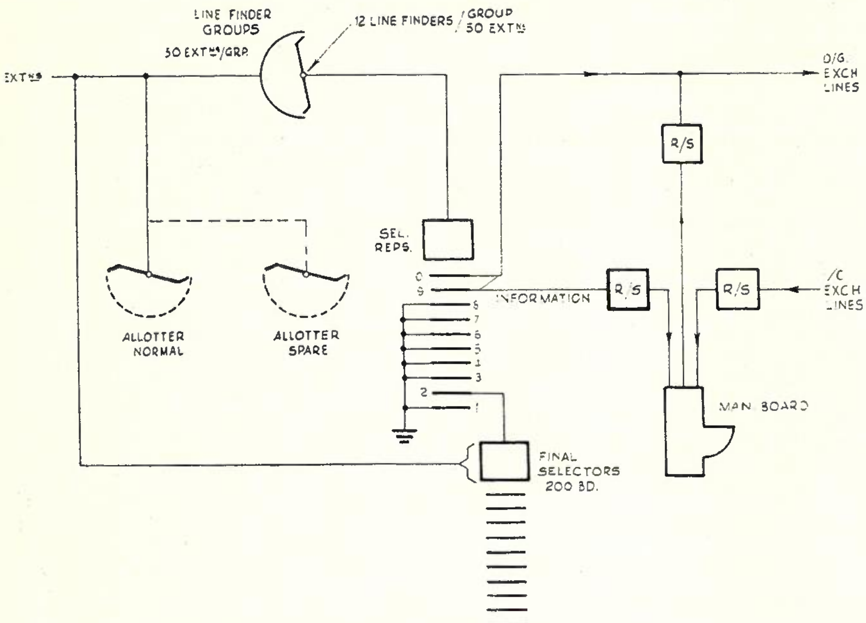


Fig. 1.—Typical Trunking Scheme for Line Finder P.A.B.X.

the floors can handle with safety. Advantage was, therefore, taken in the standardisation of the equipment to provide, as far as possible, for conditions which are likely to be met with modern building design. The extent to which packaging or prefabrication is permissible with these types of P.A.B.X. equipment is limited to the individual units such as racks and manual switchboards and even so it is not always possible to deliver these units to some locations without modifications. In general, 4′ 6″ wide racks are used and the height of these has been standardised at 7′ 9″, enabling their use in the latest buildings having floor to ceiling height of 9′. The superimposed load of such equipment will not exceed 135 lbs. per sq. ft., as compared to 180 lbs. per sq. ft. for standard 10′ 6½″ exchange equipment racks.

LINE FINDER TYPE P.A.B.X.

Fig. 1 shows a typical trunking diagram for a 100 line P.A.B.X. using linefinder primary equipment. Of the items of equipment indicated, the line finders, final selectors, and relay sets are mounted on the one rack, referred to as the linefinder rack. The selector repeaters are mounted on a separate selector repeater rack, whilst the manual switchboard is a floor pattern type. Associated with the installation are other items of equipment such as the Main Distributing Frame, Miscellaneous Apparatus Panel, Power Rectifier, Batteries, etc. It is of interest to note that separate incoming and outgoing exchange line groups are used to meet the higher traffic requirement as compared to the unit type P.A.B.X. which use Bothway exchange lines.

Line Finder Rack: A typical layout of a linefinder rack of 100 extension capacity is shown in Fig. 2. This is a single sided rack 7′ 9″ high x 4′ 6″ wide, and has capacity for 2 shelves of uniselector type linefinders, each shelf having access to a group 50 extensions; 100 L and K relays; 2 relay set shelves, and 2 shelves for accommodating bimotional switches. Normal practice on 3 or more digit systems (that is 100 extensions or greater) is to supply only one shelf initially for bimotional switches (final selectors). For 2 digit systems (90 extensions) the bimotional switches used are final selector repeaters and two shelves are supplied initially whilst the space at the bottom of the rack shown as occupied by the second relay shelf is reserved to mount the ringing and tone machine if supplied. The final selector repeater as its name implies, performs the functions of both a final selector and selector repeater. Each linefinder shelf has a capacity of 12 linefinders and in addition to the normal allotter, a spare allotter with manual changeover is supplied. The "T" switch and its associated circuit, previously part of this type of equipment, have been dispensed with. The modifications to this rack to incorporate the relay set self have, in conjunction with the type of manual switchboard adopted, enabled the relay set rack to be dispensed with for P.A.B.X. installations as a general rule.

Selector Repeater Rack: The selector repeater switch functions both as a selector and repeater and searches over ten outlets per level using 300 point banks. The switches are mounted on a 7′ 9″ x 4′ 6″ rack having a capacity for 60 switches over 6 shelves. The rack provides for the connection of the linefinder groups to these switches and also for

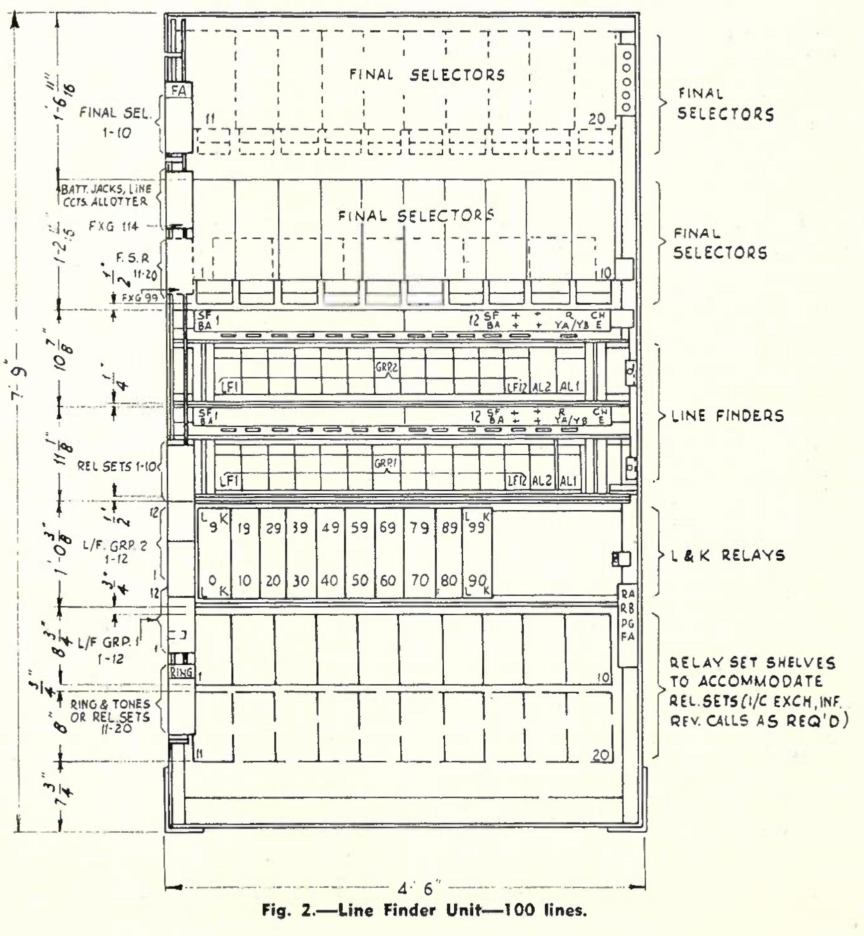


Fig. 2.—Line Finder Unit—100 lines.

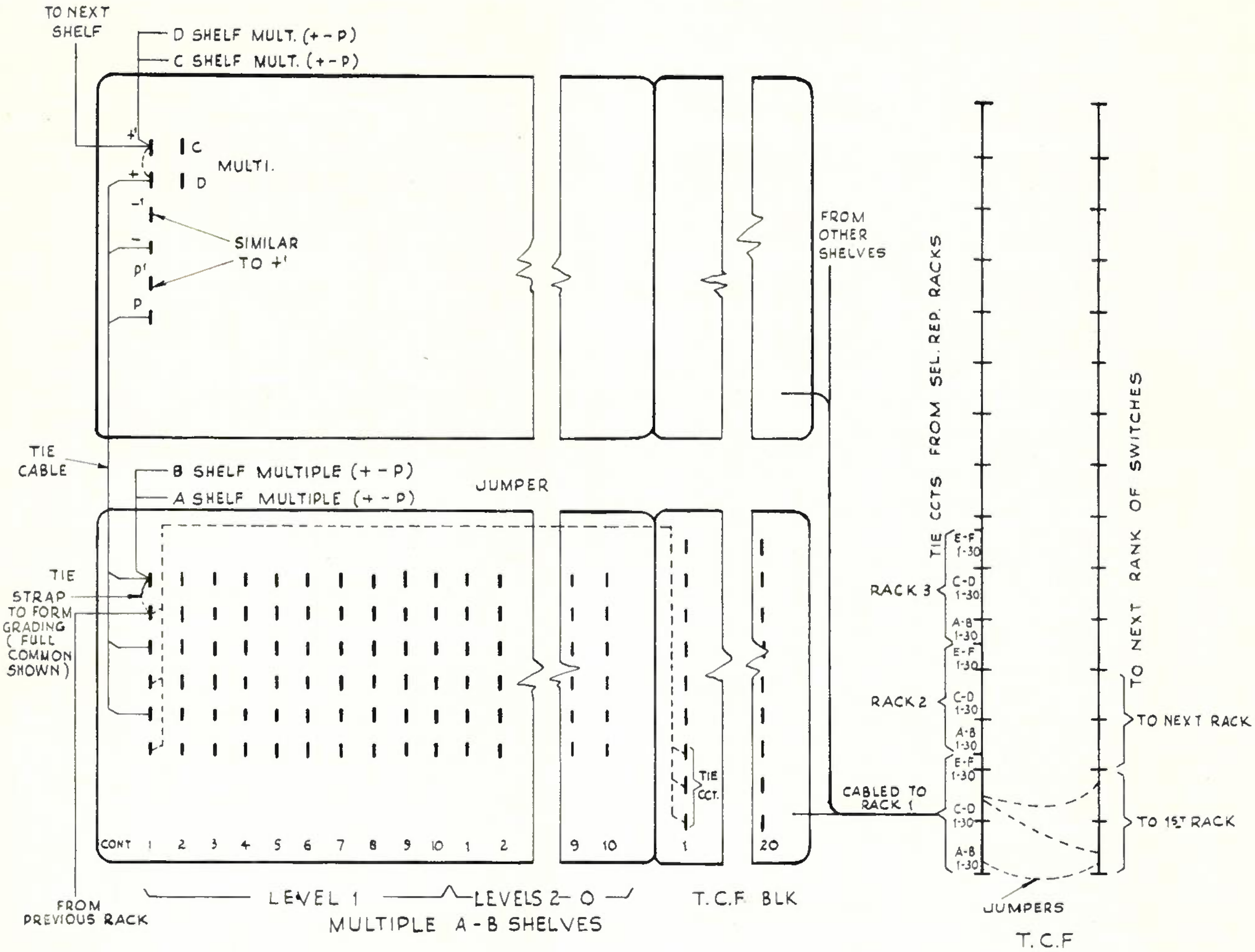


Fig. 3.—Typical Grading and Connecting Method for Selector Repeater Rack.

connecting of the bank outlets to the next rank of switches, relay sets or circuits as the case may be. For linefinder installations a small interconnecting frame is fitted to the top rear of the rack to facilitate the connecting of the linefinder groups to the respective selector repeaters. This frame, apart from being the interconnecting point, enables the outlets to be distributed over the various selector repeater shelves, although each group of 50 extensions on a linefinder rack is rigidly tied to its own individual trunking group. On large installations where a T.C.F. is fitted this is not necessary, the selector repeaters being wired direct from the shelf to the T.C.F. verticals. On small installations, connecting and grading of the bank outlets can be done on the associated tag strips at the rear of the shelf, but on large installations it is necessary to grade the bank outlets, using a somewhat conventional method of tie cable and additional tags on the strip. The outlets of all levels are connected to a T.C.F. via a common outlet cable, where they are connected to their respective groups. A typical illustration of this method is shown in Fig. 3.

Manual Switchboard: The manual switchboard permits the calls from the public network to be acknowledged and switched via an extension multiple field to the appropriate extension. It also switches outgoing exchange calls for those extensions barred automatic exchange access, serves as an information point, provides night switching functions and also performs other minor functions. The number of manual positions provided on an installation is related to the number of incoming exchange, information, revertive and other lines requiring the services of an operator. The basic switchboard is a metal carcase type, the carcase being similar in overall dimensions and manufacture to that used for the standard A.P.O./P.B.X. This type of carcase is most suitable for the mounting of relay sets and accommodation is provided for the cord circuit and telephonist relay sets. On earlier P.A.B.Xs, these relay sets were mounted remotely on a relay set rack and as mentioned previously the design of the switchboard has obviated the need for this rack. Front and rear views of the switchboard are illustrated in Fig. 4. The switchboard is equipped with 16 cord circuits, 2 trunk offering cords and 1 extension test cord (for testing extensions from exchange test desk using an exchange line). The front of the switchboard is divided into two panels, each having capacity for 2 strips of 10 lamps and jacks, for incoming exchange line and other circuits and for 200 jacks of extension multiple. The connection between the relay sets and local lamps and jacks is made via an I.D.F. to facilitate rearrangement. On small installations an I.D.F. using 2,000 type terminating strips mounted on the L.F. rack is used, but where more than 2 manual switchboards are likely to be required, floor mounted I.D.F. verticals are required. A standard multiple provides for a full appearance over every three panels, giving a maximum capacity of 600 lines of extension multiple and 60 terminating lines for this size of switchboard. In practice, however, the maximum upper limit is restricted to 500 lines. For P.A.B.Xs. of larger size, a similar type switchboard, but having the height of the front panel enlarged by 6½ inches is used. This increases the 3 panel multiple capacity to a limit of 1,200 extensions.

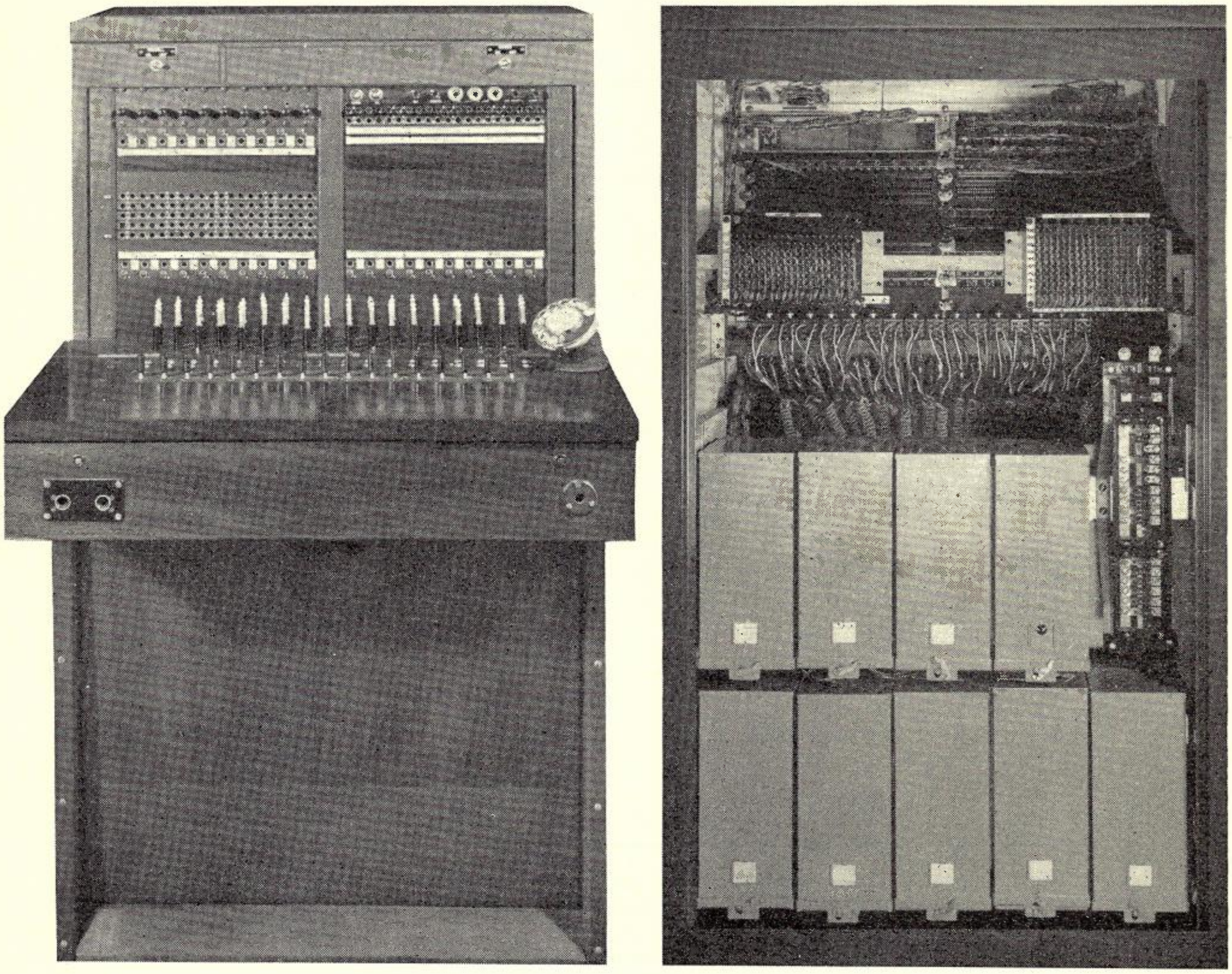


Fig. 4.—Front and Rear Views of Manual Switchboard.

Beyond 1,200 extensions, switchboards having standard C.B. sleeve control and switchboard carcases but fitted for P.A.B.X. requirements are used. On each switchboard, provision is made for 10 revertive circuits, for reverting outgoing exchange calls and also a test, busy, and night switching strip of 20 jacks for outgoing lines. A flexible night switching system is obtained by utilising the third position of the cord circuit speak key to connect the answering and calling cords together. Using the cords under these conditions enables any extension to be connected to any exchange line for night switching purposes.

This type of switchboard was first used in installations in Victoria over the past three years and has proved very successful. Its principal advantages can be summarised as follows:—

(1) A basic standard carcase is used for both P.A.B.X. manual switchboards and A.P.O. P.B.X's.

(2) It is most suitable for the mounting of relay sets.

(3) It is modern and attractive in appearance.

(4) It eliminates the need for a relay set rack.

(5) It reduces space requirements for P.A.B.X. with consequential savings in installation costs.

(6) It is readily grouped in a suite of two or more positions.

Ring and Tone Supply: Standard exchange ringing current and tones are used for P.A.B.Xs. For linefinder type P.A.B.Xs ringing current is supplied from the exchange over a cable pair whilst the busy and dial tones are generated by local oscillators. The periodic interruption for busy tone is obtained by means of relays. Warning tone is supplied by an uninterrupted 400 cycle supply from the busy tone oscillator whilst ringing tone is obtained by modulating 400 cycle continuous tone with $16\frac{2}{3}$ cycle ringing current. Provision is made for a standby ringing and tone machine which comes into operation automatically in the event of failure of ringing current or busy tone. This provision is optional for P.A.B.Xs up to 400 extensions capacity. Similar provision to the above is made on uniselector type P.A.B.Xs, except that for installations above 400 extensions the provision of a standby ring and tone machine is essential. However, for P.A.B.Xs above 600 extensions, ringing current and tones are obtained direct from a ring and tone generator with an alternative machine equipped to automatically take over in the event of failure of the normal machine.

The ring and tone equipment is integrated with the alarm equipment on a Miscellaneous Apparatus Panel for a 50 and 90 extensions installation or a miscellaneous apparatus rack for installation of 100 extension or greater. Where an M.A.P. is used, the standby dynamotor is mounted on the lower section of the linefinder rack whereas on an installation having an M.A.R. the machines are mounted on the lower section of the M.A.R. itself. The control and supervision of the P.A.B.X operation is coordinated on these panels. Local alarms are given in the event of certain failures and provision exists to extend these to the parent exchange.

UNISELECTOR TYPE P.A.B.Xs.

With the exception of the primary extension equipment, the trunking scheme for a uniselector P.A.B.X. is generally similar to that shown in Fig. 2. However, an important difference is that the outlets from the uniselectors are able to be graded over a number of uniselector racks and are not rigidly tied to groups of 50 extensions as in the linefinder case. Apart from the uniselector's greater traffic carrying capacity, the increased efficiency in trunking makes this equipment more economic for installations greater than 300 extensions.

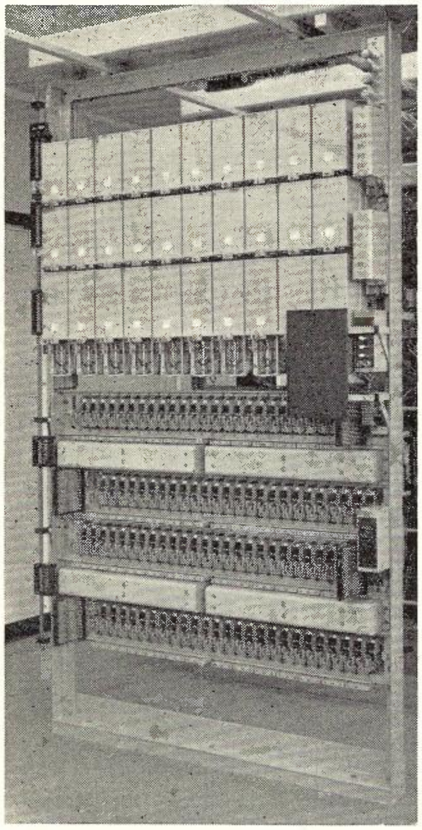


Fig. 5.—Composite Rack, Uniselector type, 100 Extensions.

To meet the primary requirements of this type of P.A.B.X. a 100 line P.A.B.X. composite rack has been developed, and is illustrated in Fig. 5. This consists of a 7 ft. 9 in. x 4 ft. 6 in. rack on which is mounted 100 uniselectors and either 1 shelf of 200 outlet final selectors and 2 relay set shelves each accommodating 10 relay sets or alternatively 2 shelves or 200 outlet final selectors. The alternative design of the rack is based on using one of each type together to give 2 racks with provision for 200 uniselectors, 2 shelves of relay sets and thirty 200 outlet final selectors the final selector bank outlets on each rack being tied. Extension of uniselector P.A.B.Xs in multiples of 100 extensions, which is a realistic requirement, is easily obtainable and at the same time the design gives sufficient capacity to meet the requirements for final selectors often called for on this type of P.A.B.X. A relay set rack is not normally required where these racks are used.

It is most desirable that 5 wiper level uniselectors be used for this type of P.A.B.X. rack to facilitate barred exchange access circuitry. If four wiper level uniselectors are used, the circuit arrangements to provide this facility are more complex.

MAIN DISTRIBUTION FRAME

The M.D.F. is made up of 7′ 9″ single-sided verticals, spaced at 6¾″ centres, each vertical accommodating 100 lines of equipment on the top section and 200 pairs of distribution cable on the lower section. The equipment terminations are made on tag strips whereas the cable distribution is made on to link mountings.

Each link mounting accommodates 50 pairs and provides a ready means of opening a circuit for testing, etc. Only one type of vertical is used on the M.D.F. except that on verticals which are used to terminate the exchange line circuits, the tag strip arrangements must be varied accordingly. Two main jumper rings are provided per vertical to facilitate inter vertical jumpering but additional rings can be fitted on large installations where two may be insufficient. A typical M.D.F. using these verticals is shown in Fig. 6. This type of M.D.F. gives a good balance between equipment and cable requirements and conserves space. Relay Set racks, T.C.Fs and I.D.Fs follow a similar pattern to those used in exchange equipment, the only difference being that the height is limited to 7′ 9″.

POWER SUPPLY

The equipment is operated on standard exchange voltage limits 46-54 volts. The power supply provision includes an automatic voltage control rectifier of appropriate capacity together with one enclosed type battery of suitable capacity, the battery being continuously floated across the load and rectifier. Current practice is to house the battery in a cabinet or cubicle in the equipment room. The design of these cabinets has been revised to accommodate batteries with clear polystyrene cases equipped with specific gravity indicators.

ACCOMMODATION AND LAYOUT OF EQUIPMENT

It is an accepted principle, supported by long experience, that the standard of accommodation for P.A.B.X.s has a bearing on the service obtained from a P.A.B.X., and particular attention has therefore been paid to this aspect. A

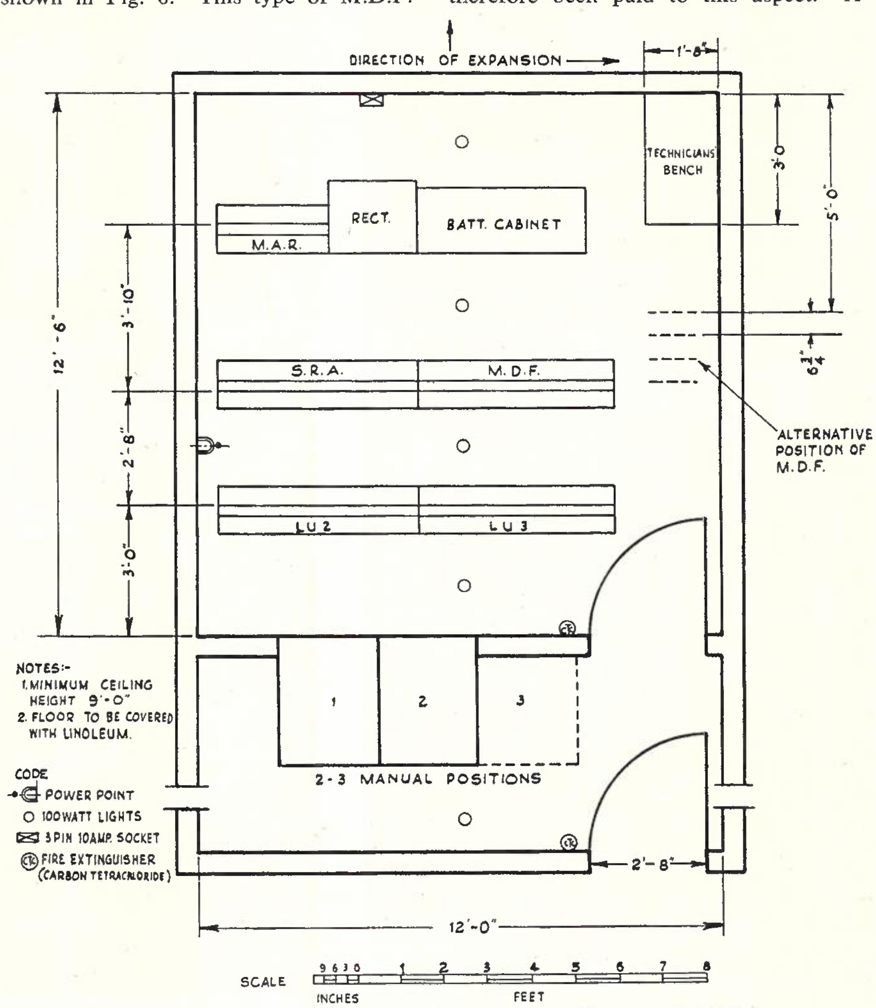


Fig. 7.—Typical Accommodation Layout for 200 Extension P.A.B.X.

typical layout for a linefinder type P.A.B.X is shown in Fig. 7.

Principal features of the layout are the provision of alternate equipment and wiring aisles and the mounting of the power equipment in the same room as the equipment racks. The location of the manual switchboard in a section of the wall between the equipment and manual rooms is of valued assistance to maintenance, as well as effecting considerable saving of space. Provision of adequate lighting and power points is made and the required finish of the room is required to be of a standard which will not raise any hazards from dust and will, in general, inspire a high grade of maintenance for the equipment. There is a growing appreciation by architects and others of the importance of the P.A.B.X. and the increased willingness to provide adequate and suitable accommodation for this service has been most noticeable.

INSTALLATION METHODS

Although it is not intended to cover installation methods, it is fitting that some reference should be made to this aspect. In general, the methods and practices associated with the installation of automatic and C.B. exchanges are followed with some minor variations to cover features which are particular to P.A.B.X.s. Consequently a high standard of installation is achieved and the subsequent maintenance and extension of the equipment are readily facilitated. For the running of cabling either steel fabricated runway or asbestos cement troughing may be used, in each case the same standard of finish being required. On some installations either method may have some economic advantage over the other but in general, there appears to be no great economic advantage between the two. Possibly where plastic covered cables are used troughing may have some advantage because of the difficulties in obtaining a neat appearance with such cables on open runways.

CONCLUSION

The types of equipment referred to are now being installed throughout the Commonwealth and are assisting to facilitate an increased installation rate of P.A.B.X.s. Apart from a few minor items associated with temporary supply difficulties, the advancements in design have not presented any difficulty. Simplification of cabling and wiring has been achieved, whilst the requirement for space to accommodate the P.A.B.X. has been made very reasonable. Additional installation work can be completed in the factory resulting in greater efficiency and lower costs. The time taken in installing the P.A.B.X. on the job, though still considerable, has been considerably reduced.

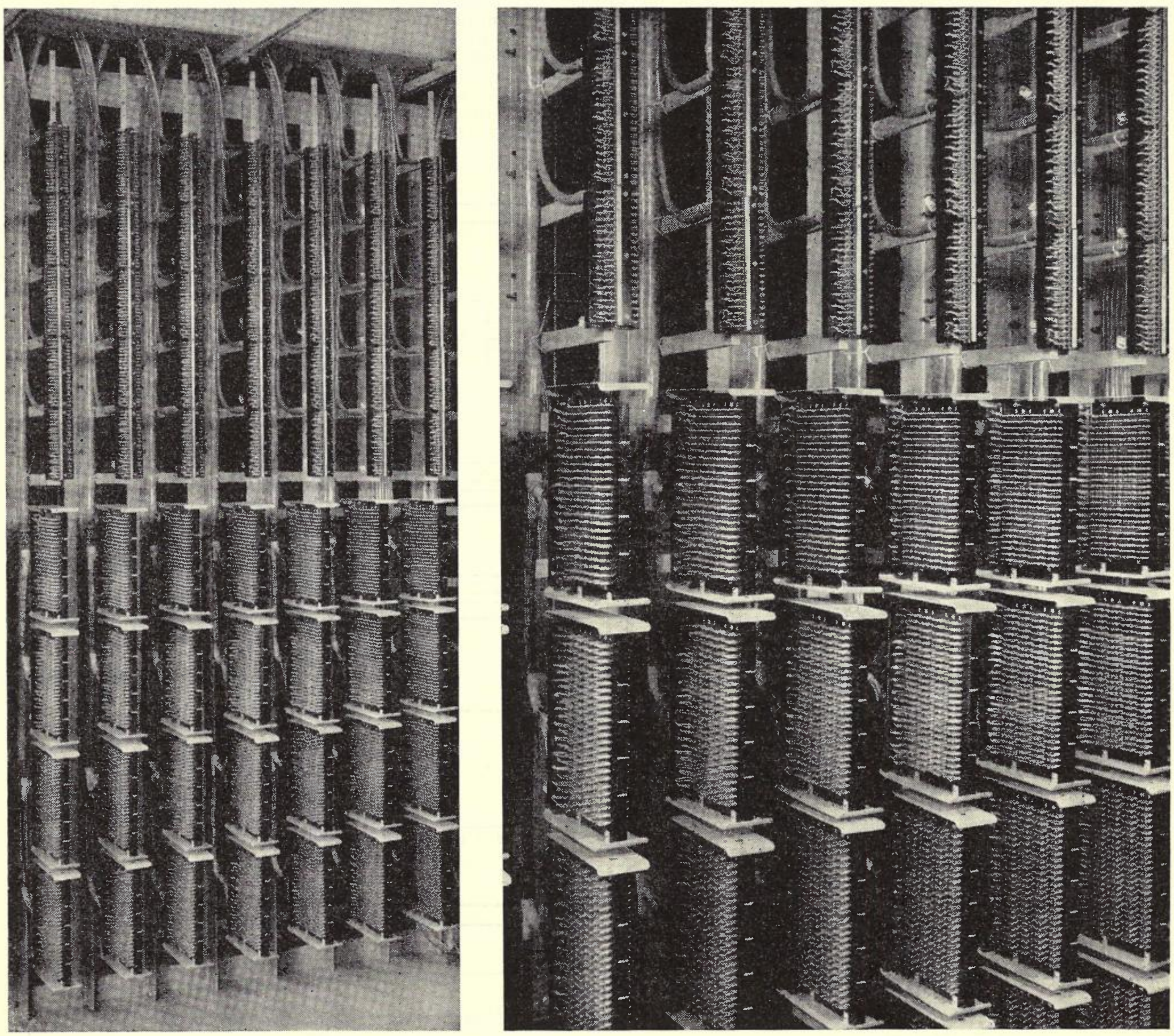


Fig. 6.—Views of M.D.F. using Link Mountings.

REFERENCES

1. Private Automative Branch Exchange Equipment—Unit Type, A. R. Gourley; Telecommunication Journal of Australia, Vol. 2, No. 1, Page 21, June 1958.

2. Line Finder Equipment for P.A.B.X.s, Types E and F, A. R. Gourley; Telecommunication Journal of Australia, Vol. 3, No. 1, Page 36, June 1940.

3. Use of Asbestos Cement Troughing in 2000 Type Automatic Exchanges, E. Sawkins; Telecommunication Journal of Australia, Vol. 3, No. 1, Page 36, June 1940.

4. Tight Corners for P.A.B.X. Racks, E. G. Wormald; Telecommunication Journal of Australia, Vol. 8, No. 1, Page 55, June 1950.

AN INTRODUCTION TO COAXIAL CABLES

*D. BARRY, B.E.**

INTRODUCTION

The announcement by the Post Office of its intention to install a coaxial cable between Sydney and Melbourne has focussed the attention of telecommunication engineers in Australia on this type of transmission medium which, although used for many years by overseas administrations is nevertheless novel in Australia. Since it is planned that the Sydney-Melbourne cable will be the forerunner of a number of coaxial installations it is felt that a brief introduction to coaxial cable technique would be welcomed by those readers not already acquainted with the subject.

Numerous articles on coaxial cables and their associated equipment have been published in journals and text books some of which have been listed in the bibliography and, to these, readers requiring more detail are referred. This article gives a brief history of coaxial cable development, some constructional details, a general discussion of the characteristics of the coaxial cable and some practical aspects of installation and jointing.

HISTORICAL

Prior to 1934 the use of coaxial cables was confined to two distinctly separate fields, submarine telegraph lines and radio aerial feeders, each of which required the transmission of narrow frequency bands only. In 1934 the Bell Telephone Laboratories published two articles (1) & (2) which indicated that they had successfully investigated the possibility of using the coaxial line as a transmission medium for very wide frequency bands with a view to using it as a multi-channel telephone line or as a television relay link. The conclusion reached from this experiment was that the transmission of wide frequency bands over coaxial cables presented no great technical difficulty and their commercial application required only a demand for large groups of telephone circuits or for television relay links.

In 1935 the British Post Office commenced work on the installation of their first commercial coaxial system, between London and Birmingham (3), a route distance of 125 miles. This system commenced carrying traffic in April, 1938. From the literature it appears that the introduction of coaxial cables in America was somewhat slower. In 1938 an experimental television relay circuit over coaxial cables between New York and Philadelphia was established and in 1940 another link over the same route was used to successfully transmit television over a distance of approximately 100 miles. Since 1945 coaxial cable develop-

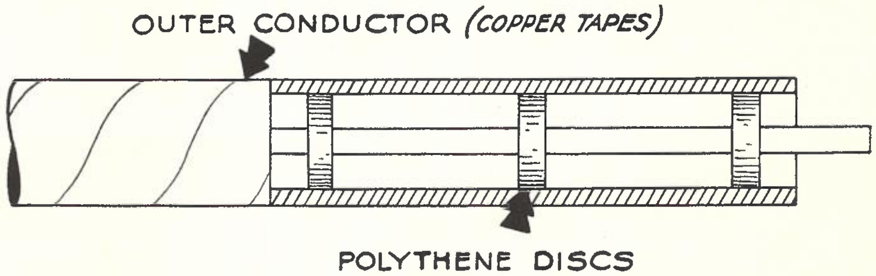


Fig. 1.—Co-axial Construction with Spacing Discs.

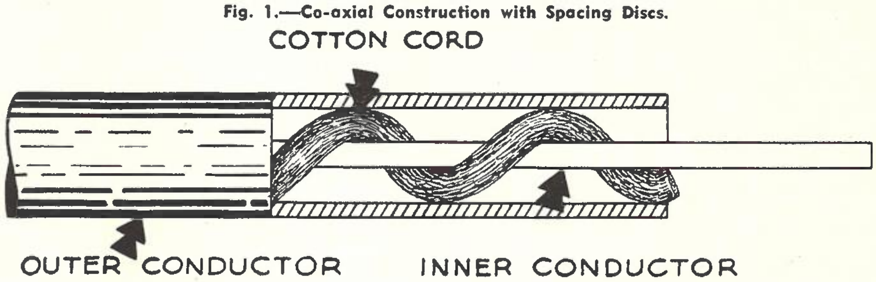


Fig. 2.—Co-axial Construction with Spinal Cord Separation.

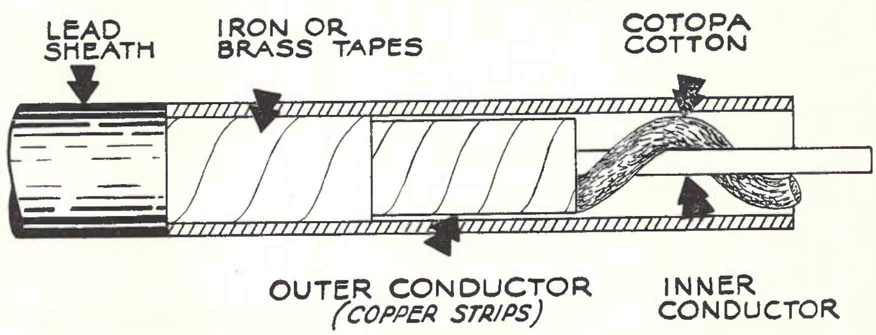


Fig. 3.—Early Experimental Co-axial Cable.

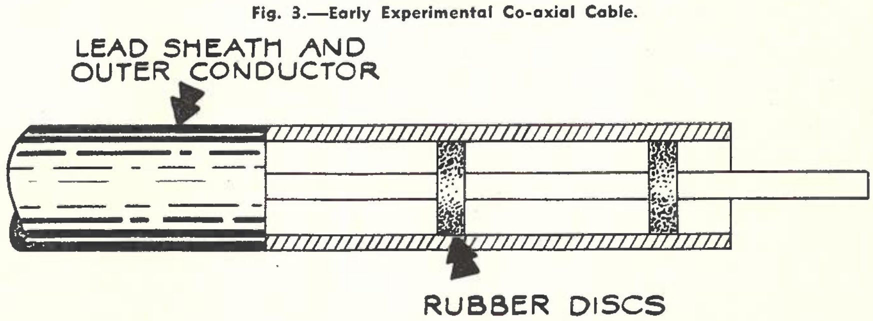


Fig. 4.—Another Early Experimental Co-axial Cable.

*Mr. Barry is a Group Engineer in the Planning Branch, Engineering Division, New South Wales.

ment has been very rapid in Britain, America and Europe, and coaxial cables are now regarded as standard transmission media. The number of channels transmitted has been progressively increased. The present maximum for American systems is 1860 telephone channels on each pair of tubes provided by the Bell Company's L3 Coaxial System. Alternatively, in lieu of 1260 of these channels a television channel can be provided in each direction. Systems providing 2700 channels on one pair of tubes have also been developed recently by British and European manufacturers.

COAXIAL CABLE CONSTRUCTION

A coaxial line consists of an inner conductor (which is usually a solid copper wire, but may be a hollow tube) surrounded by a concentric outer conductor (which may be copper, lead, aluminium, etc. and may be formed from a single metal strip or from spirally wound overlapping tapes). The inner conductor is separated from the outer by means of some insulating medium which may be

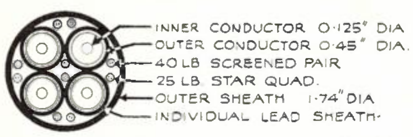


Fig. 5.—Cross-section of Original London-Birmingham Cable.

solid or may be discs of some low loss material such as polythene or may be a cotton cord wound spirally around the inner conductor (Figs. 1 and 2). It is usual practice to lap up two or more coaxial tubes in the one common sheath and to include within the sheath a number of paper insulated pairs which may be used as low frequency trunk lines and for supervisory and control purposes.

Figs. 3 and 4 show two single tube cables used in early experiments. In Fig. 3, the outer conductor consisted of overlapping copper tapes held in place by a binding of brass or iron tapes. The insulating spacer was a cotopa cotton string wound spirally around the inner conductor which was a solid copper wire. In Fig. 4, the outer conductor is a lead sheath and is separated from the copper inner conductor by rubber discs. Since lead is a poorer conductor than copper it was necessary to use a larger diameter outer conductor to obtain equivalent transmission efficiency. Lead is also inferior to copper in its shielding properties and to obtain the same degree of

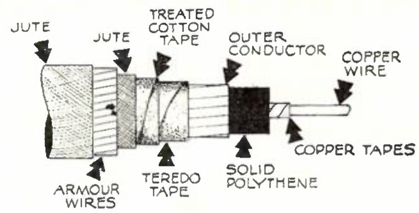


Fig. 7.—Trans-Atlantic Submarine Cable.

shielding the lead tube was made thicker than would have been necessary with a copper tube.

Fig. 5 shows the layout of the first British composite cable which was laid between London and Birmingham. It consisted of 4 coaxial tubes with the interstices between the tubes occupied by six 25 lb. star quads and four 40 lb. screened pairs. The centre conductor of each coaxial pair was a solid copper wire and the outer conductor was formed from 12 spirally wound interlocking copper tapes. Cotopa cotton was used to separate inner and outer conductors. The outer conductor was bound by thin brass tapes and a thin lead sheath was extruded over the brass bindings. All pairs were wrapped with paper and a common lead sheath was formed around them.

A modern 6 tube composite cable, similar to the type proposed between Sydney and Melbourne is illustrated in Fig. 6. The centre core of quad cable and the interstitial pairs are used for minor trunk, supervisory and control purposes. The inner conductor of the coaxial pair is a copper wire 0.104 inch diameter. The .375 inch diameter outer conductor is formed from a single copper tape bent round and butt joined, the edges of the tape being serrated to prevent overlapping. Separation is by high grade polythene discs 0.075 inch thick spaced at 1.3 inch intervals. Steel binding tapes, to provide mechanical strength and additional shielding, are wrapped around the outer conductor and a common lead sheath is provided for coaxials and quads.

The recently laid Trans-Atlantic submarine telephone cable is shown in Fig. 7. It is included here because it represents a typical modern submarine coaxial structure and incorporates some interesting and novel features. The centre conductor consists of a solid wire wrapped with three copper tapes. This type of structure was used to provide a conductive path across a possible break in any of its elements due to a hidden defect such as inclusion of foreign material in the copper. A crack-resistant type of polythene was used as the solid dielectric and the outer conductor consisted of six copper tapes applied helically over the core. A thin copper tape was wound over the outer conductor to protect the cable against teredo attack. Jute and armouring wrappings were then placed round the cable for protection and mechanical strength.

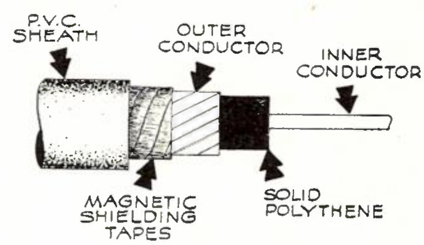


Fig. 8.—B.P.O. Co-axial Interruption Cable.

The standard type of British interruption cable used for temporary repair purposes is illustrated in Fig. 8. It is a single tube with solid polythene dielectric and a P.V.C. sheath. Magnetic shielding tapes are provided between the outer conductor (which consists of copper tapes) and the sheath to reduce the risk of interference. The inner conductor diameter is smaller than would be necessary with polythene disc separation in order to obtain a characteristic impedance of 75 ohms and thus avoid an impedance mismatch when inserted in a normal 75 ohm cable.

In modern coaxial cables the early practice of forming the outer conductor from interlocking copper tapes has been abandoned, as it was found that this structure was unstable and resulted in an increase of attenuation with age due to an increase in the contact resistance of the tapes. The separation of inner and outer conductors is now almost universally provided by polythene discs as the low dielectric loss means lower attenuation at higher frequencies than cotopa cotton or hard rubber. The exceptions are submarine and interruption cables where solid polythene is used to provide greater resistance to distortion. Solid

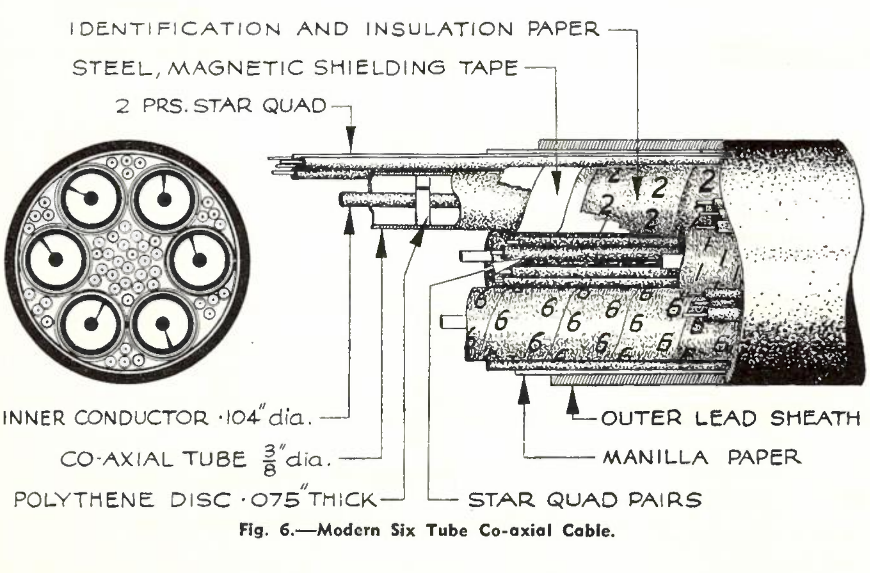


Fig. 6.—Modern Six Tube Co-axial Cable.

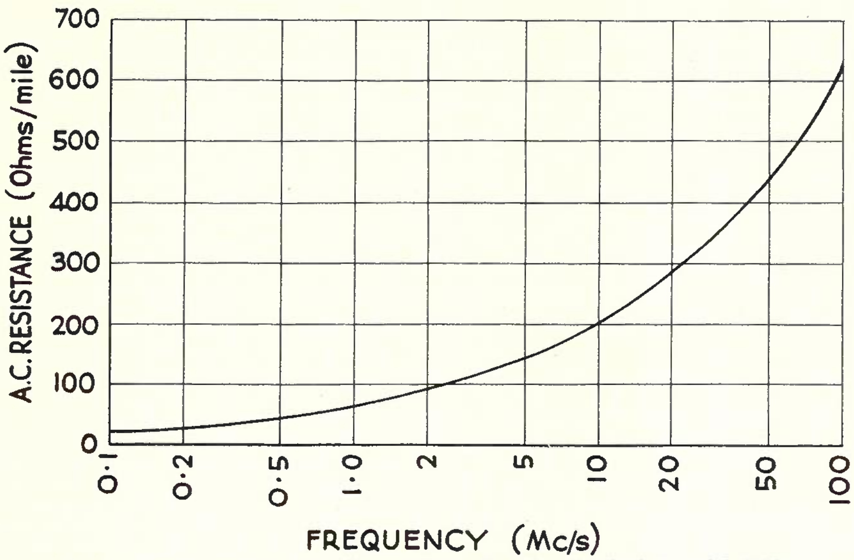


Fig. 9.—Resistance/Frequency Characteristic of British Standard Co-axial Cable.

small diameter cables of about ⅛ inch diameter are also being developed for application on routes where small numbers of telephone circuits only are required. An outer conductor diameter of 0.375 inch has been chosen universally as standard for major systems as it represents an economic compromise between cable and equipment costs. However, as will be shown later, the attenuation of a coaxial cable is inversely proportional to the diameter of the outer conductor and it was found desirable for certain applications to increase this diameter. A cable having two 0.975 inch and four 0.375 inch tubes was laid between London and Birmingham in 1948, the larger tubes being provided for the possible future transmission of colour television. However no further cables of this type will be provided in future.

It will be shown later that there is a ratio between inner diameter of outer conductor and outer diameter of inner conductor which gives optimum transmission efficiency. This ratio for copper inner and outer conductors is 3.59.

WHY COAXIAL CABLES ARE USED

The characteristics of coaxial cables which have resulted in their widespread use as trunk and television lines are:

(i) **Low Attenuation.** The attenuation of coaxial cables particularly at high frequencies is very much lower than that of ordinary paper insulated cable and approaches that of open wire construction.

(ii) **H. F. Shielding.** The outer conductor of a coaxial cable provides a very effective high frequency shield, resulting in freedom from external interference. This shielding also prevents the system under consideration from interfering with neighbouring systems. This enables go and return tubes to be included in the one cable, as compared with two cables or a frequency division system employed in other cable carrier applications. The coaxial line is unbalanced and hence the out-of-balance problems associated with ordinary cable or aerial wires are not encountered.

(iii) **Simple Construction.** The simple construction and the large channel carrying capacity of coaxial cables means reduced installation (jointing, terminating and balancing) costs and facilitates repairs. The overall cost of providing such cables is also generally less than that of paper insulated carrier cables which have been used on most trunk cable routes in this country up to the present.

LINE CHARACTERISTICS OF COAXIAL CABLES

So that a quantitative appreciation of the transmission characteristics can be obtained, a brief discussion of some of the more interesting and important aspects of the characteristics follows. Formulae have been stated without derivations but these are readily available in the texts listed. It is customary to use equivalent characteristics to those of an ordinary cable or aerial line, that is resistance, inductance, capacitance and conductance per unit length.

Resistance per Unit Length: The high frequency resistance of the line will vary appreciably from the D.C. value because of the tendency of the high frequency current to concentrate on the outer surface of the inner conductor and on the inner surface of the outer conductor. This results in the high frequency "skin effect" increase of resistance with frequency. A fairly accurate value of the high frequency resistance of a coaxial pair is given by the formula:

$$R = \sqrt{\frac{f}{10^7}} \times \left[\frac{1}{a\sqrt{\sigma_a}} + \frac{1}{b\sqrt{\sigma_b}} \right]$$

Where R = resistance in ohms/metre
f = frequency in cycles/second
a = outer radius of inner conductor in metres
b = inner radius of outer conductor in metres
σ_a = Conductivity of inner conductor in mhos/metre
σ_b = Conductivity of outer conductor in mhos/metre

For any given cable the resistance varies as the square root of the frequency and Fig. 9 is a resistance/frequency curve plotted from values obtained by using the above formula for the British Standard ⅜ inch cable with both conductors of copper (σ_{copper} = 5.8 × 10^7 mhos per metre)

Inductance per Unit Length: The total inductance of the line is made of two separate inductances, namely:

(i) The internal inductance, L_I, within the body of the conductor material.

(ii) The external inductance, L_E, associated with the dielectric between conductors.

$$L_I = \frac{1}{2\pi\sqrt{10^7 f}} \left[\frac{1}{a\sqrt{\sigma_a}} + \frac{1}{b\sqrt{\sigma_b}} \right]$$

henrys/metre

$$L_E = \frac{1}{2\pi} u_o \, . \log_e \frac{b}{a} \text{ henrys/metre}$$

$$= 2 \times 10^{-7} \log_e \frac{b}{a} \text{ henrys/metre since}$$

u_o = permeability of free space = $4\pi \times 10^{-7}$ henrys/metre.

Then $L_{Total} = L_I + L_E$.

Now L_I decreases as the square root of the frequency and at high frequencies is negligible compared with L_E. Fig. 10

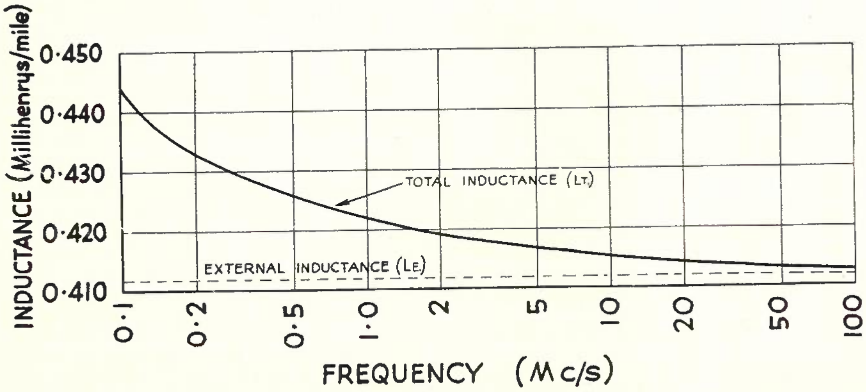


Fig. 10.—Inductance/Frequency Characteristic.

is a plot of total inductance against frequency for the $\frac{3}{8}$ inch cable and shows that L_I can be neglected at high frequencies, whence the total inductance can be written

$$L = 2 \times 10^{-7} \log_e \frac{b}{a} \text{ henrys/metre.}$$

Capacitance per Unit Length: The capacitance per unit length of a coaxial line is given by the formula

$$C = \frac{1}{1.8 \times 10^{10}} \times \frac{\frac{\varepsilon}{\varepsilon_0}}{\log_e \frac{b}{a}}$$

farads/metre

where $(\frac{\varepsilon}{\varepsilon_0})$ is the relative permittivity of the dielectric medium. If the effect of the polythene discs is neglected and the dielectric is considered all air, $\frac{\varepsilon}{\varepsilon_0} = 1$ and the capacity of the British standard $\frac{3}{8}$ inch tube becomes

C = 0.070 microfarads per mile.

A more accurate value for the capacitance of the standard tube can be obtained by making a correction for the effect of replacing some of the air by the polythene discs. This can be done by using the term

$$\left[1 + \left(\frac{\varepsilon}{\varepsilon_0} - 1 \right) \frac{D}{S} \right]$$

in place of $\frac{\varepsilon}{\varepsilon_0} = 1$ in the above formula

where

D = disc thickness = 0.075 inch.
S = disc spacing = 1.3 inch.
$\frac{\varepsilon}{\varepsilon_0}$ for polythene = 2.3.

The capacitance of the standard $\frac{3}{8}$ inch tube then becomes C = 0.075 microfarads/mile.

Conductance per Unit Length: The conductance per unit length is given by the formula

$$G = \frac{2\pi f \cdot \frac{\varepsilon}{\varepsilon_0} \tan\delta}{1.8 \times 10^{10} \cdot \log_e \frac{b}{a}} \text{ mhos/metre}$$

For good dielectrics tan δ = the power factor of the dielectric material which

for air = 0
for polythene = 0.0003

If we neglect the effect of the discs G = O.

A more accurate value may be obtained by allowing for the effect of the polythene discs by making the following substitutions in the above equation.

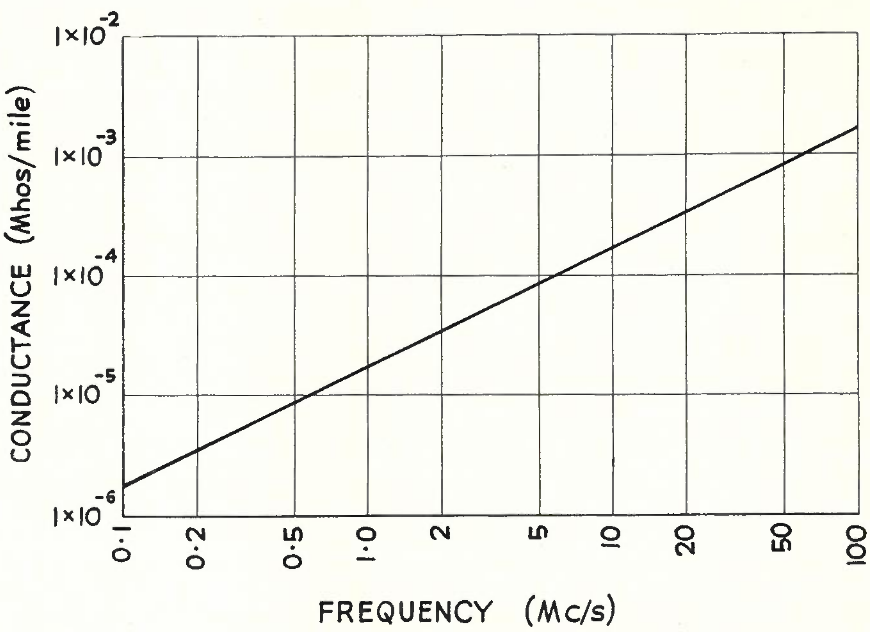


Fig. 11—Conductance/Frequency Characteristic.

(1) $\left[1 + \left(\frac{\varepsilon}{\varepsilon_0} - 1 \right) \frac{D}{S} \right]$ for $\left(\frac{\varepsilon}{\varepsilon_0}\right)$

(ii) $\dfrac{\frac{\varepsilon}{\varepsilon_0} \frac{D}{S} \tan\delta}{\left[1 + \left(\frac{\varepsilon}{\varepsilon_0} - 1 \right) \frac{D}{S} \right]}$ for tan δ

Fig. 11 is a conductance versus frequency curve for the standard $\frac{3}{8}$ inch tube from which it can be seen that the leakage resistance between conductors is very high.

However, the formula for G above shows that since G is proportional to frequency it is essential to keep the amount of solid material to a minimum to avoid large losses in the dielectric at high frequencies.

Characteristic Impedance: The characteristic impedance is given by the usual formula

$$Z_0 + \sqrt{\frac{R + j\omega L}{G + j\omega C}} \text{ ohms.}$$

Now R increases as $\sqrt{f}$ and $\omega L = 2\pi f L$ increases as f.

Hence, at high frequencies R becomes negligible compared with $2\pi f L$.

Also $\frac{G}{\omega C} = \tan\delta$, which for the dielectric, should approximate zero.

Hence the characteristic impedance, in these circumstances, can, with a fair accuracy, be written

$$Z_0 = \sqrt{\frac{L}{C}} \text{ ohms}$$

This expression for Z_0 is real and hence Z_0 is a pure resistance and the voltage and current in an infinite line or in a correctly terminated line are in phase at all points along it.

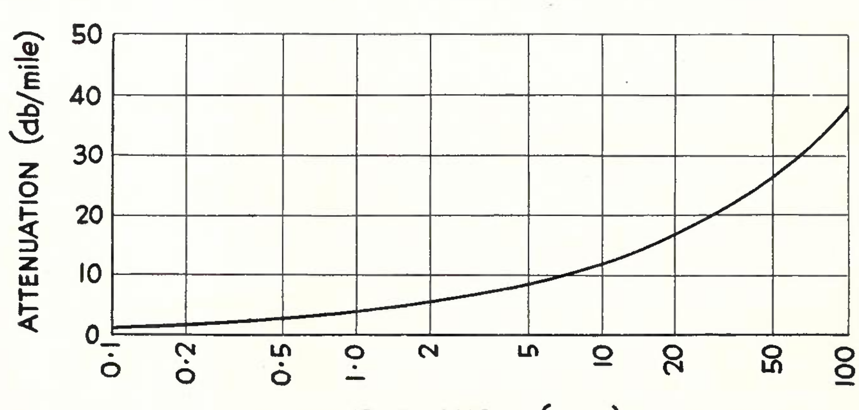


Fig. 12.—Attenuation/Frequency Characteristic.

Substituting for L and C in the above expression gives

$$Z_o = \frac{60 \log_e \frac{b}{a}}{\frac{\varepsilon}{\varepsilon_o}}$$

which, if the dielectric is considered all air reduces to

$$Z_o = 60 \log_e \frac{b}{a}$$

Attenuation and Phase Constants: The propagation constant, P, is given by

$P = \sqrt{(R + j\omega L)(G + j\omega C)} = \alpha + j\beta$

Where α is the attenuation constant and β is the phase constant.

For low loss lines at high frequencies,

$$\frac{R}{\omega L} \ll 1 \quad \& \quad \frac{G}{\omega C} \ll 1$$

so that approximate values of α and β can be obtained by retaining up to second order terms in a binominal expansion of the above equation.

This gives

$$\text{(i)}\ \alpha \doteqdot \frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}}$$

$$= \frac{1}{2}\left[\frac{R}{Z_o} + G Z_o\right] \text{ nepers/metre}$$

$$= 4.34\left[\frac{R}{Z_o} + G Z_o\right] \text{ decibels/metre}$$

where R and G are the resistance and conductance per metre respectively. Fig. 12 is an attenuation/frequency plot for $\frac{3}{8}$ inch cable.

(ii) $\beta \doteqdot \sqrt{LC}$ radians/metre where L & C are the inductance and capacitance per metre respectively.

Now $\beta = \frac{2\pi}{\lambda}$ where λ is the wavelength, hence $\lambda = \frac{1}{f\sqrt{LC}}$ metres and the velocity of the principal wave $v = \lambda f = \frac{1}{\sqrt{LC}}$

Neglecting L internal this gives $v = \sqrt{\frac{\varepsilon}{\varepsilon_o}}$ x 3 x 10^8 metres per second which for air dielectric becomes the velocity of light, 3 x 10^8 metres/second.

If we substitute for R, G & Z_o in the equation

$$\alpha = \tfrac{1}{2}\left[\frac{R}{Z_o} + G Z_o\right]$$

this equation takes the form $\alpha =$

$$\left[\frac{k_1}{\log_e \frac{b}{a}} \sqrt{f} \times \left(\frac{1}{a\sqrt{\sigma_a}} + \frac{1}{b\sqrt{\sigma_b}}\right)\right] + k_2 f$$

The first term in this equation is the attenuation caused by ohmic losses in the conductor and is seen to increase as the square root of the frequency. The second term is the attenuation caused by losses in the dielectric and increases as the frequency. The importance, at high frequencies, of using a low loss insulating material and of keeping this material to a minimum can be appreciated. For the frequencies used in carrier telephony the dielectric losses are relatively unimportant in modern cables. Fig. 12 shows how attenuation of standard coaxial cable varies with frequency.

Optimum Diameter Ratio: The equation for α above shows that the attenuation varies with the ratio b/a and indicates that a value of this ratio can be found which will give a minimum attenuation.

Equating the partial differential coefficient $\frac{\partial \alpha}{\partial \frac{b}{a}}$ to zero results in $\log_e \frac{b}{a} = 1 + \frac{a}{b}\sqrt{\frac{\sigma_a}{\sigma_b}}$.

For copper inner and outer conductors this gives a value of $\frac{b}{a} = 3.59$ for minimum attenuation.

Substituting this value in the formula $Z_o = 60 \log_e \frac{b}{a}$ (assuming all air dielectric) gives a value of 76.7 ohms for the characteristic impedance.

In the standard $\frac{3}{8}$ inch cable, if the effects of the polythene discs is to be taken into account the formula becomes

$$Z_o = \frac{60 \log_e \frac{b}{a}}{\sqrt{1 + \left(\frac{\varepsilon}{\varepsilon_o} - 1\right)\frac{D}{S}}}$$

$$= \frac{76.7}{\sqrt{1.075}} = 74 \text{ ohms.}$$

Temperature Coefficient of Attenuation: The temperature coefficient of resistance of a coaxial line varies with frequency and for a copper tube at high frequencies approaches half the D.C. value of 0.004 per degree Centigrade.

Since $\alpha = \tfrac{1}{2}\left[\frac{R}{Z_o} + G Z_o\right]$

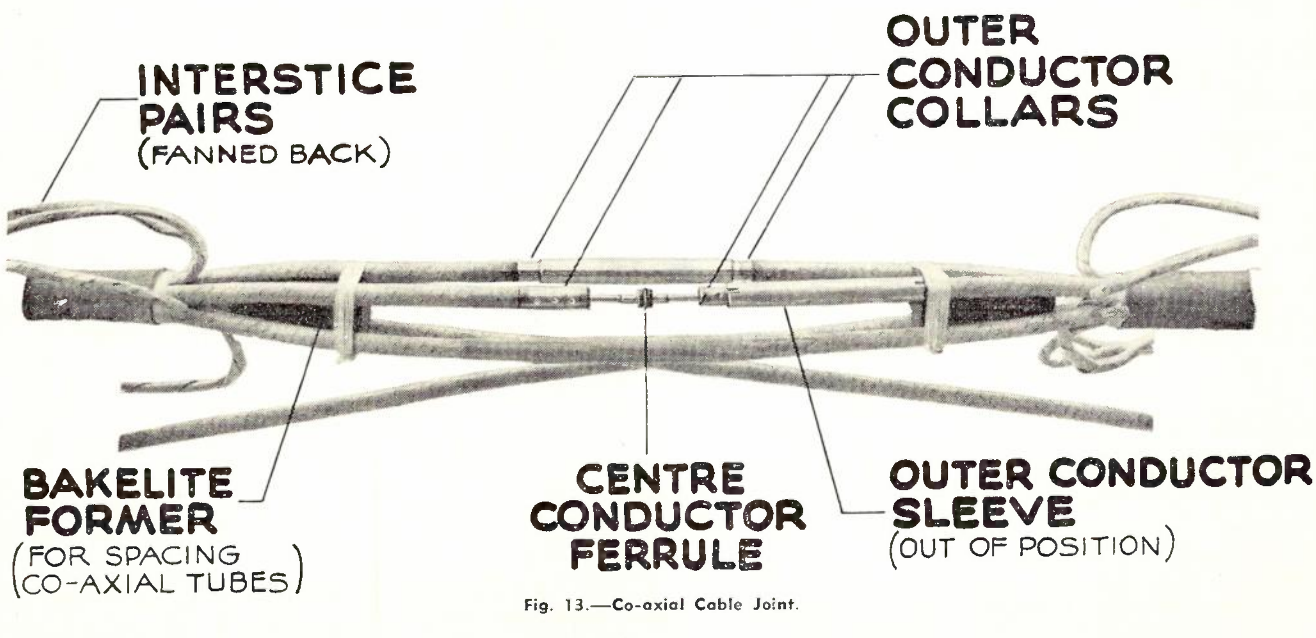


Fig. 13.—Co-axial Cable Joint.

if the dielectric losses are small, the temperature coefficient of attenuation is equal to the temperature coefficient of resistance. As temperature variations of 10-15° C. are not exceptional, it is necessary to make provision in the repeater equipment for equalisation of the attenuation variations.

INSTALLING COAXIAL CABLES

Coaxial cables are manufactured with or without armouring and may be installed by the usual methods provided adequate precautions are taken during installation to avoid mechanical damage to the cable. Although the mole plough has been used extensively overseas to install coaxial cables, it was decided after careful consideration not to use this method for the installation of the Sydney-Melbourne cable, but to provide a trench along the whole of the buried cable sections so that safe bedding of the cable would be assured. Particular care must be taken to avoid crushing or indentation of the cable during and subsequent to installation as these may result in electrical discontinuities which could adversely affect the transmission, particularly of television programmes. Providing bedding layers of rock free soil under and over the cable and ensuring adequate depth of laying are particularly important in this regard. Bending of the cable about small radii may also distort the tubes and should be avoided. A minimum radius of curvature for bends is usually specified by the manufacturer.

The importance of coaxial cables, because of their large channel carrying capacity, makes it essential that the installation be thoroughly reliable so as to avoid as far as possible any subsequent cable failures. To this end every aspect of the route planning and installation should be considered in detail well in advance of the commencement of work.

JOINTING OF COAXIAL CABLES

The coaxial joint must be designed to avoid electrical discontinuities by correct proportioning of the components of the joint to obtain the required value of characteristic impedance. It must also be mechanically strong and should be simple enough to enable it to be made readily in the field. The British standard jointing method is described here. (Fig. 13). In this method the centre conductors are joined by inserting their ends in a centre conductor ferrule, which is then filled with solder. The outer conductors are joined by an outer conductor sleeve which is soldered to collars, the collars being sealed previously over the cut ends of the outer conductors.

To avoid distortion of the polythene discs during jointing, a number of the discs are extracted and replaced by ebonite discs prior to the application of any heat. The joint is sealed by a lead sleeve and may be housed in a pit or manhole or buried in the ground in accordance with usual practice.

CONCLUSION

It is recognised that the foregoing article is brief and incomplete and that no mention has been made of the terminal and repeater equipment which together with the cable make up the complete carrier installation. However it is hoped that the information contained in the article will provide an introduction to coaxial cables as it seems certain that in the near future their use throughout Australia will be widespread.

FURTHER READING

1. The Electromagnetic Theory of Coaxial Transmission Lines and Cylindrical Shields; Bell System Technical Journal, October 1934.

2. System for Wide Band Transmission over Coaxial Cables; Bell System Technical Journal, October 1934.

3. Wideband Transmission over Coaxial Cables; Institution of Post Office Electrical Engineers' Paper No. 190.

4. A New Coaxial Cable Joint; Post Office Electrical Engineers' Journal, April 1952.

5. Modern Coaxial Cable Technique in Great Britain; Electrical Communications, September 1953.

6. Setting Up and Testing a Coaxial Line Link for Telephony; Post Office Electrical Engineers' Journal, July 1956.

7. A New 4 Mc/s Coaxial Line Equipment; Post Office Electrical Engineers' Journal, April 1957.

8. A Pulse Echo Test Set for the Quality Control and Maintenance of Impedance Uniformity in Coaxial Cables; Post Office Electrical Engineers' Journal, January 1952.

9. Field and Waves in Modern Radio; Ramo & Whinnery (Wiley).

10. High Frequency Transmission Lines; Willis Jackson (Methuen).

The Ruskin Press Pty. Ltd.
39 Leveson Street,
North Melbourne