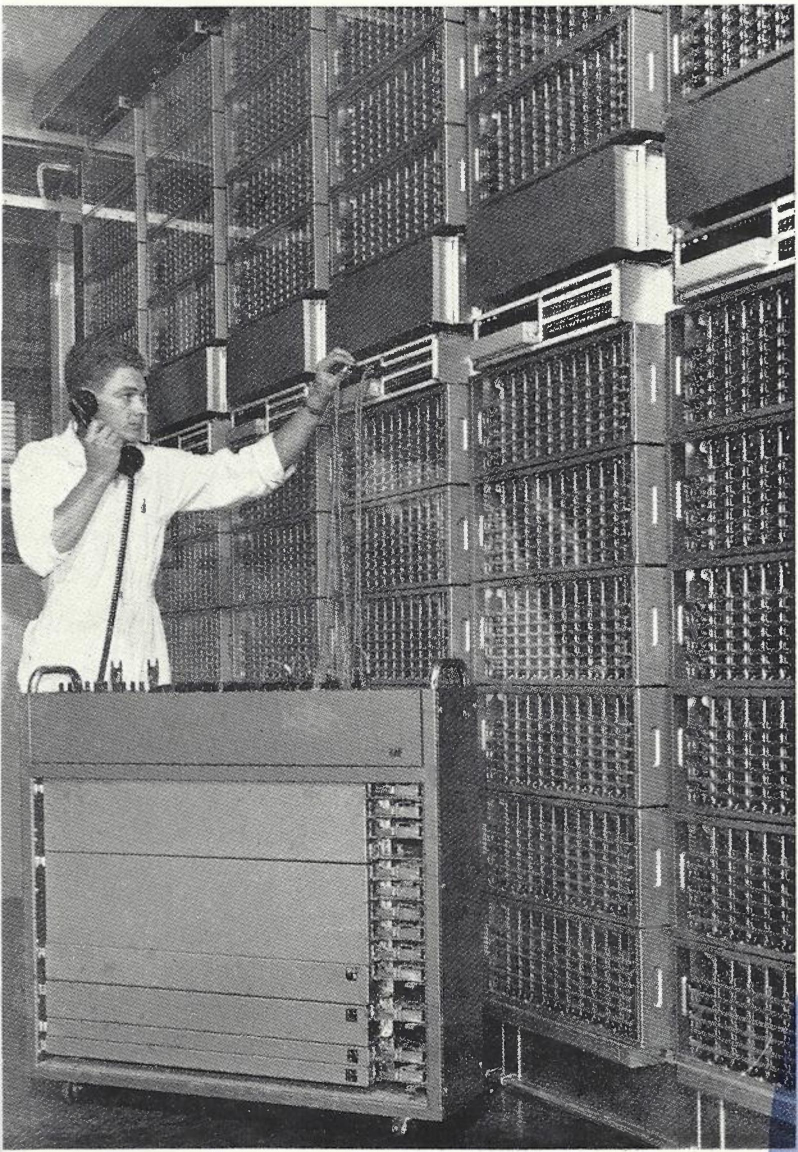
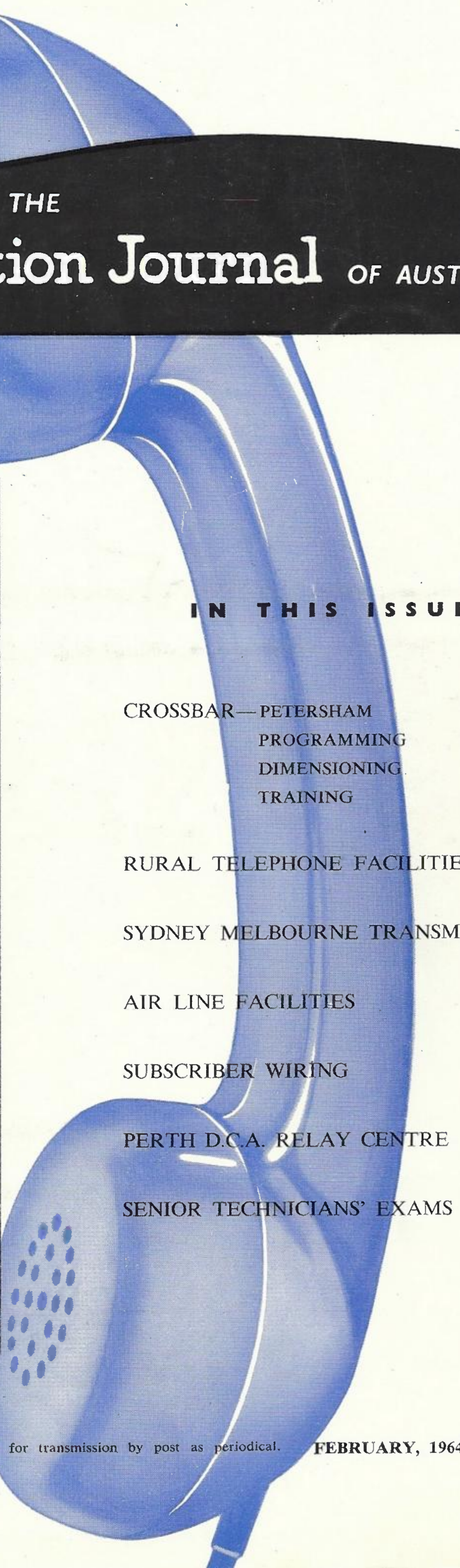
THE
Telecommunication Journal OF AUSTRALIA





IN THIS ISSUE

VOL. 14, No. 3 Registered at the General Post Office, Melbourne, for transmission by post as periodical. FEBRUARY, 1964

The
TELECOMMUNICATION JOURNAL
of Australia

VOL. 14, No. 3

Registered at the General Post Office, Melbourne, for transmission by post as a periodical.

FEBRUARY, 1964

BOARD OF EDITORS

Editor-in-Chief:
N. M. MACDONALD, B.Sc., M.I.E.Aust.

Editors:
R. C. M. MELGAARD, A.M.I.E.Aust.
E. R. BANKS, B.E.E., A.M.I.E.Aust.
D. P. BRADLEY, B.Sc., B.Com., A.M.I.E. Aust.
V. J. WHITE, B.A.(Hons.), B.Sc., A.M.I.E. Aust., M.Br.Ps.Soc.

Sub-Editors:
European Agent:
P. S. BETHELL, B.Sc., Dip.P.A.
Australia House, London.
Headquarters Representatives:
R. D. KERR
J. W. POLLARD, B.Sc., A.M.I.E.Aust.
K. B. SMITH, B.Sc., A.M.I.E.Aust.
H. TREZISE
H. S. WRAGGE, B.E.E., M.Eng.Sc., A.M.I.E.E., A.M.I.E.Aust.
D. A. BROOKE, B.Sc.
R. W. E. HARNATH, A.R.M.T.C., Grad. I.E.Aust.
New South Wales Representatives
G. R. LEWIS, B.E., A.M.I.E.Aust.
M. J. POWER, A.M.I.E.Aust.
Victorian Representatives
E. J. BULTE, B.Sc.
W. R. TRELOAR, A.M.I.E.Aust.
Queensland Representative
C. R. ANDERSON, A.M.I.E.Aust.
South Australian Representative
K. VAWSER, B.E., Grad.I.E.E., Grad.I.E. Aust.
Western Australian Representative
J. MEAD, Dip.E.E., A.M.I.E.Aust., A.I.E.E.

Secretary:
R. G. KITCHENN, B.Sc. (Eng.), A.M.I.E.E., A.M.Brit.I.R.E.

CONTENTS

This Journal is issued three times a year by the Telecommunication Society of Australia. A year's subscription commenced with the June issue; succeeding numbers are published in October and February. A complete volume comprises six numbers issued over two years, and a volume index appears in No. 6 of each volume.**

Residents of Australia may order the Journal from the State Secretary* of their State of residence; others should apply to the General Secretary*. The subscription fee is 10 shillings per year (Australian currency) or 4 shillings each for single numbers. Back numbers are available at the rate of 10 shillings for any three, or 4 shillings for single numbers. Remittances should be made payable to the Telecommunication Society of Australia; exchange need not be added to Australian cheques.

The Journal is not an official journal of the Postmaster-General's Department of Australia. The Department and the Board of Editors are not responsible for statements made or opinions expressed by authors of articles in this Journal.

Editors of other publications are welcome to use not more than one-third of any article, provided credit is given at the beginning or end, thus "The Telecommunication Journal of Australia." Permission to reprint larger extracts or complete articles will normally be granted on application to the General Secretary.

* For addresses see page 255.

** For proposed changes see page 238.

INTRODUCTION OF COMMON CONTROL SWITCHING EQUIPMENT IN AUSTRALIA

*N. A. S. WOOD, A.M.I.E.Aust.**

Editorial Note: This is the first of a comprehensive series of articles on all aspects of the introduction of common control switching equipment in Australia. Some of the articles in this series appear in this issue of the Journal; the remaining articles will appear in subsequent issues.

One of the major events in the development of the Australian telephone networks during the past decade has been the introduction of crossbar switching equipment with common control as the standard for all automatic telephone and switching functions throughout the local and trunk networks. Such events, because of the magnitude of the task of implementation, cannot occur at frequent intervals. The body of experience built up during the months and years of defining and resolving problems and of practical achievement, if not adequately recorded, may not be available to assist in the next major change. Further, a major change in switching philosophy in a high telephone density country such as Australia has proved to be a matter of interest to many other Administrations throughout the world. For these two reasons a number of authors whose work has placed them in close touch with the practical aspects of implementing the decisions taken in 1959 have offered to record their experience in articles to appear in this *Journal.*

Many countries of the world have introduced common control systems but, so far as is known, no other country has attempted a changeover as complete as that in progress in Australia. The decisions were taken and the project launched following many years of detailed investigation as has been indicated in a number of articles appearing in earlier issues of this *Journal,* references to which appear at the end of this article. Almost five years have passed since the first major decision was taken and, at this stage, integration of the new type equipment into terminal exchanges in both metropolitan and country areas has been successfully completed. Two existing factories have completely changed over their production to the new equipment and one new factory has been established.

The course of implementation of a decision to change the standard automatic switching equipment is determined by a number of factors which are likely to vary in importance for different Administrations. In Australia, as in other countries, an important factor is the economic one of rapidly rising demand for all kinds of national development services against a background of insufficient resources of capital and rising cost of labour. Other factors for Australia have been the approach of the main step-by-step networks to the point where this type of equipment and trunking is no longer economic, the adoption of a closed numbering plan for the national network to provide for eventual direct subscriber dialling of all calls, the appropriateness of timing for factory retooling in relation to existing agreements and amortisation arrangements, and the ability of both manufacturers and the Department to engineer the project.

The actual course of implementation for Australia has passed through a number of phases and some are still incomplete. It was necessary initially to determine a broad programme of implementation which would establish realisable targets for all parties concerned including the owner company of the system selected, existing Australian factories and the Department's design, installation and maintenance staffs. Financial and contractual arrangements acceptable to all parties for both the short and long term were also vital preliminaries. Agreement on these matters made it practicable to establish time tables for the completion of other essential preliminaries such as:—

Final specification of facilities and interworking boundary requirements for design.
Review of materials and finishes in relation to Australian manufacturing and operating conditions.
Development of detailed requirements for bulk ordering of material.
Development of designs for interworking with existing systems.

In addition, it has been necessary to develop procedures and determine standards which would ensure satisfactory manufacture in Australia and performance in the field. Examples of these are as follows:—

Acceptance testing of imported and locally manufactured material.
Documentation of design performance standards and rationalisation for Australian requirements.
Planning for the progressive integration of new equipment requirements into building design and exchange dimensioning.
Training of staff.
Documentation for installation and maintenance.
Provision of supervisory and maintenance auxiliary equipment.
The use of pilot installations for evaluation of designs.
Control of staffing and material supply changes arising from the introduction of the new equipment.

The foregoing is not a complete survey but gives an indication of the wide range of activities generated by the introduction of a new switching system into an already established national telephone network. The investigations which are necessary to enable new systems to be evaluated require relatively less engineering effort within an administration compared to the task of implementation. A significant reason for this is that in the investigatory period manufacturers and operators of various systems can, and do, give considerable assistance. However, during implementation an administration itself must bear the main burden of deciding between alternative designs for interworking arrangements, specifying its requirements in detail, and developing practical methods of integration of the new equipment with the existing networks.

During the past four years there has been in the Department a progressive diversion of effort at Headquarters and in the State Administrations to the crossbar project in the fields of facility and system specification, programme, design, planning and pilot installation and maintenance engineering. Very few officers have been set aside at any time exclusively on the crossbar project, the task force being found mainly by the gradual cessation of activity on programming, design and development of step-by-step equipment in favour of the new equipment. Similar investment of skilled staff by the licensing manufacturer as well as the Australian factories has been necessary to achieve Australian production in volume and to resolve problems jointly with the Department.

The Department has been fortunate in having available a reservoir of the essential skills from which to draw its needs for the crossbar project, at the same time coping with such major developments as television, broadband bearers in both cable and radio, new types of telephones and increasing contributions in the international sphere of the I.T.U., C.C.I.T.T. Study Groups, and technical assistance to new and developing countries.

The Department's strength, in this regard, comes from long-term policies which have been based on self-sufficiency as the objective. The Department for many years followed the British Post Office in matters of equipment standards and standard methods and practices but, in the post-war period, set about accelerating the development of local manufacture of all the major components of telecommunication networks. This experience, together with experience gained from many years of independent equipment and cable construction work, plant operation and maintenance, and the development of independent research, planning and design potential paved the way for the

---

* Mr. Wood is Sectional Engineer, Telephone Equipment Section, Headquarters. See page 250.

major decisions which have been taken and provided the basis for successful implementation.

Although good progress has been made, there can be no doubt that the project could have proceeded more rapidly if greater engineering resources had been available at critical times. However, this is a limitation from which very few Administrations or manufacturers can escape when undertaking major changes. It is further axiomatic that programmes and plans can only be as good as the basic information available and, for this reason, it is hoped that the proposed recording in this *Journal* of at least some of the phases of introducing a new switching system into local production and operation will be of benefit to those engaged in similar activities now or in the future.

REFERENCES

All references are to articles published in the Telecommunication Journal of Australia.

1. F. P. O'Grady, "Australian Post Office Adopts Crossbar Automatic Switching System"; Vol. 12, No. 1, page 6.
2. F. P. O'Grady, "Developments Leading to Subscriber Trunk Dialling in Australia"; Vol. 12, No. 2, page 63.
3. N. A. S. Wood, "Automatic Switching Systems—The Key to Economic Telephone Networks"; Vol. 12, No. 1, page 7.
4. E. R. Banks, "Crossbar Switching Equipment for the Australian Telephone Network"; Vol. 13, No. 2, page 85.
5. R. W. Turnbull, B. F. Marrows and W. J. B. Pollock, "Nationwide Dialling System for Australia"; Vol. 11, No. 5, page 134.
6. R. W. Turnbull, G. E. Hams and W. J. B. Pollock, "National Telephone Plan
    - —Numbering"; Vol. 12, No. 1, page 3.
    - —Charging"; Vol. 12, No. 3, page 143.
    - —Switching"; Vol. 12, No. 4, page 226.

TECHNICAL NEWS ITEM

NEW L M ERICSSON FACTORY IN AUSTRALIA

As a result of the decision by the Australian Post Office in 1959 to adopt the L M Ericsson Crossbar automatic telephone exchange system for the development of the Australian automatic telephone network, L M Ericsson Pty. Ltd. has established a factory at Broadmeadows, Victoria, about 9 miles from the centre of Melbourne, to manufacture the range of Crossbar equipment being introduced into the national network.

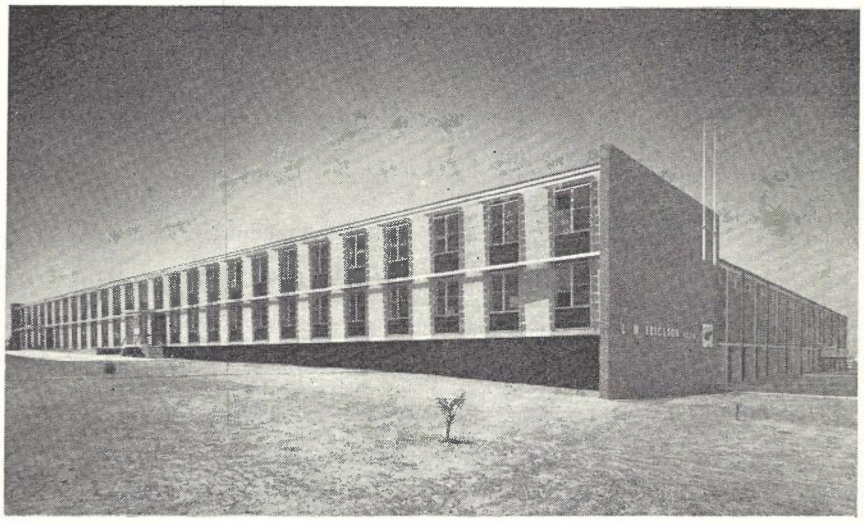
The factory was officially opened on 6th December, 1963, by the Hon. C. W. Davidson, O.B.E., M.P., who was at that time Postmaster-General.

The building has some 140,000 square feet of covered area situated on a site of 18 acres. The building is of completely modern design with large unrestricted areas, and incorporating a new system of natural roof lighting using semi-cylindrical perspex insets in the roofing, which gives a uniform light intensity over the production areas with exclusion of direct sunlight. The overall building design takes advantage of the slightly sloping site, enabling staff amenities such as canteen and locker rooms, and storage space, to be located on a lower ground floor level beneath part of the production area. Staff access is through the lower ground floor level, and then via a stairway to the centre of the factory area. This obviates the need for staff to pass through other sections to reach their places of work, and also minimises the need for additional emergency fire exits.

The factory area is divided into two main sections, one for primary production, and one for secondary production. The secondary production area has vinyl tile flooring which together with the mechanical ventilation and filtered air, minimises dust. The surface treatment is handled in separate rooms with special air control. The plant has been designed for the production techniques used in the L M Ericsson Swedish factories, modified where necessary to suit local conditions. The maximum possible amount of Australian produced machine plant and tools is being used.

The office block is about 300 feet long and has two storeys planned to give maximum natural lighting. It is separated from the main factory by internal courtyards which minimise sound transmission from the factory area to the office.

The attractive factory building, along with the production equipment in it, and the staff training program which gives proper emphasis to statistical quality control, forms an important step forward in the development of the Australian telecommunications industry. The introduction of the L M Ericsson factory at Broadmeadows brings the number of crossbar telephone equipment manufacturers in Australia to three, the other two being Standard Telephones and Cables, an I.T.T. associate, and Telephone and Electrical Industries, a member of the Plessey Group.



The New L M Ericsson Factory at Broadmeadows, Victoria.

PROGRAMMING THE INTRODUCTION OF CROSSBAR EQUIPMENT

*N. A. S. WOOD, A.M.I.E.Aust.**
*A. C. WRIGHT, A.M.I.E.Aust.**

INTRODUCTION

The preparation of programmes is a basic requirement for every major enterprise. The introduction of a new switching system into established factories already in full production and into a capital works programme, which is already engaging the full resources of an administration, is a highly complex project and it is necessary to provide for a great many factors foreseen and unforeseen. In Australia broad targets based on completing the changeover from the old to the new type equipment within four years, were established very early after the type of new system was firmly decided. This broad programme was followed up with subsidiary programmes for the most critical phases of the project such as the supply of manufacturing information and piece parts from overseas, the gradual expansion of the crossbar content in Australian manufacture and the annual exchange installation works programmes. It is proposed in this article to discuss the factors which influenced the development of the programmes, their usefulness in the project as a whole, and to review the progress actually achieved.

Date	Estimated Programme Requirements	Australian Manufacture		Imported	
		Step by Step	Crossbar	Crossbar	Other types
1960/61	110,000	90,000	—	16,400	3,600
1961/62	117,000	63,000	40,000	14,000	—
1962/63	125,000	30,000	80,000	15,000	—
1963/64	132,000	10,000	117,000	5,000	—

Fig. 1.—Automatic Equipment Requirements 1960 to 1964 (Exchange Lines)

RATE OF PROGRESS

The most important consideration following the decision that a common control crossbar system was essential to the economic expansion of the Australian telephone network was to obtain the benefits of reduced cost in network developments and improved facilities as rapidly as possible. However, the rate of progress had to be adjusted to take account of the fundamental requirement of maintaining two well-established factories, which depended almost entirely on the Department for the disposal of their telecommunication products, in economic production. In addition, time had to be allowed for the development of interworking designs, the changeover of planning and design activities for the installation of equipment from step-by-step to common control techniques, the assimilation of company documentation of the standards of design, methods and practices, and retraining of staff for both installation and maintenance work.

The policy of the Postmaster-General's Department is to use a very high percentage of locally manufactured equipment in its capital works programme. For this reason substantial changes of equipment type in the works programme must be preceded by changes in factory production in order to avoid serious discontinuity in the factories or over-stocking in Departmental Stores. Therefore, the first programme prepared was designed to give the manufacturers a basis for assessing practical rate of changeover of production. This initial programme appears as Fig. 1 and, because the Department is not an authority in the field of manufacture, it is based primarily on the ability of the Department's organisation to absorb increasing volumes of the new equipment, at the same time exhausting existing stocks of step-by-step equipment and tapering off new orders for this superseded equipment.

Principles

From the Department's viewpoint the following principles had to be observed:

(a) The flow of new numbers throughout Australia at a rate of 9,000 to 10,000 per month to meet the requirements of new subscribers' development must be sustained and increased annually at the normal rate.
(b) Staff employment should be maintained reasonably stable and efficient, any variations being effected gradually.
(c) New exchanges and large extensions are to be preferred initially so that costs of common control equipment will be distributed, thereby minimising the need for increased capital expenditure in the early years.
(d) The purchase of obsolescent discriminating selectors with inadequate capacity for direct routing of traffic and for subscriber trunk dialling should be discontinued.
(e) The volume of new type equipment should be progressively increased to 100% of the works programme as early as practicable.
(f) Stocks of superseded equipment should not be allowed to accumulate in store.

Preliminary Targets

The target figures shown in Fig. 1 were derived by examination of the existing capital works Three Year Programme for 1960/63 and selecting exchange locations which would admit crossbar almost simultaneously to each of the six Australian States where new exchanges and extensions in excess of 6-800 lines were planned. The importance of adequate lead time for initial installations to act as pilots and training grounds for key personnel firstly for the whole of Australia and then for each State was recognised. This factor, as well as recognition of the importance of design development and testing to proceed simultaneously with manufacture under the direct control of the Company responsible for design, influenced the determination of quantities of equipment to be obtained from overseas. A further factor to be considered was the maximum insurance of deliveries during the initial changeover period when it might be expected that unforeseen disruptions could arise.

The actual levels in each year were determined after consideration of the proportions of installing and maintenance staff who would become progressively involved. In this respect the first and second years were the most critical as after this time adequate key personnel would be available to provide the nucleus of as many installing groups as would be needed for a total crossbar programme.

It was decided to install approximately 19,000 lines of crossbar during the years 1960/61 and 1961/62. This equipment would be tailor-made by L M Ericsson for specific jobs and this would enable Departmental staff to gain both engineering and installation experience. In subsequent years the material required for installation would be ordered in bulk and would be 95,000 lines for 1962/63 and rising to 122,000 lines in 1963/64. The latter two years would be supplied from both local and overseas sources. The requirements of step-by-step equipment were reduced in these years to avoid any large change in production level in the factories.

Production Capacity

The programme shown in Fig. 1 was offered to the licensing (L M Ericsson, Sweden) and licensee manufacturers (Standard Telephones and Cables and Telephone and Electrical Industries, both of Sydney) as the preferred objective for the Department. The manufacturers then, independently of the Department, reviewed the practical manufacturing problems of meeting the programme. For the established Australian manufacturers these problems included assimilation of manufacturing information from L.M.E., Sweden, development of orders for material, conversion of factory production layouts for a completely changed work flow pattern, retooling for completely changed switch, relay and equipment mounting piece parts requiring a higher proportion of pressing operations, retraining of staff and progressive changeover of production in order to

---

* Mr. Wood and Mr. Wright are Sectional Engineers, Telephone Equipment Section, Headquarters. See page 250.

maintain economic levels of production and deliveries to the Department to supply its works programme. For L.M.E. the problems were to provide manufacturing documents in English in the order of requirement for production, to advise on tooling and general production knowhow, to estimate approximate distributions of components and piece parts for the various annual requirements for manufacture and installation, and to programme the delivery of production material for assembly in Australia and for complete items of equipment direct to the Department.

Both Australian manufacturers found it essential to provide substantial additional building accommodation to facilitate the changeover from one type of equipment to another. Generally the layout of machines and equipment for crossbar system manufacture requires more floor space for complete local production than step-by-step equipment. However, opportunity was wisely taken during such major changes to provide accommodation for increased levels of production in line with future needs.

Production planning groups in each Australian factory initially prepared broad programmes in graphical form to establish the available lead times for the various phases of production designed to meet the Department's targets. In one case the programme took the form shown in Fig. 2. These programmes helped to establish the target dates which would be necessary for the supply of information and material from the licensing company. The simple forms of tabular and bar chart programmes proved to be adequate for the early stages when a great deal of detailed information was unavailable and the urgency of the project, so far as the Department and Australian manufacturers were concerned, would not permit long periods of investigation and planning.

An interesting and important consideration in this matter has been the rate at which the Australian content of the initial deliveries should be increased. Although the Department's targets were optimistic, the Australian factories had great incentive to increase the local content of their product as rapidly as possible. To accelerate progress in this regard, rationalisation was agreed between the two companies to the extent that one concentrated on switch production and the other on relay production, each supplying the other with part of the needs in these fields. A study of the top section of Fig. 2 will show the rate of increase in local content which was typical of the objective of the Australian factories.

L.M.E., Sweden, made available production and system design experts in Australia to discuss the proposed programmes from a practical viewpoint and, in addition, provided for several representatives of each of the Australian companies to visit the Swedish factories to obtain details of production requirements at first hand. Thus, it was after careful examination by all parties that the programme suggested by the Department was accepted.

Initial Orders

It then became necessary to place orders for the actual equipment details required and to advise the manufacturers of the priorities and volumes of deliveries which would be appropriate to the Department's Works Programme. At this stage the States, who normally advise of the particular items required for their works programmes, did not have sufficient information of the crossbar system to enable them to compute their requirements. Headquarters advised each State of the quantities of crossbar equipment which would be purchased for them in terms of lines and requested traffic information, call holding times, etc., for particular installations to be returned based on the established step-by-step trunking diagrams. The available knowledge could then be concentrated to convert the step-by-step diagrams into crossbar trunking with the documentation available. This conversion was done by

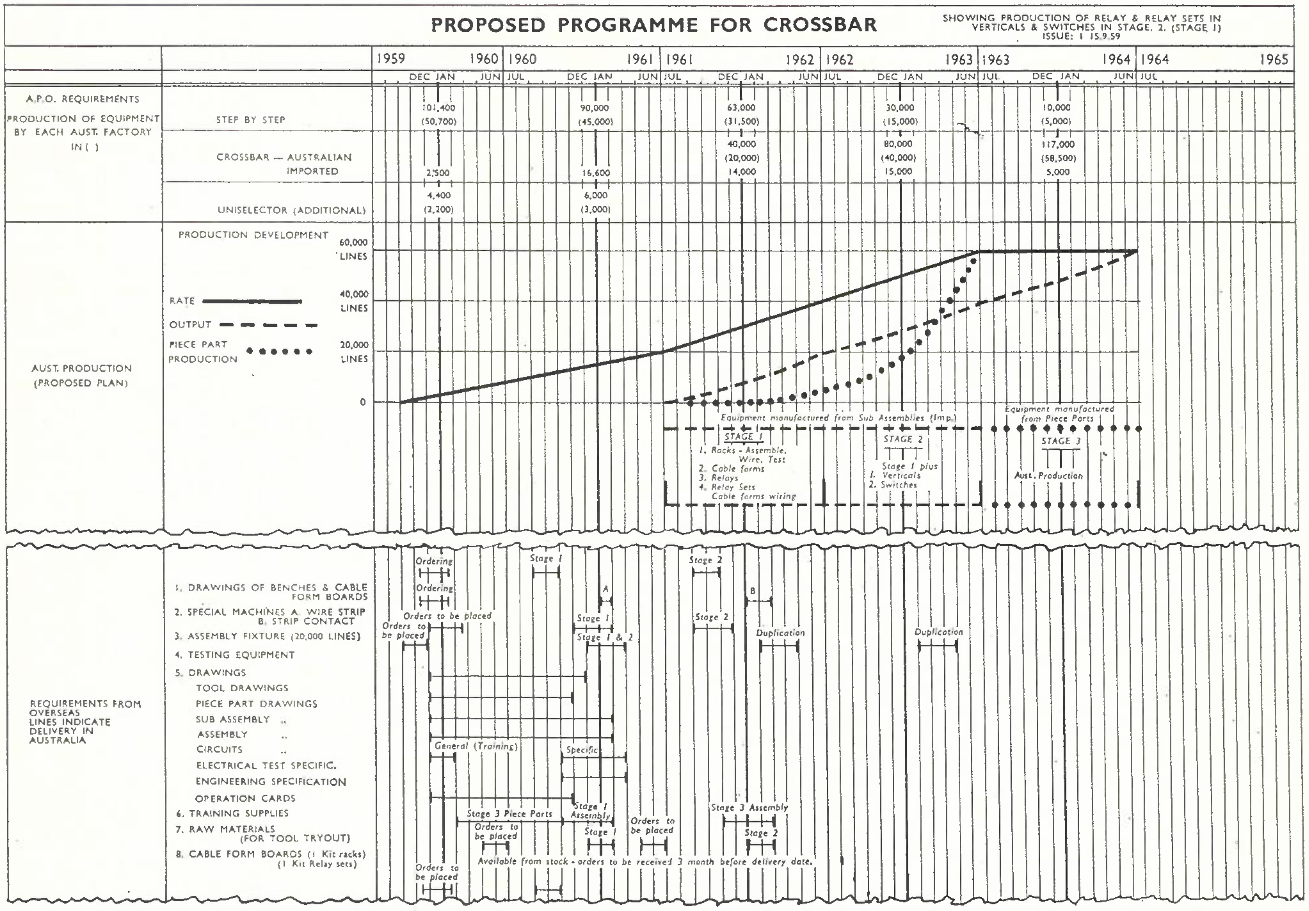


Fig. 2.

two engineers in Central Office with the assistance of an L M Ericsson systems expert from Sweden who oversighted the trunking information to ensure that the basic principles were satisfactory.

From the trunking diagrams it was possible to compute the number of racks required and many of the relay sets but certain items such as markers and registers were not known in sufficient detail to enable the component parts to be separately identified although the quantities of complete registers and markers required could be established. The first orders placed for equipment, therefore, called up only the major groups of equipment and it was not until some considerable time later when more information became available that these broader groups were broken down into the detailed relay sets required.

In addition to major items of equipment, which could be established from the trunking diagrams, it was necessary to determine and obtain such items as I.D.F.'s, alarm equipment, test equipment, superstructure, cable and sundry other items which are required to enable an exchange to be installed. This information was not available in any written form and L M Ericsson were asked to recommend the quantities required. This recommendation was accepted but proved inadequate because of the relatively smaller size of the Department's installations compared with the more usual size installed by L M Ericsson.

Fig. 3 shows the table of delivery requirements for the main items of equipment sought by the Department to secure a flow of material during 1960/61 which would enable installation of crossbar equipment to proceed in increasing volume in an orderly manner. These requirements provided the basis of production planning in the Australian factories and production and shipping schedules for L M Ericsson. This table together with related preliminary schedules produced by LME were discussed and developed by the Technical Development Committee which is described below.

PROJECT ORGANISATION

The Department has already considerable experience in co-operative working with the Australian manufacturers of automatic switching equipment through the agencies of two committees, one dealing with equipment ordering, raw material supply and programmes for deliveries, and the other with matters of technical design and performance standards. Therefore, attention was given very early in the crossbar project to the constitution of similar committees for the purpose of setting the objectives, defining the problems, jointly seeking the solutions and reviewing the progress of the crossbar project.

The first of the new committees is known as the Main Crossbar Advisory Committee and includes representation at Managing Director level from each of the three manufacturers concerned. The Chairman of this Committee was initially the Deputy Director-General and later an Executive Engineer of the Postmaster-General's Department. Senior executives of the Engineering, Finance and Telecommunications Divisions of the Department are also members of the Committee. This Committee held its first meeting in December 1959 and has continued to meet at regular intervals, usually every three months, since that time. Its main functions have been to develop policy and co-ordinate the programmes for the changeover of Australian production of automatic switching equipment to the crossbar equipment following the completion of the licensing agreements; to discuss the levels and distribution of orders for crossbar equipment, financial arrangements, rationalisation of production and the progressive substitution of raw materials and components available from Australian sources for imported materials.

The second committee was set up by the Main Committee to examine the more detailed aspects of technical design and production planning. It is known as the Technical Development Committee and held its first meeting early in 1960. It has continued to meet regularly since that time at intervals of 5 and 6 weeks. Representation at this Committee comprises senior engineering represenatives concerned with design, production and standards from the Department and the manufacturers. The

Item No.	Description	Code No.	Quantity %								
			Oct. 1961	Nov. 1961	Dec. 1961	Jan. 1962	Feb. 1962	March 1962	April 1962	May 1962	June 1962
	Installation Iron		10	15	15	15	15	15	15	1962/63 Reqts.	1962/63 Reqts.
	Installation Tools		10	30	30	30					
	ARF (40,400 Lines Approx.)										
1–7, 33, 34	Racks	BDD					10	20	20	20	30
8, 9, 23, 24 35–41*c*, 45 50	Racks	BDH	10	10	10	10	15	15	15	15	1962/63 Reqts.
7(*a*)–(*d*)	Relay Sets CD Code Rec.	BCD ROA					10	20	20	20	30
11–13	SLM	BCH					10	20	20	20	30
16–17, 44	Registers	BCH						20	20	30	30
19–22	Register Finders	BCH					10	20	20	20	30
18	SR	BCH				10	20	20	20	30	1962/63 Reqts.
27–29	FIR, FUR, FDR	BCH					10	20	20	20	30
25, 26	GVM	BCH ROA						20	20	30	30
30–32	Code Senders							20	20	30	30
43–49	P.B.X. W.T.R. etc.						10	20	20	20	30
42	LR/BR	BCD					10	20	20	20	30
	Miscellaneous:										
	MR					10	20	20	20	30	1962/63
	Testing					10	20	20	20	30	1962/63
	Observation						10	20	20	30	30
	Interception						10	20	20	30	30
1–17	*ARK.51 (1,600 lines approx.)*										
	Complete Units					30	30	40			
	ARK.52 (8,000 lines approx.)										
1–5	Racks	BDH				10	20	20	20	30	1962/63
6–26	Relay Sets	BDH					10	20	20	20	30

Fig. 3.—Order of Delivery of Crossbar Material to suit the Department's Installation Requirements—1961/62

Chairman is a senior Engineer in the Department.

The work of this Technical Development Committee (T.D.C.) has included the review of materials, surface finishes and components used in the new switching system for suitability in Australian climatic conditions. A number of alterations were specified and will be referred to in a later issue of this *Journal*. The T.D.C. initiated the development of detailed delivery schedules for manufacturing documents including equipment specifications, circuits and wiring diagrams, assembly drawings, testing instructions, and piece parts. The T.D.C. has followed up the design of miscellaneous equipment, such as ring and tone equipment and subscribers equipment meter racks, the development of acceptance testing standards, programmes for the delivery of manufacturing information and piece parts and the building of prototypes to the final testing stage of each separate rack and relay set item of the new equipment.

The T.D.C. reports regularly to the Main Committee and, in addition, maintains formal minutes of proceedings which, in accordance with the constitution of the Committee, are confirmed at the first succeeding T.D.C. meeting and ratified at the second succeeding meeting. In this way the T.D.C. minutes have become a most useful and accurate reference for the problems which have emerged and the decisions reached.

One of the most significant decisions of the Main Committee was taken in 1960 and has had a profound influence on the course of the project. This decision required that the production of items of equipment, subject to design modification to meet the Department's specifications, should proceed in Australia in parallel with prototype production in the Swedish factories of L M Ericsson. The items for which the Department specified changes to meet the special problems of the Australian networks were limited to a range of common control and interworking relay set equipment items. In normal circumstances both the designer and the user prefer to design and manufacture a new or modified item right through to final factory testing and even field testing before entering bulk production. However, the urgency of the whole project for the Department and the Australian manufacturers called for special measures and it was recognised that, although normal procedures are safer, many weeks of production and shipping delays, because of the remoteness of Australia from Sweden, would occur. Parallel production gains time because any information for final trimming of designs, which may be found necessary, can be conveyed more rapidly than the actual equipment items themselves. This approach, while bringing its problems, did advance the rate at which production has been achieved in Australia of crossbar terminal exchange systems, which represent more than 80% of the automatic switching equipment requirements of the Department.

The decision to proceed with parallel design and development and factory production made it even more essential to programme the project in greater detail and it was in this task that the T.D.C. made its most important contribution in the early stages. It should be understood that the Department adopted the LME crossbar system as the standard for the Australian telephone networks because of its potential to meet the requirements of the Community Development Plan for Australia at the lowest cost, its relatively higher state of development as a system suitable for application in all parts of the national network, and its long record of satisfactory performance in a wide range of applications. The Department at the outset had very little experience in the design and development of circuits for common control switching systems and therefore adopted the policy of placing full responsibility for design and the performance of the equipment with the Company. The Department further established policies of stabilising the designs developed by L M Ericsson until adequate field experience has been obtained. In consequence of these policies the T.D.C. limited its activities in the design area to the supervision of suggested modifications which naturally flowed from Australian manufacturers and from the Department's engineers, as circuits became available for study. Only modifications essential for performance in Australian conditions were admitted into manufacture and these only after agreement between the Department and LME in design and with the Australian factories on produc-

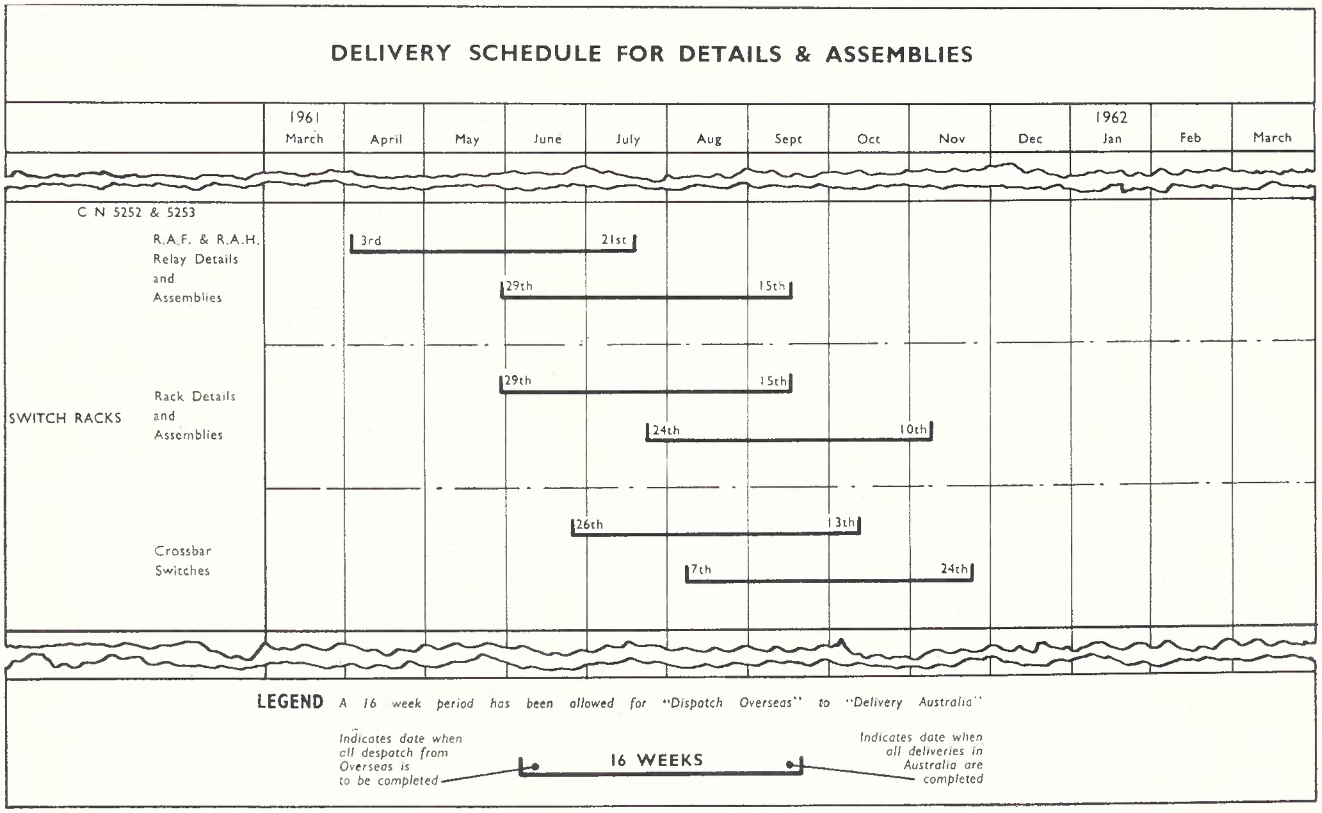


Fig. 4

Complete Kits of Parts and Documents **Relative Swedish Factory**

Line No.	C8469 Corr. Item	Note	ARF.10 Article		Switches or relays per unit	Australian Factory (*a*) 1961–1962											Shop Production Order
			Code No.	Designation		Qty.	8	9	10	11	12	1	2	3	4	5	
1	57		BCH 13122	3F		8											333–9097
2	61		BCH 151210	REG–L R1		247		S	P	V	F	L3	L4	T2 L3			231–2293
3	62		BCH 151211	REG–L R2		247		S	P	V	F	L3	L4	T2 L3			231–2294
4	63		BCH 156107	REG–LKV		247		S		PV	F	L3	L4	T2 L3			231–1488, 231–1453 (KV)
5	64		BCH 16138	REG–I R1		89			P	F			L4	L3			231–2218
6	65		BCH 141178	REG–I R2		89			PV	F	T2	L3	L4	L3			231–2219
7	56		BCH 141153	K		35			L T2								231–1342
8	66		BCH 131269	SR		545		L5 T2	L5								231–1342 L245 Oct., 231–1278 L300 Sept.
9	67		BCH 16674	RS		158		SP	VF			T2					231–1278 Sept., 231–1281 KV June

Denominations used in Delivery Plans for Manufacture at Co-operating Companies

J = Final delivery of parts for crossbar racks
K = Final delivery of parts for crossbar switches
L = Final delivery of parts for relay frames and also relays, condensers, rectifiers etc. that are delivered ready from LME.
N = Final delivery of parts for relays to be assembled by the co-operating company
S = Specification and relay data
P = Circuit Diagram
V = List of lacing boards (drawing if any)
F = Lacing list and connecting diagram
T_1 = List of test equipment
T_2 = Test instruction (test equipment if any)

The figures stated give the number of units to be *delivered* during the month in question.

* Indicates a new article not manufactured earlier.

(*) Indicates an article not manufactured earlier by the co-operating company.

"Relays per unit" indicates the number of relays per set manufactured by the co-operating company. The relays delivered by LME are accordingly not included in those numbers.

If the relay set contains more than one circuit this is indicated by a figure within brackets in connection with the denomination. Ex SR (2) means that the relay set contains two SR's.

First Issue	Approved	Corr.	A	B	C				Key to the signs see	No.	Page
Yx 21.6.61		Date	6.9.61	27.11.61	1.3.62					SKS 68293	5 (13)

Fig. 5.—Delivery Schedule for Australian Factory Relay Sets.

tion aspects. The T.D.C. did, however, concern itself with the design of the miscellaneous equipment to be associated with crossbar exchanges but which were not being provided by L M Ericsson. It follows that initially the T.D.C. was not heavily engaged in the design activities, which will become its most important work, and was able to devote its attentions to co-ordinating the production programmes with deliveries from overseas and the solution of problems which could lead to late deliveries to the Department.

Factory Programmes

A sample section of the type of programme which was prepared by S.T.C. and T.E.I. to establish the lead times necessary if the Department's delivery requirements were to be met, appears in Fig. 4. This programme was developed by working back from the target dates set by the Department's requirements in Fig. 3 allowing for all the phases of production, including cable form making, assembly, wiring, testing, trimming and packing for despatch in the factory. From this type of survey the critical dates began to emerge when manufacturing documents and piece parts to be supplied by LME should be despatched from Sweden. In general manufacturing documents need to be available well in advance of actual production work and for the greater part this was achieved. However, in a number of cases documents could not be sent as early as required or needed modification and this introduced special problems. The solution of these problems of documentation and the procedures established will be described in another article to appear in a later issue of this *Journal.*

A further more detailed programme was now prepared by LME to co-ordinate the delivery of manufacturing documents and material ordered by the Australian factories and Fig. 5 illustrates a section of this programme together with an explanation of the symbols and abbreviations used. The item number in the second column refers to the item number used in the early ordering schedules of the Department and the Code Number and Designation are the contractors' identifications. The months of delivery are indicated by a number at the head of the columns containing the coded information. For example, Item 61 is a local register relay set having the code number BCH150210 in the

State: South Australia **Plant:** Exchange Equipment (XEP)

Item	Priority	Locality Description	Estimated Total Expenditure	1961/62			1962/63			1963/64			Est. Expenditure in subsequent years	Co-ordinating Reference	
				Quantity of Plant	Man Hours	Est. Expenditure	Quantity of Plant	Man Hours	Est. Expenditure	Quantity of Plant	Man Hours	Est. Expenditure		Other Engineering Projects	Building Programme
		Carry Over	£			£			£			£	£		
1	4	*Henley Beach* Equipment extension by 1,000 lines to 3,400	40,000	1,000	2,000	31,000								XUP 66	Available
		New Works													
17	21	*Brighton* Equipment extension 1,600 lines to 7,800	63,000	600 Step by Step	6,000	18,000	1,000 Crossbar	6,500	32,000		1,500	13,000			Available
21	63	*Crystal Brook* Replace magneto exchange with 400 lines of ARK crossbar	10,900							400 Crossbar	3,000	10,900		TXP 7 TZP 116	Item 204
48	32	*Paradise* (*i*) Equipment extension of 1,600 lines of ARF in new building	169,000	1,600 Crossbar	4,000	8,500		12,000	63,500					XUP 93	Available
		(*ii*) Extension of 2,400 lines of ARF and recover 2,000 lines of 2000 type								2,400 Crossbar	18,500	97,000			

Fig. 6.—Three Year Programme of Works

Swedish factory. The Australian factory holds an order for 247 relay sets of this type and LME planned to despatch specifications and relay data in September 1961, circuit diagrams in October, list of lacing boards in November, lacing lists and connecting diagrams in December, final delivery of parts for 30% of relay sets in January, 40% in February and 30% in March, together with test instructions and test equipment, if any. The figures at the right are the Swedish factory reference for enquiries. The programme refers to orders for delivery to the Department in 1961/62 and it will be noted that the register relay sets which are not required until late in an installation are programmed late in the delivery year. Other items, such as the cord circuit relay sets SR, were programmed for earlier delivery of information and material from Sweden.

The delivery schedules were revised at regular intervals and the date of revision is indicated at the bottom of the sheet. These documents proved to be an invaluable aid to all parties in maintaining work programmes under review and calling attention to changes in an orderly way. In some cases the consequences of changes to work flow in Australia were such that special efforts such as airfreighting of critical material were negotiated with LME to minimise the effects of delays. Overall it was possible to maintain good co-operation in circumstances where all parties encountered difficulties.

The form of this programme was evolved over several months as experience was gained and the need for additional information became apparent. An immediate benefit was the highlighting of the so-called unspecified items for which the BDH or BCH code number was incomplete. Efforts were concentrated on bringing those items to a state of stable design as early as possible. An essential step in this process was the stabilisation of facility and design requirements at the end of 1960 in an exchange of letters between the Department and LME. It was intended that these statements should be the firm basis for the initial production in Australia and generally this has been so. Further clarifying discussions proceeded as designs were developed and a limited number of changes were introduced during 1961.

THE WORKS PROGRAMME OF THE P.M.G.'s DEPARTMENT

The Department prepares a three-year programme of works and the crossbar material, now on order, had to be introduced into this programme on a firm basis in lieu of the more tentative and broader approach used to obtain the quantities of material for the original orders.

It would be unrealistic to expect the transition from step-by-step to crossbar installation to be achieved without any interruption. The desirable arrangement to ensure a smooth transition would be to have adequate stocks of both step-by-step and crossbar equipment available, but due to the limited funds which the Department has to do all its capital works, only a limited amount of extra step-by-step stock could be purchased. The intention was that the crossbar equipment would not be withdrawn immediately but stocks would be allowed to build up in store for a period of approximately three months and additional step by-step equipment was purchased to cover the needs for this period.

Following the placing of contracts, and the acceptance by the contractors of the delivery requirements of the Department both in order of delivery and time of delivery of the individual items, the Three Year Project Programmes were prepared in each State to incorporate the crossbar material coming forward with other exchange equipment. A section of a typical programme is shown in Fig. 6.

Co-ordination of Material Supply

Previous experience showed that even with established production, shortage of individual items of equipment could be experienced in individual States. To minimise these difficulties the States review their needs for a six-month period and conferences of the States and Headquarters are held at four monthly intervals to balance supplies, in stock and coming forward in the period, against needs. Most anticipated shortages can be relieved by changing delivery priorities between States and where this cannot be achieved physical transfer between States is arranged if stock is held. The need for this conference to minimise difficulties in supply of crossbar material has been greater than for 2000 type equipment, due to delays in delivery for various reasons, and many supply problems have been solved at the conference. The conference has not been completely successful, however, due to the absence of any deliveries of some items.

The dependence on stock coming forward placed a greater emphasis on both the factory delivery schedules and the installers installation programme. It became apparent that the supply situation could not be solved completely by the regular conferences and that Headquarters staff would be involved to an increasing extent in the intervals between conferences in arranging contract diversion and stock transfers and in arranging priorities of delivery. Headquarters staff do not normally become involved in State programmes in such detail that they are able to assess priorities between States. It therefore became necessary to set an officer aside from normal duties to visit all States to determine relative priorities of all current works and those planned to commence in the near future.

The investigation required an assessment to be made of the time at which various classes of material would be required, i.e., superstructure, racks, relay sets, etc., and of the particular items in each class that were causing concern. Visits were made to the local factories to discuss production schedules and where possible to change these to suit the installers needs. Where this was not possible a priority for delivery was established and equipment transferred to suit the higher priority jobs.

When no equipment could be made available changes to the installation programme were required. The 2000 type equipment available was utilised to the full extent of stock available and additional crossbar jobs commenced. The increased amount of crossbar work in progress caused an increased demand for superstructure and other items associated with the early stages of installation and created new shortages. Some of these shortages were capable of relief within the State by manufacture in the Postal Workshops and others by special urgent purchases or the use of commercial material as an expedient. Examples of these items are tiebar, IDF strips, and installation testing equipment.

Due to the parallel development and production of equipment it was unavoidable that some changes in design would be made to equipment which had been delivered and modification material is being purchased in kit form to bring equipment supplied up to the latest issue of drawings. The modifications are being made in the field as required.

The result of the shortages and delays in delivery of crossbar equipment is that more crossbar jobs are in an incomplete state than would normally be expected, less 2000 type equipment is in store than was planned, and some loss of installation efficiency has occurred. However, it is expected that the exchanges now waiting equipment will be brought into service at an early date and that the flow of new numbers in regular increments will be quickly restored.

INSTALLATION AND MAINTENANCE CONFERENCES

With the flow of crossbar material gathering volume in the first half of 1962 and the development of a firm Works Programme including the installation of crossbar equipment in all six States of Australia, the problems of assimilation of new materials, tools, techniques and documents which had confronted the Australian factories now presented themselves to the Department's installation organisations. An equivalent forum for exchange of information and the co-operative solution of problems, which functioned so well for the earlier phases of introduction of the new equipment into local manufacture, was set up and held its first meeting in July, 1962.

This forum is known as the Installation and Maintenance Conference for the Introduction of Crossbar. It is attended primarily by Supervising Engineers responsible for the installation and maintenance of exchange equipment in each State and Headquarters Engineers responsible for the various aspects of design, installation and maintenance methods and practices and documentation. The Chairman is supplied by Headquarters. This conference is complementary to the Materials Supply Conference referred to earlier and does not normally concern itself with material deliveries. Meetings have been held at intervals of four to five months and are planned to follow closely the Materials Supply Conferences and major events such as the establishment of the pilot ARF and ARK type exchanges. At the invitation of the Department L M Ericsson made available two experienced Engineers for the initial conference to advise on particular design and installation problems. However, subsequent meetings have had exclusively Departmental representation.

The agenda for these conferences which have generally continued over two to three days have included the following typical items:—

Reports on Crossbar Design Projects (Headquarters).
- Local Manufacture—Items Outstanding.
- Interworking Problems.
- Strapping of Common Equipment for routing and numbering.
- Suite Control—Design and Installation.
- Test Equipment and Maintenance Aids.
- Modifications.

Reports on Crossbar Installation Projects (States).
- Works Current in each State—Progress.

Progress with Instructions and Documentation for Installation.
- Installation Staffing.
- Miscellaneous exchange services.

Feedback of Information and Quality Control.
- Performance Reports — Headquarters and States responsibilities.
- Design changes and modifications—Definition of responsibilities.
- Standardisation of Exchange Equipment.

Cutover Arrangements.
- Installation Testing.
- Subscriber Education.
- Planning of Numbering and Routing changes.
- Grading and Interconnecting.
- Sub-station plant—compatibility.

Progress with Instructions and Documentation for Maintenance.
- Maintenance Philosophies.
- Maintenance Staffing.
- Review of Maintenance Procedures.

This phase of programming the crossbar project became the turning point in the handing over of the main responsibility for successful integration of the new equipment, from Headquarters to the State organisations. The series of conferences have been successful in resolving problems, avoiding duplication of effort by rapid exchange of information and the establishment of personal contacts so essential in a fluid situation of change and shortages of material and information. An important factor has been the steady build up of confidence due to the sharing of experience by those further advanced with particular projects and the general evidence of co-ordinated purposeful activity.

ACTUAL PROGRESS

As may well be anticipated many unforeseen problems and some delays occurred which required changes of programme so that the schedule of deliveries had to allow for systematic review. A great deal of effort has been necessary by all participants in the project in order to minimise delays and the effects of delays. The production flow in factories, as well as the flow of installation in the field, cannot easily be altered, but frequent adjustments were necessary both in the factories and the Department's installation organisation. However, the initial targets were chosen with some anticipation of delays with the result that, although some loss of efficiency occurred from time to time, the end result in terms of shortage of plant to connect new services has not been serious with less than 5% of the annual connections being affected during 1963.

The time table proceeded generally as follows:—

April, 1959—Decision to adopt crossbar.

July, 1959—Decision to adopt L M Ericsson crossbar system.

November, 1959—Licensing of Australian manufacturers.

December, 1959—Co-ordinating committees set up.

November, 1959 - November, 1960—Practical programmes for Australian manufacture, and specifications of facility and interworking designs, were evolved.

July, 1960—Initial schedules for delivery of manufacturing information and piece parts to Australian manufacturers prepared.

September, 1960—Confirmation of orders from Australian manufacturers for delivery of crossbar equipment in 1961/62 financial year.

December, 1960—Facility and design specifications stabilised for initial deliveries.

January, 1961—Procedures established to investigate and make adjustments for unavoidable changes in programme.

August, 1961—First crossbar equipment delivered from an Australian factory.

January, 1961—Deliveries in volume achieved by two Australian manufacturers of locally assembled equipment with 20% locally made parts.

June, 1962—Total of 40,000 lines of locally manufactured equipment delivered. Orders for 1962/63 delivery confirmed.

July, 1962—Installation and maintenance Conferences commenced.

May, 1963—Pilot metropolitan terminal exchange placed in service using fully imported equipment.

June, 1963—First exchange installation using crossbar equipment supplied by Australian manufacturers placed in service. Local content of Australian manufactured equipment increased to 80% and a further total of 67,000 lines delivered from Australian factories. Orders for 1963/64 delivery confirmed.

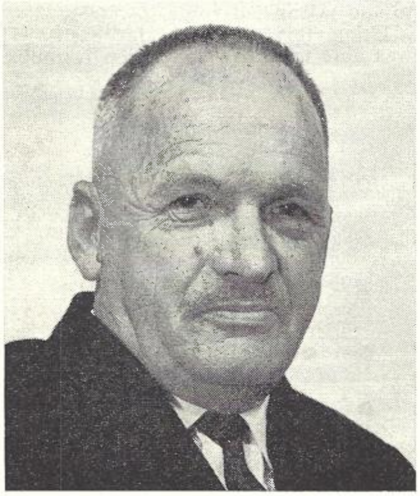
September, 1963—A total of 125,000 lines of crossbar equipment being installed in 100 separate locations and at a further 16 locations, crossbar group selector stages being installed in step-by-step exchanges.

November, 1963—Four ARF and one ARK 52 exchange placed in service.

CONCLUSION

The original programme proposed was capable of being executed by the Department's staff but because of delays in delivery of a limited range of items, due to various causes, the original programme of crossbar cutovers has fallen behind by about 12 months. This has not meant a delay in installation of equipment to this extent as stocks of step-by-step equipment were consumed at an increased rate to offset the delays and more crossbar jobs are in an advanced state of installation than is normally to be expected.

The introduction of crossbar into the Australian network has required the co-operation and goodwill of all concerned. It has involved the development of close associations between the staffs of L M Ericsson, Standard Telephones and Cables, Telephone and Electrical Industries and the Headquarters staff of the Postmaster-General's Department, and has called for a great deal of patience and understanding by State staffs who are responsible for bringing the equipment into service.



VALE HARRY LITTLE

Albert Henry Little, Deputy Superintending Engineer, Metropolitan Branch, Engineering Division, Sydney, died in hospital on 9th July, 1963, from coronary failure. Known throughout the Engineering Divisions of the Australian Post Office in every State of the Commonwealth for his expert knowledge and long experience of telecommunication transmission matters, his loss will be keenly felt by his many friends and colleagues. Born in 1901, he commenced his Post Office engineering career as a Junior Mechanic in Training in 1917, advancing to Mechanic in 1922. After passing the "open" examination for Engineers in 1929, he was successively advanced as Divisional Engineer in 1944, Supervising Engineer in 1950 and Deputy Superintending Engineer in 1961. During his 46 years in the Engineering Division, he not only witnessed, but took a very active part in a number of revolutionary developments in long-distance communication technique. He saw methods of provision of circuits for long-distance communication change from unamplified physical conductors through the various kinds of aerial and cable carrier systems to the latest broad-band types on both coaxial cable and radio bearers. A dedicated man in the full meaning of the term, his life's work was the improvement of communications within the State, particularly the more remote portions, such as the area west of the Darling and his work in this area will be remembered for many years. The world in general, and the art of Telecommunication in particular, is the poorer for his passing.—H.W.

DIMENSIONING OF CROSSBAR EQUIPMENT

*J. RUBAS, A.R.M.T.C., Grad.I.E.Aust.**

INTRODUCTION

The inclusion of crossbar equipment with common control in the equipment purchasing and installation programmes of the Postmaster-General's Department called for a review of the established methods of determining material quantities and engineering design for particular installations. The staff responsible for exchange dimensioning in each State of Australia were well experienced in traffic engineering for step-by-step automatic equipment. However, dimensioning of link trunked, register controlled crossbar exchanges differs in many respects from that of step-by-step exchanges. Firstly, link trunking, with conditional selection over two or more stages, introduces another variable, namely, link congestion. Secondly, in addition to speech circuits, various groups of common control equipments must also be dimensioned. Thirdly, to exploit fully the advantages of register control, extensive alternate routing must be employed, requiring the use of new and more elaborate methods of dimensioning. Finally, a different approach must be used in fixing grade of service standards—allocation of fixed loss probabilities per switching stage is no longer practicable where alternate routing is employed, the only valid criterion being the overall grade of service. Additional service standards have to be introduced, where delay working is employed, in order to ensure adequate provision of common control equipment.

This article outlines the principles of dimensioning link trunked crossbar exchanges, with particular reference to methods adopted by the Department.

DIMENSIONING LINK TRUNKED STAGES

The principle of link trunking is not new. In fact, it has been employed on manual switchboards since the earliest days of telephony. The concept has been defined and subjected to mathematical analysis, however, only after the introduction of automatic working.

A link system consists of two or more selecting stages connected in tandem, all stages being controlled by the same intelligence, which may be a human operator, or some electro-mechanical or electronic device. The positioning of a switch in the last stage is determined by the wanted direction (e.g., a certain route), whereas the switches in the remaining stages are positioned in such a way that together they form a path between the calling line (inlet) and a last stage switch, which has access to a free trunk in the wanted group. It is important to realise that in a link system the following conditions apply, which distinguish it from step selector stages connected in tandem. (This does not include two-stage arrangements with group control (backward busying), which are a form of link trunking.)

(a) The circuit in the chosen group and the link, or links, selected to provide a path to it from the calling inlet are all seized simultaneously (or very nearly so).

(b) Only that link or combination of links (intermediate selectors) is seized which connects the calling inlet to the chosen circuit (outlet).

This method of setting up calls through the system is often referred to as conditional selection.

In analysing link systems it is very convenient to use the so-called "chicken" diagram which is a symbolic representation, where selecting devices and their outlets (crosspoints) are indicated by **o-** and **o**. The short line ("beak") attached to the first symbol indicates the direction of multipling. All outlets in line with the beak are accessible from the devices indicated by **o-**. The symbol **o-** usually represents a vertical and **o** an outlet of a crossbar switch.

The grouping plan (or "chicken" diagram) of a simple two-stage link system is given in Fig. 1.

Referring to Fig. 1, the devices in stage A represent the inlets, those in stage B the links, while the group of devices designated by C are the outlets of the B stage. The filled-in circles represent busy devices. Link systems can be classified into three main types, depending on whether the number of links per column (m) is smaller, equal to, or greater than the number of inlets per column (n). When $m<n$, we have a system with concentration in the B stage (e.g., SLA-SLB stages in the ARK.52 system). When $m = n$ there is neither expansion nor concentration between A and B stages, like in the arrangement shown in Fig. 1. When $m>n$, we have a system with expansion in the B stage (e.g., the GV unit in the ARF 10 system).

The boxed-in outlet column in Fig. 1 represents a particular route leaving the link selector stage. The boxed-in inlet (and other inlets in the same column) can reach the route in question via any one of the links in the boxed-in column. In this system a call will fail under any one of the following conditions:—

(a) All trunks in the route are busy.

(b) All links in the boxed-in column are busy.

(c) The occupancy of links (in the boxed-in column) and the outlets to the route is such that all links standing opposite free outlets are busy on other calls (one such condition is shown in Fig. 1).

It is convenient to consider the congestion function in a link-trunked stage as consisting of two components—route congestion and internal (or link) congestion. By assuming that these two components of congestion are mutually independent (which they are not), fairly simple expressions can be derived for the total congestion or the probability that a calling inlet cannot be connected to the nominated route.

Using this approach Jacobaeus [1] was able to derive congestion formulae

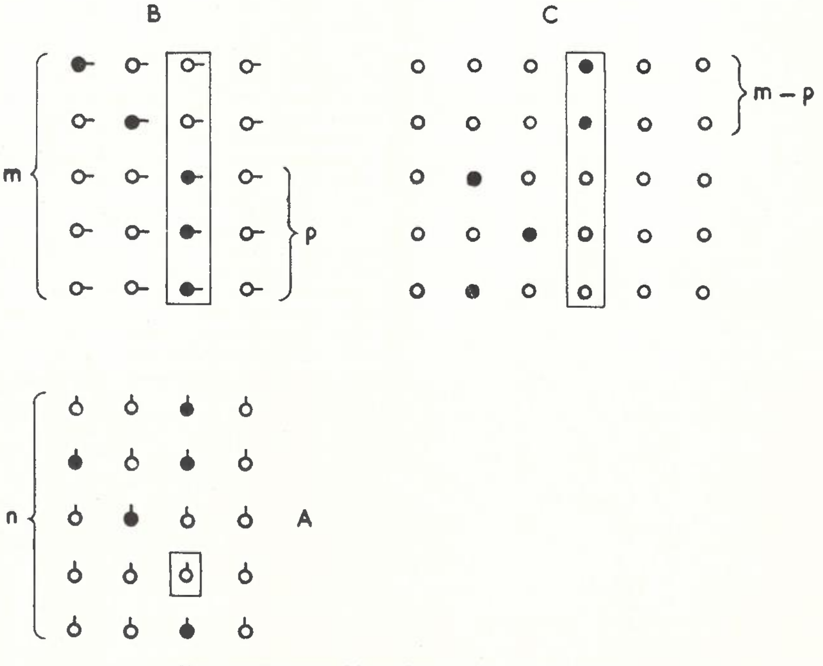


Fig. 1.—Grouping Plan of a 2-Stage Link System.

---

* Mr. Rubas is Divisional Engineer, Fundamental Planning Section, Headquarters. See page 250.

for various types of link systems then in use. The crossbar dimensioning graphs published by L M Ericsson are based on his work. These graphs have been prepared for certain fixed values of congestion, with offered traffic as the leading argument. We will now survey the congestion formulae used to calculate these graphs.

Referring again to Fig. 1, the congestion between the boxed-in inlet and the route is generally given by the following:—

$$E = \sum_{p=o}^{m} G(p).H(m-p) \quad \ldots.(1)$$

Here $G(p)$ is the probability that p out of m links in the column are occupied, while $H(m\text{-}p)$ is the probability that at least $(m\text{-}p)$ specific outlets in the route are engaged. The final form which equation (1) will take depends on the traffic distribution functions assumed for the link column and the route. Usually Bernoulli distribution is assumed for the links and Erlang distribution for the route. Under these assumptions the total congestion simplifies to a ratio of two Erlang loss expressions:—

$$E = \frac{E_{1,m}(A)}{E_{1,m}(A/b)} \quad \ldots\ldots\ldots(2)$$

Where A is the mean traffic offered to the route and b is mean traffic load per link.

When the route contains not one but q columns, equation (2) becomes

$$E = \frac{E_{1,mq}(A)}{E_{1,mq}(A/b)} \quad \ldots\ldots\ldots(3)$$

Equation (3) has been derived assuming sequential occupation of outlet columns (sequential selection of columns, but random testing within columns). It gives a good approximation also in the case of completely random testing of outlets. However, the approximation is satisfactory only when congestion in the link columns does not smooth the traffic offered to the route.

It has been shown by Jacobaeus [1] that equation (3) provides a fairly good approximation (subject to the limitation referred to above) to total congestion also for systems employing concentration in the B stage (i.e., $n>m$), provided that the same assumptions are made about the traffic distributions. In two-stage link systems with expansion in the B stage, however, the congestion expression takes a slightly different form:—

$$E = \frac{E_{1,mq}(A)}{E_{1,nq}(A/a)} \quad \ldots\ldots\ldots(4)$$

where a is the average load per inlet and n is the number of inlets per column.

When Binomial distribution is assumed to apply both to the link columns and the route, an even simpler expression for over-all congestion is obtained for a system of the type shown in Fig. 1:—

$$E = (b + c^q - bc^q)^m \quad \ldots\ldots\ldots(5)$$

Here c is the average occupancy per trunk in the route. Other symbols have been defined before.

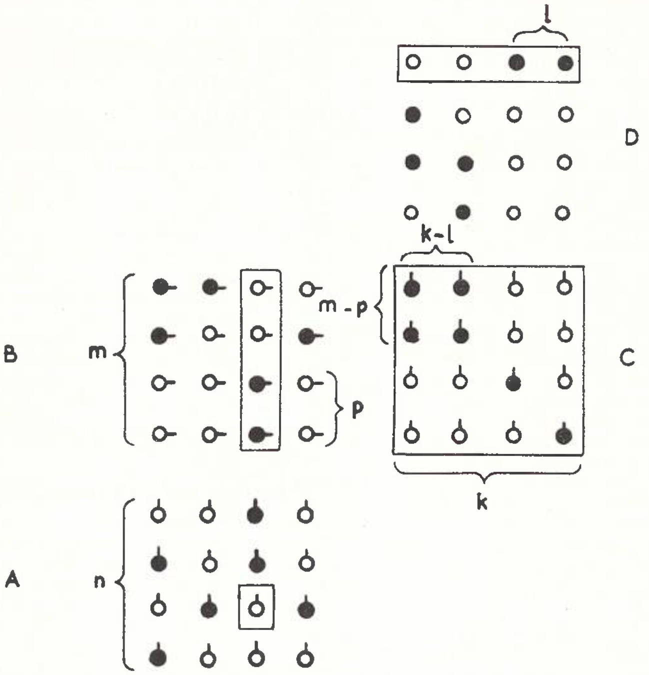


Fig. 2.—Grouping Plan of a 3-Stage Link System.

Fig. 2 shows the grouping plan of a three-stage link system without expansion or concentration between partial stages. To connect an inlet (array A) to the route (boxed-in row in array D), any pair of boxed-in links in arrays B and C can be used. The devices engaged at the moment are filled-in, and the figure shows one of the many possible ways in which congestion can occur.

When the number of partial stages in a link-trunked system is increased beyond two, the analysis becomes more difficult. Grading of outlets of interstage links introduces further complications and more approximate methods have to be used. The assumption of independence between traffic distributions in the partial stages still leads to simplest formulation, particularly if Bernoulli distribution is assumed for most or all of the partial stages.

The general expression for congestion in a three-stage system shown in Fig. 2 is:—

$$E = \sum_{p=0}^{m} G(p) \sum_{l=o}^{k} F(l).H(x) \quad \ldots\ldots\ldots(6)$$

Where

$F(l)$ = probability of l trunks being busy in the route.

$G(p)$ = probability of p links in a column of the B stage being busy.

$H(x)$ = probability of at least a particular set of x links in the C stage being busy.

$x = (m\text{-}p).(k\text{-}l).$

When appropriate Bernoulli probabilities are substituted for the $F(l)$, $G(p)$ and $H(x)$ terms, equation (6) simplifies to the following single sum:—

$$E = \sum_{p=o}^{m} \binom{m}{p} b^p(1-b)^{m-p}.(d+c^{m-p}-dc^{m-p})^k \quad \ldots\ldots\ldots(7)$$

The additional quantities introduced, b, c and d, represent the average traffic load per device in the B, C and D stages, respectively. Incidentally, equation (7) has been used by Elldin [2] to estimate terminating congestion in the SL stage of the ARF.10 system, and forms the basis of L M Ericsson SL stage dimensioning graphs, which are used in the Department. (A good explanation of L M Ericsson dimensioning methods for system ARF.10 will be found in reference [3].) The use of Bernoulli probabilities in all partial stages here leads to a good approximation of the over-all congestion, because the SL Marker distributes the load evenly over inlets and links, and because an SLD inlet always has access to a free SLC link (and thus to a full row of SLB links), since it does not occupy it.

It may be noted at this stage that three-stage link systems (and systems with more stages) generally have lower internal congestion than comparably loaded two-stage systems. The reason for this, of course, is due to provision in the former of more parallel connecting paths between any given inlet and a given outlet. Reference to Figs. 1 and 2 will show that in the system of Fig. 1 there is only one such path, while in the system of Fig. 2 m paths can be used to reach any particular outlet. An exception to the above observations is provided by two-stage incomplete link systems. In this class of systems the number of outlets per column is less than the number of links per column, so that more than one link can be used to reach any one particular outlet.

As mentioned earlier, the congestion expressions given above have been derived assuming independence between traffic distributions in the partial stages.

This assumption is quite justified in a lightly loaded system where all routes are operated at a good grade of service (say $\leqslant$ 0.005). Therefore, congestion expressions derived by Jacobaeus work quite well in lightly loaded systems.

The conditions are considerably different when alternate routing is employed. The bulk of the traffic is then disposed of via direct routes, which are heavily loaded and operate at a high level of congestion. Consequently, the link columns also work at fairly high average occupancies and exert a distorting or smoothing effect on the traffic distributions in the routes. Another effect present in such systems is the interaction between routes via the common links. This particularly applies to direct routes and their alternatives, where it is termed the correlated availability effect. Referring to Fig. 1, if a call originating in a particular inlet column overflows from the boxed-in route (which still contains free outlets), we know that some links in the column concerned are busy and hence cannot be used for access to the overflow route (assumed to occupy another column of outlets). The result is a slight reduction in effective availability to the overflow routes.

With respect to total congestion, the two effects described in the foregoing paragraph tend to compensate each other to some extent, but this compensation is only partial and the formulae based on independence between stages become inaccurate. The nett effect is that by neglecting the distortion of the traffic distributions in the routes by link congestion the overflow traffics are over-estimated. A more accurate formulation is, therefore, necessary.

The method, which will be outlined now, is more general. It takes into consideration the correlation between traffic distributions in the link columns and the routes, and is also applicable to link systems with grading. It is based on the "loss factor" approach (see [5] and [6]) and permits calculation of both mean and variance of the overflow traffic at all levels of congestion.

The loss factor $\beta(n)$ is defined as the average probability that when n circuits in the route are engaged the next call offered to this route will overflow. If we also define $P(n)$ as the probability of finding n circuits in the route engaged, the probability of congestion is given by:—

$$E = \sum_{n=o}^{c} \beta(n) . P(n) \quad \ldots\ldots(8)$$

where c is the total number of circuits in the route. The idea is to evaluate the $\beta(n)$ factors, then use these to derive the $P(n)$ terms (the distribution of traffic in the route) by some recursive process. When the traffic offered to the route, A, is pure chance, the $P(n)$ terms can be generated by the following recursion:—

$$P(n+1) = \frac{A(1-\beta(n))}{n+1} . P(n) \quad \ldots(9)$$

The distribution is then normalised to satisfy the condition:—

$$\sum_{n=o}^{c} P(n) = 1 \quad \ldots\ldots\ldots(10)$$

The form taken by the loss factor distribution depends on the system through which the circuits in the route are reached. In the simple case of full availability access $\beta(n) = O$ for all n from O *to* c-1, while for $n = c$ $\beta(n) = 1$. When $\beta(n) = O$ is inserted in equation (8), the terms generated will be those of an Erlang distribution. In certain homogeneous interconnecting schemes (Erlang's "Ideal Grading"), $\beta(n)$ terms are obtained from the Hypergeometric distribution:—

$$\beta(n) = \binom{n}{k}\binom{k}{k} \Big/ \binom{c}{k} \quad \ldots.(11)$$

where k is the availability. In link systems the availability cannot be regarded as constant, however, as it depends on the occupancy of the links. One has to employ the concept of distributed availability, which varies between limits imposed by the configuration of the system. In two-stage link systems without expansion in the link stage the lower limit is zero. In systems with expansion (e.g., ARF.10 Group Selector) the minimum availability is greater than zero, as the maximum number of occupied links per column cannot exceed the number of inlets per column. Thus, in a complete two-stage link system with the outlets interconnected in accordance to a particular set of conditions (Erlangs "Ideal Grading") and hunted randomly, the loss factors can be computed from the following equation:—

$$\beta(n) = \sum_{k=min}^{max} P(k) \binom{n}{k} \Big/ \binom{c}{k} \quad \ldots(12)$$

Here $P(k)$ is the probability of the instantaneous availability being k. The remaining term in the expression (the ratio of two Binomial co-efficients) represents the probability of finding the k available outlets among those occupied by the n busy trunks.

Under the conditions described above, the instantaneous availability is numerically equal to the number of free links in the column, l, multiplied by the number of outlet columns, q, containing the route in question. That is,

$$k = lq \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

Thus knowing the traffic distribution in the inlet columns—and hence the link columns—one can determine $\beta(n)$ for all values of n.

Assuming that the traffic offered to a selector stage as a whole is pure chance (Poisson), the traffic offered to an individual inlet column will be partitioned Poisson, for which Erlang and Binomial distributions can be regarded as the upper and lower limits. To compensate for the idealized assumptions made about the interconnecting schemes through which the outgoing routes are

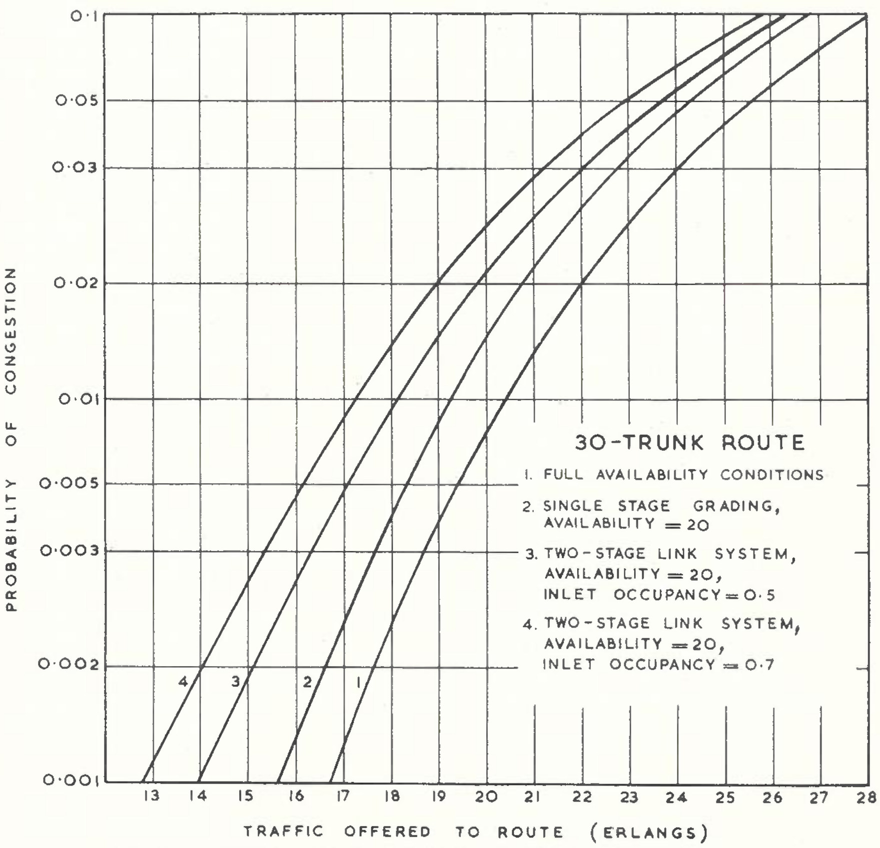


Fig. 3.—Comparison of Loss Functions for Different Access Systems.

reached, Erlang distribution in the inlet and link columns has been used to calculate the ARF.10 dimensioning curves (CP.368) issued by the Department.

The above described methods permit the computation of congestion and hence the overflow traffic. The calculation of the higher moments of overflow traffic is considerably more complicated and would occupy too much space to reproduce here. Briefly, the system of simultaneous difference — differential equations relating the probability states in the direct and the overflow route is converted to a system of linear difference equations, and the moments are obtained by solving the system using matrix inversion. Details of this work are to be published in an Australian Telecommunication Monograph.

To give an idea about the relative efficiency of the various trunking arrangements, the congestion function of a 30-trunk route offered pure chance traffic is given in Fig. 3.

Curve (2) has been calculated using the modified Palm-Jacobaeus formula (modified "BC" Table formula). Curves (2) and (3) were obtained from the relevant CP.368 graphs and hence are based on the more accurate loss factor method.

A comparison of the two dimensioning methods described in this section, as applied to a typical two-stage link system (ARF.10 Group Selector), is given in Fig. 4. The congestion functions plotted are:—

(a) Binomial distribution in link columns, Erlang distribution in the route (equation (2)).
(b) Binomial distribution in both the link columns and the route (equation (5)).
(c) Erlang distribution in link columns, route distribution derived from equation (9) (the "loss factor" method).

It is seen from Fig. 4 that curve (1) represents a good approximation at low loadings while curve (2) is a good fit at high loads. Since equations (2) and (5) are relatively simple functions, they are useful substitutes for the more accurate process at very light and very heavy loads.

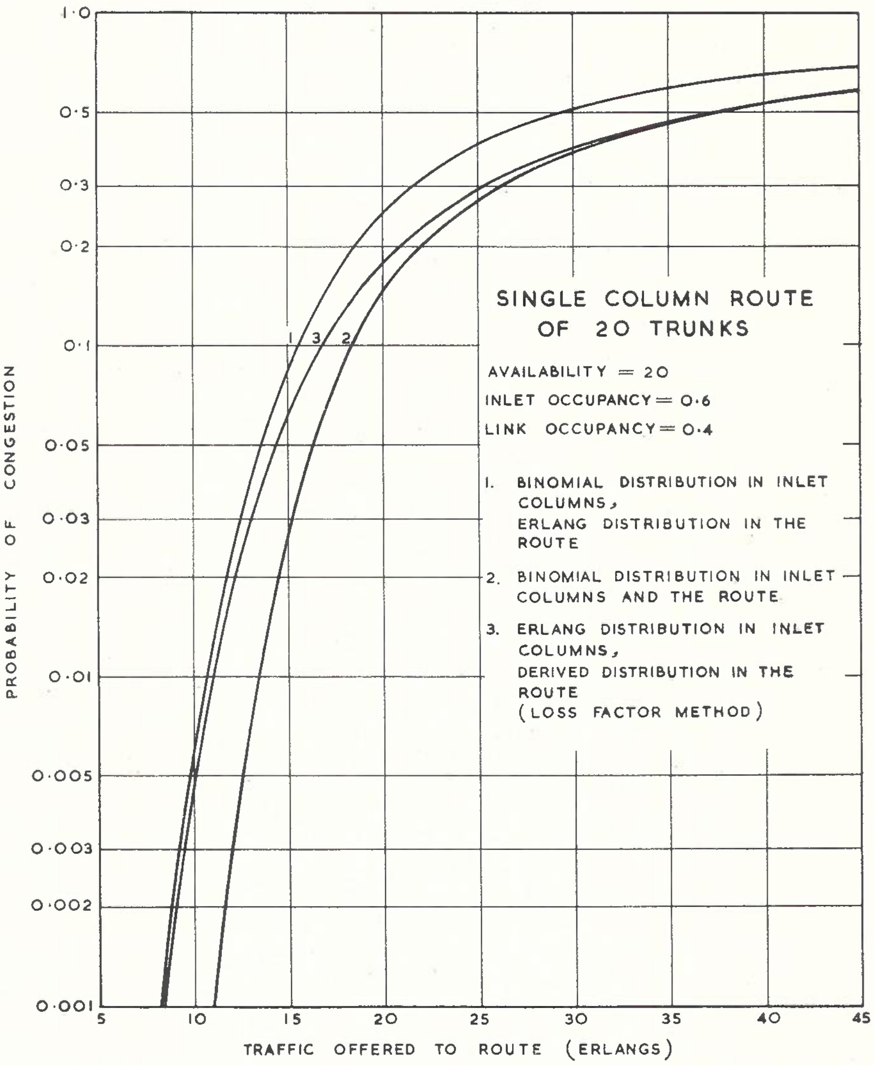


Fig. 4.—Comparison of Congestion Formulae for a 2-Stage Link System (ARF 10 GV Unit).

ALTERNATE ROUTING

To take full economic advantage of register controlled equipment, multi-choice alternate routing must be employed. Therefore, the L M Ericsson crossbar system ARF.101, adopted by the Department as the standard for our metropolitan networks, was modified to provide this facility (originally it catered only for one alternate route).

Unfortunately, accurate dimensioning of networks employing alternate routing is very difficult. Therefore, approximate methods of one kind or another have been used in all practical designs to date. The most accurate of the approximate methods is, undoubtedly, the "equivalent random" method, first published by R. Wilkinson [7]. It is a two-parameter method, the traffic being defined either by their first two cumulants (mean and variance) or by the average value of random traffic and the number of circuits in a full availability group to which this random traffic must be offered to overflow the traffic specified. This method is now widely used to dimension alternate routing networks where full availability trunking is employed.

The equivalent random theory applies only if the successive alternate routes have the same loss characteristic (or loss factor, β). Obviously, all full availability groups have the same $\beta(n)$, since—

$$\beta(n) = 0 \text{ for } n < c$$
$$\beta(n) = 1 \text{ for } n = c$$

The symbols have the same meaning as in equations (8) to (12). In the case of restricted access systems, however (e.g., gradings, link systems or a combination of both) the loss factors generally vary from route to route due to different availabilities and different trunk loadings.

The method used by L M Ericsson [8] is based on a single parameter—the mean traffic—with empirical correction factors. Jacobaeus formulae are used to calculate the overflow traffics. The method is safe and relies on traffic measurements after installation for adjustment of the initial design. Frequent measurements of traffic on the final choice routes is, therefore, an essential feature of the design process.

The Department has adopted a method, which is based on the Geometric Group approximation and equivalent random theory. A short resumé of the Geometric Group concept and its application in approximating actual trunking arrangements will, therefore, be given.

It was indicated in the preceding section that every trunking arrangement can be defined by its loss factor function $\beta(n)$. When this function is a geometric progression, that is, when—

$$\beta(n) = p^{c-n} \quad \ldots\ldots\ldots\ldots\ldots\ldots (14)$$
$$(0 \leqslant p < 1)$$

we have an arrangement which has been termed the Geometric Group, with p as its single parameter. It has been found that the Geometric Group model can be used to approximate almost any trunking arrangement operated as a loss system. What is even more important, by describing every access system in

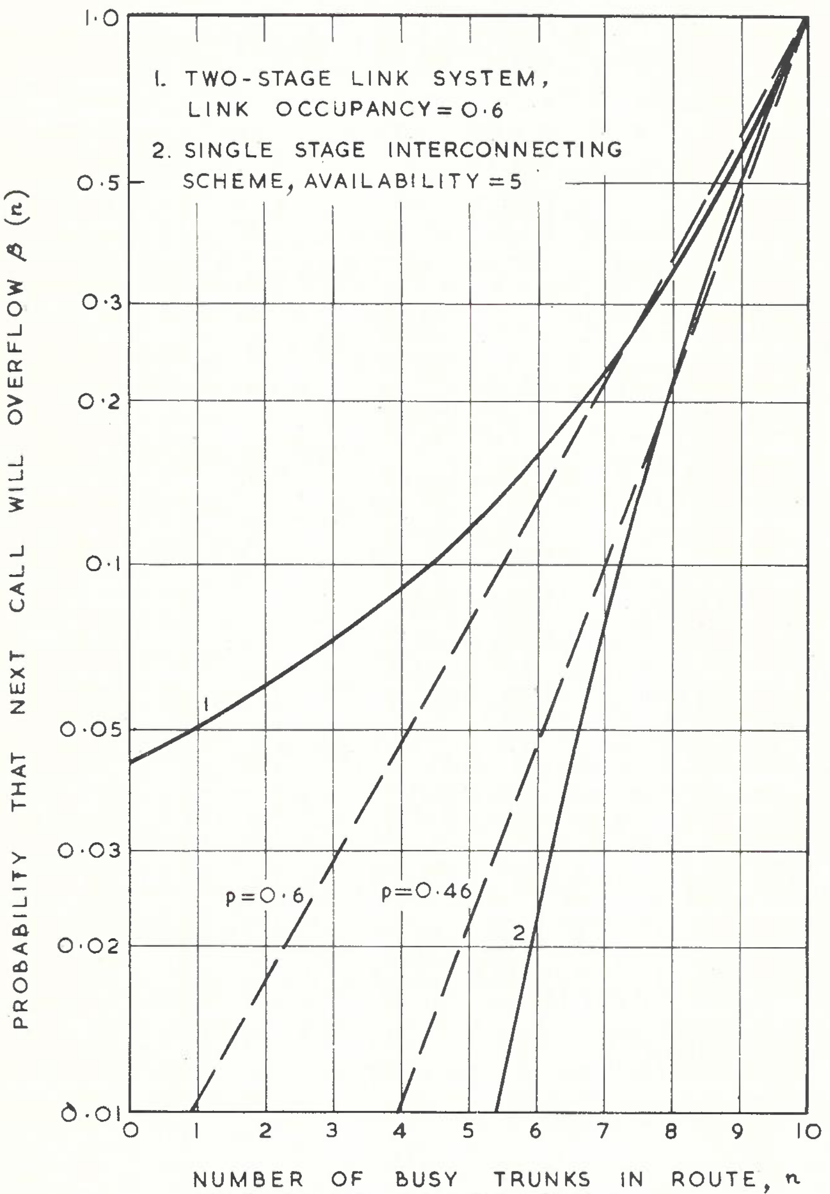


Fig. 5.—Comparison of Loss Factor Functions.

terms of the Geometric Group model it is possible to employ the equivalent random techniques for dimensioning such systems. That is, knowing the p value of a G.G. with N_1 trunks and the mean and variance of the traffic offered to it, it is possible to estimate the moments of the traffic overflowing from it, by first finding the equivalent random traffic A_r and a fictitious G.G. with N_0 trunks (but the same p), which, when offered A_r, would overflow traffic of required characteristics. The required overflow traffic from the original G.G. (with N_1 trunks) is obtained by offering A_r to the combined G.G. with $N_0 + N_1$ trunks. A family of G.G. graphs for various values of parameter p has, therefore, been prepared, from which the mean and variance of the overflow traffic can be read off for a given number of trunks and pure chance offered traffic.

By employing the Geometric Group approximation, we replace a generally complicated $\beta(n)$ function by a simple geometric series with a common ratio p as the only parameter. It is evident, therefore, that to provide a good fit, p must be derived from the physical parameters of the actual system approximated.

To get a better appreciation of what is involved let us have a look at Fig. 5. Here the loss factors of a two-stage link system and a single stage interconnecting scheme are plotted as a function of n the number of busy trunks, in the route containing 10 trunks. The dotted lines represent possible Geometric Group approximations to these loss factor functions. (Note that a geometric series always plots as a straight line on log-linear grid).

All curves are pivoted on the point $\beta(10) = 1$. The gradient of the p lines is controlled by the value given to p, so that by varying this parameter we can approximate any section of the actual loss factor characteristic. Over which section of the $\beta(n)$ function one should provide the best fit depends on the relative magnitude of the traffic load carried by the route in question. In heavily loaded routes (e.g., direct routes) the most probable condition will be only one or two trunks free, hence we should select a p value to provide the best fit over the top section of the $\beta(n)$ characteristic.

Conversely, in lighter loaded routes the most probable states correspond to a greater proportion of free trunks and p should be chosen to intersect the $\beta(n)$ characteristic of the actual system at a lower point ("high" and "low" are used with reference to Fig. 5). It may be noted here, that a two-stage link system without grading, and Binomially loaded link columns is a true Geometric Group, with the parameter p equal to the average link occupancy. For curve (1) in Fig. 5, Erlang distribution for the traffic in link columns was assumed, hence the $\beta(n)$ function is not a straight line but a concave curve. In actual link systems the traffic distribution in link columns lies between the Binomial and Erlang models.

Analysis of link systems shows that the over-all congestion probability does not depend much on traffic distribution in the link columns. This means that the Geometric Group model, with a well chosen parameter p, can provide a very good approximation in the great majority of the cases. For an illustration turn back to Fig. 4. The same congestion function, computed using the Geometric Group approximation with $p = 0.4$ and plotted on the same grid, would be indistinguishable from curve (3). Since in the stages employing alternate routing, the loading of most routes is high, the parameter p is chosen to intersect the actual loss factor function at the point corresponding to one free trunk in the route. That is—

$$p = \beta(c-1) \quad \ldots\ldots\ldots\ldots\ldots\ldots (15)$$

and can be determined from the relevant expression for $\beta(n)$. In link systems, where the availability is not fixed but distributed, this involves a summation. For all practical purposes, however, the average availability, $\bar{k}$ can be used. The required p is then found from either of the following two simple formulae:—

$$p = \frac{c-\bar{k}}{c} \text{ when } c \geqslant mq \ldots . (16)$$

and

$$p = b^{mq/c} \text{ when } c < mq \quad ..(17)$$

The symbols used in (16) and (17) have the following meanings:—

c = total number of trunks in the route;

$\bar{k} = mq(1 - b)$ = average availability, where b is the average load per link;

m = number of links (per column) which can connect to the route in question;

q = number of outlet columns occupied by the route.

All dimensioning processes evolved for the design of alternate routing networks have the same objective—namely, to minimise the over-all cost of the network, subject to constraints imposed by the grade of service and transmission standards, and the location of existing plant. In this respect the methods adopted by the Department are no exception. In essence, they are analogous to the techniques developed by Wilkinson for full availability trunking, which are now well known. Therefore, only an outline of the Department's method will be given. The method will be described in full detail in the A.P.O. Engineering Instruction PLANNING Traffic J1300, now in preparation.

The process starts with the evaluation of the economic marginal occupancies ("H" factors) for every route, except the final choice fixed grade of service routes. Then the selector outlets are divided among the proposed routes.

The economic marginal occupancy (H) is determined from network parameters using the following equation:—

$$H = \frac{\text{Cost of a direct circuit}}{\displaystyle\sum_{all\, j} \frac{\text{Cost per circuit in the } j^{th} \text{ section of alternate route}}{\text{Marginal capacity of the } j^{th} \text{ section of alternate route}}}$$

Marginal capacity is the change in offered traffic required to restore the proportionate loss in a group of circuits when another circuit is added.

The allocation of selector availability depends on the traffics offered to the various routes and their "H" factors. In the simplified manual process the "H" factors are assumed to be constant and the availabilities are allocated in proportion to the traffics offered to the various routes. The outlet allocation is adjusted to standard availabilities, staying within the limits of the total number of outlets available. For subsequent calculations the nominal availabilities *(mq)* are converted to average availabilities $(\bar{k})$.

The next step is the determination of the number of circuits for every direct route. Sufficient number of circuits is provided to make the marginal occupancy of the route equal (as nearly as possible) to the "H" factor computed for it previously. The marginal occupancy is defined as the increase in the traffic carried by a group of circuits when an additional circuit is provided, the offered traffic having remained the same. The marginal occupancy of a group of trunks is a function of the traffic offered to it and the availability.

Knowing the number of direct route circuits and the traffic (assumed pure chance) offered to them, one can obtain the first two cumulants of the traffic overflowing to second choice routes. Before these routes can be dimensioned, however, it is necessary to calculate the reduction in their effective availability due to correlation effects. It is also necessary to represent the nonrandom traffic offered to it by a fictitious system, defined by the number of circuits, effective availability, and the value of random traffic which would generate the actual overflow traffic when offered to the fictitious system. The number of circuits and the availability of the fictitious system is so chosen that the *p* parameter of it is equal to the *anticipated p* value of the alternate route (the true value of *p* for the latter route is not yet known, since it depends on the number of circuits, still to be determined, as well as on the effective availability, already established). The number of circuits for the alternate route is so chosen that the marginal occupancy for the combined group (including fictitious circuits) has the required value.

The actual *p* value for the alternate route is then obtained and, if it is significantly different from the initially assumed value, a repetition of the calculation with adjusted values is necessary.

The required moments of traffic overflowing from the alternate route are determined by offering the equivalent pure chance traffic to the combined group.

The same technique is repeated with later choice routes, until only the final choice routes are left. These are dimensioned not for an economic marginal occupancy, but for a prescribed loss probability. The same equivalent random techniques based on the Geometric Group approximation are again employed. To avoid, during periods of overload, undesirable deterioration in the grade of service experienced by the first choice traffic component, some of the circuits on the backbone route can be made exclusive to this traffic. The final choice route will then be, effectively, divided into a direct and a backbone component.

The dimensioning process described above can be performed manually, with the aid of a few graphs (CP364, CP367 series). Alternatively, the work can be done on a digital computer. Programs are now available to perform most of the steps in the process.

DIMENSIONING OF COMMON CONTROL EQUIPMENT

In the conventional step-by-step networks, each selector switch has its own controlling mechanism, which receives routing information (dial impulses), selects the wanted route, hunts for a free trunk in that route, and either extends the connection to the next stage by seizing a free circuit, or, failing to find a free circuit, feeds back a busy signal. During the conversation—or when the switch is not in use—the steering mechanism and the controlling relays are idle. The number of switches—and hence the number of control mechanisms — is determined solely by the requirements of speech paths.

In register controlled crossbar systems the controlling equipment is separated from the selectors switching the speech paths. At the same time, one control unit can attend to a large number of selectors, serving each selector in turn. Furthermore, the centralised control gear is sub-divided into functional units, each designed to perform only a particular control function. For example, registers receive and store dialled routing information and pass this information (in a coded form) to markers, markers set up calls through the crossbar switches, as directed by the coded information received from registers in the same or another exchange. It is, therefore, clear that the quantities of the various common control relay sets must be determined independently of the speech circuits and to different service standards.

To be efficient the common control equipment must be fast operating. In other words, the holding times necessary to perform their specified control functions must be short in relation to the average length of a telephone conversation. Under these conditions delay (instead of loss) working becomes an atractive proposition, as it helps to increase the utilization of expensive control equipment considerably. Consequently, in common control systems delay working (or a mixture of loss and delay) is the usual mode of operation. It is, therefore, necessary to make a brief survey of delay systems and their behaviour.

Delay systems differ from loss systems in one major aspect: the calls, which cannot be switched through immediately because of congestion, are not rejected, but held in suspense (i.e., stored) and connected when a line becomes free. The behaviour of both loss and delay systems depends on the character of the traffic offered and the trunking configuration. The delay systems, however, are also dependent on the distribution of call holding times and on the method of removing delayed calls from the queue.

The mathematical analysis of delay systems is generally more difficult than in the case of loss systems. Usable theoretical solutions exist only for full availability serving trunk groups and the following combinations of other variables:—

(a) Server holding times distributed exponentially.

Number of Traffic Sources	Method of Removal from Queue	Number of Servers
Infinite (Poisson input)	Either random or in order of arrival	Unrestricted
Finite	In order of arrival	Unrestricted

(b) Server holding times constant; Poisson input.

Method of Removal from Queue	Number of Servers
In order of arrival	Unrestricted
Random	One

It is customary to describe the performance of a delay system by any one (or all) of the following parameters:—

D_1 = average delay on all calls,
D_2 = average delay for delayed calls,
$P(>0)$ = probability of delay,
$P(>t)$ = probability of delay greater than t.

All of the above listed parameters depend on the holding time distribution of the serving devices, but only the last one depends on the method of taking the calls from the queue. Consequently, the last parameter is the most important in assessing the performance of a delay system and is used to set the service standards.

Although the actual holding time distributions of crossbar common control relay sets do not follow a simple mathematical law, both constant and negative exponential holding time distribution models are used in dimensioning common control units operating on a delay basis. To give some idea of the dependence of the main parameter, $P(>t)$, on the holding time distribution and the queueing discipline, the case for one server is illustrated in Fig. 6. Pure chance traffic of 0.5 erlang is offered to one serving trunk, and the probability of delay exceeding t holding times is plotted against the actual delay (in multiples of the holding time, h) under four different conditions.

It is evident from Fig. 6 that exponential holding times lead to longer delays than constant holding times. It is also apparent that the probability of long delays is less, when the calls are served in the order of their arrival (queued operation), than in the case of random service. The position is reversed, when we consider short delays—of the order of two holding times or less. It should be noted that the mean holding time is the mean occupation time per call of the serving device and does not include the waiting time.

In general, the probability of delay exceeding a prescribed value cannot be expressed as a simple equation. Simpler expressions, however, are possible for the other parameters of a delay distribution, particularly in the special case of one server. These are given for both holding time distributions in Table 1.

TABLE 1

	Exponential Holding Times	Constant Holding Times
Probability of Delay	$P(>o) = A$	$P(>o) = A$
Average delay on all calls	$D_1 = \dfrac{Ah}{1-A}$	$D_1 = \dfrac{Ah}{2(1-A)}$
Average delay on calls delayed	$D_2 = \dfrac{h}{1-A}$	$D_2 = \dfrac{h}{2(1-A)}$

A = pure chance traffic offered in erlangs ($o<A<1$)
h = mean holding time of server.

In the case of exponential service times, the same parameters for N servers are:—

$$P(>o) = \frac{NE_{1,N}(A)}{N-A(1-E_{1,N}(A))} \quad ..(18)$$

$$D_1 = \frac{hP(>o)}{N-A} \quad ....(19)$$

$$D_2 = \frac{h}{N-A} \quad ....(20)$$

No such simple expressions can be derived for the constant holding time delay distributions. Graphs of all important parameters are, however, available (see, for instance, Refs. [9], [10], [11] and [12]) and can be used for dimensioning purposes. At the same time it should be noted that the probability of delay, the average delay on all calls, and the average delay on calls delayed are linearly related, so that knowing any two variables it is easy to find the third. This relationship, which is independent of the holding time distribution and the queueing discipline, is given below:—

$$D_1 = D_2.P(>o) \quad ....(21)$$
$$(N,A = \text{const.})$$

As stated before, common control equipments in a crossbar system are, as a rule, operated on a delay basis. One major exception to this rule in L.M.E. crossbar systems is represented by registers, where loss working is employed. To appreciate the reason for this exception let us consider the effect of cumulative delays. In a typical register controlled crossbar exchange, several types of specialised common control units co-operate in putting the call through the various switching stages. For the most part the operation of control units is sequential on any one call. That is, each control unit performs its function towards the completion of the call in turn, the timing of the execution of this function depending on the completion of another operation by the

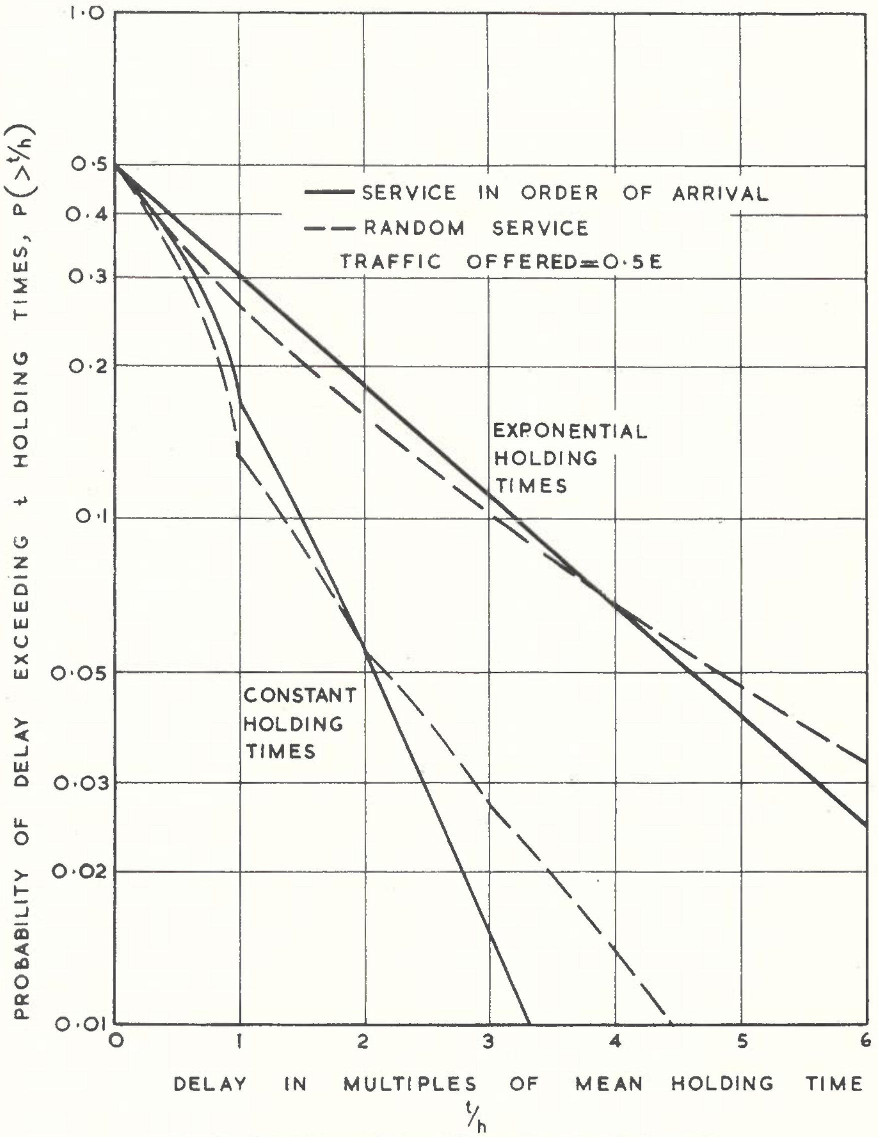


Fig. 6.—Comparison of Delay Distributions for One Server.

preceding control unit. To take a practical example from the subscriber stage of an ARF.10 exchange (one SL Marker per 1,000 lines), we have, essentially, the following sequence of operations on an originating call. SL Marker searches for the calling line, selects a free SR, then calls an RS Marker which can connect to the chosen SR; RS Marker selects a free register and signals the SL Marker that the connection can now be established between the calling line and the register. SL Marker completes this connection and releases itself to serve other calls. The SL Marker holding time, thus, includes the RS Marker holding time, plus any waiting time for it (in case all RS Markers were busy when the SL Marker needed one). Since the RS Marker holding time is very short (a small fraction of a second) and the traffic offered per RSM low, the average delay is small and does not add significantly to the SL Marker holding time. If, on the other hand, the SL Marker also had to wait for a register (in cases when all registers are busy), the mean holding time of the SL Marker would increase considerably, even if registers were provided liberally. This is because the average holding time of a register is very much longer than that of an SL Marker, so that even at low probabilities of delay, the actual average delay would be long compared to the Marker holding time. Therefore, employing delay working of registers would significantly increase SL Marker traffic, leading to uneconomic provision of these expensive relay groups. It must be pointed out that this does not necessarily apply to all common control systems. With a different organization of the common controls, and a lower marker/register cost ratio it may be economical to employ delay working on the registers also.

The effect of cumulative delays has an important bearing on the distribution of holding times for the various units. Let us again consider the holding time of the SL Marker. While the actual operation times of RS and SL Markers are practically constant for every originating call, the delay on the RS Marker is variable, so that the over-all holding time of the SL Marker is not constant. The position is further complicated, when two SL Markers are provided per 1,000 lines, and when the interference of the terminating calls is considered. Since only one SL Marker can operate in a 200-line group at any one time, another component of delay (due to the second SL Marker setting up a different call in the wanted 200-line group) must be included in the SL Marker holding time. On terminating calls the SL Marker holding time consists of an approximately constant operating component and, if two SL Markers serve the 1000 line group, there is also the delay component due to both Markers wanting to set up calls in a particular 200-line group at the same time.

The situation is similar in the case of other common control units—GV Markers, Code Senders, Code Receivers, etc.—where the actual holding times are composed of constant and variable components. A detailed analysis of common control equipment in L.M.E. crossbar exchanges of the type ARF.10 will be found in Ref. [3].

In order to estimate the quantities of the various common control units, it is necessary to calculate the traffics offered to them and also the distribution of their holding times. The traffic offered to a device is the product of the average number of calls offered to the device per unit time and its average holding time. The estimation of the number of calls offered usually presents no difficulties, but the calculation of the average holding time of the device may not be so simple. In the general case, we must add a number of constant operating times and delay components. To get the averages of the delay components, we must, in turn, calculate the traffic loads on the devices causing the delay and compute (or read off from a suitable graph) the average delay for all calls. At this level the holding time distributions are generally constant or composed of constant elements only, so that pretty accurate estimates of the average delays can be obtained.

To compute the holding time distributions of the higher order common control devices (i.e., those units, whose holding times include delays and functioning times of other devices), we must statistically combine (convolute) the component delay distributions which make up the total holding time of the device. To do this accurately, however, would lead to very serious mathematical difficulties, even if all the component distributions would conform to either of the two idealised models discussed previously. To take a typical case, the holding time of the SL Marker is a weighted average of five constant and three variable components (two SLM per 1,000 lines). Exact analysis of such a system is well beyond the bounds of practicability. The practical design approach would be to take one of the following three courses. If the sum of the delay components is very much less than the sum of the constant components, the system is approximated by the constant holding time model. If the converse is true, the exponential distribution of the over-all holding time is assumed. Finally, if both constant and variable components are of the same order of magnitude, we can proportionate between the constant and exponential models in accordance with the relative magnitudes of the constant and the variable components respectively. The standard of service is measured by the probability of the delay exceeding a certain time, which is usually expressed in terms of the average holding time.

To simplify the work of the design engineer, the capacity of a common control unit is often expressed in terms of the number of calls it can handle per hour for the specified delay service standard. Obviously, call capacities for two, three or more units of the same type working as group are not simple multiples of the single unit capacity and must be stated separately for every grouping.

GRADE OF SERVICE STANDARDS

All telephone systems are designed to provide a certain service standard, which is a compromise between what is desirable from the subscribers' point of view and what is economical. The service standard we are concerned with here is the over-all design probability of not being able to connect the calling party to the called party because of lack of circuits. In Australian unit fee networks (with exception of connections including certain groups of junction circuits) this over-all design grade of service is one lost call in 100.

In step-by-step networks the over-all grade of service can be fixed by allocating maximum permissible loss probabilities per switching stage, so that their sum equals the required over-all standard. When alternate routing is introduced, the setting of the over-all service standard becomes more complicated. In addition, when a combination of loss and delay working is employed — as is the case in a crossbar system — the loss standard alone is no longer adequate. Let us examine each aspect of the service standard in turn.

In a network employing multi-alternate routing, different parcels of traffic have different numbers of alternate paths to choose in seeking their destinations. To a first approximation, the grade of service experienced by a particular parcel of traffic is equal to the product of the loss probabilities encountered on all parallel paths (alternate routes) available to this traffic. To protect the first choice traffic on the backbone routes which have no alternative routes to overflow to, good grade of service is provided on the final choice routes. It is obvious that under such conditions traffics, which have a choice of one or more routes before overflowing to the backbone route, enjoy a far better grade of service than the design standard. This indicates that the network can be cut back without degrading the over-all grade of service. The simplest way to achieve this is by providing exclusive circuits for the first choice traffic on the backbone routes. The remaining circuits, then as before, make up the final choice route for the various overflow components. The number of circuits on the common part of a final choice route should be calculated so that the least favoured parcel of traffic overflowing to this route experiences the over-all specified grade of service.

The service standards in delay systems are not as clearly defined as in loss systems. The permissible probability of delay exceeding a certain time is usually specified separately for each group of devices where delay working is employed. Excepting the delay in receiving dial tone, the service standards in a delay system are based on the functional requirements of the equipment and its overload capacity rather than on subscriber's inconvenience. In any case, the operating times and average internal delays of modern common control equipment are so short that they are not noticed by the subscriber, except during periods of severe overload.

The proper way to specify the design standards of service for delay systems is to give the probability with which a delay of so many holding times may be exceeded. The alternative methods of specifying the probability of delay exceeding so many units of time (e.g., seconds) lacks the basis for comparing delay systems operating at different mean holding times. Table 2 illustrates this point. Here the probabilities of waiting more than one, two and three seconds is compared for two groups of devices with average holding times of 0.2 and two seconds respectively. There are four devices in each group, full availability conditions obtain in each case, holding times are exponentially distributed, and the service is random.

TABLE 2: COMPARISON OF DELAY SYSTEM STANDARDS

	Traffic Load per Server	Probability of Delay Greater than:—			
		0 sec.	1 sec.	2 secs.	3 secs.
Group "A" $\bar{h} = 0.2$ sec.	0.70	0.43	0.025	0.0045	0.0011
Group "B" $\bar{h} = 2$ secs.	0.40	0.090	0.025	0.010	0.004

It is clear that in system "A" the probability of short delays (<1 sec.) is higher, and that of long delays (>1 sec.) lower than in system "B". At the same time, system "A" handles 75% more traffic than system "B". Thus, specifying the same probability of delay greater than one second would produce quite different conditions in systems with greatly unequal holding times.

OVERLOAD

The last, but not least, problem to consider when dimensioning telephone systems is that of overload. It is well known to traffic engineers that there are several days each year, when traffic in the network rises well above its busy season busy-hour value. Long-term traffic measurements here and overseas indicate that, on the average, there are four or five days in the year when the traffic intensity rises 30% or more above the average busy season level. It would be uneconomical to provide enough plant to maintain the standard grade of service even on such high load days. On the other hand, we must ensure that a tolerable service is provided even under overload conditions. This is less of a problem in step-by-step networks, which have individual controls and a certain amount of overload capacity in every route. In crossbar networks, employing alternate routing and delay working in the vital common control units, overload characteristics are quite different and must be carefully considered.

In a network employing extensive alternate routing, local overloads at any part of the network are transferred to the backbone routes and hence affect the whole network. Some spare capacity must, therefore, be provided, which is usually incorporated in the final choice routes.

The effects of traffic overload in delay systems are somewhat different. A loss system normally shakes off a proportion of its overload in so far that some lost calls are not repeated during the busy hour. Hence unless the overload is severe and the grade of service is pushed beyond about 0.05, the loss system continues to function normally and without loss of efficiency. In a delay system, the effect of overload is to increase the average delay on all calls. When the load per serving device reaches one erlang, the delays become infinite and the system blocks up. The saturation point will come well before this loading is reached in systems where several control devices have to operate in sequence to put a call through. This applies to most common control systems, but in particular to those designed with a complex interlocking control structure (e.g., ARM.20 trunk exchange; a penetrating analysis of the call handling capacity of this exchange type will be found in Ref. [13]). The delays accumulate along the control chain, increasing the holding times of the individual control units, and rapidly pushing the occupancy per device to one erlang. Thus, an overload in any one control unit in the chain is sufficient to block the whole system.

In view of what was said in the preceding paragraphs, it is desirable to specifiy a double standard for the design grade of service. That is, a normal standard for the average busy season load, and an overload standard, at which the system is to work under the specified overload. This idea is not new and has been incorporated in the standard step-by-step traffic capacity tables. Such automatic overload protection, however, is not available to the traffic engineer dimensioning crossbar networks, so that each trunking design must be evaluated under overload as well as normal load conditions.

CONCLUSIONS

The register controlled switching system provides additional facilities for the more efficient disposal of traffic and necessitates a radical departure from the dimensioning techniques employed in step networks. In view of extensive alternate routing, individual exchanges can be no longer regarded in isolation —they are only nodal points of the network, which must be treated as a whole. Link trunking, common control, multi-alternate routing, all make the dimensioning of the network a rather complex process. More sophisticated mathematical techniques are required and the sheer volume of numerical calculations make the assistance of electronic digital computers essential.

ACKNOWLEDGEMENTS

The author wishes to thank Mr. N. M. H. Smith and Mr. J. N. Bridgford for many valuable comments and suggestions.

REFERENCES

1. C. Jacobaeus, "A Study of Congestion in Link Systems"; Ericsson Technics, No. 48, 1950.
2. A. Elldin, "Switch Calculations—General Survey"; L M Ericsson Book B 11265.
3. A. Elldin, "Basis of Traffic Tables Used in L M Ericsson System ARF.10"; P.M.G.'s Department Planning Information Bulletin, No. 14, Part 2.
4. N. M. H. Smith, "Traffic and Trunking Principles in Link-Trunked Crossbar"; P.M.G.'s Department Planning Information Bulletin, No. 14, Part 1.
5. N. M. H. Smith, "More Accurate Calculation of Overflow Traffic from Crossbar Group Selectors"; Telecommunication Journal of Aust., Vol. 13, No. 6, page 473.
6. N. M. H. Smith, "More Accurate Calculation of Overflow Traffic from Link Trunked Crossbar Group Selectors"; Paper published at the 3rd Teletraffic Congress in Paris, 1961.
7. R. I. Wilkinson, "Theories for Toll Traffic Engineering in the U.S.A."; Bell Systems Technical Journal, No. 2, 1956.
8. A. Elldin, "Application of Alternate Routing for Local Networks with System ARF.10"; L M Ericsson Book S-11447.
9. E. C. Molina, "Application of the Theory of Probability to Telephone Trunking Problems"; Bell System Technical Journal, Sept., 1927.
10. C. D. Crommelin, "Delay Probability Formulae"; Post Office Electrical Engineers Journal, January, 1934.
11. R. I. Wilkinson, "Working Curves for Delayed Exponential Calls Served in Random Order"; Bell System Tech. Journal, March, 1953.
12. P. S. Burke, "Equilibrium Delay Distributions for One Channel with constant Holding Time, Poisson Input and Random Service"; Bell System Tech. Journal, July, 1959.
13. N. M. H. Smith, "Crossbar Trunk Exchange Type ARM.20; Call Handling Capacity of Control System"; A.P.O. Traffic Engineering Report No. 1.
14. J. Rubas, "ARM.50 — Traffic Capacity of Speech Circuit Trunking"; A.P.O. Traffic Engineering Report No. 2.

PETERSHAM ARF.102 – CROSSBAR EXCHANGE INSTALLATION

*W. McMURRAY**

INTRODUCTION

The Petersham step-by-step exchange was cutover in the 1930's with Strowger equipment. At the date of the establishment of the crossbar extension (May, 1963) the step-by-step exchange consisted of 9,300 lines of mixed Strowger and 2,000 type equipment, 1,300 numbers of which were in a temporary location in the power room on the ground floor. The reasons for the adoption of a common control system employing the crossbar principle have been described in previous issues of this *Journal* (1), (2), (3), but are recapitulated here. This system will:—

(i) meet the technical requirements for operation of Australia's telephone communication network at the highest possible standards better than any other system employing different principles;
(ii) cater better and more economically than any other available different type of system for the expansion of the numbering capacity of the large metropolitan networks and the creation of rural linked numbering areas;
(iii) be suitable for economic local manufacture;
(iv) be more adaptable than any other available system of a different type to foreseeable future developments such as full electronic control and push button telephones, as these become commercially attractive;
(v) be capable of complete integration with existing switching equipment;
(vi) permit of a worthwhile reduction in the overall cost of automatic telephone exchange equipment;
(vii) permit more readily than in other systems of the introduction of complete maintenance and service observation aids and of a substantial reduction in the cost of maintenance of telephone exchange plant generally;
(viii) provide the most effective known available means of achieving greater value for a given expenditure on the network as a whole.

In August, 1958, the Postmaster-General's Department sought a suitable locality in which to install approximately 2,000 numbers of LME ARF.102 crossbar equipment on a trial basis. What was required was a practical network example on which LME could finalise the detailed design of their ARF.102 system for the Department in a situation where the LME equipment was required to work into an Australian metropolitan network. Petersham was chosen because:—

(a) though a member of '5' Tandem exchange group, it had high community of interest with the '2', '7' and '8' groups, and in particular, with the adjacent '7' group;
(b) the capacity of the first floor area was 8,000 lines of step-by-step equipment and this had been extended to 9,300 lines by installing 1,300 lines in a temporary location in the power room. It was necessary to recover this equipment from the power room, to allow for extension of the power equipment;
(c) subscribers' development justified the installation of 2,800 numbers of equipment at this stage.

The first deliveries of equipment were made in March, 1961, and the last in November, 1962. The installation commenced in May, 1961, and between this date and the date of the last shipment, 24 shipments were received.

Facilities. The facilities provided at Petersham are shown in Appendix A.

FEATURES OF THE INSTALLATION

The installation differs from the Toowoomba ARF.101, described in a previous issue of this *Journal* (4), in the following way:—

(a) The 1GV stage (see Appendix B for list of abbreviations) is changed to meet the requirements of a metropolitan network with from four to eight figure numbering requiring the identification of over a hundred outgoing routes and the analysis of a considerable number of dialling codes.

The basic group selector stage of 80 inlets and 400 outlets is the same but an availability of 5 is possible and the addition of an analyser (GVAN) permits the identification of up to 80 routes after receipt of the first, second, third or fourth digit and the analysis of number lengths of from three to eight digits. In the Sydney telephone network the code number lengths are seven 3 digit, eighteen 4 digit, ninety-six 5 digit, five hundred and eighty-one 6 digit, ninety-four 7 digit, and two 8 digit. The Petersham equipment is capable of analysing 100 codes to the second digit, 1,000 to the third digit and 38 of the third digit codes to the fourth digit. If more than 38 codes require analysis to the fourth digit they must be categorised to the register as number length unknown. The design of the Petersham equipment does not cater for codes with number lengths of 3, 4, 8 or more than 8 digits. These codes must be categorised as number length unknown.

Therefore it was necessary to make some number changes to rationalise the number lengths and bring them within the limits of the system design.

(b) Multi-frequency signalling is employed on crossbar to crossbar calls and the register is designed to convert from multi-frequency signalling to decadic for crossbar to step-by-step calls.
(c) Troughing was used to house the cables instead of runways.
(d) The suite control wiring (common services) differs from step-by-step in that instead of one ring and tone feed being wired from each rack to the suite control box with isolating keys on the rack, a feed from each relay set is taken to the suite control box where isolating for fault tracing is carried out.
(e) Because of the troughing, the BDD rack jack units are vertically mounted to allow access to the jack field.

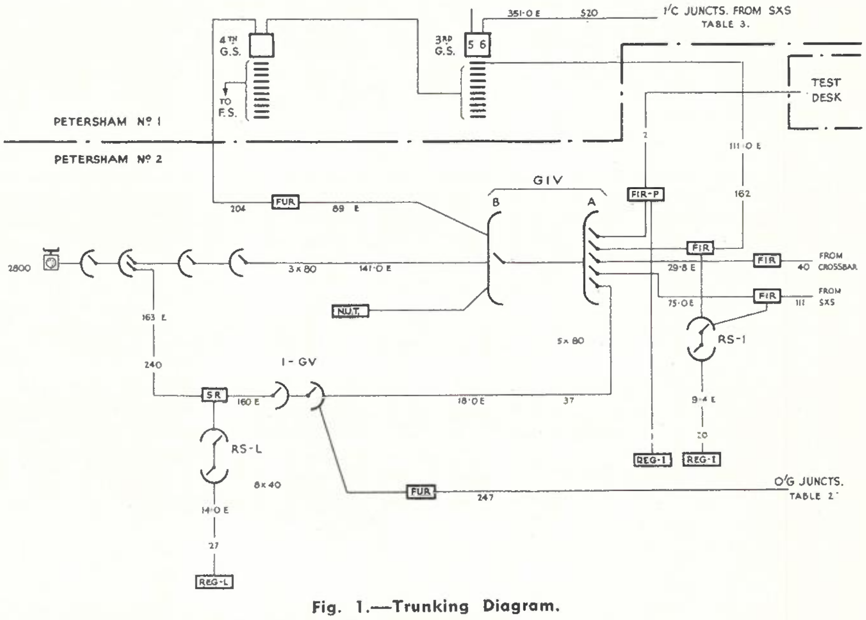


Fig. 1.—Trunking Diagram.

---

*Mr. McMurray is Divisional Engineer, Exchange Installation, N.S.W. See page 250

TABLE 1. OUTGOING JUNCTIONS

From Petersham to	Terminating Equipment		Serving Codes	Estimated Offered Busy-Hour Traffic-Erlangs		No. of Outgoing Junctions		Junction Loop Resistance Ohms	Avail-ability at 1962
	Selector Rank	Type of Equip-ment		1962	1965	1962	1965		
Dalley Trunk	"01" 3rd Sels	2000 S & R		1.23	1.58	7	7	940	10
City South	"21" ,,	2000 S	"21"	1.56	—	2	—	890	10
Haymarket	"21" ,,	Crossbar	"21"	—	4.71	—	7	890	10
Central	"25" ,,	Strowger S	"25"	1.90	5.13	2	8	900	10
City South	"26" ,,	2000 S	"26"	2.00	—	3	—	980	10
Haymarket	"26" ,,	Crossbar	"26"	—	2.56	—	3	980	10
Dalley	"27" ,,	2000 S	"27"	2.70	3.46	3	5	930	10
City North	"28" ,,	Strowger S	"28"	3.56	4.58	5	6	900	10
York	"29" ,,	2000 S	"29"	3.46	4.44	5	7	990	10
City South	"20" ,,	2000 S & R	"20"	7.70	9.62	10	12	890	20
East	"31" ,,	Strowger S	"31"	3.70	4.77	5	6	880	10
East	"3" 2nd Sels	2000 S & R	"3" codes not direct routed plus overflow to all "3" codes.	8.29	11.37	9	13	900	20
Chatswood	"4" ,,	Strowger S & R	"4"	4.40	6.33	4	6	2360	10
Newtown	"51" 3rd Sels	2000 S	"51"	7.10	9.12	9	12	460	10
Undercliffe	"55" ,,	2000 S	"55"	3.08	3.96	5	6	490	10
Kingsgrove	"50" ,,	2000 S	"50"	—	2.09	—	3	1375	—
Newtown	"5" 2nd Sels	2000 S & R	"5" codes not direct routed plus overflow traffic to all "5" codes.	10.90	16.79	13	20	460	20
Mascot	"67" 3rd Sels	2000 S	"67"	2.71	3.82	3	5	1400	10
Glebe	"68" ,,	Strowger S	"68"	2.54	3.39	4	6	870	10
Redfern	"69" ,,	2000 S	"69"	3.24	4.16	4	5	950	10
Redfern	"6" 2nd Sels	2000 S & R	"6" codes not direct routed plus overflow to all "6" codes.	10.40	9.8	12	11	640	20
Ashfield	"71" 3rd Sels	2000 S	"71"	4.24	5.45	5	7	650	10
Burwood	"74" ,,	Crossbar	"74"	2.44	3.14	4	4	950	10
Campsie	"78" ,,	2000 S	"78"	3.74	4.83	6	7	950	10
Ashfield	"7" 2nd Sels	2000 S & R	"7" codes not direct routed plus overflow to all "7" codes.	8.60	11.14	9	13	650	20
Balmain	"82" 3rd Sels	2000 S	"82"	1.88	2.41	3	4	970	10
Five Dock	"83" ,,	2000 S	"83"	—	2.06	—	3	1240	—
Drummoyne	"8" 2nd Sels	2000 S & R	All "8" codes	7.20	11.52	7	11	1740	20
North Sydney	"9" ,,	2000 S	All "9" codes	3.98	5.2	4	5	2070	10
Homebush	"Y" ,,	2000 S	All "Y" codes	2.70	—	3	—	1630	10
Local Link	"56" GIV	Crossbar	"56"	14.10	18.0	32	37	—	20
Newtown Backbone Route	1st Selectors	2000 S & R	Overflow to 2, 3, 4, 5, 6 codes.	13.20	16.59	28	32	460	20
Ashfield Backbone Route	1st Selectors	2000 S & R	Overflow to 7, 8, 9, Y codes.	4.52	4.46	13	13	670	20

TABLE 2. INCOMING JUNCTIONS

To Petersham from	Trunking from		Traffic—Erlangs Junctions				Junction Loop Resistance Ohms
	Selector Rank	Type of Equipment	1962	1965	1962	1965	
Haymarket	GV	Crossbar	—	14.0	—	19	980
Phillip	,,	,,	—	4.8	—	7	1380
Burwood	,,	,,	—	11.0	—	14	950
Miranda	"52" D.S.R.'s	2000 & Strowger	4.6	5.3	7	8	3500
Peakhurst	"53" ,,	2000	2.3	2.4	4	4	1739
Blakehurst	"54" ,,	2000	2.3	2.4	4	4	2300
Undercliff	"55" ,,	2000	11.8	13.4	17	19	490
Hurstville	"57" ,,	2000	2.7	3.3	5	6	2550
Kogarah	"58" ,,	Strowger	5.7	6.5	9	10	1182
Rockdale	"59" ,,	2000	5.3	5.8	8	9	950
Kingsgrove	"50" ,,	2000	6.1	6.9	10	11	1375
Newtown Main	"5" 2nd Sels.	2000 S & R	351.0	351.0	16	550	460

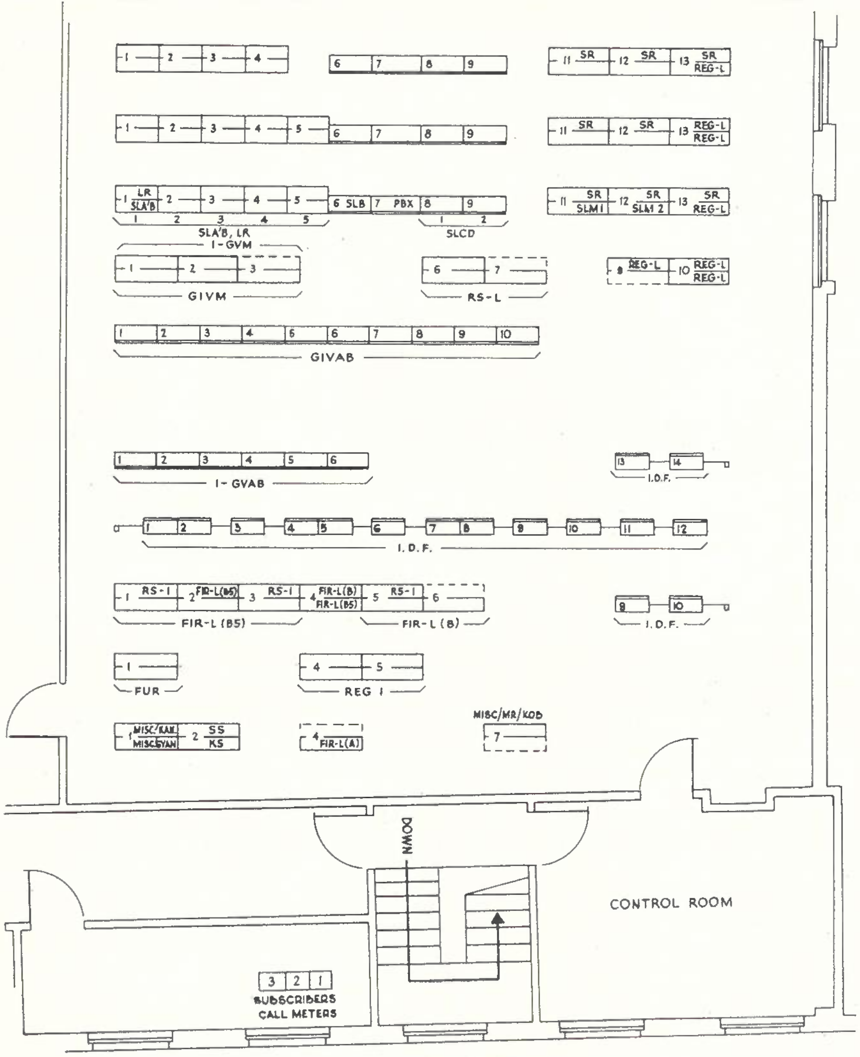


Fig. 2.—Floor Layout.

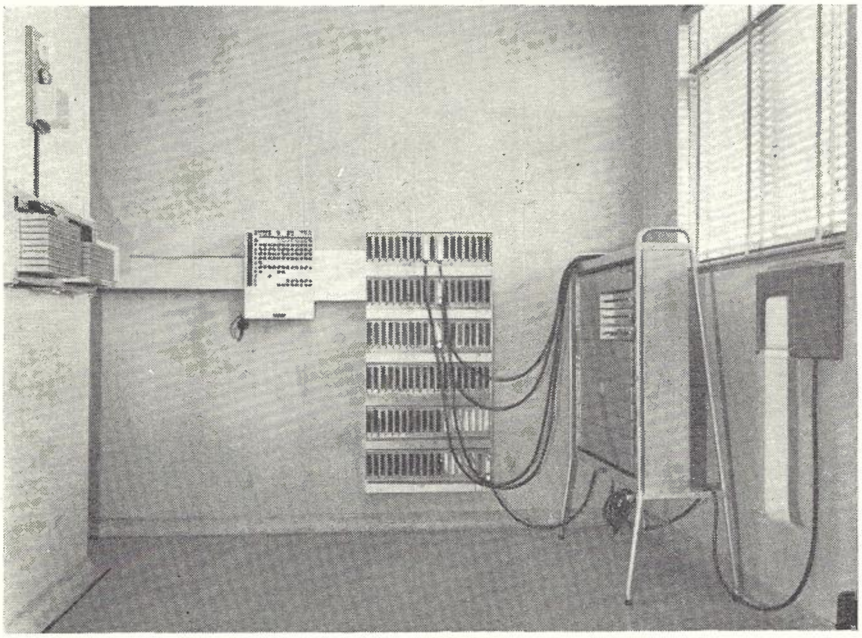


Fig. 3.—Control Room.

The trunking is shown in Fig. 1 and Tables 1 and 2. It will be seen that the step-by-step exchange remains 6-digit, 56XXXX and the crossbar exchange became 7-digit-5607XXX, 5608XXX and 5609XXX and that 33 outgoing routes are provided. Because of the mixed number length it is necessary for the Reg. I to insert the digit '0' on calls to the crossbar portion of the exchange. This is achieved by strapping in the register, described later in this article.

Equipment Layout

The floor layout is shown in Fig. 2. For the 2,800 numbers 43 BDD racks, 48 BDH racks and 16 IDF racks were installed. Three LME type meter racks and 2,800 meters were installed in a separate room and the service supervision equipment was wall mounted in the control room. (See Fig. 3.) The ultimate capacity of the equipment room is 8,000 lines and because of the cabling and jumpering difficulties which may occur later the IDF has been appropriated for the ultimate capacity of the room.

Lighting is by single 40 watt fluorescent tubes suspended by chains from the ceiling and placed midway between the edge of the cable troughs and the racks so that the maximum light is thrown into the aisles. The length of the chains is one foot thus placing the fitting in an equivalent position to a flush fitting with a 12′ 6″ clear ceiling height.

Equipment Handling

All crates were unpacked in an area sealed off from the equipment room. No mechanical aids were used to place the racks in position although the chain hoist was used to lift the racks from their cases.

The distance from the uncrating room to the fartherest BDD rack is approximately 70 feet, therefore it was no great effort for six men to lift a BDD rack of 600 lbs. and carry it into position.

The large number of small items associated with this equipment were stored in the uncrating room in steel lockers equipped with small drawers. Each item was identified and the compartments labelled with the item number on the specification. This method of storing saved manhours during the installation.

Dust Precautions

During installation the following precautions were taken against the ingress of dust:—

(a) The equipment room is air conditioned;

(b) All unpacking was done in the sealed off area;

(c) The racks were encased in non-inflammable plastic envelopes pending wiring;

(d) The staff were equipped with anti-static overalls and dust coats;

(e) The floor was cleaned daily using impregnated cloths and the racks were wiped over frequently. As the cable was pulled off the drum the sheathing was wiped clean with impregnated cloths.

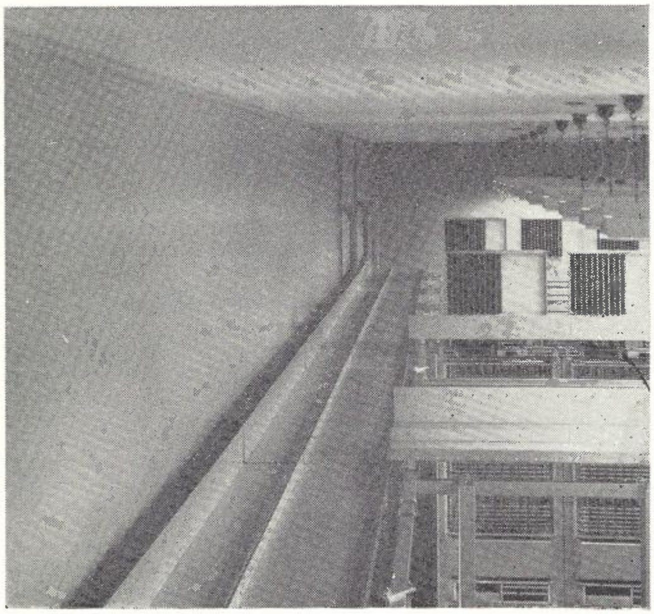


Fig. 4.—Ironwork and Troughing.

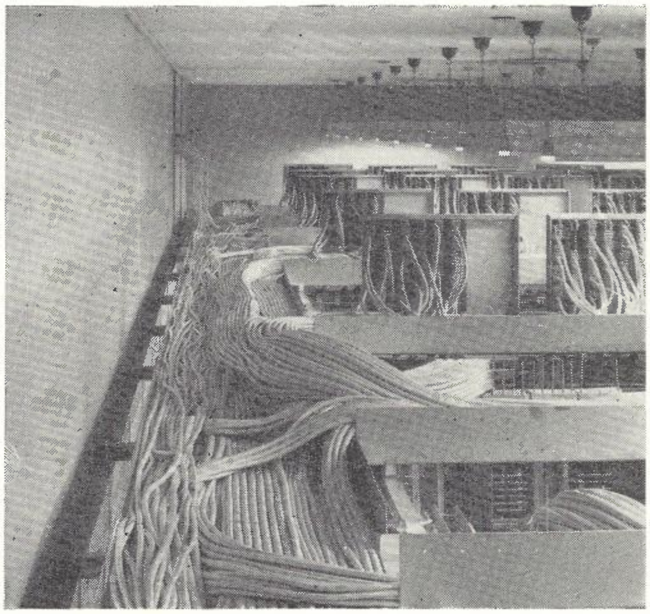


Fig. 6.—Main Cable Run.

Erection of Racks and Ironwork

Apart from the normal difficulties when dealing with unfamiliar equipment, that is, identifying and classifying the various items of iron work screws, nuts and bolts, etc., the erection of the overhead iron work and racks was straightforward and simpler than for 2,000 type equipment. The worst variation in floor level was $\frac{3}{8}$″ over 16 feet, therefore no special action was necessary to keep the racks level. Fig. 4 shows a section of iron work and troughing. The troughing was supplied in two metre lengths and in three sizes, 200 mm. wide, 300 mm. and 400 mm. Fig. 5 shows the layout of the overhead iron work and troughing. The power cables are accommodated in a 400 mm. (approx. 16 inch) trough mounted directly underneath the main troughing run on the MDF side of the room. With the standard A.P.O. MDF it was found easier to take off from the trough to the MDF on runway rather than in trough. Cabling in troughing can be seen from Fig. 6. This allowed for the cables to "drop off" in their correct positions down each MDF vertical.

Cabling

LME cables 42 wire, 63 wire, 84 wire and 105 wire were used and Fig. 7 shows the various cable runs and sizes. Some 63 wire cable supplied was older LME type with no colour code and the pairs made up in rotation with marker and reference pairs as used at Toowoomba.

Cable section plans were not necessary except in the runs to the MDF and on the vertical runway down the IDF racks. Due to the confined runway widths of 300 and 500 mm. (approx. 12 and 20 inches) the appropriation of space on the runways is critical. Because of this cables at the IDF were so placed that access to spare terminal strips would be easy later.

By laying the cables in groups in the trough it was easy to maintain reasonable order without extra effort. The use of troughing reduced the cable running time to a quarter of the time taken for conventional laced cable on runway. Fig. 8 shows the suite trough feeding the first thousand line suite.

Wiring

The wires were formed out using the LME forming boards except on the BDH racks where because of a shortage of the LME type a forming board using 66 rows of 15 holes was used. This board is illustrated in Fig. 9. By using the hole rows as a guide to the wire lengths prior to terminating, a second identification before terminating was eliminated. The other forming boards illustrated in Fig. 10 were used in the conventional way except for the suite control forming boards. Here two significant changes were made. The board used to form the wiring along the suites is made on the job out of scrap timber. This was done at Petersham, but in addition, the board used to form the

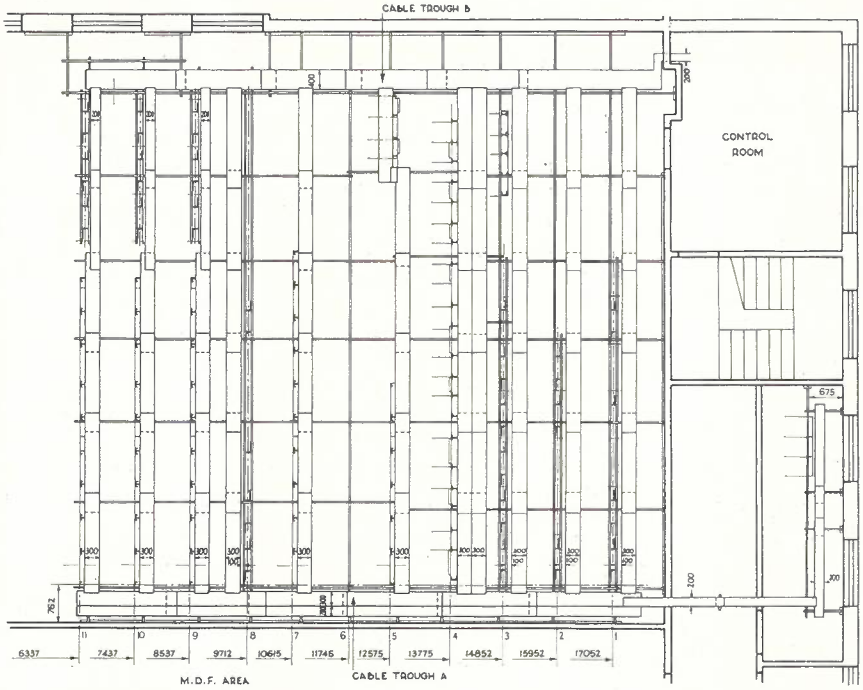
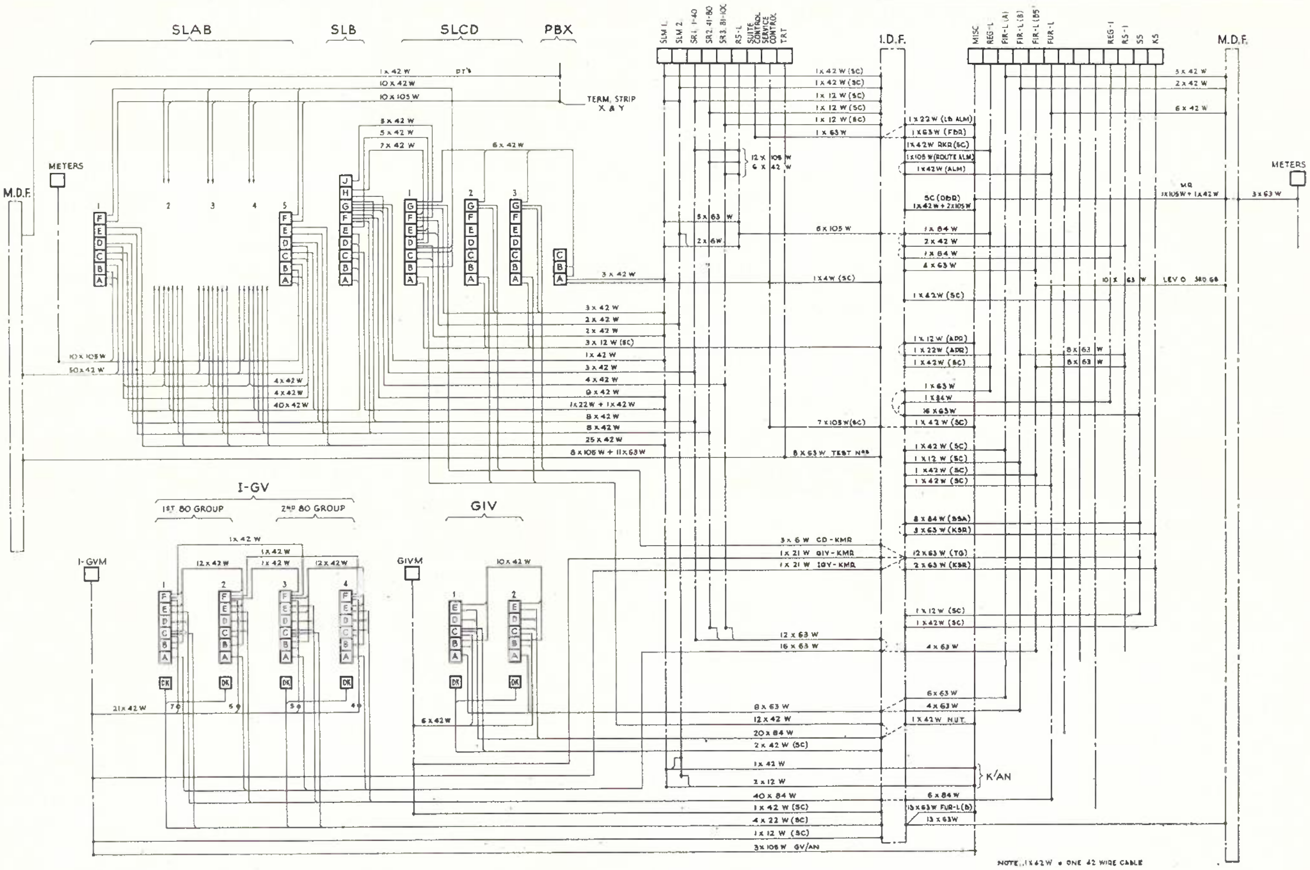


Fig. 5.—Diagram of Overhead Ironwork and Troughing.



NOTE. 1X42W = ONE 42 WIRE CABLE

Fig. 7.—Diagram of Cable Runs.

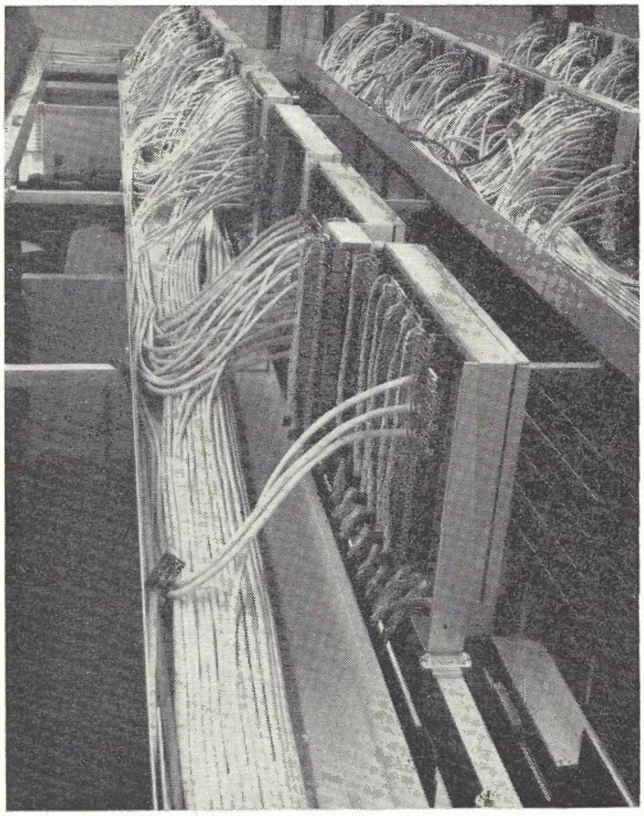


Fig. 8.—Suite Cable Run.

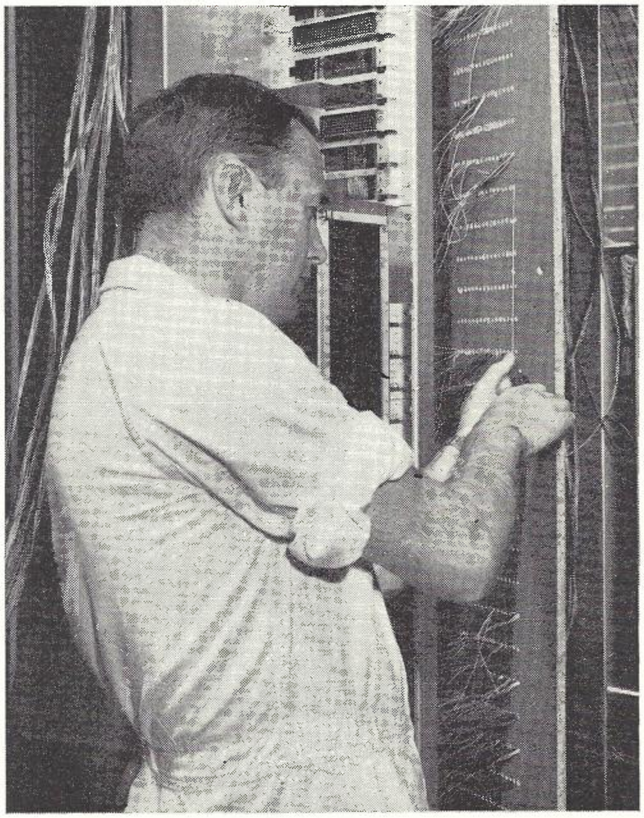
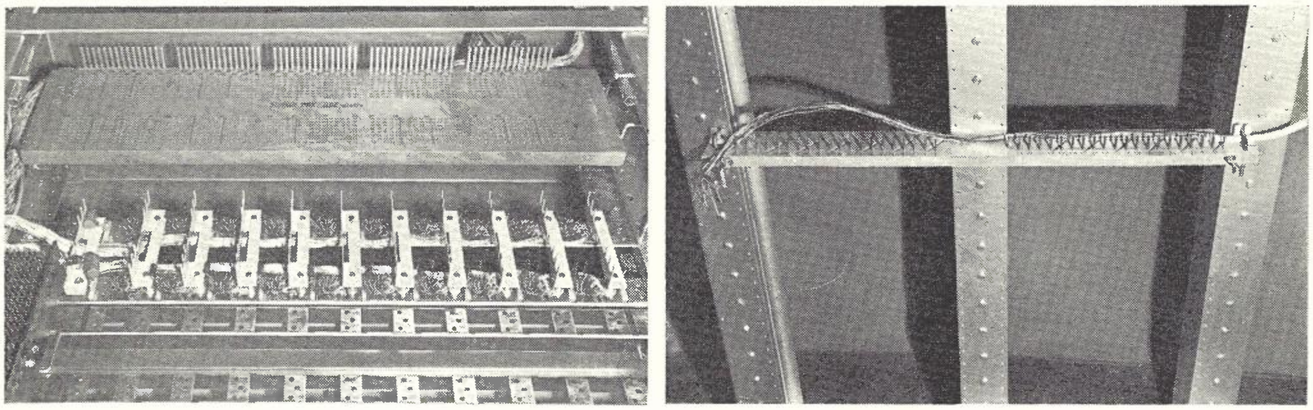
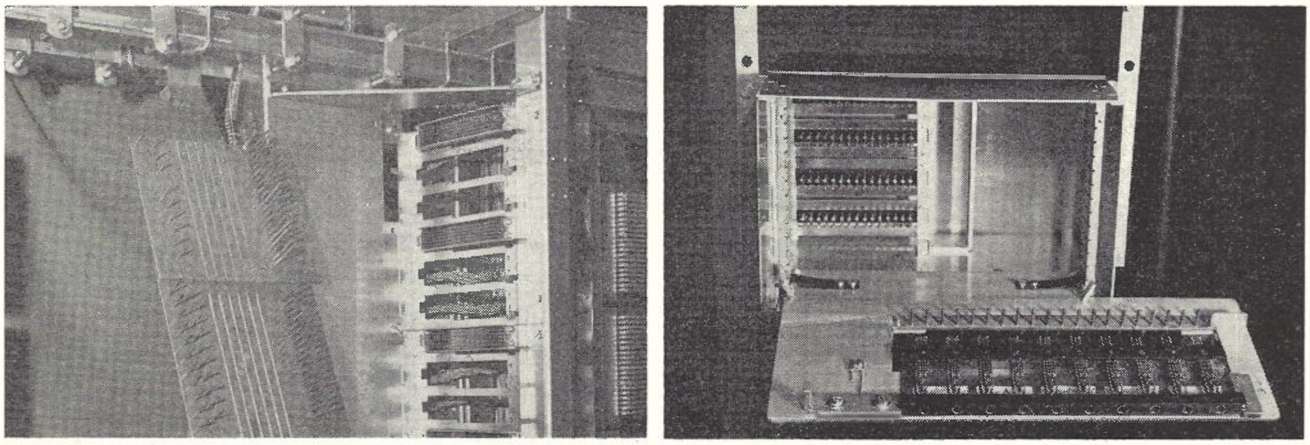


Fig. 9.—BDH Forming Board.



(a) For P.B.X. Rack.

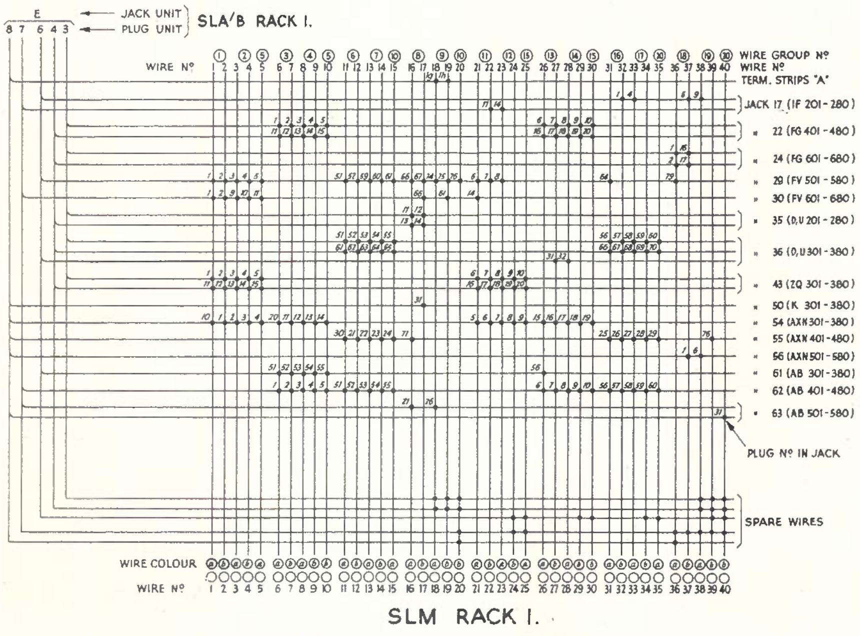
(b) For I.D.F. Type B.A.B. 947, 948.



(c) For A. B. and C Terminal Blocks on BDH Racks.

(d) Forming Board for Suite Control Box.

Fig. 10.—Forming Boards.



WIRE Nº	JACK	TAG	HOLE	LENGTH
1	43	1	1	1
2	"	2	1	2
3	"	3	1	3
4	"	4	1	4
5	"	5	1	5
6	22	1	1	1
7	"	2	1	2
8	"	3	1	3
9	"	4	1	4
10	"	5	1	5
11	36	51	11	1
12	"	52	11	2
13	"	53	11	3
14	"	54	11	4
15	"	55	11	5
16	35	11	3	1
17	"	12	3	2
18	S	S		
19	S	S		
20	S	S		
21	43	6	2	1
22	"	7	2	2
23	"	8	2	3
24	"	9	2	4
25	"	10	2	5
26	22	6	2	1
27	"	7	2	2
28	"	8	2	3
29	"	9	2	4
30	"	10	2	5
31	36	56	12	1
32	"	57	12	2
33	"	58	12	3
34	"	59	12	4
35	"	60	12	5
36	24	1	1	1
37	"	16	4	1
38	S	S		
39	S	S		
40	S	S		

PLUG UNIT Nº E4

WIRE Nº	JACK	TAG	HOLE	LENGTH
1	43	11	3	1
2	"	12	3	2
3	"	13	3	3
4	"	14	3	4
5	"	15	3	5
6	22	11	3	1
7	"	12	3	2
8	"	13	3	3
9	"	14	3	4
10	"	15	3	5
11	36	61	13	1
12	"	62	13	2
13	"	63	13	3
14	"	64	13	4
15	"	65	13	5
16	35	13	3	3
17	"	14	3	4
18	S	S		
19	S	S		
20	S	S		
21	43	16	4	1
22	"	17	4	2
23	"	18	4	3
24	"	19	4	4
25	"	20	4	5
26	22	16	4	1
27	"	17	4	2
28	"	18	4	3
29	"	19	4	4
30	"	20	4	5
31	36	66	14	1
32	"	67	14	2
33	"	68	14	3
34	"	69	14	4
35	"	70	14	5
36	24	2	1	2
37	"	17	4	2
38	S	S		
39	S	S		
40	S	S		

Fig. 12.—Wiring Diagram and Wiring Table.

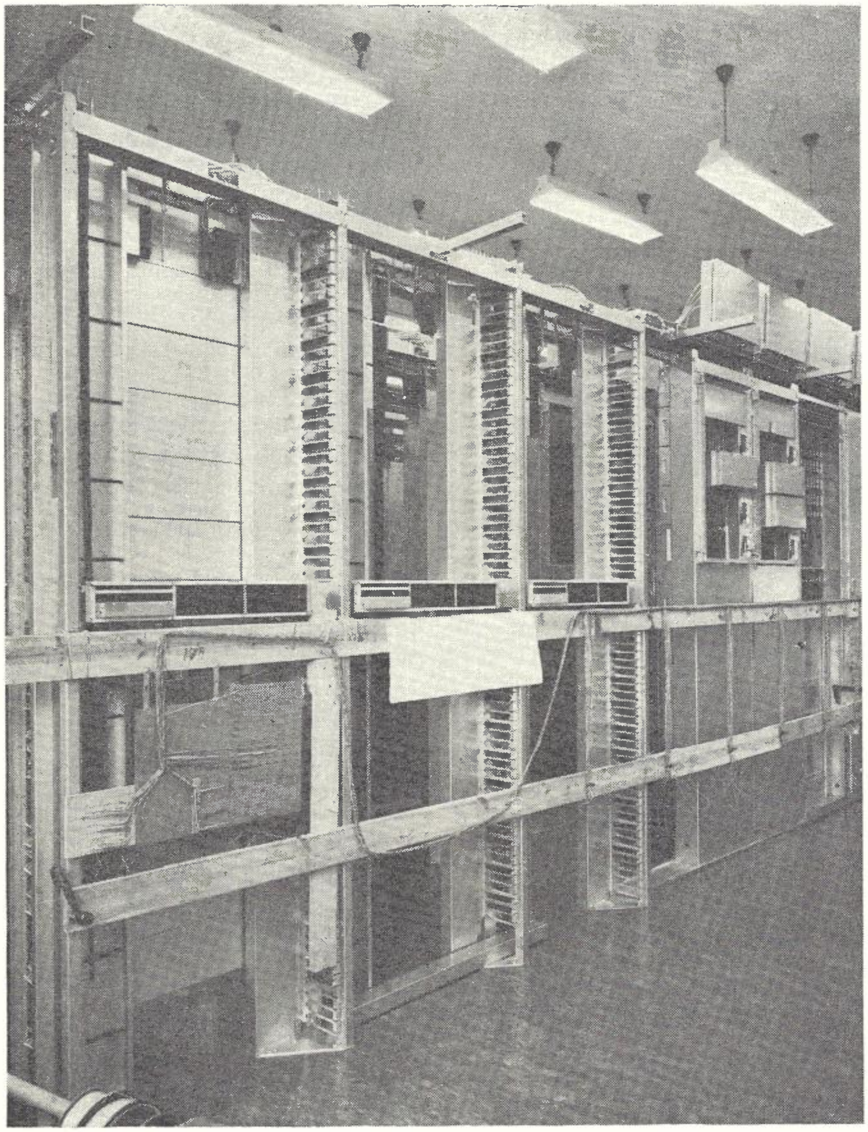


Fig. 11.—Suite Control Forming.

wires on the suite control box was attached to the makeshift board and the whole form made up on the floor. Also a smaller forming board was made up and attached to the side of the suite control box forming board, to cater for the second terminal strip in these boxes. A comparison of times between the old and new methods explained above, shows a saving of 50% in the times for forming on the suite control box. Fig. 11 shows the boards in use. The suite control forms were wrapped with plastic tape for support and as a precaution against mechanical damage, and the whole form lifted into the trough.

Some 75 wiring diagrams covering the details of the terminations of each end of the cables were supplied. As some of these were rather difficult to interpret and use they were converted to simple wiring tables. Fig. 12 shows the conversion of an SLA/B to SLM wiring diagram to a wiring table.

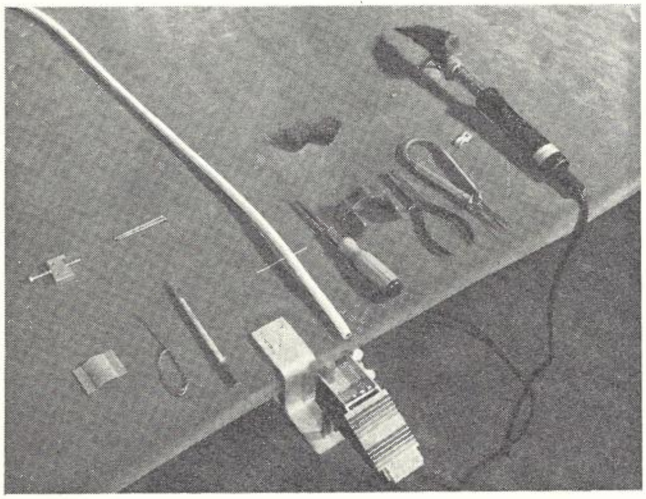
The LME terminating tools and the jigs illustrated in Fig. 13 were used throughout. The detailed use of these tools and jigs will be described in a later issue of this *Journal*.

Wire identification for other than plug ended cables was made using the LME type "talk back and identify" unit illustrated in Fig. 14. The lamp identification unit shown in Fig. 15 and described in a previous issue of this *Journal* (4) was used for the plug ended cables.

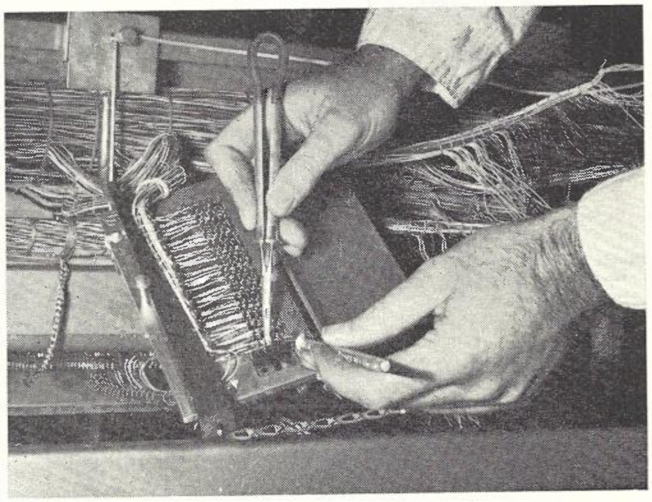
Recording

An important part of this installation was the recording of the trunking details interconnection and gradings, etc. It is essential that this information be complete and accurate and be compiled in a form easily read and interpreted by the maintenance staff, therefore, considerable thought was given to this aspect by both LME and the Department's engineers. In general the forms suggested by LME were used with variations to suit the local trunking.

Because of its importance from the



(a) For BDD Racks and Terminating Tools.



(b) In Use for BDH Racks.

Fig. 13.—Terminating Jigs.

maintenance point of view the IDF has been liberally designated by signwriting. Here 1G.V inlets have been designated to show the Suite Number, Rack Number, and Switch Number. In addition each rack has been labelled to show the devices and their positions on the rack.

For those racks such as SR's, FUR's, FIR's, etc., concerned in backward and forward trunking, sufficient trunking information has been shown to facilitate call tracing, e.g., an FIR rack shows the following information on a designation strip screwed to the rack:

From Local 3rd Selectors				
Junction No.	FIR No.	GIV Inlet		
		Rack	Switch	Vertical

Fig. 14.—Wire Identifying Set.

CONCLUSION

The design and execution of the installation at Petersham will be seen to have much in common with the installation of other types of equipment. However, exchange installers were required to master new techniques in assembly, wiring and terminating with a large range of new tools, the provision of unfamiliar supervisory alarm systems, and testing in dynamic situations imposed by common control working with high speed voice frequency signalling.

Petersham was the pilot model for the ARFIO2 system in Australia and its prime objective was to form a basis for design to provide the interworking and multiple alternative routing requirements of the Department in metropolitan networks. However, the experience gained in installing this exchange has confirmed the potential of this equipment for installation economics which was foreseen in the initial system investigations.

REFERENCES

1. F. P. O'Grady, "Australian Post Office Adopts Crossbar Switching System"; Telecommunication Journal of Aust., Vol. 12, No. 1, page 6.

2. N. A. S. Wood, "Automatic Switching Systems — The Key to Economic Telephone Networks"; Telecommunication Journal of Aust., Vol. 12, No. 1, page 7.

3. E. R. Banks, "Crossbar Switching Equipment for the Australian Telephone Network"; Telecommunication Journal of Aust., Vol. 13, No. 2, page 85.

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

APPENDIX A

FACILITY SCHEDULE FOR ARF102 EXCHANGES IN THE SYDNEY TELEPHONE NETWORK

Classification of Subscribers' Services

(a) Ordinary subscribers' services will have unrestricted access, barring will be achieved by key control at the subscribers' premises.

(b) Variable Tariff Public Telephones will be barred to trunk levels. 011, 016, 018, 0176, 2077, 2075, 20700.

(c) Multi-Coin Public Telephones will have access only to:
  (i) Unit Fee calls,
  (ii) 0176 (trunk bookings) and,
  (iii) 2077 phonograms.

(d) Leased variable tariff Public Telephones will be barred to trunk levels. 011, 016, 018, 0176, 2077, 2075, 20700.

(e) Leased variable tariff Public Telephones similar to those supplied by Victa Ltd. will be barred access to S.T.D. and trunk levels but the barring can be lifted by the operation of a key at the subscribers' premises.

(f) within a 1,000 line group 230 individual numbers may be marked for different classes of service with the following restrictions in each hundreds group. (See Table on page 199.)

P.B.X. Facilities: The standing equipment provides a maximum of 40 both way lines in any one group. The numbers in the groups will not be consecutive with one another and with the first number in the group. The pattern of search for a free line in the group is sequential for up to 20 lines with the directory number being chosen last but where more than 20 lines are required the search is random. Where more than 40 lines are required, special large group equipment can be provided. In this case the search is random.

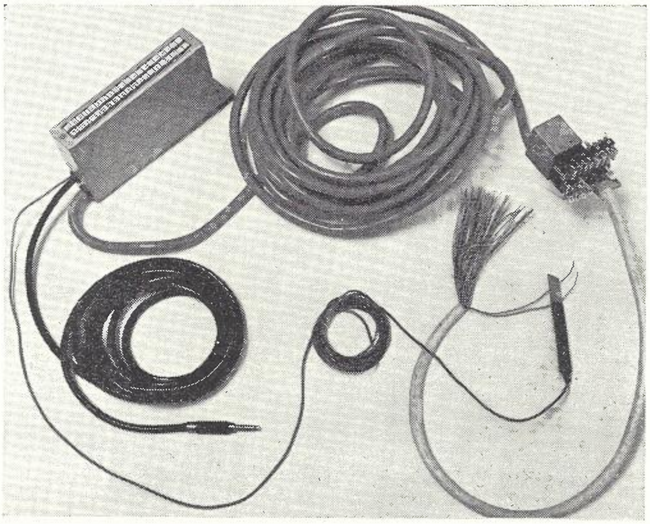


Fig. 15.—Wire Identifying Set Lamp Type.

Hundreds Groups	Classified Subs. per 100 Group	Restrictions
111-100 311-300 511-500	25	With up to three in any tens group marked for different classes of service. If three numbers are so marked in a particular tens group, one number must have a units digit in the range 1-5.
211-200 411-400 611-600	25	With up to three in any tens group marked for different classes of service. If three numbers are so marked in a particular tens group one number must have a units digit in the range 6-0.
711-700 811-800 911-900 011-000	20	With a maximum of two in any particular tens group marked for different classes of service.

P.A.B.X. "In Dialling": In dialling to P.A.B.X.'s can be provided.

Night Switching: For groups of up to 20 lines the lamp and jack positions on the P.B.X. can be arranged to correspond to the sequence of search of the numbers in the group with the directory number always last. The lines can therefore be night switched in the normal manner. Where a special after hours number is listed, connection is made directly to this number.

Where the P.B.X. group is more than twenty lines, night switching of any number of lines will require a P.A.B.X. Night Attendants Cabinet.

Duplex Services: Duplex services can be provided.

Metering: For unit fee calls metering will take place at the end of the call except where:—

(a) subscribers are connected to uniselectors associated with first stage crossbar equipment and,

(b) subscribers are provided with high calling rate out lines, connected directly to the IGV stage.

For these conditions metering takes place when the called subscriber answers.

For multi-metered calls metering commences immediately the called subscriber answers. In this case the 90 secs. answer time out supervision is cancelled.

Metering controlled by a key can be provided.

Holding of Malicious Calls: By means of a strapping in the exchange, any crossbar subscriber can return an indication to an originating crossbar exchange which will hold the connection after the calling party has released until such time as the called party clears. The line of the calling party can originate and receive calls while the connection is held to the called party. To enable the call to be traced, the called party must advise the assistance operator from another telephone. However, it is not possible to hold a connection back to an originating step by step exchange. This facility will only be available to subscribers in the same crossbar exchange as crossbar to crossbar calls may route via step by step exchanges.

Filtered Interception: The Department's standard interception facilities will be provided. Incoming calls will be diverted to an operator who will control the connection of the call to the called subscriber or inform the calling party of the particular subscriber required. Metering will not take place until the called subscriber answers.

Changed Number: Calls to a changed number will be diverted to the test desk or operator.

Unequipped Levels: A voice announcement will be connected to all unequipped levels.

Unequipped 100 Line Groups in a Partially Equipped 1,000 Line Group. Calls to these numbers will be switched to a selected number to which will be connected a voice announcement. A number will be reserved for this purpose and cannot be allotted.

Unallotted Lines in Partially Allocated 100 Line Groups: Ring tone will be returned to the calling party. It is therefore important that numbers are released in 100 line groups.

Disconnected Lines: A voice announcement will be connected to these numbers.

Observations: Both service observation and subscribers' observation equipment will be provided.

P.T. Tone Identification: Public telephones will send forward an identification tone on manual access levels.

Barred Codes: If a barred code is dialled, the call is switched to a number reserved for this purpose and which cannot be allotted and a voice announcement will be returned to the caller.

Line Lock Out: Line lock out will be applied and "try again" tone returned to the caller when:—

(a) the register cannot complete a call to a crossbar destination due to the called subscriber being busy or to congestion in the intermediate plant,

(b) the register or S.R. times out either for a P.G. line or due to the called subscriber not answering within 90 seconds. This time limitation is cancelled on calls to step by step exchanges, and manual operators,

(c) the called subscriber only replaces his receiver after a call. In this case the 90 seconds time delay applies from the moment the called subscriber replaces his receiver.

Time Supervision: (a) The total time available from seizure of the register, i.e., from the time the subscriber receives dial tone until the register releases, i.e., all digits sent out and call set up is 45 seconds. In other words the register cannot be held for longer than 45 seconds. If dialling is not completed or commenced in this time, the register is released and "try again" tone is returned to the caller.

(b) where the number length is unknown, a period of four seconds is allowed between digits received in the register after the fourth. If the subsequent digits are not received within four seconds of each other the register will "ready connect", i.e., it will send out all digits in the store and then release. The period of four seconds may vary as the actual time is measured from the time the last digit is stored providing it is at least the fourth. However, it should not exceed 6 seconds. In this case, "try again" tone is not returned to the caller because the call has been through connected.

(c) The register will release immediately an answer supervisory signal (reversal) is received.

Post Dialling Delay: The post dialling delay is affected by many variations including the subscriber speed of dialling the route taken, etc.

Key Metering: Metering under key control from manual positions can be provided.

Test Distributor Access: Access will be provided on the same basis as for step by step. Answer time out will be disconnected under these conditions.

Trunk and Service Levels in Sydney

May 1963	
*011	Intrastate Calls
*018	Interstate Calls
*016	Overseas Calls
019) 013) Tied	Arcadia, Dural, Glenorie, Kenthurst
520	Engadine Access
000	Emergency
0172	Mobile Radio
0175	Directory Enquiries (Country & Interstate)
*0176	P.T. Assistance
*2077	Phonograms from Multi Coin P.T.'s
*2075	Phonograms from Subscribers
2078	Phonogram Enquiries
2073	Directory Enquiries Sydney
2074	Time
2071	Weather
2076	Sport
205073	Reminder Calls

* Access barred from Variable Tariff Public Telephones and Leased Variable Tariff Coin Attachments.

APPENDIX "B"

ABBREVIATIONS

LME	L M Ericsson
ARF.102	Code name for the system.
M.D.F.	Main Distributing Frame.
BDD	Code name for LME crossbar selector rack.
BDH	Code name for LME relay set rack.
IDF	Intermediate Distribution Frame.
SLA/B	Code name for subscribers' stage selector rack equipped with SLA and SLB selectors.
SLM	Subscribers' stage marker.
GIV	Terminating group selector.
1GV	Originating group selector.
FUR	Outgoing junction relay set.
FIR	Incoming junction relay set.
Reg-L	Local register.
Reg-I	Incoming register.
SSA/B	Code sender finder.
CD/KMR	Subscribers' stage code receiver.
T.G.	Tone generator.
1GV/KMR	Originating group selector stage code receiver.
GIV/KMR	Terminating group selector stage code receiver.
KSR	Code sender.
GV-W	W (Route identification) relay set in group selector marker.
GV-AN	AN (Analyser) relay set in group selector marker.
KAN	Subscriber category analyser in subscribers' stage marker.
PBX	Private branch exchange.
GS	Step-by-step group selector.
TRT	Traffic route tester.
SC	Service Control.
OBR	Observation relay set.
RKR	Relay set to convert Reg-L to a control register Reg-K.
APR	Test robot.
PT	Public telephone.

BACK COPIES

The Society has available in quantity, back copies of most issues of the Journal from Volume 5 onwards. Volume 12, Number 1, is out of print, but reprints of the two articles on coaxial cables may be obtained for a total cost of 3/-. These Journals may now be supplied on demand from State Secretaries* 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 State Secretary,* as to the availability of any particular number. In the event of the Society being unable to supply any number, it will 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 State Secretary,* who may thus be able to advise other readers where the back copies may be obtained.

* For addresses see page 255.

PILOT ARF 102 CROSSBAR EXCHANGE—PETERSHAM

*D. W. ARCHER**

INTRODUCTION

On 18th May, 1963, the first ARF 102 crossbar exchange was placed in service at Petersham, New South Wales. The equipment for this project was developed and manufactured by L M Ericsson Pty. Ltd., Sweden, and installed by the Postmaster-General's Department with assistance in specialised testing being rendered by L M Ericsson. The Petersham installation was the first field trial of the exchange equipment developed for the larger metropolitan networks and the first experience in Australia of multi-frequency code signalling within an exchange. Since cutover, routes have been established to Haymarket crossbar exchange using M.F.C. signalling on these junction circuits.

SIGNALLING SYSTEM

Multi-frequency code (M.F.C.) signalling employs two simultaneous voice frequency signals for each signal transmitted between devices within an ARF 102 exchange or between crossbar exchanges. For a code receiver (KM) to operate it must identify only two frequencies, if one only or more than two frequencies are received a fault condition is registered. The signalling scheme provides for six frequencies for forward signals (transmission of received information stored in the register) and six different frequencies for revertive signals (transmission of controlling information from code receivers to the register).

The scheme allows for 15 "forward" signals and 15 "revertive" signals and the grouping of frequencies used is shown in Table 1.
Signals 11-15 are reserved and were not used at Petersham.

The signalling is transmitted with continuous compelled sequence signals as shown in Fig. 1, assuming the local register transfers digit 5 to the KSR which causes two frequencies to be sent to the distant code receiver which recognises both frequencies of the signal and stores the digit on relays, 1S1 and 1S4 and due to strapping causes revertive signal 1 to be sent from the code receiver to the code sender. At this stage there are four frequencies simultaneously on the line. The code sender interprets both frequencies of the revertive signal and transfers the information to the register. When the revertive signal was received in the code sender the forward signal is disconnected resulting in the code receiver disconnecting the revertive signal as the B0 and B1 relays are held operated to the ground from the channel receivers, the code sender will transmit the next stored digit.

TABLE 1: FREQUENCIES USED FOR FORWARD AND REVERTIVE SIGNALS

Forward Signal	Frequency in cycles per second					
	1380	1500	1620	1740	1860	1980
Revertive Signal	1140	1020	900	780	660	540
1	×	×				
2	×		×			
3		×	×			
4	×			×		
5		×		×		
6			×	×		
7	×				×	
8		×			×	
9			×		×	
10				×	×	
11	×					×
12		×				×
13			×			×
14				×		×
15					×	×

The signalling speed is determined by the operating times of the various components in senders and receivers and 6-7 digits per second can be transmitted.

The revertive signals are arranged in four groups with meanings as shown below. The first group, A, is employed until sufficient digits have been received and analysed to determine the type of equipment at the destination of the call and the number length; the second and third groups, 2A and 3A, are used depending on the type of equipment at the destination exchange; the fourth group B is used to advise the register of the condition of the called party line.

A

1. Send next digit.
2. Restart.
3. Transition to B signals.
4. 5 digits
5. 6 digits
6. 7 digits
7. 5 digits
8. 6 digits
9. 7 digits
10. Number length unknown.
    M.F.C. Terminal
    Exchange Transition
    to 2A signals
    S x S Terminal
    Exchange Transition
    to 3A signals

2A

1. Send next digit.
2. Restart.
3. Transition to B signals.
4. Send 1st digit decadic.
5. Send 2nd digit decadic.
6. Send 3rd digit decadic.
7. Waiting place, next digit.
8. Waiting place, restart.
9. Waiting place, same digit.
10. Waiting place, previous digit.

3A

1. Send next digit.
2. Restart.
3. Transition to B signals.
4. Send 1st digit decadic.
5. Send 2nd digit decadic.
6. Send 3rd digit decadic.
7. Send 4th digit decadic.
8. Send 5th digit decadic.
9. Send 6th digit decadic.
10. Send previous digit.

B

1. Idle subscriber.
2. Busy subscriber.
3. No time throwout.
4. Congestion.
5. Idle subscriber, non-metering.
6. Malicious call tracing.

A1—is given when the particular device requires the next digit to be sent M.F.C.

A2—is given when repetition of the digits, already sent, is required.

---

* Mr. Archer is Group Engineer, Equipment Installation, New South Wales. See page 249. quarters. See page 250.

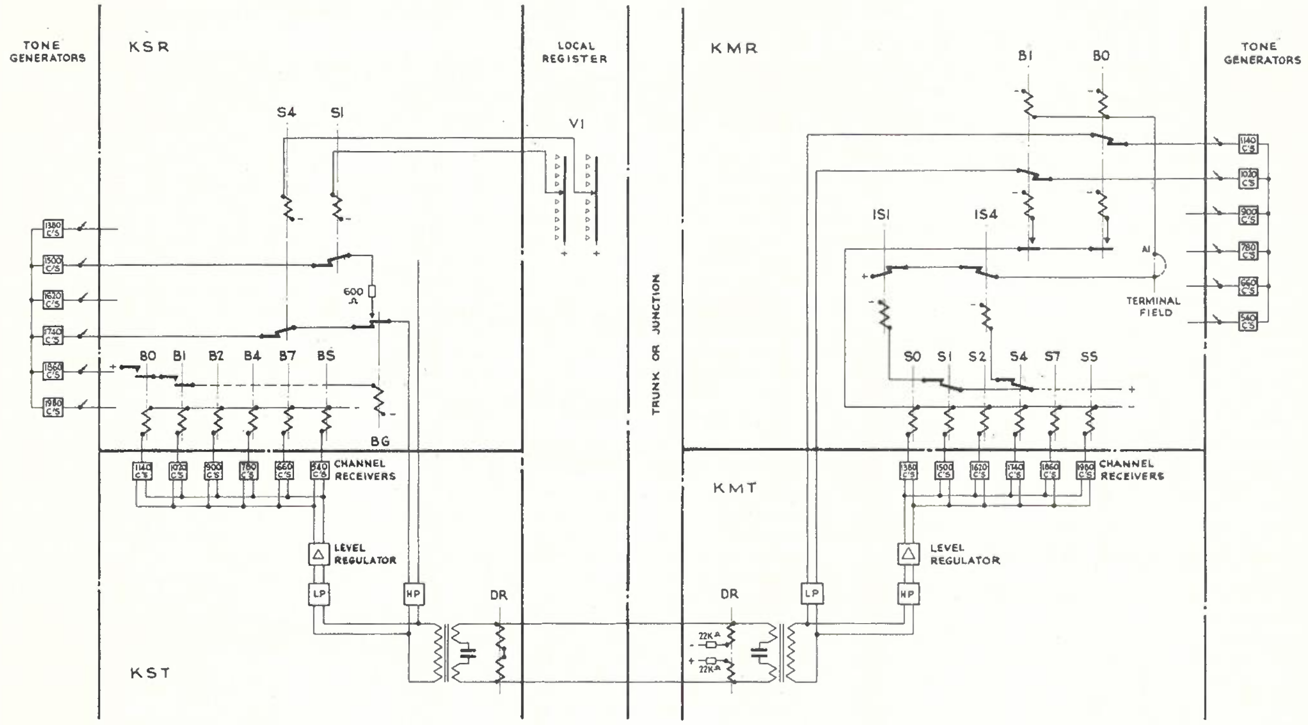


Fig. 1.—Block Diagram of Signalling System.

A3—is given when all the necessary digit information about the called party is obtained from the register. An A3 signal is always followed by a B signal which indicates the condition of the line after test.

Signals A4-A10 are only sent from the originating group selector stage, A4-A6 indicating number length on traffic to ARF terminal exchanges, A7-A9 indicating number length on traffic to S x S terminal exchanges and A10 on traffic to S x S exchanges when it is not possible to decide the number length as 5, 6 or 7 digits. At Petersham number length unknown signals were required for all three and four digit numbers in the Sydney network and indialling P.A.B.X. lines requiring more than seven digits.

The register interprets any revertive signal after an A4-A6 signal has been received as a 2A series signal and a 3A

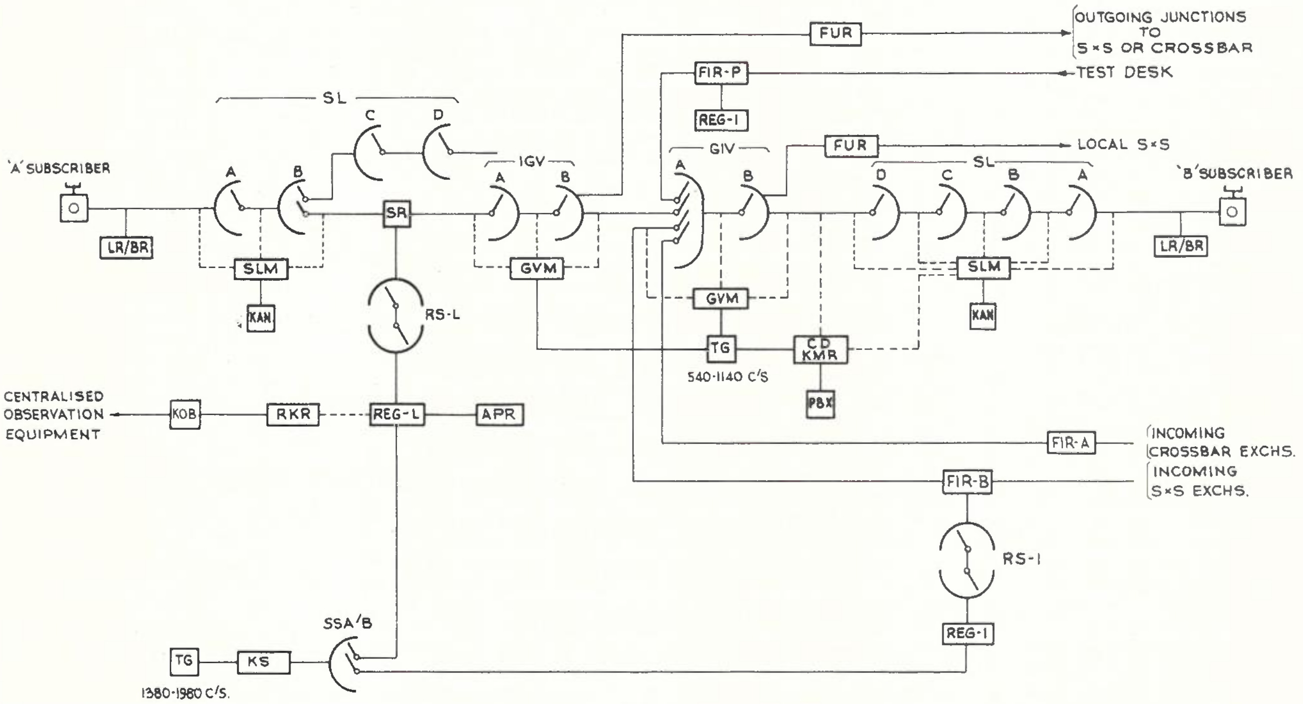


Fig. 2.—Crossbar Trunking Diagram—Simplified.

series signal if an A7-A10 signal has been sent from the group selector stage.

In the 2A series signals 4, 5 and 6 are necessary in case a call to a crossbar terminal exchange is routed via a S x S tandem and once decadic impulses are sent the register will not return to M.F.C. signalling. The remaining 2A signals (7-10) indicate the call will be completed using M.F.C. signalling.

In the 3A series the information required, after the register receives signals 1, 2 or 10, is sent with M.F.C. and signals 4-9 will be followed with decadic impulses.

The number length series of signals allow the register to be disconnected as soon as the indicated number of digits have been transmitted, so reducing the register holding time. On number length unknown calls the register is "timed out" 4-6 seconds after receiving the last digit, provided all the information in the store has been discharged.

MFC Signalling Equipment

All electronic devices, associated with the M.F.C. signalling system, employ transistors and miniature components mounted on printed circuit boards and connected within standard relay sets by gold-plated plug and jack contacts.

Operating Characteristics:

Nominal impedance: 600 to 800 ohms.

Power Supply: 24 V DC variation—10% to + 20%.

Temperature Range: + 10°C. to + 40°C.

Sending Equipment:

Nominal sending level: —8 dbm per frequency.

Tolerances: The signalling frequencies sent out do not deviate more than ± 1 db in level and ± 5 C/s in frequency from the nominal values. The maximum difference in level between two frequencies constituting a signal is 1 db.

Alarm and changeover to stand-by generator:

Level limit for non-operation of supervisory circuit is 2 db below nominal.

Level limit for positive operation of supervisory circuit is 4 db below nominal.

Receiving Equipment:

Working range: Permissible variation in level —6 to —38 dbm per frequency up to 5 db maximum difference in level between two simultaneous frequencies. Permissible frequency deviation ± 10 c/s from nominal.

Response Time: The sum of operate and release times is less than 35 m.s. for signalling levels between —6 and —36 dbm per frequency.

Sensitivity to interference: The signalling receiver is not affected by an arbitrary frequency having a level which is less than —50 dbm. Interference frequencies which enter the receiver at the same time as the desired signalling frequencies do not affect any receiver relay, if the interference frequencies have a level which is 25 db lower than the stronger of the desired signalling frequencies.

CROSSBAR TRUNKING

The connection of the various devices in the crossbar exchange is shown in simplified form in Fig 2. The abbreviations and functions are as follows:—

Line and Cut-off relays LR/BR—associated with each subscriber's line and mounted 20 circuits per relay set at the rear of SLA/B racks.

Subscribers' Stage SL—is made up of units for connection of 1000 lines using four partial stages called A, B, C and D. The SLA stage is individual to 200 subscribers (corresponding to 200 outlets of a crossbar switch). SLB is common to a 1000 line group, with verticals 1-5 for originating traffic and verticals 6-10 for terminating traffic. SLC and SLD stages are exclusively for incoming traffic.

Subscribers' Line Marker SLM—controls the identification, by-path hunting and setting of the selectors for originating and terminating calls within a 1000 line group. Two markers are provided for each 1000 line group and each marker occupies a BDH rack.

Subscriber Category Analyser KAN—provides a means of strapping a subscriber's line to one of ten originating classifications and one of five terminating classifications up to a maximum of 230 subscribers within a 1000 line group. One KAN relay set is provided per 1000 line group.

Subscriber Stage Code Receiver CD KMR—incoming code receiver for reception of M.F.C. signals from registers. The receivers, mounted at the rear of SLC/D racks (Fig. 3), provide facilities for identification and connection to the calling inlet, reception and storing of the last three digits of the called

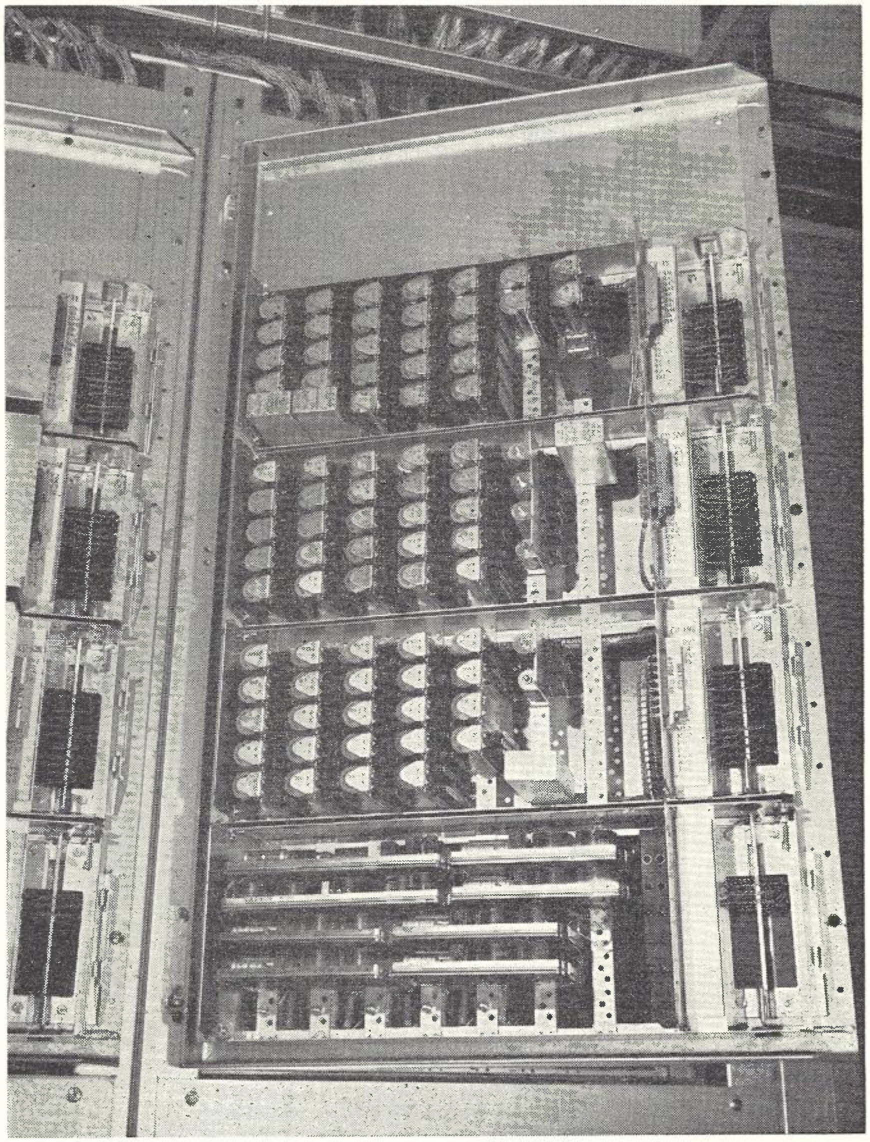


Fig. 3.—SLC/D Code Receiver.

subscriber, connection to the P.B.X. equipment and to either of the two SL markers.

P.B.X. Equipment — facilitates the grouping of lines within a 1000 line group and is mounted on a separate BDD rack in the SL suite.

Local Register (Reg-L)—consists of three relay sets; one contains a crossbar selector with five horizontal bars and ten verticals for storing the received digits (vertical 1—1st digit, etc.) with a maximum of nine digits. If more than nine digits have to be transmitted this is effected by repeated use of the crossbar switch.

The functions of the relay sets are as follows:—

Part 1—

1. On seizure provides a balanced circuit towards the calling subscriber for tone feeding and reception of dialled impulses which may vary between 7 and 22 impulses per second with an impulse ratio 30 : 70 per cent make with a maximum line resistance of 1800 ohms and minimum leakage resistance of 20,000 ohms.
2. Repeats the received digits to Part 3 for storing.
3. Registers restriction categories associated with a calling subscriber.
4. Controls re-direction for restricted subscriber calling a barred access code.
5. Generates decadic impulses for calls to S x S exchanges. The interdigital pause is adjustable between 500-900 milliseconds.
6. Controls the disconnection of the register on completion of digit sending or reversal received on decadic impulsing before the required number of digits have been transmitted (stop on busy).
7. Sends first burst of ring tone on all calls and first burst of ring current on local calls during the release time of the register.
8. Connects time supervision circuit on seizure of the register.

Part 2—

1. Controls the connection and disconnection of a register to a code sender (KS).
2. Controls digit transmission and reception of revertive signals.
3. Interprets revertive signals from code receivers and acknowledges these signals.

Part 3—

1. Stores digits on crossbar switch.
2. Translation field for controlling start of setting up of a call.
3. Strapping field for ready connection of register on three or four digit numbers.

Four Reg-L's are mounted on a single BDH rack.

SR Relay Set—cord circuit relay set for outgoing traffic and is connected direct to a SLB vertical and GVA inlet. On local calls SR contains transmission bridges for the A and B subscribers and ringing equipment and on outgoing junction calls transmission bridge for the calling subscriber and loop supervision circuit on the junction side with relays for time supervision and metering on all calls.

Forty SR's are mounted per BDH rack.

Local Register Finder RS-L—each unit consists of a marker and two crossbar switches coupling 40 SR's to 10 Reg-L's. Three units are mounted per BDH rack.

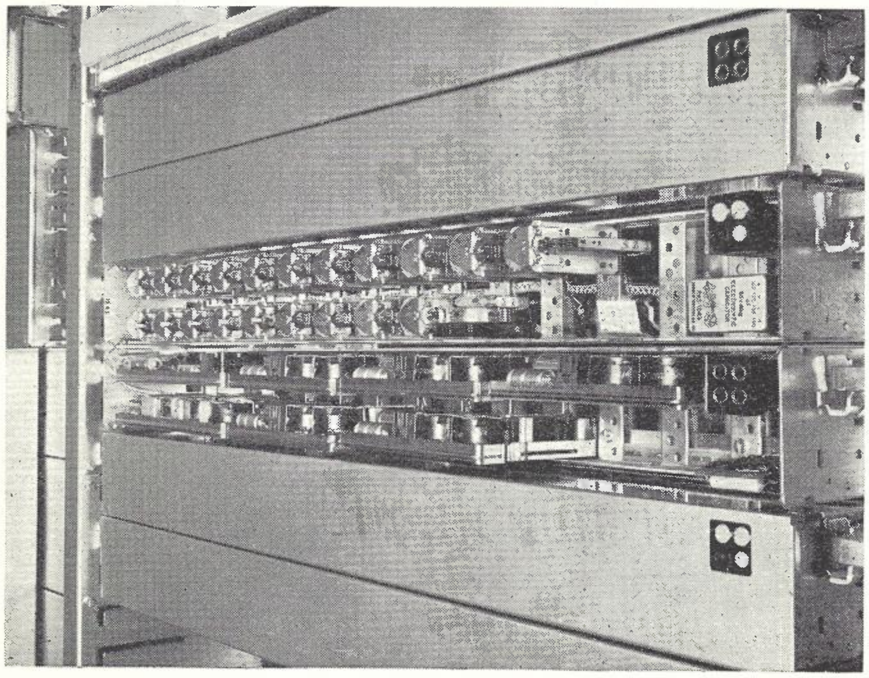
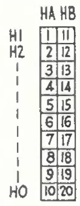


Fig. 4.—Code Sender, KS



CONNECTION OF THE LINKS IN THE MULTIPLE

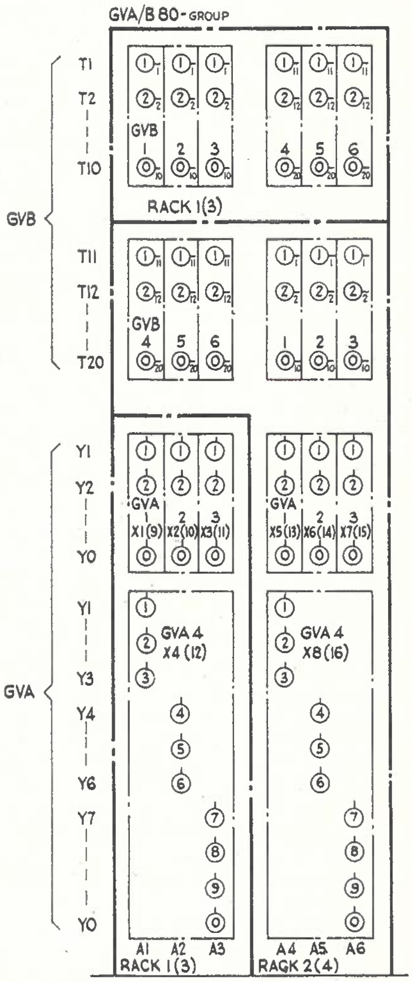


Fig. 5.—Grouping Plan for Group Selector Unit.

Code Sender Finder SSA/B—consisting of two relay sets SSA and SSB, is a device for connecting 20 registers to 12 code senders. Four SSA/B's are mounted on a single BDH rack together with 12 tone generators.

Code Sender KS—consisting of two relay sets KSR and KST, is connected to a register when the digit information stored is to be sent by multi-frequency code. The sender controls the sending of the digits as well as the reception and repetition of the controlling signals to the register. Fifteen KS's are mounted on a single BDH rack. Fig. 4 shows a KSR and KST with the covers removed.

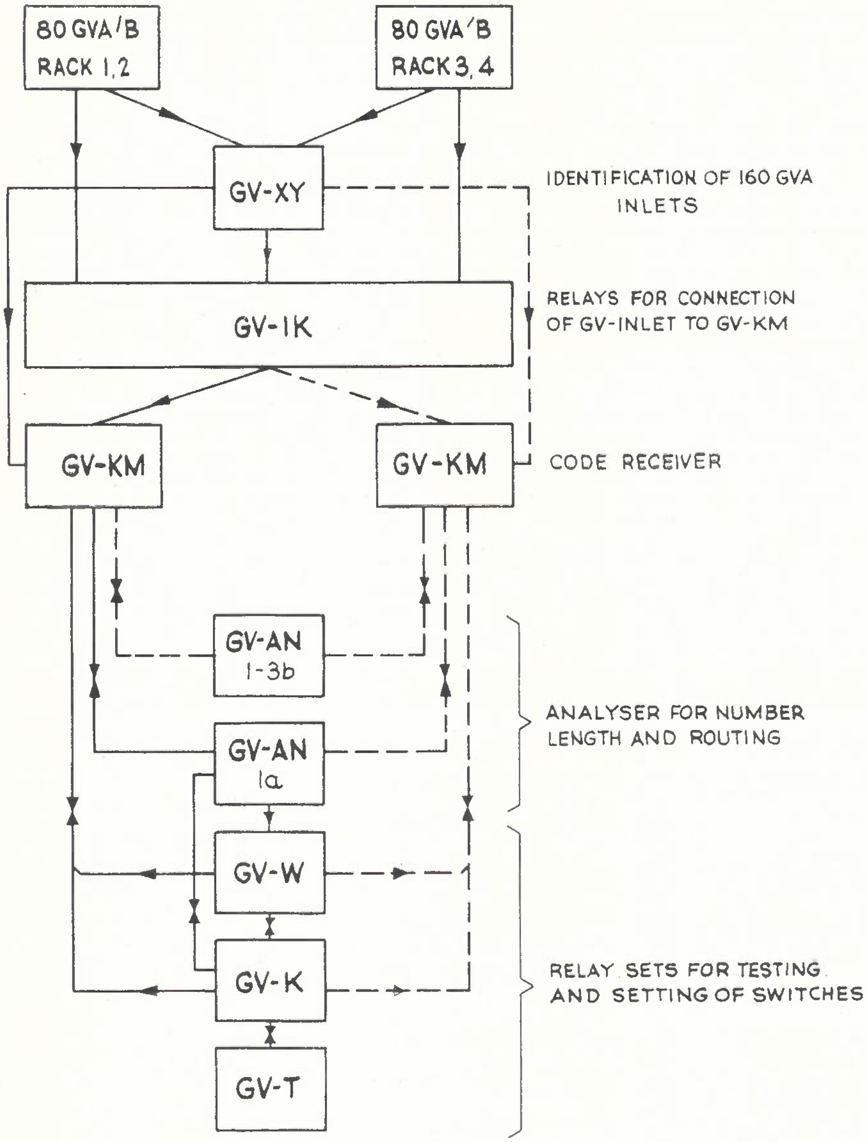


Fig. 6.—Block Connections of IGV Markers.

Voice Frequency Generator TB—one relay set per frequency consisting of an oscillator and stand-by oscillator, output transformer and decoupling resistors for 60 outputs. Twelve tone generators are mounted on a SSA/B rack.

Group Selector Stage GV—consisting of two partial stages, GVA and GVB, interconnected according to the link principle. The group selector unit is built up using two racks each containing four GVA selectors and six GVB selectors giving 80 inlets and 400 outlets. Fig. 5 shows the grouping plan for a group selector unit.

Group Selector Marker IGV—used in the larger metropolitan networks controlling the originating group selector stage. Fig. 6 shows the connection between the various relay sets which provide the following facilities:—

1. Identification for 160 GVA inlets.
2. Connects the calling inlet to either of the two code receivers (KM).
3. Stores the received digits in KM up to a maximum of three digits.
4. Determines the number length of the called number, giving 100% translation for two and three digits and can analyse 38 three digit codes to four digits, and sends the appropriate revertive signal to the local register.
5. Transistorised testing of a free outlet in the required route and after test returns a controlling signal to the register. The marker allows testing on routes with an availability of 5, 10, 20 or 40 with no restriction on the number of alternate routes.
6. Controls the setting operation of the selected GVA and GVB selectors.
7. Disconnects itself from the calling inlet when the GVA vertical is operated or if the marker is held for a predetermined time.

The number length analysis at Petersham involved approximately 800 strappings due to the variations in numbering within the Sydney network. The strappings are carried out on replaceable terminal blocks mounted in the analysing relay sets and an example of the strappings for GV-AN 1b is shown in Fig. 7.

Group Selector Marker GIVM—used for controlling the incoming group selector stage. The identifying relay set and code receiver control 80 GV inlets for identification and reception with access to the GVM relay set, controlling 160 inlets for route finding and selector setting operations. The routes out of the stage may have availability of 10, 20 and 40. At Petersham, routes from the GIV stage to SLD inlets were graded with an availability of 60 by combining an availability of 40 with an alternate route availability 20.

Equipment for controlling 160 inlets is mounted on a single BDH rack.

Junction Guard Circuit FUR—is the inlet to a two-wire junction line for traffic to ARF or S x S exchanges. Provides testing battery in the case of a free junction and automatic busying of the junction during fault conditions (open circuit, short circuit, reversal).

Incoming Junction Relay Set FIR-B—is designed to connect junction circuits from S x S exchanges to ARF exchanges. Connected between the junction and GIV inlet and via RS-I gains access to an incoming register.

Incoming Junction Relay Set FIR-A—connects incoming junction circuit from crossbar exchanges to GIV inlet. Not connected to Reg-I as distant Reg-L controls connection.

Incoming Register Reg-1—controls all incoming traffic from S x S to ARF exchanges and consists of two relay sets when decadic impulsing is required and one relay set on traffic to ARF exchanges only. The functions of the relay sets are as follows:—

Part 1—

1. Receives incoming dial pulses, repeated from FIR-B's and stores the digits on relay up to a maximum of six digits.
2. On traffic from the S x S part of a hybrid exchange, sends one permanently strapped digit before the received ones.
3. On traffic direct to the SL stage of an ARF exchange (without GIV) suppresses digits that are not required.
4. Controls the connection and disconnection to a code sender.
5. Controls digit transmission and reception of revertive signals.
6. Interprets revertive signals from code receivers and acknowledges these signals.
7. Sends first burst of ring tone, on all calls, during the release time of the register.
8. Connects time supervision circuit on seizure of the register.

Part 2—

1. Determines number length on calls to S x S exchanges.
2. Generates decadic impulses for calls to S x S exchanges.
3. On the number length unknown calls controls ready connection of register 4-6 seconds after the last digit has been received.

Six Reg-Is are mounted on one BDH rack when Parts 1 and 2 are required and 10 Reg-I's to a BDH rack on traffic to ARF exchanges only.

Incoming Register Finder RS-1—each unit provides connection of 64 FIR-B's to any one of twenty registers. Two units mounted per BDH rack.

FIR-P—test desk access circuit for testing, subscribers' lines connected to ARF exchanges.

OPERATION

Local Call

When the subscriber lifts his handset his line relay operates and calls a free SLM which identifies the calling subscriber's number and connects itself to the SLA/B rack from which the call originates. SLM calls the K/AN relay set for information of the subscriber's category marking, if any, and records any condition strapped in K/AN. SLM conditionally selects a by-path via SLA and SLB selectors to a free SR that has access to a free register and sets the horizontal bars and verticals for these selectors and calls the marker associated with RS-L which connects the selected SR to a free register. SLM transfers any stored category to the register and when the subscriber is connected his BR relay is operated from the register and disconnects the call to SLM which is freed. The subscriber receives dial tone from the register which holds the RS-L and SL selector verticals operated.

The subscriber dials and the received digits are stored on the crossbar switch part of Reg.-L. A strapping is made on the crossbar switch so that the local prefix operates a relay which disconnects the start for calling the 1st group selector stage until all the digits have been received. When the last digit has been received the register calls the marker of SSA/B for connection to a free KS which when connected causes the register to call the group selector marker and sends the two frequencies for the first digit to the "a" and "b" wires. The group selector marker identifies the calling inlet and connects its code receiver across the "a" and "b" wires of the calling inlet. The digit is stored in KM and as more information is required an A1 signal is returned to the KS, this procedure is repeated until enough digits are stored to determine the number length of the called number when a revertive signal is returned to Reg.-L. GVM then selects a free line in the local route and "sets" the GVA and GVB selectors; GVA vertical in operating disconnects the call to GVM and GVB operated calls the GVM associated with the GIV selector stage.

The GIV code receiver is connected across the inlet and the two digits required to determine the 1000 line group are stored. Selection of a free SLD inlet takes place and GVM operates the GVA and GVB selector stages. GVA disconnects the call to the marker which informs the register that the next digit shall be sent and GVB operated calls the appropriate CD-KMR. The CD-KMR is connected across the calling inlet and the three remaining digits are transferred from Reg.-L. When the units digit has been stored the P.B.X. equipment is called

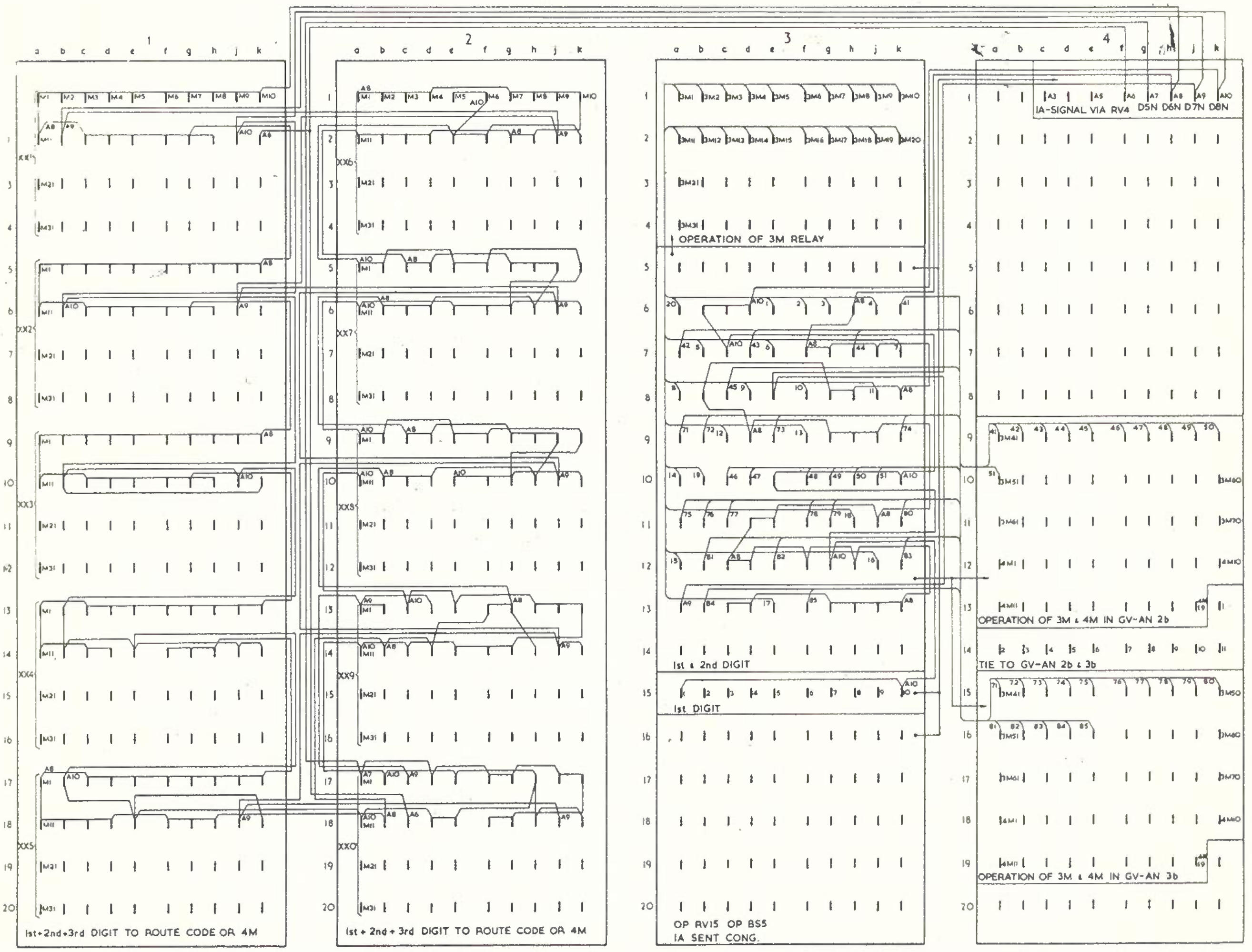


Fig. 7.—Example of IGV-AN 1b Strappings.

to investigate if the called number is the directory number of the P.B.X. group. If a directory number has been called, a test is made of the auxiliary lines in the group and the first free line is selected, the stored digits in the code receiver are cancelled and the selected line digits transferred. If a non-P.B.X. line is called the P.B.X. equipment is released and the stored digits remain in CD-KMR. The code receiver calls SLM and transfers the stored digits and sends an end of selection signal (A3) to the register for switching to B signals and is acknowledged by the register sending "extra digit" 2. SLM calls KAN and transfers the called subscriber's number to investigate whether the subscriber is category marked and if a strapping exists the marking is transmitted to SLM. The marker tests the B subscriber's C wire and sends the appropriate B signal to the register depending on the line condition.

B Subscriber Idle: CD-KMR will send a B1 signal to the KS and SLM will set the four SL selectors. During the release time of the register the first ringing signal is sent to the B subscriber and the first ringing tone is returned to the A subscriber before end of selection signal is sent to the SR which takes over the holding of the connection. The RS-L and register are released.

If the B subscriber answers during the first ring signal from the register the SR relay set is through connected and ringing current disconnected. Release of the connection is under control of the calling subscriber and a meter pulse is connected during the release time of the connection.

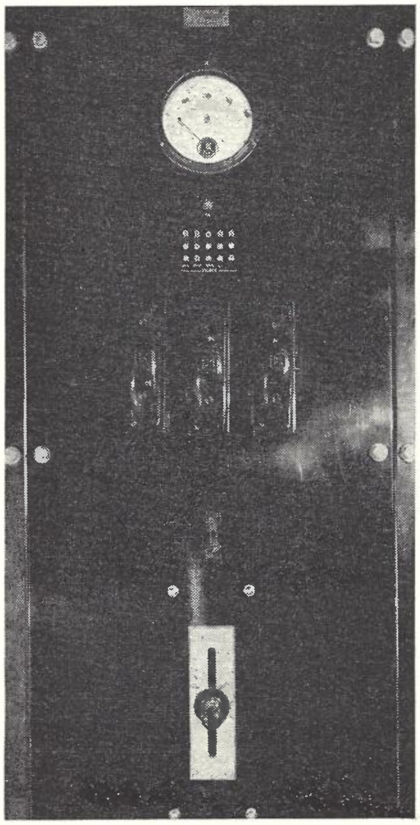


Fig. 8.—Crossbar Exchange Discharge Panel.

B Subscriber Busy: SLM will cause a B2 signal to be sent to KS and when the signal is transferred to the register the holding circuit of the verticals in RS-L and SL is disconnected and releases the holding circuit of the subscriber's line relay and the subscriber receives busy tone from his own line equipment.

Outgoing Call

As in the case of a local call, the subscriber, on lifting his receiver, is connected through the SL stage to a register and after four digits have been stored a code sender is connected to the register, and the originating group selector marker is called, connecting a code receiver across the speech wires. Digit transmission continues until the required number of digits to determine number length of the called number have been received the appropriate revertive signal is sent to the register. This signal sets the register for the type of terminal exchange, either S x S or crossbar, and the number of digits to be sent before ready connection takes place. The number length signal is disconnected by the register sending the same digit as was sent before the reception of the signal. The testing component of the marker seizes a free junction on the required route and sends a revertive signal to the register indicating how the remaining digits are to be transmitted.

A crossbar terminal exchange will be indicated by number length signals A4-A6 and after test, if a direct junction has been seized, GVM sends a waiting place signal, 2A7-2A10, to the register which releases the KS and open circuits the forward loop so that the FIR, at the distant exchange, is not called but the junction is marked busy. This procedure is necessary so that the distant code receiver will not be held if the local register has not received all of the digits required to complete the connection.

When the number of digits has been received which corresponds to the number length signal, previously received, the speech wire loop is again closed and a call made to SSA/B for reconnection of a KS to the register. The digit transmission now starts again and continues in the same way as described for local traffic with the exception that the SR is switched for loop conditions, this connecting the ring and battery feed relays, and connecting relays to receive loop signals. Ringing current and speaking battery for the B subscriber is provided by the distant FIR relay set. A meter pulse is given when the calling subscriber, who controls the release of the connection, clears.

Step-by-step terminal exchanges will be indicated by number length signals A7-A10 and after a successful test the revertive signal sent to the register, interpreted as a 3A signal, indicates the digit to be sent, decadic impulsing commences and the KS is released. Decadic impulsing can continue while digits are being received in the register and when the required number of digits, indicated by the number length signal, have been sent, the register through connects the SR and disconnects itself. During the release time of the register a burst of ring tone is sent in order to keep the post dialling delay to a minimum.

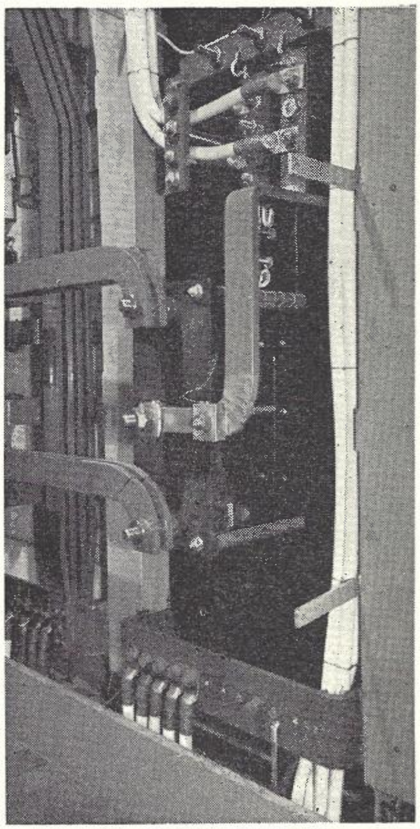


Fig. 9.—Rear of Discharge Panel.

Incoming Call

From S x S exchanges FIR-B will be seized over the junction and will call RSM for connection to a free register which must be connected by the completion of the first impulse otherwise the FIR returns busy tone to the calling subscriber. The register receives and stores the incoming digits and when sufficient digits have been received, Reg.-I calls the GIV marker and transfers the digits with M.F.C. signals. After test the GIV selectors are set and a signal is returned to the register to indicate how the remaining digits are to be sent.

For a call to the S x S part of a hybrid exchange the register sends the remaining digits with decadic impulses and through connects the FIR so that ring, transmission battery and supervision are provided by the final selector. On calls to ARF subscribers the register completes the connection with M.F.C. signalling and the FIR is set to provide ringing signals, transmission battery and reversal on answer to the distant outgoing relay set.

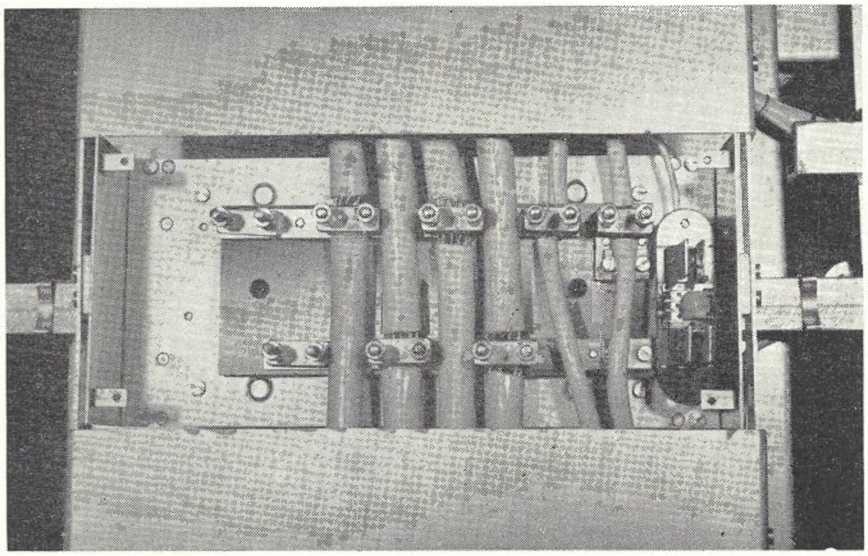


Fig. 10.—Connection of Cables to Suite Distribution Box.

CHARACTERISTIC FEATURES

P.B.X. Lines

With the equipment installed at Petersham all lines in a 1000 line group appear on the P.B.X. rack facilitating any line being associated with a P.B.X. group. The directory number should have the last two digits the same (e.g., 55) as the rack is prewired on this assumption, but a few contacts are left spare so that a limited number of directory numbers may be wired without restriction. The P.B.X. equipment can test up to a maximum of 20 lines, including the directory number, selection being in sequence one to twenty, but calls will not be switched to the directory number unless all auxiliary lines are busy. If more than 20 lines are required they are split into groups and a call distributor connected and testing is alternatively between the groups decided by the position of the call distributor.

The directory number is only selected if all the intermediate lines are busy and if an auxiliary number is dialled the call is routed as for a straight line subscriber. At Petersham, the directory number was terminated on the first exchange line position at P.B.X.'s so that for an increase or decrease in the number of lines it is not necessary to re-arrange the connections at the P.B.X.

Public Telephones

As no reversal on answer is given from SR relay sets it is necessary to wire a supervisory relay set (MR) in series with P.T. lines. To provide a convenient means of connecting MR relay sets 3% of numbers were reserved for public telephones and all necessary wiring extended to the M.D.F. enabling all cross connections to be carried out at the one point.

Release Features

Line lock out: If a subscriber holds any common equipment for a predetermined time he is automatically disconnected and receives busy tone from his line circuit.

Register disconnection: If a register is held for longer than 45 secs. the circuit is automatically disconnected and the calling party connected to line lock out.

SLM: If the marker fails to complete a connection within approximately 800 milli-seconds the calling subscriber is connected to line lock out and try again tone (previously called busy tone) is fed to the caller.

SR: On local calls if the called party does not answer or answers and hangs up the circuit is released after 90 seconds and the subscriber connected to line lock out. On calls to S x S exchanges "time throw-out" is disconnected.

GVM: If any relay set associated with a marker is held longer than a predetermined time the calling inlet is disconnected to free the marker and the calling subscriber receives busy tone.

FIR-B: In line with present Departmental policy, time supervision was disconnected on circuits incoming from S x S exchanges.

Route Alarm

All outgoing junctions are equipped with back-busying features which busy the junctions in the event of a fault and by strapping alarm relays it is possible to give major alarm after 2, 4, 7-9 or 13-18 faulty junctions on the various outgoing routes.

Subscriber Category Marking

A subscriber's number can be category marked for outgoing traffic, incoming traffic, or for both directions to provide restriction to various codes on outgoing traffic and special facilities on answer condition. Fifteen categories are available, 1-10 originating and 11-15 terminating but at Petersham only three originating classifications and four terminating classifications were used.

Category 1: Variable tariff public telephones which are restricted to unit fee calls and are barred to trunk and phonogram access codes. If a caller dials a barred code from a telephone strapped for category 1 the register redirects the call to a local number connected to N.U. tone.

Category 2: Multi-coin public telephones which are restricted to unit fee calls and trunk and phonogram access via special manual positions when the calls will be re-routed to N.U. tone if a barred access code is dialled.

Category 5: Test lines within the exchange are connected to this category to disconnect time throw out on calls to facilitate fault tracing.

Category 11: SLM returns a B3 in lieu of a B1 signal on a free test to numbers strapped to this category, e.g., incoming test desk trunks, junctions to manual exchanges trunked directly from group selector stages, etc.

Category 12: SLM returns a B5 signal on a free test, to lines strapped to this category to provide non-metering on calls to Departmental services.

Category 13: Reserved for malicious call tracing when the release of the connection is under control of the called subscriber. The register will receive a B6 signal from SLM after a free test.

Category 15: This category is used for re-direction of a subscriber to the spare level recorded announcement if an unequipped one hundred line group is called.

POWER SUPPLY, RING AND TONES, ALARMS

Power Supply

The existing power supply facilities for the S x S exchange were used with a separate discharge panel being installed for the crossbar exchange. Fig. 8 shows the face layout of the panel with a three position discharge switch, 10 amp. fuse for alarm negative distribution, three English Electric type S 250 amp. fuses and holders for the main distribution, associated alarm fuses and ammeter.

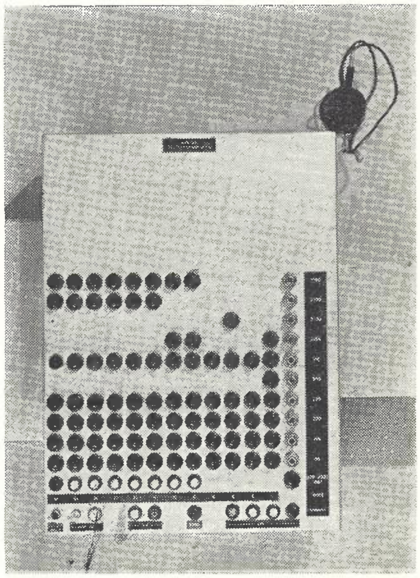


Fig. 11.—Ring and Tone Distribution Panel.

The exchange is divided into two sections of approximately five suites and the distribution to each section provided by 150 square millimeter, copper stranded cable, two cables per positive and negative feed. The design is based on the requirement that the maximum voltage drop from the battery to the distant distribution point shall not exceed 1.5 volts. Termination of the cables at the rear of the discharge panel is shown in Fig. 9. At the end of each suite a distribution fuse box is mounted and the cables are bared and clamped as they pass through the boxes. (Fig. 10.)

Suite fuse boxes are equipped with 100 amp. fuses and 35 square millimeter cable distributes power to the suite. The cable is placed in the "U" section of the top irons running the length of the suite with the insulation removed where the cable passes the 16 amp. rack fuses (15 amp. fuse + 1 amp. alarm fuse).

A separate negative supply is cabled from the discharge panel to the I.D.F. for distribution to suite control boxes and control room for alarm purposes.

A separate earth wire was run from the earth bar at the rear of the discharge panel and terminated at the top of all racks in the equipment room.

Ring and Tone Distribution

At Petersham a standard A.P.O. ringing rack, modified for battery ring, was installed in the S x S exchange and

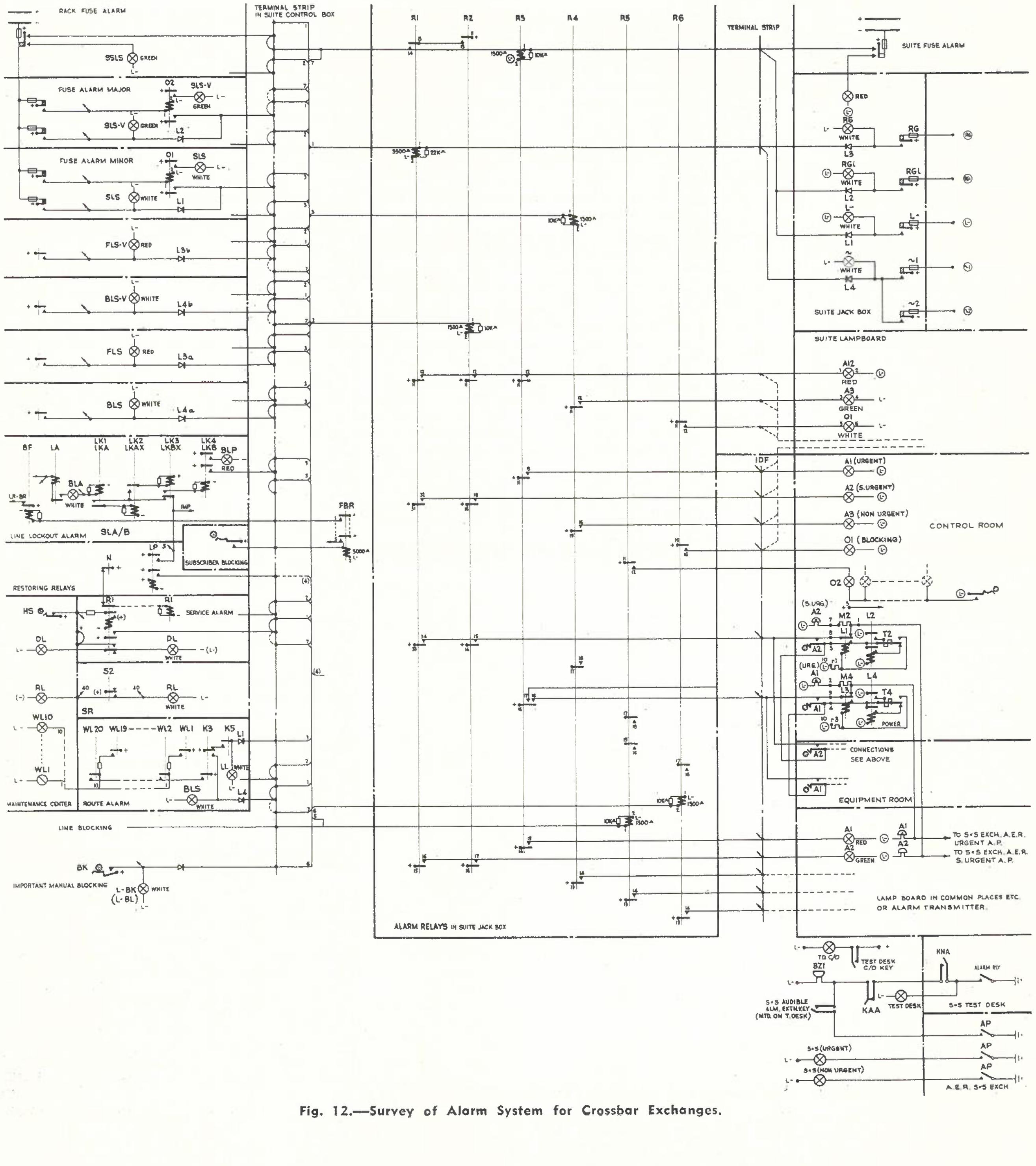


Fig. 12.—Survey of Alarm System for Crossbar Exchanges.

cabled direct to listening jacks mounted on a distribution board in the control room and thence via non-locking press buttons to each suite control box for distribution to relay sets within the suite. Fig. 11 shows the distribution board in the control room.

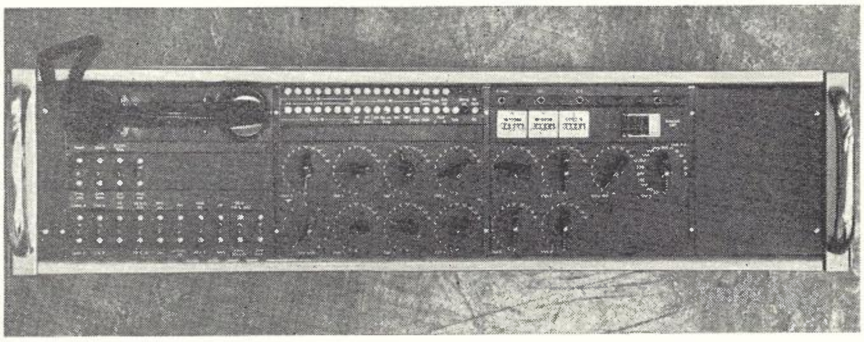


Fig. 14.—Operating Panel of Automatic Exchange Tester.

The suite control box is equipped with a listening jack per tone, fuse if required, and isolating buttons for each relay set. This arrangement provides a ready means of isolating a relay set which causes a fault condition on a tone feed.

The tone symbols shown in Fig. 11 have the following meanings:

SU—continuous ring tone.
SU1—busy tone.
SU2—dial tone.
SU3—interrupted ring tone.
SU6—number unobtainable tone.
RG—continuous ring current.
RGi—interrupted ring current.
MRG—continuous ring current connected to SLA/B racks for selection of a SLM.

Alarms

The alarms from each rack in a suite are extended to a terminal strip in the suite control box, mounted at the end of each equipment suite, where it is possible to strap any alarm for the degree of urgency required. Fig. 12 shows a survey of the alarm system installed.

The principle adopted in strapping the various alarms is as follows:

1. Urgent Alarm—operation of a fuse which interrupts service.
2. Semi-Urgent—operation of a fuse but service is not affected.
3. Non-Urgent—fuse alarm of a minor nature not requiring immediate attention as a small part of the exchange is affected.
4. Blocking Alarm—a minor alarm to give a visual indication that a device has been blocked.

The following abbreviations are used to indicate alarms on the various racks:

SLS—white lamp—minor fuse alarm.
SLS-V—green lamp—semi-urgent fuse alarm.
SSLS—green lamp—rack fuse alarm.
FLS—red lamp—fault alarm.
FLS-V—red lamp—important fault alarm.
BLS—white lamp—blocking alarm.

The suite control alarm circuits are multipled on the I.D.F. and extended to the control room together with alarms from the S x S equipment and power room. Audible alarms are provided on urgent and semi-urgent alarms.

The night alarm circuit of the test desk can be extended to the control room when a limited staff is on duty.

If a subscriber is connected to "line lock out" for more than 24 minutes the BLP lamp will glow on the SLA/B rack and an indication, under control of a non-locking press button, is extended to the control room for periodic checking of P.G.'s. The control room alarm lamps are mounted on the tone distribution board Fig. 11.

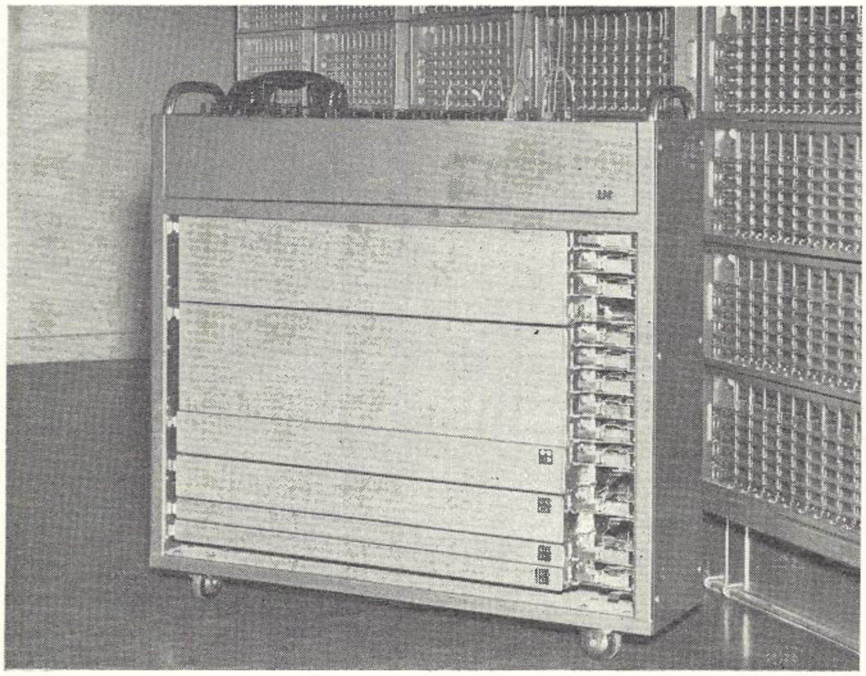


Fig. 13.—Automatic Exchange Tester for Crossbar Exchanges.

TEST EQUIPMENT

The following test sets were provided for the exchange:

Automatic Exchange Tester: The Automatic Exchange Tester (Fig. 13) is used for systematic testing of the GV and SL stages and for making separate test connections through these stages. The tester can be connected to:

1. Subscriber's line.
2. SR relay set.
3. Inlet to SLD.
4. Inlet to IGV or GIV.
5. FIR and FUR.
6. Code senders (KS).

The operating panel (Fig. 14) contains knobs and keys for selection of different test programmes, lamps for indication of the test results, jacks for connection of the tester to the racks with switching cords and a hand combination for speaking purposes. The tester can test automatically so that a connection set up to a test line is cleared after through connection and a new call is made but if a fault is encountered the tester stops and an alarm is given. Under "time control" conditions the tester repeats the test cycle independent of the result to facilitate the detection of faults in common control equipment.

The tester can test direct to a S x S exchange, decadic pulses, M.F.C. signalling crossbar—crossbar or a combination of M.F.C. and decadic signals.

Reg.-L Tester: The Reg.-L. Tester (Fig. 15) is a portable manual tester which is connected to the register control jack, group selector inlet and test line with cords. Lamps are provided to indicate the progress of the call, bells to signal that the correct test number has been obtained and speaking facilities.

SR Tester: The SR Tester is a portable manual tester, similar to the Reg-L tester, connected to a SR and test line with cords and gives lamp indication when SR seized, bells to signal that the correct number has been connected,

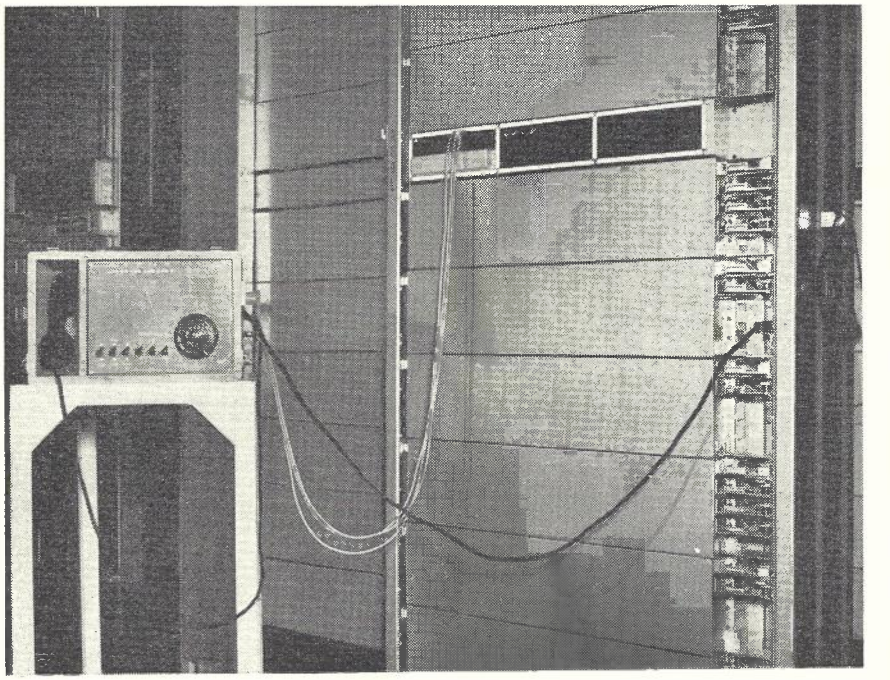


Fig. 15.—Local Register Tester.

900 C/S oscillator for transmission test on through connection, a call meter for checking metering impulses and listening and speaking facilities.

Load Tester: The Load Tester (Figs. 16 and 17), used during installation testing, is intended for marker load tests in crossbar exchanges but by the choice of suitable test numbers and utilisation of the blocking facilities it can also be used for testing every link in all switching stages. The tester sets up a maximum of ten simultaneous calls and checks that they are switched to the correct test numbers. If no fault is encountered, the connections are cleared and the calls repeated. When testing via SLM the tester checks for dial tone on the "A" numbers before impulsing commences but when testing via FIR-B relay sets it is necessary to manually start digit sending.

Connection of the "A" and "B" numbers is by 20 conductor cords and dials are provided for setting the first four digits of the "B" numbers and plugs for strapping the last three digits.

Traffic Route Tester: The Traffic Route Tester (See Fig. 3 on page 193) is an automatic tester which sets up complete test connections within an exchange or between different exchanges. A maximum of 20 test numbers can be connected to the tester at the one time with 10 "A" numbers and 10 "B" numbers, a complete test programme will comprise 100 connections, one connection being established from every "A" number to every "B" number. The T.R.T. can be used used to record faults on a Centralograph or an alarm can be given on a fault, the connection held and the necessary information displayed on a lamp panel for guidance in locating the fault.

MAINTENANCE AIDS

Traffic Meters: To provide data on the handling of traffic by different items of common control equipment traffic meters are connected to all registers and markers to indicate the total calls handled and the number of "throw-outs" from each device.

Service Alarm: An indication of an excessive number of "throw-outs" would not be detected until the traffic meter readings were recorded. A DL lead, from each marker and groups of registers, is connected to a counting relay which is reset every 20 minutes so that if the number of "throw-outs" exceeds 10, within this time, a service alarm is given. Facilities were provided to connect a group of 10 resettable meters to any service alarm for further analysis of the faulty group.

Occupation Indicators: As battery testing is used throughout the exchange a faulty inlet would not be seized and as a means of ensuring that all verticals are available for traffic all selector racks are equipped with an occupation indicator jack, each contact of which represents a vertical on the rack. When the occupation indicator is plugged into a rack a hole is burnt in the metallic paper, associated with the indicator, when a vertical is operated so that after leaving the indicator in a rack for a time, dependent on the traffic, an indication is given of any verticals not available for service.

Automatic Test Desk: An automatic test desk (APR) which is common to all registers, is meant for automatic test of a subscriber's line and dial. Calls to the test robot are made by dialling 199 from the telephone to be tested followed by certain code digits, the area technician directs the APR to carry out different tests the results of which are given by standard tones.

Control Register: One local register is common to all RS-L groups and connected to an RKR relay set to form a control register which provides supervision on all calls handled by this register. Connected to the RKR relay set are a number of control meters which show the total calls and certain types of faults thus giving an indication of the reliability of the exchange.

The control register can find the following types of faults:

1. S/C to negative polarity on the meter wire.
2. Meters connected in parallel.
3. O/C meter wire.
4. S/C meter.
5. No revertive signal from one of the selector stages (S/C between "a" and "b" wires).
6. Code receiver in one selector stage not connected (O/C "a" or "b" wires).

RKR can also be connected to centralised observation equipment via KOB relay set allowing an operator to follow a connection through the exchange. The called number is displayed on a lamp panel and at any time during the call the operator can hold the supervised connection via RKR and SR.

Traffic Measurements: From all switching devices a traffic measuring lead (TKT) is wired to the I.D.F. On seizure of any of these relay sets positive is connected via a 100 K ohm resistor and by suitable strappings on the I.D.F. it is possible to measure the traffic at any point in the exchange.

No routine testing of equipment is recommended but from a study of T.R.T. results and traffic meter readings the grade of service provided by the equipment is readily available.

INSTALLATION TESTING

On completion of all cabling, wiring and gradings, the links between the various stages were buzzed to prove continuity.

Functional tests were performed from all markers to ensure the correct operation of all selection circuits, horizontal and vertical magnets under control of the marker.

The automatic exchange tester was connected to all inlets each by-path busied in turn after a successful call until all links within the exchange have been tested.

Reg-L's were tested for correct functioning using the manual register tester. To prove the strappings in 1GVM it is necessary to dial each access code in the network, from one register, and observe that the correct number length relays operate and that the call matures.

All SR's were tested, using the SR tester to prove correct functioning on local and junction calls.

The T.R.T. is operated under fault trace conditions during working hours and on fault recording after hours. The aim before cutover should be a grade of service of at least 0.1% on local traffic.

Load testing is carried out to prove the correct operation of all markers under load conditions.

A "call round" is performed to check for the operation of all line circuits and subscribers' meters.

All alarm circuits were checked.

CONCLUSION

The ARF 102 installation at Petersham was the result of two years of discussions between representatives of the Postmaster-General's Department and the design staff of L M Ericsson Pty. Ltd. and proved the successful working of the system in a complex metropolitan network.

The system itself provides a number of features that should ensure a high grade of service to subscribers connected to crossbar exchanges namely:

1. Conditional selection of circuits.
2. Call distributors at all stages altering the order of preference for completing connections after each call through the stage.
3. Alternate routing on all junction routes out of exchange.
4. Multi-metering facilities for ready connection to subscriber trunk dialling facilities.

A disadvantage of the system is the post dialling delay on calls to S x S exchanges, the maximum delay at Petersham was 8.5 seconds on calls routed via a backbone route and it will require customer education for familiarisation with this feature. The post dialling delay on local and crossbar to crossbar calls is 1.5-2 seconds.

The most encouraging feature of the installation has been the way the Post Office technical staff, both installation and service, adapted themselves to the new system.

ACKNOWLEDGEMENTS

The author would like to express his thanks to Post Office personnel associated with the project, L M Ericsson Pty. Ltd., especially Mr. L. Estberger, and Telephone and Electrical Industries Pty. Ltd.

REFERENCES

1. F. P. O'Grady, "Australian Post Office adopts L M Ericsson Crossbar Automatic System"; Telecommunication Journal of Aust., Vol. 12, No. 2, page 62.

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

3. R. Bager and P. Carlstrom, "L M Ericsson Multi-Frequency Code Signalling System"; Ericsson Review No. 4, 1961.

4. E. Storesund, "L M Ericsson Multi-Frequency Code Signalling Equipment"; Ericsson Review, No. 4, 1961.

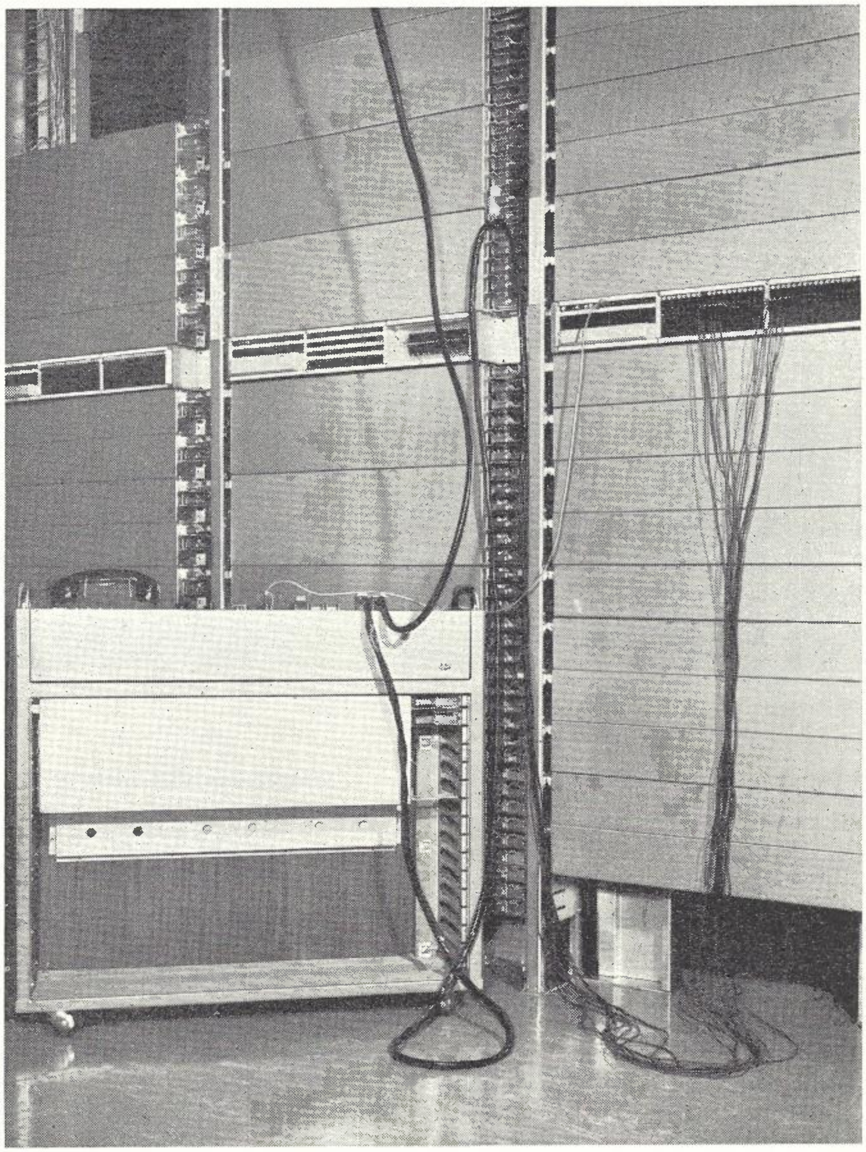


Fig. 16.—Tester for Installation Testing of Markers Under Load Conditions.

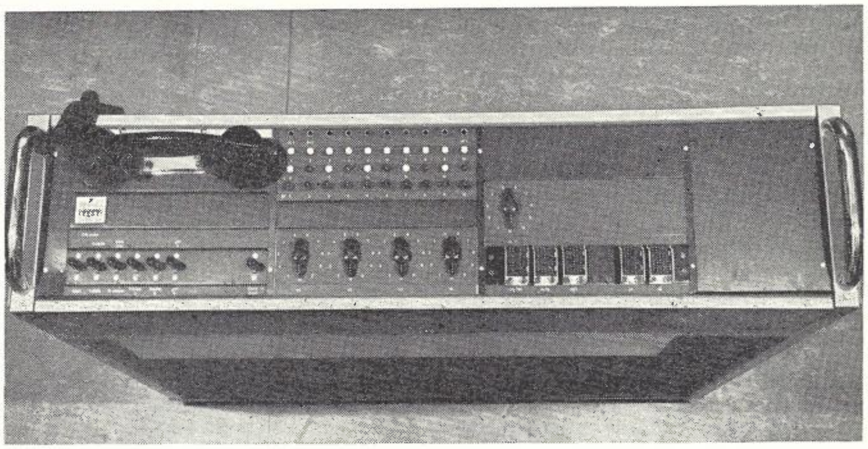


Fig. 17.—Load Tester Key Shelf.

TRAINING FOR CROSSBAR

*D. KENNER**

The decision in April, 1959, to adopt a common control switching system incorporating crossbar switches had far-reaching implications in many fields beyond those of equipment installation and maintenance. This article deals specifically with problems encountered in providing training courses in the new equipment.

Up to this time practically all of the automatic switching equipment in Australia consisted of step-by-step equipment of the 2000 SE.50 and earlier types. Experience in the use of centralised common control working was very limited, being confined to the simple versions used in bi-motional linefinder exchanges and to the several motor-uniselector exchanges. Even within this limited range it was noticeable that more tuition was required when dealing with common control equipment. As the common control circuitry of the new crossbar equipment was known to be of a more complex nature than that of the previous switching apparatus, it was soon apparent that an intensive training programme would be needed.

FORMULATING THE TRAINING PLAN

Training of the Department's technician staff has been for some years in the form of a five-year technician-in-training course. The first year of training is common to all trainees, and is a full-time course at the Department's technicians' schools in each State. At the end of the first year, trainees are allotted to various activities such as telephony (including automatic equipment, substation equipment and long line and carrier equipment), telegraphs or radio. From this stage onward most of the trainee's time is spent in the field, with regular periods (approximately one day per week) at the training school. After successfully completing the training course, each trainee graduates as a technician in telephony, telegraphs or radio.

In addition to the technician-in-training course, short-term adult courses are conducted where technical staff need additional tuition in certain specialised fields.

When trial crossbar exchanges were installed at Templestowe, Victoria, and Sefton, New South Wales, a system of "on the job" training was adopted. Talks were given to the installation staff each day by the L M Ericsson company engineer supervising the project. As each of these exchanges was comparatively small (600 lines) and did not utilise the more complicated central register common control, the knowledge gained by such instructional methods was sufficient to enable maintenance to be carried out after installation.

However, in the light of previous experience it was apparent that a much broader approach would be needed to the problem of training large numbers of installation and maintenance personnel. It was obvious that the existing technicians' schools provided the best vehicle for large scale training of technicians of all ranks. Consequently an early opportunity was sought to include instructors from the schools in each State and from Headquarters Training Sub-section in the initial short-term training courses.

At this time (1959) Toowoomba exchange was in the process of installation. This was the first Australian installation of crossbar equipment using the full register system and as such included many features that were not present in the Templestowe and Sefton installations. Accordingly, it was decided that, as a first step towards large scale training, small groups of key personnel would be sent to Toowoomba to undergo short-term training courses. These courses, which were of approximately three weeks' duration, included lectures on basic crossbar principles and inspections of the crossbar equipment. At this stage Toowoomba was not officially "cut over", but work had proceeded sufficiently to enable call tracing and other similar practical projects to be undertaken.

The first course at Toowoomba in January, 1960, contained selected instructors from each State and Headquarters and at the conclusion of this course, a conference was held between the instructors attending the course, a Headquarters Training Section Engineer, the Inspector of Technicians' Schools, the Supervisor of Technical Publications and Mr. L. Estberger of the L M Ericsson Company. Methods of instruction, necessary training aids, length and content of course were discussed and a tentative programme of training was drafted.

From the outset, it was apparent that the training programme would have two aspects—

(i) A long-term training programme in which crossbar equipment and associated circuitry would be gradually woven into the existing technician-in-training syllabus, and

(ii) A short-term programme of specialised crossbar training for staff who had already reached technician standard or higher.

As each State had its commitment of crossbar installations in the fairly near future it was felt that the plant divisions would gain the greatest benefit by concentrating for the moment on the short-term courses. For staff needing only a general knowledge of crossbar working, a basic crossbar course was devised. This basic course avoided the use of crossbar circuits and was framed with the idea of introducing officers gradually to the principles involved in crossbar working, and the different symbols, relays, trunking diagrams, functional block diagrams, and grouping plans to be encountered in this type of work. Table 1 shows the content of an early typical two week basic course.

Technical staff destined to be actively engaged on installation or maintenance of crossbar equipment received additional advanced training. However,

TABLE 1: TYPICAL BASIC COURSE

1st day	(a) National Numbering Plan; its application to crossbar. (b) Introduction to Crossbar Switching Equipment.
2nd day	(a) Relays—Types and comparisons, symbols. (b) Special features including subscriber facilities.
3rd day	(a) Crossbar Switch—construction and mechanical operation. (b) Arrangement of subscribers' numbers—100 line.
4th day	(a) Extension to 200 lines—trunking diagram. (b) Description of call within 200 lines. (c) Extension to 1,000 lines—trunking diagram.
5th day	(a) Extension beyond 1,000 lines. Trunking diagram of typical exchange. (b) M.F.C. Signalling Principles. (c) Crossbar switch as a GV stage selector. (d) Simplified description of local call. (e) Comparison of crossbar selector with step-by-step.
6th day	(a) Use of partial stages in tandem. (b) Link principle and conditional selection. (c) Simplified functional block diagram of an outgoing call through the SL stage.
7th day	(a) Functional block for GV stage and incoming call through the SL stage.
8th day	(a) "Chicken" symbols. (b) The application of "Chicken" symbols to grouping plans. (c) Comparison with switch commoning.
9th day	(a) A typical grouping plan. (b) Working into step-by-step exchanges.
10th day	Revision and Test.

---

* Mr. Kenner is Senior Technical Instructor Grade 3, Training Sub-section, Headquarters. See page 251.

TABLE 2: MODIFIED ADVANCED SYLLABUS—175 HOURS

Revision of Relays, Crossbar Switch.

Revision and Extension of Work on Grouping Plans.

Revision of Functional Block Diagrams.

Principle of Operation of M.F.C. Equipment.

Trunking on Various Types of Call, with emphasis on M.F.C. signalling.

Principle of operation of relay selection chains, call distributors, and single stage and multi-stage identifying circuits.

Functional operation and circuit description of the main elements in—
- (i) SLM and Line circuit.
- (ii) RS-L and RS-I.
- (iii) SS (code sender finder).
- (iv) REG-L and REG-I.
- (v) KS (code sender).
- (vi) GVM.
- (vii) P.B.X. operation.
- (viii) Code Receivers.

Associated practical work to include demonstrations of various circuits on the model crossbar exchange, practical applications of the strappings performed, and demonstrations and practice in the terminating techniques used in a crossbar exchange.

---

it was not desired to give advanced training too long before installation of the equipment, as it was felt that by doing so a lot of the motivation for learning would be lost. A further reason for delaying commencement of advanced training was the need to permit adequate assimilation of the fundamental principles. Table 2 shows a typical modified advanced syllabus.

TRAINING PROBLEMS

Mental Aproach

The decision to restrict short-term crossbar courses to those staff who had attained technician standard or higher ensured that all of those partaking in the courses had a reasonable background of electricity and magnetism. However, practically all such staff had their original training on step-by-step type equipment, with circuit experience based mainly on the use of detached schematic type drawings. The first few courses quickly showed that the ability of the students to handle the change-over to a completely new type of apparatus using a different type of drafting (semi-attached contact) and unfamiliar symbols varied widely among individuals. While some technicians were able to handle the transition with very little worry, others found it almost impossible to re-orient their thinking to the new conditions. One large problem in this regard was the tendency to relate all crossbar working to its equivalent in step-by-step. While this translation process is taking place, progress is usually slow.

A simple example of this is the use of different symbols. The student who has to mentally translate L.M.E. symbols to their Departmental equivalent is at a disadvantage compared to one who uses the crossbar symbols directly.

Circuit Diagrams

As already mentioned, crossbar circuit diagrams use a semi-attached contact method of drafting, and the unfamiliar look of the circuit diagrams tends to raise a mental obstacle when first encountered. Also, the principles of central register working, marker control with its associated bypath testing, and the use of multi-frequency compelled sequence signalling are all new topics to most step-by-step technicians.

Many circuit elements such as multi-stage identifiers, relay selection chains and call distributors have no counterpart in normal step-by-step circuitry but are continually used in crossbar marker circuits. A thorough understanding of such elements is therefore a necessary background to any study of crossbar circuitry. Fig. 1 shows a typical selection chain.

When training on crossbar first commenced, the only circuit diagrams and circuit descriptions available were those relating to the Toowoomba installation. Much of the later ARF.102 system circuitry, particularly that dealing with registers, 1GV markers, FIR and SR relay sets, possessed many points of difference compared with the Toowoomba circuitry, while the M.F.C. signalling system and associated code senders and code receivers in the later circuits were completely different to those used in the earlier version.

In the early stages of crossbar training, one circuit problem was a lack of information on L.M.E. drafting symbols, procedures and techniques. One example is in the simultaneous use of different types of circuit diagram. The types of diagram continually encountered are:—
- (i) Block diagrams.
- (ii) Trunking diagrams.
- (iii) Circuit diagrams.
- (iv) Survey diagrams.
- (v) Functional diagrams.

The Block Diagram is used to indicate the relationship between groups of apparatus. Each group usually represents apparatus concerned with a particular function and is shown by a rectangular block. The connections between blocks of equipment are shown by single lines which are sometimes marked with arrows to indicate the direction in which the operation is proceeding.

Trunking Diagrams are used to indicate the relationship between switching stages in an automatic crossbar exchange. Each stage is represented by a switch symbol and the connection between succeeding stages is shown by a single line, except where one stage is connected to several different types of equipment.

Circuit Diagram: The normal circuit diagram refers to one unit group of equipment such as a relay set or a rack. Only a limited amount of information is provided relating to other interconnected groups of equipment.

Functional Circuit Diagram: This is a special circuit diagram designed to give more detailed information concerning the connections between circuit

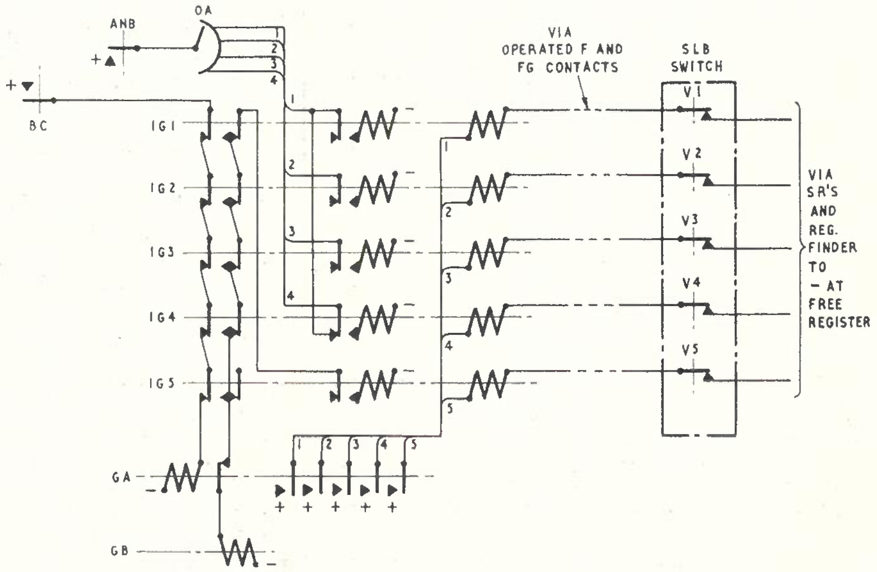


Fig. 1.—Selection Chain Circuit.

elements involved in a particular circuit function.

Survey Diagram: This is a simplified diagram designed to give an over-all appreciation of a complete stage or phase. It does not supply interconnection details between relay sets, nor does it contain the complete circuit detail, but consists of various circuits combined, simplified and abbreviated to supply sufficient information to understand the fundamental operation of that stage.

The last three types mentioned are all necessary for a detailed circuit study as the information shown on one type of diagram may not be shown on the other types of diagram relating to the same equipment.

This is indicated in Fig. 2, which represents the same section of a circuit on (a) a survey diagram, (b) normal circuit, (c) functional diagram. It will be seen that in (a) there is no division shown between relay sets on the same rack; in (b) the division is shown but there is no detail of the wiring between racks; in (c) the wiring detail for one particular circuit function is shown.

This type of information was not available in the early stages of training and such knowledge was gained mainly as a result of experience.

From a practical training classroom aspect, one of the chief difficulties associated with L.M.E. circuitry is the size and crowded nature of each drawing. For example, explanatory survey drawings of the SL stage consist of a number of drawings each approximately 36 inches long by 12 inches high. In its unreduced size it is difficult for each student to study from an individual circuit, while the crowded nature of the drawings makes it difficult to reduce drawings photographically to a workable size. The same crowded nature prevents circuits enlarged to chart size from being clearly read by students seated any distance back from the front of the classroom.

Lack of Equipment

One early training problem was the lack of equipment available for demonstration, examination or practical work, particularly in States other than Queensland. Much of the equipment being described in classroom was unfamiliar to the students, and a much better appreciation could have been achieved if the actual items of equipment were available for inspection. As the only full scale crossbar exchange in Australia was at Toowoomba, Queensland, which is, for example, some 3,000 miles from Perth, Western Australia, it can be appreciated that there would be difficulty in arranging inspection of racks, layout of equipment, cabling, etc.

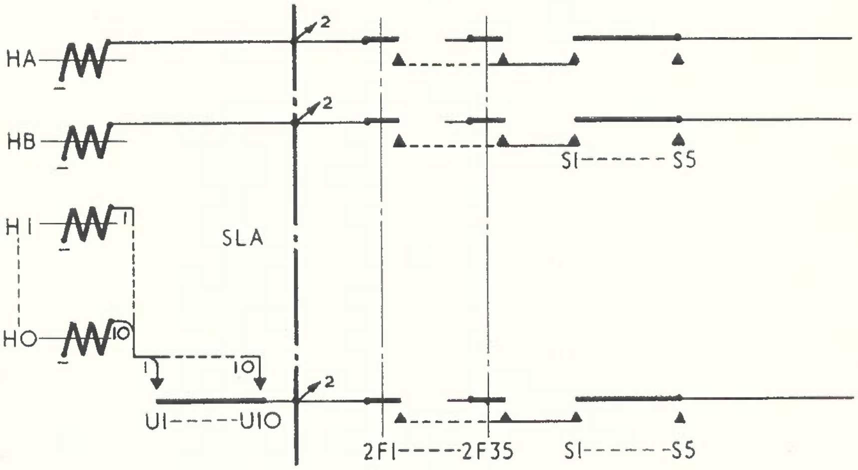
METHODS USED TO OVERCOME PROBLEMS

Circuit Simplification

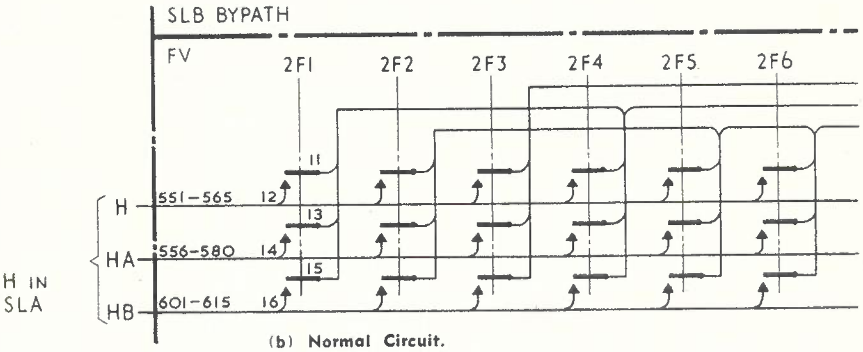
As mentioned earlier, staff accustomed to 2000 type detached schematic diagrams tend to be overwhelmed when first confronted with a large and complex-looking crossbar circuit, drawn in an unfamiliar style and using completely different symbols. The lack of familiarity with symbols, etc., can be remedied to some degree by providing them with printed sheets containing L.M.E. symbols. However, this is not the complete answer as it is necessary for the students to use the symbols in circuitry before their true meaning is retained or even appreciated.

Similarly, the seeming maze of parallel lines will daunt the bravest until they can be shown that most crossbar circuits contain fundamental sections such as identifiers, call distributors, etc., and these sections are often repeated many times.

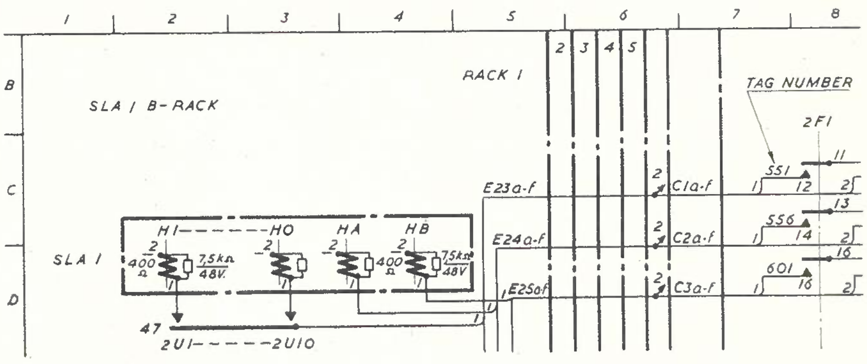
Extracting these circuit elements, and presenting them to the student in a simplified manner, enables the student to gain familiarity with the symbols, and at the same time learn aspects of the circuit that will simplify a later approach to the circuit as a whole. In practice, this simplification into small sections has been carried out to a large degree by instructors in all States and in Course of Technical Instruction books. Where it is considered of benefit to all States, drawings originated by instructors in the Technicians' Schools have been printed by The Publications Unit at Headquarters and issued as single sheets to staff undertaking cross-



(a) Survey Diagram.



(b) Normal Circuit.



OPERATION OF BARS IN SLA
[m=6A]

(c) Functional Diagram.

Fig. 2.—Comparison of Detail in Circuit Diagrams.

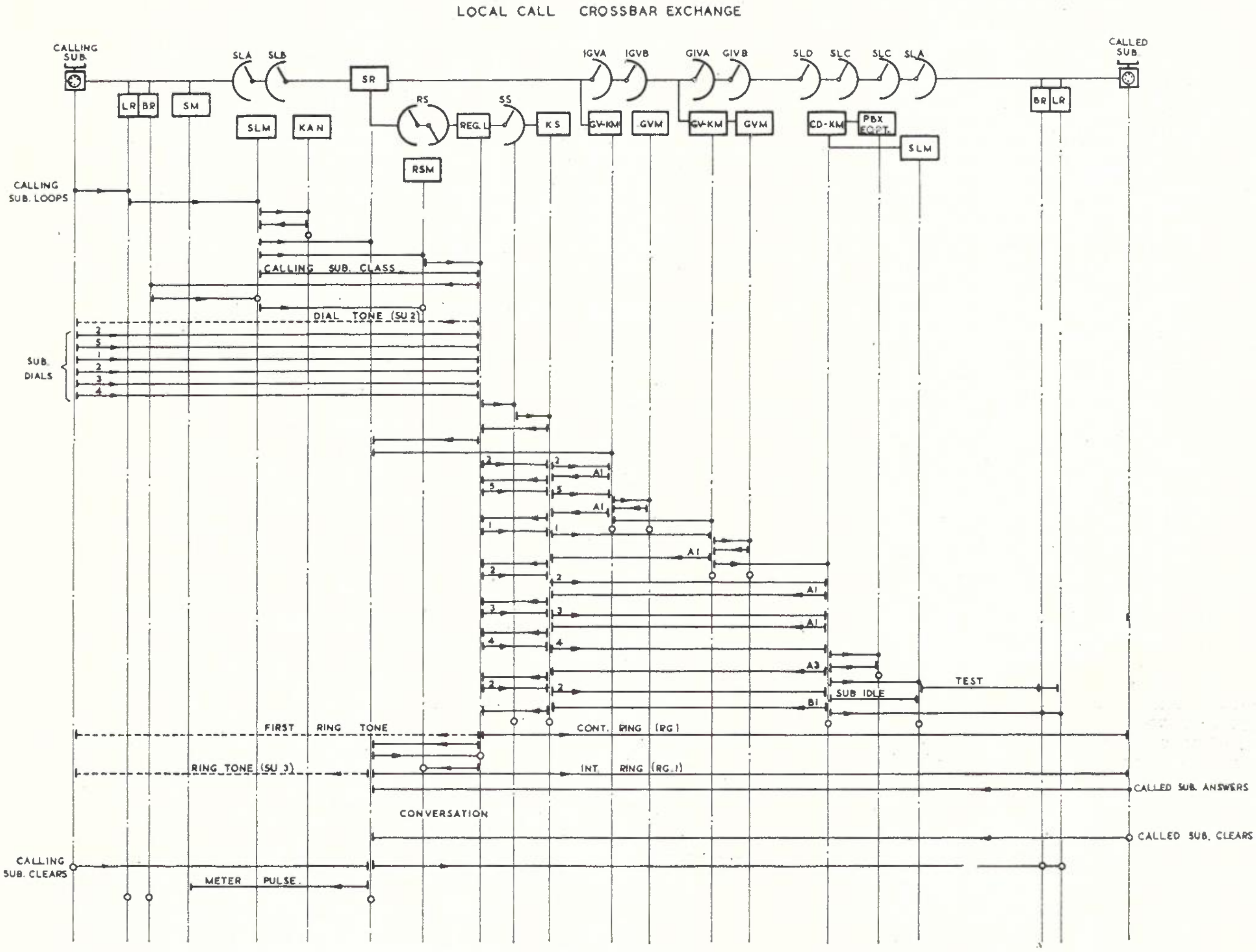


Fig. 3.—Typical Switching Sequence Diagram.

bar courses. Many other drawings are prepared locally by the schools and reproduced by local methods. When these drawings are interchanged between schools in each State it makes it possible to combine the best features of each drawing.

Charts

Some aspects of crossbar lend themselves quite admirably to the use of instructional charts (generally approx. 30 inches x 40 inches). Among these are trunking diagrams, functional block diagrams, and explanatory drawings of relays, crossbar switch sections, etc.

Many such charts have been constructed by the Headquarters Training Section and distributed to Technicians' Schools in all States. In addition, many other charts have been devised in the various schools. Fig. 3 shows a typical switching sequence diagram. This chart originated with the Queensland school and has been used, together with other similar sequence diagrams, with a noticeable improvement in the student response.

Illuminated Trunking Diagram

This training aid employing sequential illumination of coloured fluorescent perspex originated at the Technicians' School, Melbourne. It consists of a box frame 5 feet 6 inches x 6 inches with a trunking diagram of an L M Ericsson crossbar exchange on the face (Fig. 4). The connections between blocks of equipment are shown by strips of coloured fluorescent perspex. The box frame lamps are connected by a flexible coupling to a portable Power and Stepping Unit (Fig. 5). This unit is on a small frame and contains a 50 Volt D.C. rectifier for relay operation, a 230/50 V. transformer for lamp supply, and a manual/automatic stepping unit. The aim of the aid is to show the equipment required in the

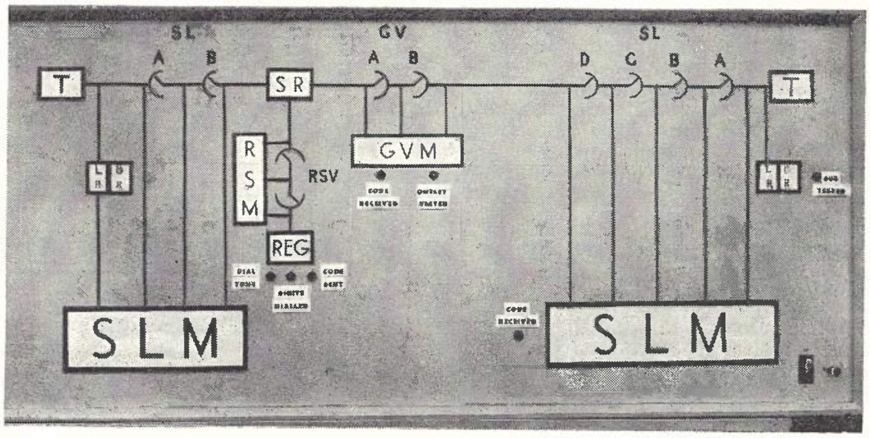


Fig. 4.—Illuminated Trunking Diagram Model-Face Layout.

setting up of a call between two subscribers connected to the same exchange. It traces the progress of the call, illuminating the items of equipment and switching paths as they are brought into use. An indication is given when each item has performed its specific function, and again when it is released for another call.

A key provides a choice of either automatic or manual operation.

Although it is not possible to mention them all, each of the other Technicians' Schools have contributed by devising their own forms of training aid models.

Model Exchange

One of the early problems mentioned was the lack of equipment available for inspection and demonstration. In Melbourne an attempt was made to offset this lack of equipment by arranging visits to the Templestowe exchange. Although this exchange was of an earlier type and did not include central register facilities, it did provide a valuable aid at the end of each course and cleared up many misconceptions. However, it could not compare with the advantages of having modern equipment with M.F.C. signalling available at the training school. This provides facilities for demonstrations and inspections immediately after the related lecture, enabling any doubts to be cleared up immediately, and with a consequent improvement in the learning rate.

This advantage was recognised by Headquarters Training Section, who arranged for the purchase from L M Ericsson of six model exchanges—one for each State—at a total cost of £70,000. Each model exchange consisted of seven racks: 1 SLA/B rack, 1 PBX rack, 1 SLC/D rack, 1 SLM rack, 2 GVA/B racks and 1 miscellaneous rack containing 1 register, 1 resistor finder and marker, 1 GV marker and the necessary M.F.C. equipment. It was decided to use standard racks in every case, as this facilitated training, enabled students to find and recognise standard components in their normal situations, and provided a better means of co-relating the theory learnt at the Technicians' School to the actual equipment encountered in the field. Practical considerations such as available room space determined the physical layout of the model. Fig. 6 shows one arrangement with the seven racks and an I.D.F. arranged in one bay. Alternative arrangements in some States divided the model so that the seven racks were placed in two bays.

Fig. 7 shows a typical trunking diagram of a model exchange. The full lines represent the model at installation and the dotted lines represent additions it is hoped to make in the near future, extending the facilities of the unit to include junction working and working into step-by-step equipment.

It is intended that scheduled testing and other maintenance facilities will be added allowing practical experience on these phases of the work. These model exchanges were the first crossbar equipment installed in some States and appreciation sessions on the equipment have already proved valuable to Engineers and others.

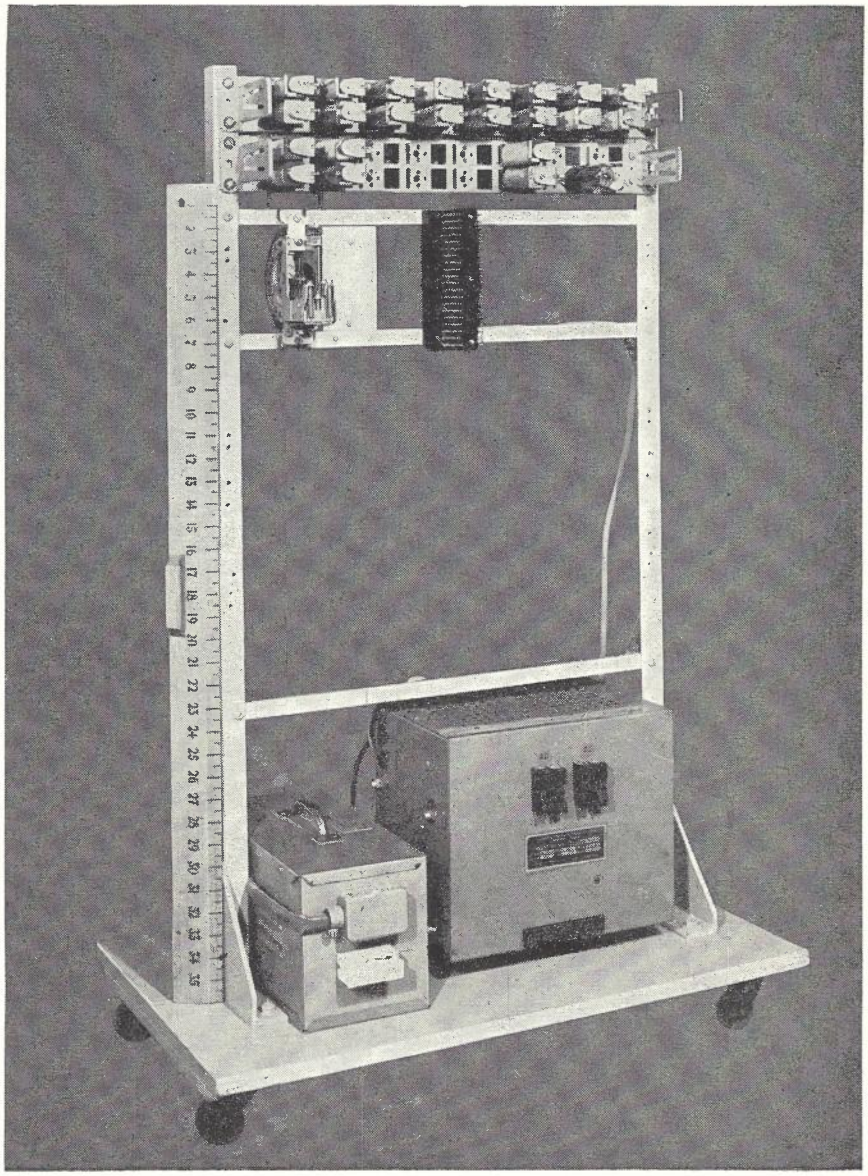


Fig. 5.—Stepping and Power Unit of Illuminated Trunking Diagram.

Course Books

When the first Course of Technical Instruction was being written, little information or circuitry was available relating to ARF. 102 systems, and discussions were still proceeding between the Department and L.M.E. regarding the facilities required for Australian conditions and the methods to be adopted to achieve these facilities. As a result, the first book "Crossbar Switching 1" had to be written in a generalised manner to cover principles only, and to cover these in such a way as to allow for future changes in planning.

In an attempt to compensate for lack of equipment in the classroom, drawings and photographs of the equipment were included wherever possible.

Explanatory sketches relating to the operation of the equipment were mainly restricted to functional block diagrams and trunking diagrams.

In the paper "Grouping Plans for ARF Exchanges", an attempt was made to overcome a lack of practical call tracing by describing in detail the methods used and the charts involved when tracing calls in either direction through each stage. Charts were included at the back of this paper to test the knowledge of the student. Fig. 8 shows a typical test chart for incoming calls through the SL stage. A fairly comprehensive knowledge of the trunking is necessary before all details can be completed.

A number of papers intended for "Crossbar Switching 2" have been written and distributed for use in the Technicians' Schools. These papers describe the principles of operation of

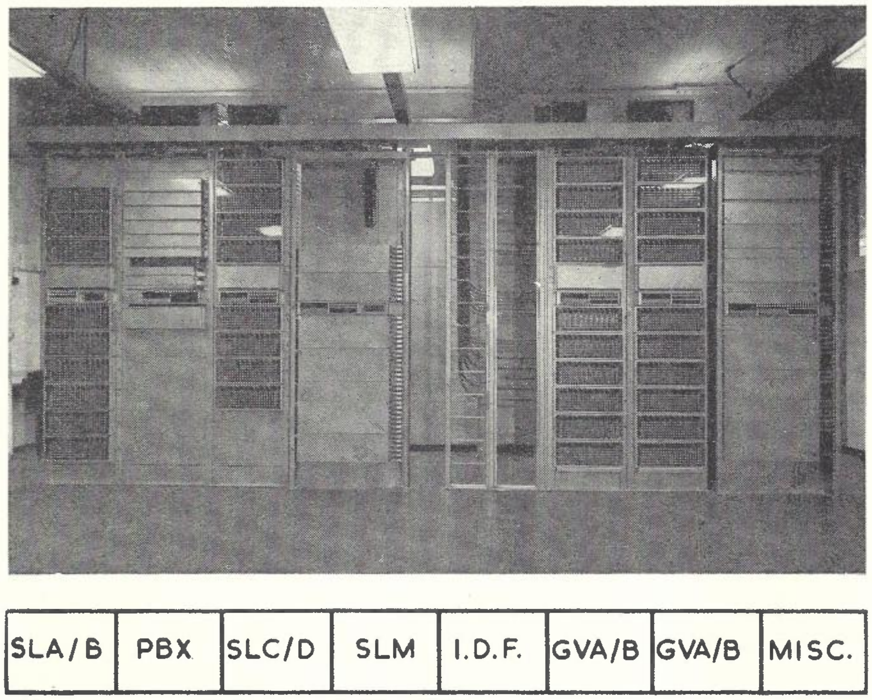


Fig. 6.—Typical Model Exchange Layout.

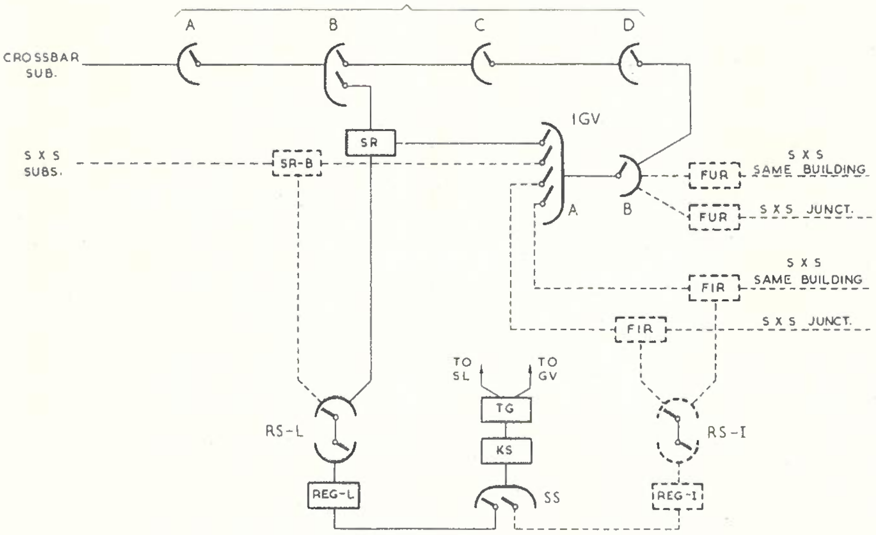


Fig. 7.—Trunking Diagram of Model Exchange.

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

Fig. 8.—Trunking Test Chart.

the main circuit elements in each switching stage, and include a large number of simplified drawings. When shown in small sections the L.M.E. semi-attached contact type of circuitry more closely resembles the circuitry of A.P.O. detached schematic diagrams and the transition problems for staff experienced in step-by-step equipment is not so pronounced. Where possible, complete semi-attached survey circuits are included at the back of each paper in the form of fold-out diagrams, so that students can learn the principles of a particular circuit element on the simplified drawing associated with the text and then immediately trace out the same circuit detail on the complete survey diagram.

In some instances, where even the simplified diagrams still look a little complex, colour has been used to outline certain operational paths.

When writing a course book of this nature, it is difficult to determine the degree of simplification necessary. In the early stages of crossbar writing, a local course was conducted at Headquarters Training. The personnel making up the course consisted of Training Engineers, technical writers, and members of Telephone Equipment Central staff, the object of the whole course being to test the effectiveness of crossbar explanatory diagrams and descriptions before they were reproduced as course book papers.

EFFECTIVENESS OF TRAINING METHODS

Since the inception of crossbar training courses in Australia, many short-term basic courses have been run in each State, but the number of advanced courses has so far been restricted. Some survey circuits and information are still not yet to hand, and this has prevented full implementation of the complete advanced crossbar training syllabus. Table 3 gives details of numbers trained in the period 1960-62.

At present, due to the relatively small amount of crossbar equipment in actual operation, a complete evaluation of the training is not possible, but from the reports received from plant sections and from the students themselves, it would appear that the training received is satisfactory and reflects the keen interest and enthusiasm displayed by crossbar instructors in all States.

Crossbar Course of Technical Instruction books have been sought after by various manufacturers of crossbar equipment and a number of copies of Crossbar Switching 1 have been supplied for use in Sweden.

FUTURE TRENDS

It is expected that in the near future the emphasis on ARF crossbar training will shift from short-term courses to integration within the technician-in-training course. With the installation of crossbar exchanges now in progress in many States, it can be expected that much more information of a practical nature will be gathered, and this type of information can then be gradually integrated into the training programme.

TABLE 3: NUMBER TRAINED EACH YEAR IN PERIOD 1960-62

Type of Course	1960	1961	1962
ARF Basic Course	200	400	500
ARF Advanced Course (Modified)	—	36	300

Training for crossbar Rural Automatic Exchanges (ARK equipment) and crossbar P.A.B.X.'s (ARD equipment) is now under consideration. ARK installations are proceeding in several States and courses on this type of equipment are about to commence.

TECHNICAL NEWS ITEM

12-TUBE COAXIAL CABLE

The first type 375 coaxial cable was installed in Australia in 1956 to provide a closed circuit television link for the E. S. & A. Bank in Melbourne. Approximately one mile of 2-tube cable was used. This was followed by other coaxial cables with progressively more tubes, e.g.—

4-tube cable — Dandenong-Morwell — installed 1959.
6-tube cable — Melbourne-Dandenong — installed 1959.
8-tube cable — Melbourne-Box Hill — installed 1962.

Requirements for tubes is now so high that the use of 12-tube coaxial cable has become a proposition on several routes. The manufacture and installation of such cable first came under notice in 1962 in both Japan and the U.S.A. where it was being used in a number of locations totalling significant lengths, and without undue manufacturing or installation difficulties.

The Postmaster-General's Department accordingly placed a contract early in 1963 for 9 miles of 12-tube coaxial cable, to be installed between Adelaide and Mt. Bonython in South Australia. The tube requirement is exceptionally high on this route as the Mt. Bonython area is the site of Adelaide's three television transmitters, tubes are required to link up with a Mt. Bonython-Mt. Barker coaxial cable recently completed, and several microwave radio systems will terminate on the mountain. It is likely that within a few years some 24 tubes will be required between Adelaide and Mt. Bonython leading to a choice of two 12-tube cables or three 8-tube cables. Cost comparisons showed that not only would there be a significant saving on the total installed cost of two 12-tube cables, but that significant duct costs would also be saved.

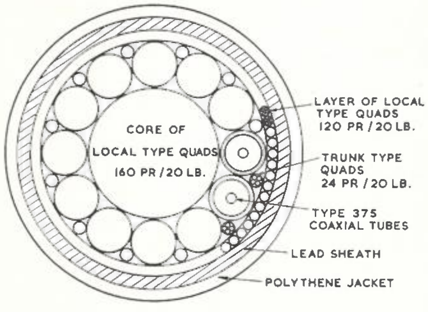


Fig. 1.—Cross Section of 12-Tube Coaxial Cable.

The simplest and most satisfactory manufacturing arrangement is to lay up the 12 tubes in one layer over a suitably sized core, which in this case was selected as 160 pr./20 lb. paper insulated local type quads. A paper insulated quad is also inserted in each of the twelve interspaces between the coaxial tubes, but in view of the limited space these are of trunk type characteristics, compared with carrier type characteristics obtainable with smaller coaxial cables. This is unimportant on this particular route as several hundred pairs can be utilised for voice frequency junctions from Adelaide to the Stirling and Summertown exchanges which are just beyond Mt. Bonython. The cable also has a layer of 120 pr./20 lb. paper insulated local type quads for the majority of its length.

The cable is conventionally lead sheathed with an outer polythene jacket to improve its resistance to chemical and electrolytic corrosion. The outside diameter of the cable is 2.95". A cross-section of the cable is shown in Fig. 1, with a photograph of this cable compared to a 4-tube cable shown in Fig. 2.

Manufacture of the cable has been completed by an Australian cable works, and satisfactory impedance uniformity of the tubes has been achieved. Impedance irregularities lead to signal reflections and distortion so that in addition to uniform tube impedance in individual drumlengths, it is necessary to ensure that mismatches at all joints in all twelve tubes are within certain specified limits. This problem becomes more severe as the number of tubes in the cable increases and as difficulties had already occurred with some 6-tube and 8-tube projects, even greater difficulties were expected with the 12-tube cable. That this did not occur is probably due largely to great care being taken during manufacture.

Based on the satisfactory manufacture of this cable, further 12-tube coaxial cable is now on order for a second cable between Melbourne and Box Hill (9 miles) to supplement the existing 8-tube cable installed in 1962. It is also expected that a third 12-tube coaxial cable will be installed shortly on the rapidly developing route between the City South trunk exchange in Sydney and the main radio terminal at Redfern (2 miles). Four further 12-tube projects are being considered for the 1964-65 financial year.—W.F.C.

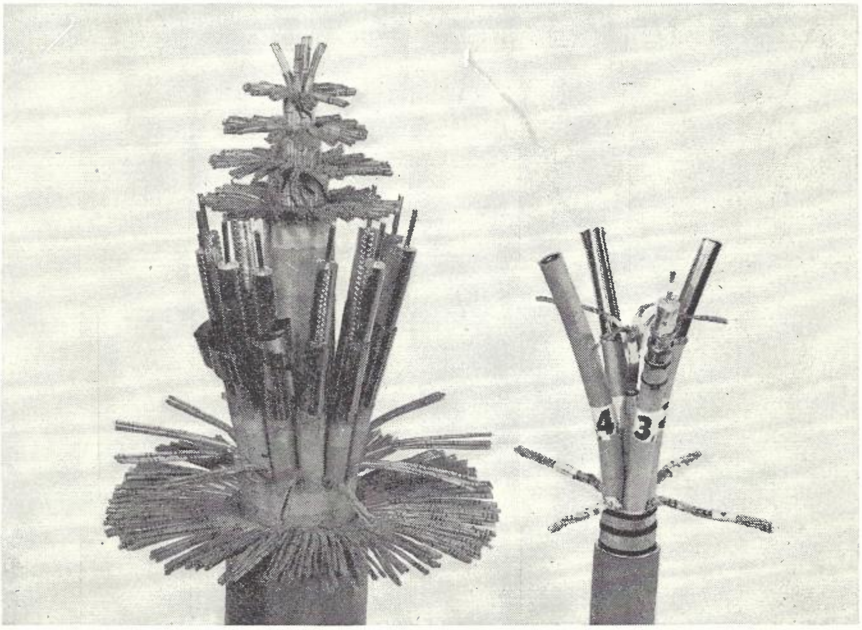


Fig. 2.—Comparison of 4-Tube and 12-Tube Cable.

PROVISION OF RURAL TELEPHONE FACILITIES UNDER UNUSUAL CONDITIONS

*P. J. O'NEILL, B.E., Grad.I.E.Aust.**

INTRODUCTION

This article describes methods used recently to provide telephone facilities in a rural area in northern New South Wales known as the "watercourse" country. The terrain in this country presented unusual problems to telephone construction and the location of the subscribers and their distribution throughout the area posed a difficult problem in selecting the most economic method of providing service.

The watercourse country is the name given to an area immediately west of the town of Moree. (Fig. 1). It covers approximately 1,600 square miles in the form of an oval of major axis some 50 miles and minor axis some 40 miles. The area is flat, lightly wooded country used for sheep and cattle grazing and is broken up by numerous small watercourses and by areas of flooded land fed by the Gwydir River which rises in highlands to the east.

A large volume of water rolls down the river from the high country, flowing with considerable velocity and carrying quantities of logs, debris and silt. When these waters reach the eastern boundary of the watercourse country there is a sudden decrease in velocity caused by the flattening out of the country, resulting in the water spreading out and running in numerous shallow watercourses. The decrease in velocity also causes the waters to deposit the burden of debris and silt; over the years a tangle of logs and other debris has, in consequence, built up at this point forming what is known as the "raft" (Fig. 2) which extends for about nine miles. It will be apprecated that the watercourse country resembles in effect a river delta area with the exception that the Gwydir River is not discharging into the sea but the water eventually finds its way into the Barwon River as Fig. 1 illustrates.

The effect of the raft in association with the large volume of water coming down the river is to cause changes from time to time in the flow of the water through this watercourse country, opening up new watercourses and permanently flooding previously dry areas with disruptive effects on the terrain as Fig. 3 indicates. It is this feature of the area which makes the provision of high security lines essential to provide continuity of service in this remote area. When an area may become permanently flooded in a matter of weeks, or when access may be cut-off from a group of subscribers for months, measures to ensure as fault-free lines as possible must be introduced.

WESTERN TELEPHONE COMPANY

The first organised system of communications in the area was introduced when the local people banded together to form the Western Telephone Company. This co-operative venture was responsible for the construction and maintenance of lines. The company served its purpose admirably for a number of years and some 700 miles of private route were erected serving about fifty subscribers connected to the Department's magneto switchboard at Moree. However, the extent of the Company's construction led to its becoming ultimately unworkable. Firstly as the routes became older the maintenance costs rose until they became so forbidding that the Company was unable to finance all of the necessary maintenance work. Lack of sufficient maintenance led, through such factors as dry joints, to poor signalling and transmission. Some of the lines were up to fifty miles long with ten parties per line. Poor enough at any time, a low standard of maintenance converted them into unbelievably bad services. As an example, two or three parties on the same line might "ring together" so that, by their combined efforts, they could drop the shutter at Moree and one of their number could shout to the telephonist. A second problem was caused by the proposed introduction of commercial power into part of the area. As the private lines did not follow definite alignments, it would have been quite impossible for the electricity authorities to avoid them. Further, as most of the lines were earth return, proximity of a high voltage line for any distance would render them useless as working services.

In 1958 a new aerial route was erected between Moree and Collarenebri and this made extension of Departmental facilities into the area appear feasible. Tentative planning was therefore commenced but it was not until early 1961, when the power extension was mooted, that the real urgency for an improved service became fully apparent. Accordingly, in November, 1961, an undertaking was given to the people in the area that five rural exchanges would be established to cater for most subscribers, that the remaining few close to Moree would remain connected to Moree and that the entire project would be completed by approximately June, 1963.

BASIC METHODS OF PROVIDING SERVICE

The decision to provide service by means of rural automatic exchanges was made after various methods had been considered. In the light of the costliness of the chosen scheme, exceeding an average of £1,000 per subscriber for external plant work, it has been suggested that less conventional methods would have been more desirable and a brief consideration of these methods may be appropriate.

Line concentrators were debarred due to the prohibitive cost of the relatively large number of junctions which would have been required. L M Ericsson A L L equipment was actually proposed for use in Combadello—the smallest area—but a traffic check revealed that the calling rate of the subscribers was far too high, that internal congestion would only result and the proposal was dropped. The use of subscribers' carrier feed directly to groups of lines was also proposed at one stage. This proposal appeared to be quite attractive. When considered in detail, however, it was realised that the two main

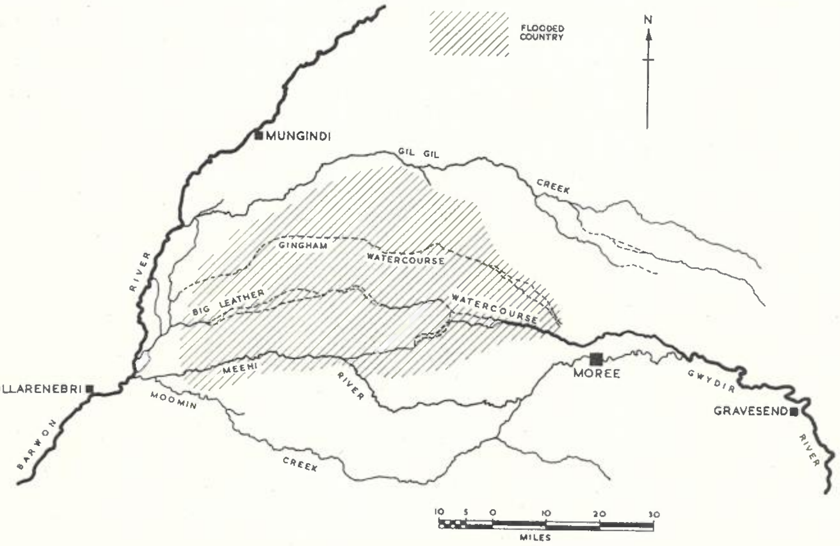


Fig. 1.—Geographical Location of the Watercourse Country.

---

* Mr. O'Neill is Engineer, Class 2, Armidale, N.S.W. See page 251.

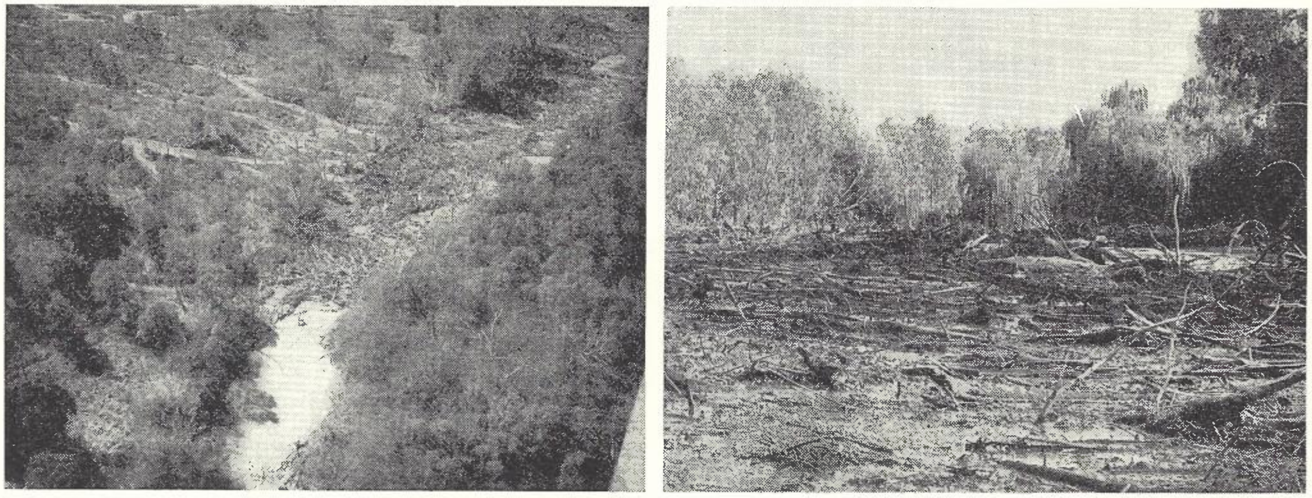


Fig. 2.—Portion of the Raft. (l) An aerial view; (r) close-up.

directions of feed would be on the Moree - Collarenebri and Moree - Watercourse routes. The former is a recognised route for providing bearers for 12-channel equipment while the latter could become an alternative route between Moree and Mungindi. This meant that incompatibility considerations would limit the number of channels of the subscribers' carrier equipment that could be used. Any limitation meant that insufficient channels could be made available for the groups of subscribers in each direction and this scheme had to be abandoned.

Subscribers V.H.F. radio was not seriously considered in the early planning because of reliability, maintenance and power requirements. However, the recent introduction of a new type of transistorised single channel system has now made this solution appear more attractive. A trial installation indicates that this system may be very reliable, requiring little maintenance and having power requirements that can be supplied on a charge-discharge basis from a small, fairly cheap, manually controlled power plant.

AREA PLANNING

The extent of existing private line construction and the boundaries of the R.A.X.'s are illustrated in Fig. 4. Exchange boundaries were designed to make use, as far as possible, of existing privately erected routes or, alternatively, to keep new privately erected construction to a minimum whilst at the same time, keeping the outline as compact as possible. Geographical features also had an influence on the design. Otherwise, mid-points between adjacent exchanges were selected. The names for the areas—Watercourse, Bunnor, Kurrabooma, Wenna and Mirriadool—were borrowed from local property names in each case.

A city dweller, not fully aware of the sparsely populated nature of the country, may regard the areas chosen as abnormally large. A theoretical analysis of optimum rural exchange area size has recently been prepared (1), and the comparison at Table 1 indicates that the actual exchange radius is close to the

TABLE 1—COMPARISON OF OPTIMUM AND ACTUAL EXCHANGE RADIUS

EXCHANGE NAME	Number of Subscribers' Lines at Cutover	Expected 20-Year Development	Subscriber Density (Sub./Sq. Mile)	Optimum Radius (Miles)	Actual Radius (Miles)
MIRRIADOOL	14	23	0.11	8.5	8.2
WATERCOURSE	11	22	0.12	8.4	7.6
BUNNOR	12	20	0.10	8.6	8.2
KURRABOOMA	10	20	0.08	9.2	9.2
WENNA	9	17	0.07	9.4	8.8

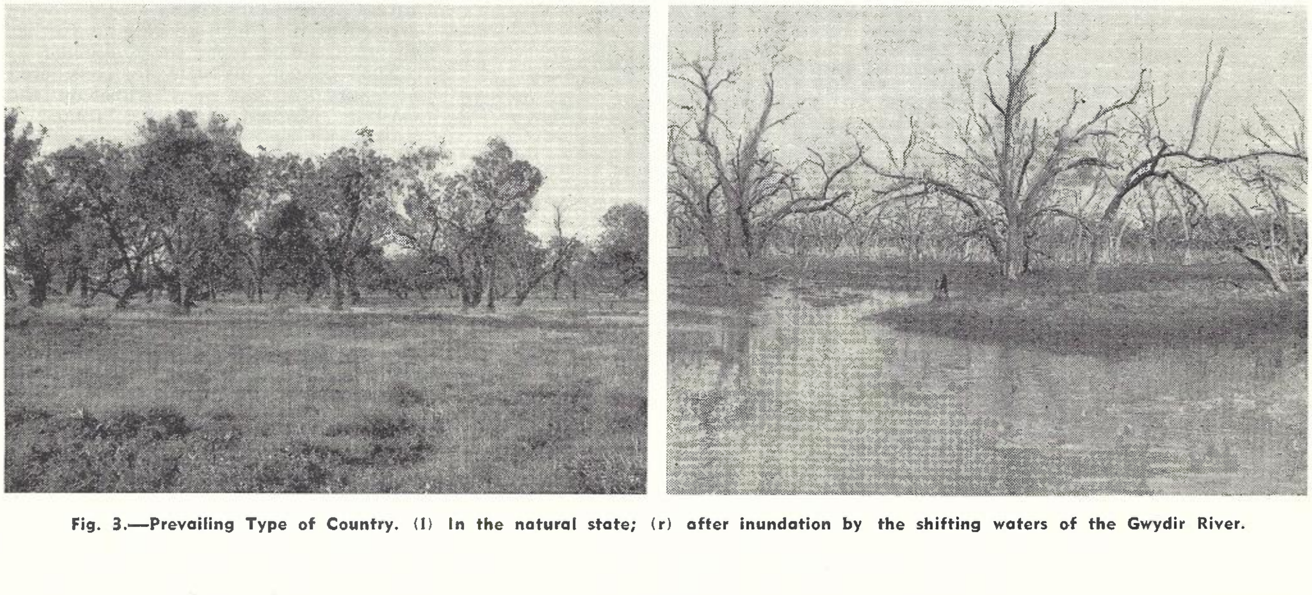


Fig. 3.—Prevailing Type of Country. (l) In the natural state; (r) after inundation by the shifting waters of the Gwydir River.

optimum for each area. Table 1 also gives the predicted number of subscribers in each area in 20 years time. The telephone development is expected to be slow as the main industry in the area is cattle raising and wool growing and there appears to be little prospect of much subdivision apart from the normal father and son arrangement.

Fig. 5.—Tractor Ploughing Cable in Flooded Country.

TRUNK AND JUNCTION OUTLETS

Wenna was classified as trunk distance from Moree while all the other exchanges were within unit fee distance. Taking this into account and allowing for the known very high calling rate of the subscribers in the area, it was estimated that the following both way circuits should be provided to Moree:—

Wenna	3
Watercourse	4
Bunnor	4
Kurrabooma	4
Mirriadool	5

The circuits to Watercourse were provided physically by erecting four pairs of 70 lb./mile cadmium copper wires on a newly constructed aerial route from the end of a loaded Moree subscribers' cable. A new bearer was provided from Moree to Bunnor by erecting a pair of new 200 lb./mile copper wires from the end of the Moree trunk cable along portion of the existing Moree-Collarenebri pole route, the newly erected route to Watercourse and additional new route from Watercourse to Bunnor. The circuits to Bunnor were then provided by utilising the physical pair together with three channels of rural carrier equipment. A further four channels of this equipment together with a 200 lb./mile pair of wires on existing and new route provided the necessary requirements to Mirriadool. Another 200/lb.mile bearer was erected from Moree to Wenna on existing route. This physical pair plus two channels of a second rural carrier installation at Moree provided the necessary trunks to Wenna while the same installation was used to provide four channels to Kurrabooma tapped out along the route.

The provision of all the bearers necessitated the erection of 42 miles of new pole route and 264 single wire miles of 200 lb./mile copper wire. The new route was through heavily timbered country for the most part and a bulldozer was employed for six weeks clearing the route. Stacking of the cleared timber could have been a major problem as the route lay along narrow roads and the timber could not be left lying in the water tables of the roads. The co-operation of nearby landowners in allowing the timber to be stacked on their properties alleviated the position, but, even so, three chain saw operators were needed for six weeks.

The holding properties of the black soil in the Watercourse country are poor and poles on the well-stayed Moree-Collarenebri trunk route, erected only in 1958, are leaning badly in places. With this experience in mind, all poles on the Moree-Watercourse-Bunnor new route were set one foot deeper in the ground than would normally be the case and the route was stayed as for an important trunk route. This route is the one most likely to be cut-off in case of flood so other extra security measures were taken. Vibration dampers were provided on all wires in every span. As the poles were at four chain spacing, plastic spreaders were inserted in all junction and subscribers' wires. The subscribers' wires were erected at nine inch spacing to further ensure freedom from short circuits.

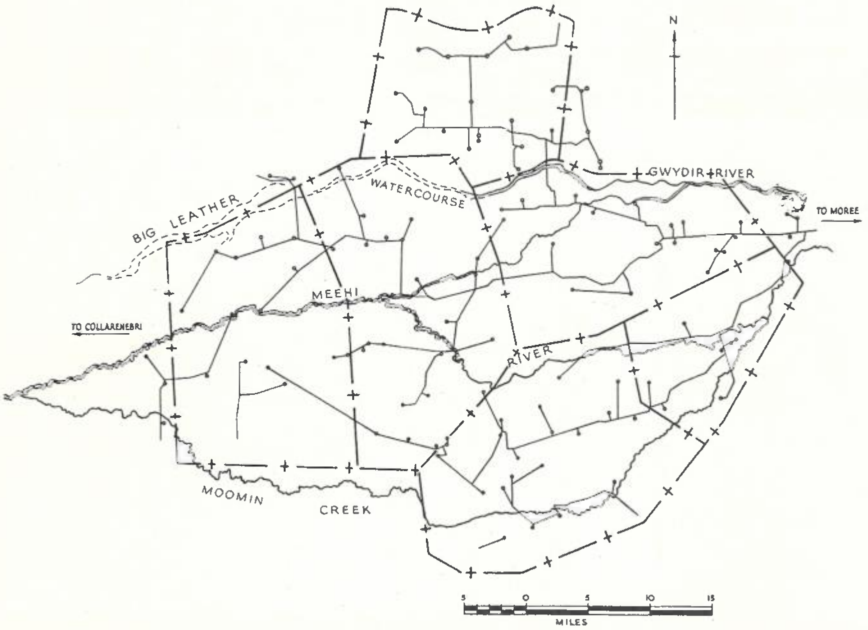


Fig. 4.—Line Layout of the Western Telephone Company and R.A.X. Boundaries.

Such precautions were not considered necessary for the new wires on the existing Moree-Collarenebri route as it is more accessible. Vibration dampers only were provided in these wires. The spur to the Mirriadool exchange was considered to be a medium security risk. Vibration dampers only were provided in the nine inch spaced trunk pair, while the subscribers' wires were erected at seven inch spacing with spreaders inserted wire to wire. The effectiveness of the various measures can only be gauged in time but the results should give a pointer to desirable precautions in the future.

SUBSCRIBERS' DISTRIBUTION

Distribution from the exchanges to the subscribers was effected as far as possible by laying underground cable with a plough. Two ploughs were

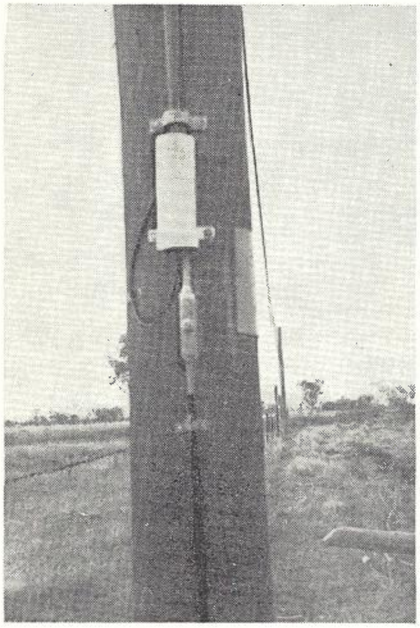


Fig. 6.—Method of Jointing Cable Terminal Box Tail to Underground Cable and Providing Gas Seal.

employed on the work, mounted on crawler type tractors with separate cable drum trailers for carrying cable. As the cable laying was mainly straight going for long distances and maximum depth of cover was desirable, the crawler mounted unit was chosen (2). The choice proved to be a particularly happy one when the rains came as the ploughs continued to function under very wet conditions as, for example, those shown in Fig. 5. Trailer-type ploughs (3) which could have been winched through the more swampy sections of route, would have been very useful and consideration could well be given to the purchase or manufacture of such a unit when other ploughing jobs in this type of country are contemplated.

As a result of the large exchange areas chosen, 20 lb./mile conductor paper insulated, lead covered (P.I.L.C.) cable was needed in every case to meet the desired transmission or signalling limits. Plastic insulated, plastic sheathed cable was not used because of the rise in attenuation which would occur if water penetrated into it. In a number of cases aerial construction was also necessary. A total of 58 route miles of cable ranging in size from six to 28 pairs was laid and this was extended with 164 single wire miles of 70 lb./mile cadmium copper wire. Almost two miles of drop wire were required to provide leads across stock routes to subscribers' premises.

Two schools of thought existed on the probable effect of soil movement on the cable. One claimed that armoured cable would be necessary to withstand the earth pressures while the other claimed that lead sheathed plastic jacketed cable would be adequate. Armoured cable was ordered for the work but, as insufficient stocks were available in time, some plastic jacketed cable was also installed.

Considering the type of country in which the cables were to be laid, all cables were put under gas pressure. An extended alarm in each exchange was provided to ensure that early advice of a drop in pressure will be given to the Moree staff. Gassing of the cables introduced difficulties in the method of providing joints, particularly as the tails of all terminal boxes were of plastic cable, and the method used to overcome these difficulties is described in the next section. All lead-in cables were plastic cables to allow for ease of terminating on the exchange frames and the lead to plastic joint in the pit outside the exchange was encased in epoxide resin. This was done as there is never likely to be a need to open the joint and the epoxy resin will provide an effective seal against the ingress of moisture so troublesome otherwise in these joints.

ABOVE-GROUND JOINTING

All drum lengths of cable were joined and all tap-outs were provided by using above-ground joints. The choice was a fairly obvious one considering the nature of the country. Fault finding in such country with underground joints would be quite impossible in the wet season. The land through which a large portion of the cable was laid would become a lake for months at a time and no water-pump would be able to dry out a pit at the bottom of a lake. Apart from its necessity from the point of view of fault finding, the above-ground joint was considered to have many other advantages; it was easy to make, the supports served a secondary purpose as cable markers, aesthetic values were unlikely to be upset in such isolated country and no greatly increased risk of mechanical damage was created.

The above-ground joint did, however, pose a number of problems. The first, as mentioned previously, was how to provide a continuity of air pressure throughout a cable. The usual aluminium sleeve and expanding rubber plug joint (4) was ruled out as not gas-tight and a single-ended joint with lead slip sleeve was substituted. The lead sleeve was prefabricated from sheathing from a suitable large cable. This solution was satisfactory for the "straight through" joints but the method of tapping out pairs along the way required a more elaborate arrangement. In this case a tap-out cable was included in the above-ground joint to make a "three-fingered" single ended joint at this point. The

Fig. 7.—Completed Above-ground Joint.

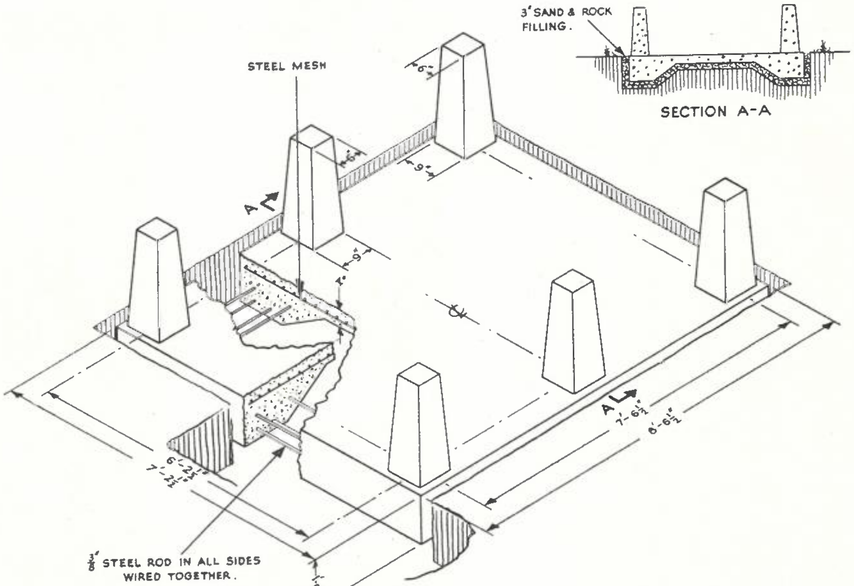


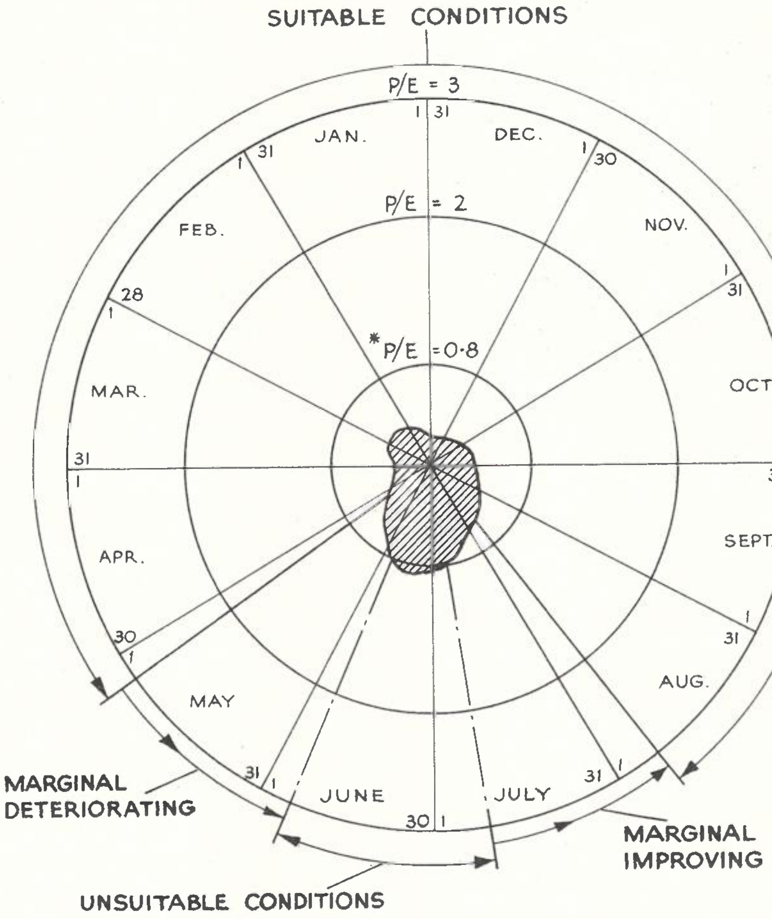
Fig. 8.—Detail of Reinforced Concrete Raft for R.A.X. Foundations.

tap-out cable was then lead away to the distribution pole and fastened vertically to the pole. A normal epoxide resin gas seal was inserted in this lead tail which was then jointed on the pole to the plastic terminal box tail with an aluminium sleeve and an expanding rubber plug. The arrangement on the pole is illustrated in Fig. 6.

The second problem associated with the above-ground joint was the method of support. Pressure treated shore poles were originally proposed but a Departmental decision not to stock these items any longer prevented their supply. It was decided to use unbored cross-arms instead. In an attempt to ensure long lives for the arms, the four feet of arm to be set in the ground was soaked in creosote for several weeks, the ground immediately around the arms was "puddled" with creosote, the upper five feet of arm was given a coat of undercoat and two coats of paint and small metal caps were specially made and fastened to the tops of the arms.

The third problem was the danger of sharpshooters, common to the district, finding the joints an inviting target. To minimise this danger the joints were placed, as far as possible, on the side of the arm away from the road. The joint itself was covered with an aluminium sleeve fastened to the arm by means of hook bolts. It was hoped that the sleeves would deflect all but direct hits.

The fourth problem was that of fire. Grass fires are particularly fierce in this country and it was thought that they could damage the cable where it was out of the ground. Tests on armoured cable indicated that it would probably withstand the heat but the same confidence could not be placed in the joint itself nor in the plastic jacketed cable. To be sure, all tails up to the joints were surrounded with four inch diameter asbestos pipe. Standard 13 feet lengths were found to provide protection for three joints exactly. The cover was not extended past the aluminium sleeve so that the joint would remain easily accessible. The pipes were attached to the arms with hoop iron, painted and stencilled. The result is illustrated in Fig. 7.



* REFERENCE DATUM REDUCED TO 0·8 TO ALLOW FOR :-
(a) POOR SUPPORTING PROPERTIES OF BLACK SOIL WHEN AT ALL WET.
(b) SEMI-TROPICAL EVAPORATION.

Fig. 9.—Polar Diagram of Precipitation/Evaporation Ratio for Moree.

R.A.X. FOUNDATIONS

The poor holding qualities of the black soil country precluded the use of conventional piers for the support of the rural automatic exchange (R.A.X.) buildings. Pilot holes were sunk to a depth of six feet, but, even at this depth, soil samples indicated that no satisfactory base could be found. It was therefore decided to use reinforced concrete rafts. Recourse to a Concrete Engineering Handbook (5) produced the following two sentences: "Mat footings have been used as floating foundations after sufficient weight of earth is excavated to about balance the weight of the structure to be built. This should be done only with very competent foundation engineering studies as many factors contributing to equilibrium are disturbed." This was the only mention of raft foundations throughout this very large reference volume and indicated that any further search might well prove fruitless. However, it seemed unlikely that any critical factors would come into force on such small projects as these and an empirical design was evolved whose details are given in Fig. 8. The concrete was supplied ready mixed from Moree while the concrete piers to support the R.A.X.'s on the foundations were prefabricated.

POWER SUPPLY

Commercial power was available at Bunnor and Watercourse but had yet to be provided in the Wenna, Kurrabooma and Mirriadool areas. Charge over trunk arrangements for these centres was considered impracticable due to their long distances from the nearest exchange and it was decided that power should be supplied by means of stop-start diesels.

The diesel machines supplied were quite heavy and required solid foundations. In addition, they had to be mounted some two feet above ground level to make sure the flood waters would not reach them. These two requirements were met by providing a special stand, made from three-inch channel iron, set in a concrete foundation similar to that described in the previous section but smaller. The diesel engine fuel supply consists of two 44-gallon drums of fuel, and these, together with the diesel, had to be provided with a suitable housing. A standard propane gas storage shed was modified to suit this purpose.

CUTOVER

It was realised that serious difficulties could arise if all heavy equipment—cable ploughs, post hole borers and trucks—were not out of the area prior to the wet season. Local opinion indicated that this season could extend from the beginning of May right through to August. Fig. 9, based on a recent article in this *Journal* (6), supports this opinion. All work was programmed to be finished by the end of April and tentative cutover dates for the R.A.X.'s were based on this target.

Most of the aerial work was completed well in advance of the dates set but unforseen manufacturing difficulties delayed the supply of cable and the first drums were not received until March, 1963. Not long afterwards rain began to fall throughout the district. Fortunately, no really heavy falls were recorded until the end of May and the last length of cable was completed the day before the floodwaters put a stop to all work for at least six months. Largely due to the efforts of the men working on the job the cutover date was met, all R.A.X.'s were working before the end of June, 1963, and some 10,000 man-hours less than estimated based on Commonwealth average Work Units were used on the whole project.

ACKNOWLEDGMENTS

The author gratefully acknowledges the efforts on this project of all Field Staffs, particularly Line Inspector A. Chapman and Line Foreman W. Williams.

REFERENCES

1. Australian Post Office Interim Engineering Instruction, "Rural Exchange Area Planning"; Planning, Transmission and Line Systems, E2000.

2. D. MacQueen, "Some aspects of the Design and use of Cable Ploughs"; Telecommunication Journal of Aust., Vol. 13, No. 6, page 459.

3. J. C. Maclay, "Evolution of Cable-Laying Ploughs"; Bell Laboratories Record, Vol. 40, No. 10, page 372.

4. V. J. White, "Jointing of Plastic Insulated and Sheathed Telephone Cables"; Telecommunication Journal of Aust., Vol. 11, No. 5, page 156.

5. La Londe, William S., Jr. and Milo F. Janes, "Concrete Engineering Handbook"; McGraw Hill, New York, 1961.

6. F. J. Harding, "Cross Country Cable Construction — Installation Programming Based on Predictable Climatic Conditions"; Telecommunication Journal of Aust., Vol. 14, No. 1, page 36.

BOOK REVIEW

MULLARD STEREO SOUND SYSTEMS

Mullard-Australia Pty. Ltd., September, 1963, qto. pp. 36, price 6/3.

This booklet, prepared by engineers of the Mullard Application Laboratory, Sydney, is a useful "how-to-do-it" book for the home constructor of radio and electronic equipment, and should be of interest to a large number of our readers.

A 2 x 10W and a 2 x 3W stereo amplifier are described, complete with component lists, circuit diagrams and mechanical details. Each amplifier has both radio and pick-up inputs, separate treble and bass controls, an output to a 15 ohm loudspeaker, an in-built mains power supply, and uses prefabricated printed-circuit boards.

Here the similarity ends, the principal differences being set out in the table below, which refers to the performance of each of the two amplifiers:

Another unit described is a radio tuner and stereophonic pre-amplifier, with a complement of seven valves, including a tuning indicator. This unit is intended for use with the Ten-ten amplifier previously described, and is designed to cater for magnetic and crystal gramophone pick-up, radio, tape playback and recording, channel reversal or combining, and tone control. (The tone-control circuits of the Ten-ten amplifier would be omitted). The radio tuner provides only a single channel, and therefore could not be used to provide stereo reproduction from the twin-station stereo broadcasts which are regularly available over some medium-frequency stations in Australia.

Other brief notes in this booklet discuss stereophonic tape recorders, cross-over networks, choosing and using loudspeakers, and loudspeaker enclosures.—R. G. K.

	Three-three (3w)	Ten-ten (10w)
Valves	1-6GW8 plus 6CA4*	1-EF86, 2-6GW8 plus GZ34*
Feedback	18 db (frequency range unspecified)	>17 db 30 c/s-30 kc/s
Sensitivity	(for 3w) 500 mV	(for 10w) 250 mV
Frequency response	50mW : within 3 db, 20 c/s to 20 kc/s 3w : 3 db down at 100 c/s and 20 kc/s	50mW : within 3 db, 3 c/s to 60 kc/s 10w : 3 db down at 25 c/s and 45 kc/s
Total harmonic distortion at 1 kc/s	about 4% at 3w	<0.1% at 10w
Output impedance at 1 kc/s	1.5 ohms	1.4 ohms
Hum and noise	65 db below 3w	70 db below 10w
Tone control: Bass	Boost : 11 db at 70 c/s	+12 db to —12 db at 30 c/s
Tone control: Treble	Cut : 16 db at 10 kc/s	+10 db to — 16 db at 15 c/s
Accessory sockets	None	6mA d.c. at 230V for stereo pre-amplifier and 18mA d.c. at 125V for radio tuner; also corresponding heater supplies.

* 1 rectifier, common to both channels.

PERTH CIVIL AVIATION TAPE RELAY CENTRE

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

INTRODUCTION

The Department of Civil Aviation operates a number of point to point radio telegraph circuits (e.g., Perth-Cocos Island, Perth-Darwin) as well as a local network for operational (aircraft movements) and administrative traffic.

In the early post-war years, a message relay centre was established in a temporary building at Perth Airport to accommodate the telegraph machines terminating the circuits. The machines originally installed were Teletype Corporation page printers and tape machines. With the addition of radio circuits the teletype centre grew and by 1961 had reached the stage where improved message handling facilities were essential. The construction of a modern terminal building at the Perth Airport presented an ideal opportunity to replace the old teletype office with a modern tape relay centre. Initial planning of the centre commenced some eighteen months prior to it being put into operation in July, 1962.

FACILITIES

After discussion between the Department of Civil Aviation traffic staff and staff of the Postmaster-General's Department on traffic, capital and rental costs, the following list of facilities for the centre was compiled:—

Broadcast from any number of tape transmitters and/or page printers to any number of lines. This allows a message addressed to a number of subscribers to be sent simultaneously to all destinations instead of transmitting the message individually to each subscriber.

Page or Tape Monitoring on broadcast and line whereby a page or tape record can be obtained of any traffic sent from any broadcast machine, or of traffic sent to any individual line. This line monitor facility allows for storage of messages in the event of a line being out of service and so avoids delays to in service lines from a broadcast position.

Automatic Sequential Numbering of individual messages if required, together with any other preamble as required. Each line has its own automatic numbering commencing with No. 1 for the first message for the day to a maximum of 2,000. The number of each message when received at an outstation is checked by the receiving operator and this automatic numbering serves as a check that all messages sent are received. Time of the day can, if required, be included as part of the preamble associated with the automatic numbering. This automatic number and preamble is generated electrically and, therefore, does not require prepared number tapes and individual number transmitters for each line as is the case with earlier tape relay centres using automatic numbering. The method of providing this tapeless automatic numbering is similar to that used in TRESS, but in this system a simplified character generator consisting of the distributor section of a Model 14 TD and rectifier

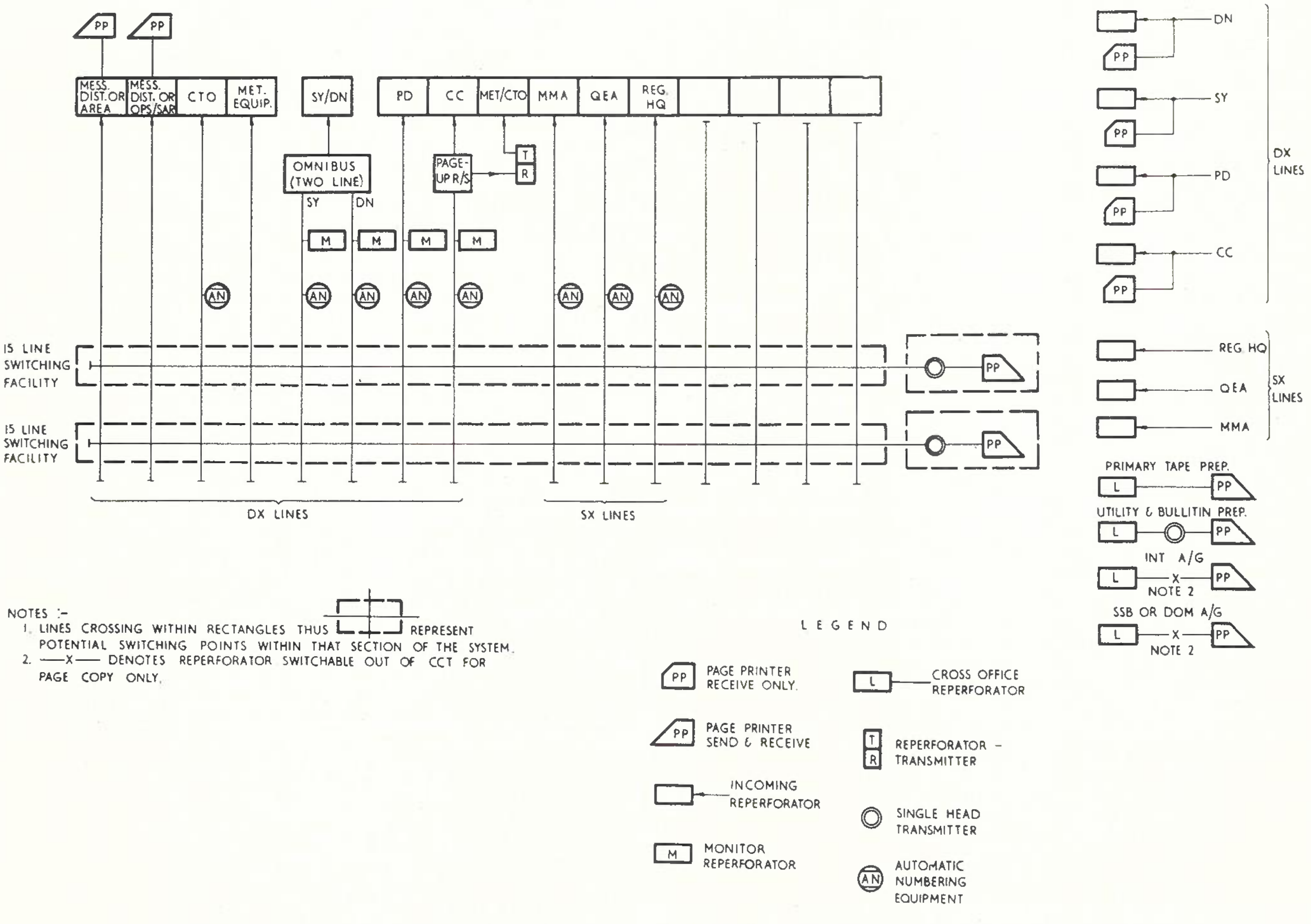


Fig. 1.—Trunking Diagram.

---

* Mr. Kirkman is Divisional Engineer, Telegraphs and Trunk Services, Perth. See page 251.

matrix is used together with magnetic counters and B.P.O. No. 4 miniature uniselectors in lieu of A.P.O. uniselectors.

Automatic Check Message which can be sent to any line at any predetermined time intervals. This check message which can take any form as required (including time and/or automatic number) is used as a means of checking that the line and equipment is in a working condition. Should no check message be received at the predetermined time, then this is an indication that a possible fault exists and is reported to the switching centre.

Simplex or Duplex Line Operation. With both simplex and duplex operation the incoming line from an outstation terminates on a typing reperforator, and in the case of simplex operation, controls from the simplex equipment prevent broadcasting to that line while it is transmitting in.

Intercept on Through Line with Automatic "Page Up". This facility is required where only one line exists to a particular outstation and is shared by another subscriber who sends less urgent traffic. In this case the through traffic is received in the switching centre on a reperforator-transmitter and normally proceeds without interruption. The selection of this line by the switching centre stops the transmitter section of the reperforator-transmitter but does not affect the reperforator which continues to receive and stores traffic. Should the switching centre "break in" during a through message, a series of line feeds is sent to the outstation before any message is transmitted in order to separate the part of the through message which was stopped, from the message being sent from the switching centre. This is done automatically, and after transmission is completed from the switching centre, the remainder of the through message which was interrupted is allowed to proceed.

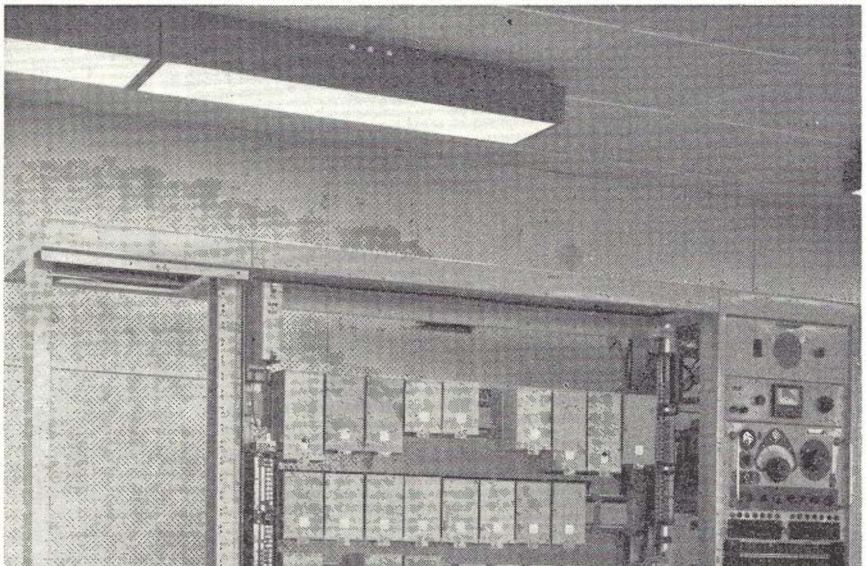


Fig. 2.—Rack Mounted Equipment; Character Generators on left.

Omnibus Working, where a line is shared by two or more subscribers. With this facility automatic numbering is transmitted only for the subscribers selected. Although any message for any line in an omnibus group is received by all subscribers in the group, the only messages they take action on, are those containing their number series. If a broadcast includes only one station in an omnibus group then the other stations in the group are also busy to any other broadcast transmitter.

Single or Double Headed Transmitter Working from Broadcast Positions. With single headed transmission as described earlier, the connection is automatically released at the end of a message tape. If batches of messages are received for onward transmission to the same station or stations, it is more convenient to retain the connection at the end of each message and so save time and labour in setting up a new connection for each message. By using a double headed transmitter a second message may be placed in the second head while the first head is transmitting, and at the end of the transmission of the first message the connection is not released. The next automatic number is sent to line and transmission of the second message commences. A third message can then be placed in the first head and this "flip-flop" action continues until there is no tape in either head.

Night Switching whereby messages may be automatically re-routed to another destination at certain times without the necessity for the operator to select the alternate route.

Safeguards incorporated in the system to ensure that messages are not lost or undue delays introduced by maloperation include:—

(i) Connection cannot be obtained to any line unless a tape is in the transmitter and the transmitter is switched on.
(ii) Transmission cannot proceed if any automatic number circuit fails to operate.
(iii) Transmission stops if any fuse associated with any relay set connected with a particular broadcast operates.
(iv) Connection will not be released if a Simplex line "spaces in" during outward transmission, or if a tape alarm on an outgoing monitor operates.

OPERATION

The method of operation from the subscriber's point of view is fairly simple. Messages for onward transmission are received in the switching centre on perforated paper tape or prepared at the centre on similar tape being torn off as received or prepared. The tapes may be held temporarily in a "washboard" type holder or, under light traffic conditions, placed directly in the transmitter. After inserting the tape in the transmitter the operator selects the line or lines, to which the message is to be sent, by operating a push-button for each line and then operates a common "start" push-button. Lamps associated with each line indicate whether the line is busy or out of service, but it is not necessary to wait until lines are free before being selected. From this stage the operation is automatic. The lines are checked to determine whether they are free, i.e., no other transmitter in the office is connected to any of the lines selected, or in the case of a Simplex line that no message is being received from that line. Should more than one broadcast transmitter be calling the same line or lines, the lines are tested sequentially from each transmitter to ensure that only one transmitter can be connected to any line at any one time. When all selected lines are free, transmission of the message commences and continues until the end of tape passes through the transmitter.

After transmission of the message has been completed, a predetermined number of "letters" characters are automatically transmitted to feed tape out at the receiving machines so that the message can be torn off without mutilating the text of the message. At the completion of this tape feed out the lines are automatically disconnected from the broadcast transmitter and are then free to be connected to another broadcast transmitter. Any number of simultaneous broadcasts are possible.

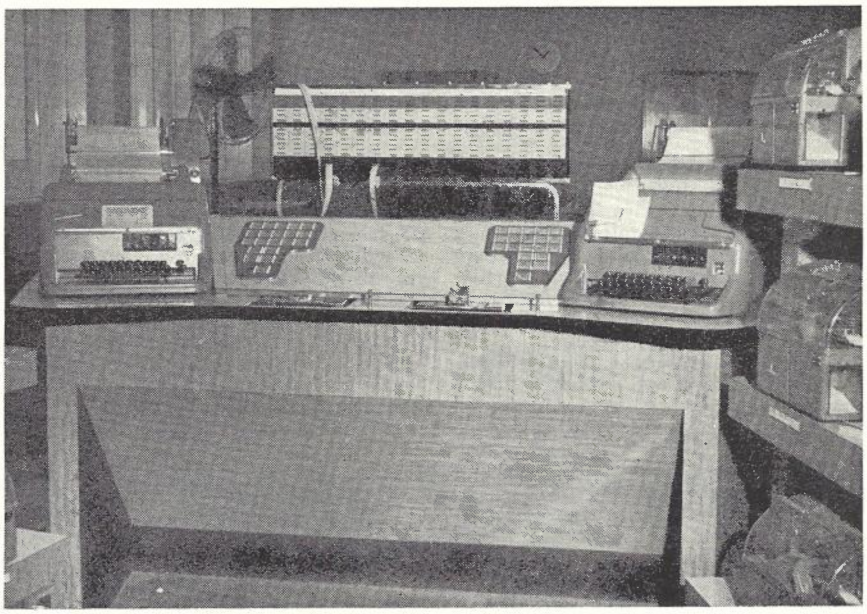


Fig. 4.—Close-up View of Operator's Position.

Trunking

From Fig. 1, it will be seen that the receive leg of all point to point circuits is terminated in a typing reperforator so that a tape is perforated for all incoming messages. Page monitors are provided on the receive side of all radio circuits. This is shown on the right-hand side of the figure. The send side of each circuit may be switched by operation of the appropriate push button to either tape transmitter.

As indicated in the list of facilities it is possible to broadcast to all lines simultaneoulsy from either transmitter. The circuitry also permits the use of any number of transmitters.

An automatic numbering unit is associated with each external line. It arranges for all outgoing messages to be sequentially numbered to permit message tracing. The time is also inserted at the beginning of each message from a common programme switch. As shown on the trunking diagram, page monitors are connected to the send leg of the radio circuits.

Cocos Island is a special case which has a reperforator-transmitter on the send leg. The reperforator accepts meteorological traffic from the C.T.O. which is retransmitted to Cocos. During transmission of an operational message the transmitter is automatically stopped and disconnected from the circuit.

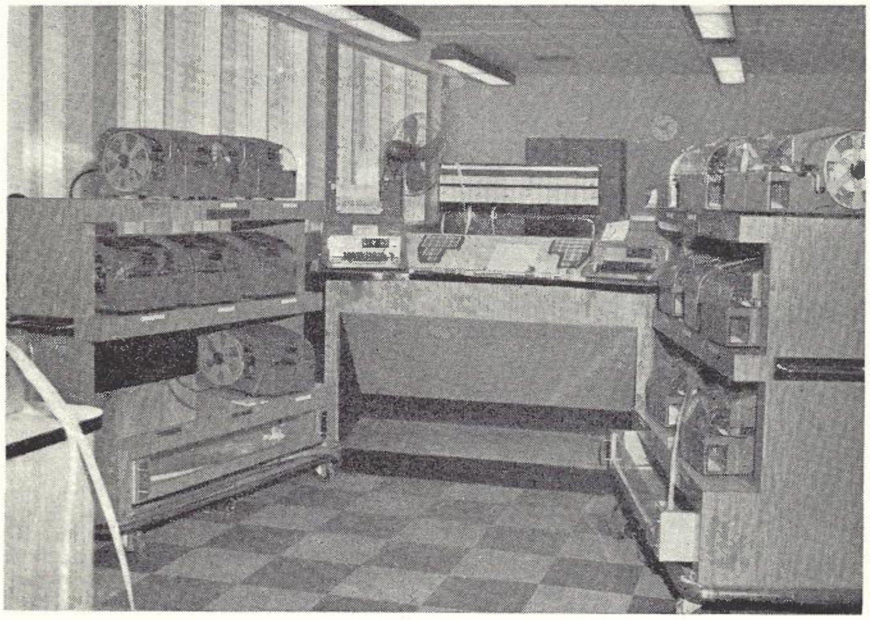


Fig. 3.—General View of Operator's Position.

Construction and Components

2000 Type rack construction is used to mount all relay equipment and is illustrated in Fig. 2. Additional rack mounted equipment includes the character generator and the supervisor's panel. Machines are mounted on consoles which can be seen from the view of the operator's position in Figs. 3 and 4. Machines used include Siemens and Halske Model 100 page printers, T loch 15 reperforators and T send 77 tape transmitters. Teletype Corporation model 14 transmitter distributors are used as character generators. A diode matrix forms part of the associated character generator circuitry.

3000 Type switching relays are used for switching. Mix and Geness magnetic counters are used as programme switches in the automatic numbering units. B.P.O. No. 4 Midget Uniselectors are used to direct characters from the character generator to the programme switch. Combination lamp and push button keys are used for line and mode selection.

4H 39 carpenter relays are used for repeating signals. Inverse neutral hub signalling is used within the switching system—all switching being carried out on the hub. Each line relay transmits polar (double current) signals. The receive side can be strapped to accept either double or single current.

CONCLUSION

As one would expect, this installation involved considerable co-operation between the D.C.A. and P.M.G. Department, the D.C.A. providing all the radio circuits and associated equipment and the P.M.G., the telegraph machines and switching equipment. Considering the complexity of the equipment and the need to keep traffic operating, the cutover from the old to the new tape relay centre went very smoothly.

Communication staff of the Department of Civil Aviation have been more than pleased with the system. It meets the current traffic requirements and will satisfy the probable expansion for a number of years.

ACKNOWLEDGMENTS

The author gratefully acknowledges assistance from colleagues at Headquarters and in N.S.W. where a similar system has been installed.

LETTER TO EDITOR

Dear Sir,

As the Kew Pentaconta Crossbar Exchange has been in service for 12 months, it may be appropriate to follow the article published in the June, 1963, issue of the Telecommunication Journal with a brief report on the performance of the equipment to date. Opportunity could also be taken at this time to comment on the various features which were under review at the time the article was written.

This exchange, which was installed under private contract by Standard Telephones and Cables Pty. Ltd., Australia, has 3,800 subscribers connected to it and during the first year it has handled approximately 7,000,000 calls with a very low fault incidence.

Since cutover the exchange has been maintained on the principle of "Ordered Corrective Maintenance", that is, that entry into the equipment room to test or adjust the equipment is only made when the various service indicators indicate that such action is warranted. The service indicators in use can be divided into two sections:—

- (i) Internal Service Indicators—
  - (a) The Automatic Maintenance Robot
  - (b) Traffic Occupation and Congestion Meters.
  - (c) Exchange Alarms.
- (ii) External Service Indicators—
  - (a) Traffic Route Tester (T.R.T.) Test Calls.
  - (b) Reports from Subscribers and Distant Exchanges.
  - (c) Reports from the Complaints Analysis Centre "C.A.R.G.O." (Described in the article by D. J. Omond in Vol. 13, No. 6, of this *Journal.)*

The main service indicator in use is the maintenance robot which permanently supervises the switching function of the equipment, and of a grand total of 227 faults for the 12 month period, 137 faults or 60% were detected by the robot, and the remaining 40% by the T.R.T., alarms, reports from subscribers and distant exchanges, or reports from C.A.R.G.O. It should also be noted that of the total of 227 faults recorded, 149 or 66% occurred during the first three months after cutover.

It is also evident from the readings on the various traffic and congestion meters that no internal congestion exists, and that the junctions provided are ample for the traffic offered. It will be recalled that on this system each switching stage constitutes a full availability group.

Since cutover the grade of service has been continually sampled using two T.R.T.'s. One is a Pentaconta portable T.R.T. which is in fact a load tester as it generates ten simultaneous calls to ten test lines and is used for generating local and incoming traffic to the exchange. The other is a standard step by step type T.R.T. and is used to test out over the various junction routes. The results of the T.R.T. tests show that only 0.08% of local test calls fail due to equipment defects.

Over the 12 month period, 44 faults patterns were received from C.A.R.G.O., seven faults were detected at Kew, 23 in the network and in 13 cases no fault could be found. From the analysis of the Technical Assistance Component of subscribers' faults forwarded from C.A.R.G.O., the performance of the Kew exchange has been consistently far better than the network average, which indicates that although the Kew exchange works into the step by-step network, considerable advantage is gained by having as much switching as possible carried out in the one common control stage.

The majority of the reports from subscribers and distant exchanges were received immediately after cutover. The subscribers' complaints were mainly related to wrong number troubles experienced with fast dials and low loop lines whilst reports from distant exchanges were in the majority of cases due to the back-busying circuit of the outgoing junctor which was under modification to increase the loop presented to the selector "A" relay at the distant end of the junction.

In the article published in the June issue of this *Journal* it was mentioned that a number of local feed junctors were fused to the one fusing point. For seven junctors there are two fuses, one fuse for the relays and one fuse for the filtered DC supply to the transmission bridge, and as the operation of a fuse does not remove the availability, the circuit could be tested as available but as the switching circuit would not be effective the system would indicate a second attempt and the call would be routed via a different feed junctor, also our experience to date indicates that failure of a fuse is a very remote possibility.

Whilst the exchange is unattended the perforator associated with the maintenance robot is switched off but the lead which calls the robot is connected to a counting relay which extends an urgent alarm to the parent exchange if more than a predetermined number of calls are made within four minutes. This feature has been most satisfactory as it will give early indication of faults which would normally not bring in an alarm.

I would like to clarify the following point in the section of the article in the June issue headed Marking and Control by High Specialised Common Control Equipment. The register is designed to call in a translator as soon as two digits are stored by the register. The register forwards in two out of five code to the translator these two digits as well as the category of the calling line. If the category is such that a subscriber is barred access to that route the translator returns a signal to the register which releases and the calling subscriber receives Try Again tone from his line circuit. If the category allows connection the translator forwards the routing information to the group marker in order that the route may be tested and the call switched through group selection. If the reception of two digits is not sufficent for the translator to determine the required route it signals to the register that additional digits are required. The register can then forward three or four digits as necessary. The information is transferred from the translator to the marker via a circuit called Faisceau Connector. These circuits do not store the information but merely act as a connecting path. The fee determining feature of the register is not in use at Kew. I would also point out that, in error, figure 14 which is labelled a 50 selector is a Terminal Selector frame.

From the results of the first year's operation it is evident that the Pentaconta Exchange at Kew is providing the very high grade of service expected from a crossbar installation.

The exchange was handed over complete with every maintenance aid required, including full circuit descriptions, circuits, wiring and relay data, also a complete recording method for maintenance purpose. The original three members of the maintenance staff who were trained by the installing contractor have completely mastered the circuitry of the system and are now training the other technicians at the exchange.

B. J. CARROLL,
Group Engineer, Metro.
Service, Eastern Division,
Melbourne.

SYDNEY-MELBOURNE COAXIAL TRANSMISSION — PART II

*P. KRASTEV, Dipl.Ing., A.M.I.E.E.**

INTRODUCTION

The coaxial cable transmission system installed between Sydney and Melbourne has been described in some detail in previous issues of this *Journal* (1) (2).

This paper covers some general concepts on the equalization and regulation of the H.F. bearer and details the testing and the alignment work during the installation. Some of the technical features of the line equipment are described only in connection with the equalization and regulation problems and the reader should refer for further information to the specialized articles on the subject.

At the outset, it is necessary to clarify how the terms "H.F. line" and "deviations" or "shapes" will be used in this context. The term "H.F. line" or simply "line" is used to refer to an equipment which transmits a given frequency band from one terminal to another, with a constant (within some tolerances) predetermined loss or gain and with a certain constant group time delay (for the television transmission). The terms "deviations" or "shapes" are used to refer to the amplitude distortion deviation or shapes as function of the frequency.

The main task of the equalization is to compensate for the cable loss which amounts to approximately 54 db at 6 Mc/s per repeater section. As there are 117 repeater sections between Sydney and Melbourne, the total loss of the line is 6,300 db which should be equalized within ± 1.0 db. This is achieved by distribution of the equalization and regulation devices in every repeater along the line and by special equalizers allocated to the terminals and to some intermediate stations. The characteristics of the line, i.e., the cable and the line equipment, vary with temperature and time. Generally, a deviation of the frequency response at any point of the transmission band should not exceed 5 db because then some signal malalignment may cause a derating of the signal-to-noise-ratio.

A 5 db deviation would mean 5/145 = 0.034 db gain variation per amplifier. (There are 145 amplifiers in the transmission path between Sydney and Melbourne). This is an illustration of the severe equalization and regulation problems as well as of the very special requirements for the manufacturing tolerances, quality and stability of all the components and units in the transmission path.

EQUALIZATION AND REGULATION

The object of the equalization and the regulation is to obtain and maintain a flat gain and delay time characteristics of the line.

Any equalization system provides the solution of the following problems:

1. Transmission objectives of the line, i.e., tolerances of the frequency responses for the different transmission modes (in our case telephony, programme transmission, telegraphy and television).
2. Economic design of the basic equalization unit, i.e., the equalization facilities in an unattended repeater station.
3. Allocation of specialized equalization and regulation equipment along the route.

The frequency response requirements for the speech and programme channels determine the telephony line transmission objective. It has been found that a tolerance of ± 1.0 db in the band 60 kc/s — 4028 kc/s is satisfactory. It is estimated that the quality of the transmission would not deteriorate substantially by extending this tolerance to ± 2.5 db provided there are restrictions and qualifications about the shape of the error and its place in the transmission band.

The television transmission target is ± 0.5 db in the range 500-3000 kc/s and then tapering linearly out to ± 1.0 db at 6 Mc/s. The group time delay target is 0.1 μsec (100 nanoseconds) in the band 500-6000 kc/s.

The practical solution of points 2 and 3 is found usually by special investigations, experience and analogies in order to determine all possible deviations and second order errors which may occur in the lifetime of the system. The economics of the equalization set-up are also a decisive factor.

The equalization plan of the coaxial system is explained in the block schematic, Fig. 1. It gives the deviation sources in single frame blocks and the equalizers in double frames. The grouping is according to the types of repeater stations. The reader should imagine a series of unattended stations which are followed by an attended station in which the cumulative errors have been compensated by the system and fine equalizers.

The shapes and the functions of the various types of equalizers are illustrated in Fig. 2 for the telephony terminal station. The other repeater stations contain a different complement of equalizers according to their function within the transmission system.

The fixed shapes for the artificial line and the basic equalizer are determined by the cable loss characteristic which follows the $\sqrt{f}$ (square root of the frequency) law above 500 kc/s.

The temperature attentuation variations are regarded as a short-term deviation because they require usually a correction only once a week. The other deviations due to the ambient temperature and the tube aging take a considerable time to affect the line performance. The long-term deviations are compensated in the coaxial system automatically.

The line amplifier is also part of the equalization chain. The frequency response of the amplifier is shown in Fig. 3 against the loss of a standard repeater section. The difference of the curves is the loss contribution of the artificial line, the temperature equalizer and the basic equalizer.

The attentuation of the repeater section is approximately 9 db/mile at 6 Mc/s. The line amplifier gain at 6 Mc/s is 58 db ± 0.3 db (i.e., 0.5% tolerance). This close tolerance illustrates the manufacturing efforts necessary for maintaining the stability of the line.

The smallest equalization and regulation unit in the transmission system is the unattended repeater station. On the other hand, the unattended stations are the main contributors of long-term and second order deviations. The repeater layout is shown in Fig. 4.

The temperature equalizer regulation is automatic and is controlled by a pilot receiver sensing the line pilot level (4092 kc/s) in ± 0.5 db limits.

The exact curves of the shapes introduced by the artificial line, the temperature equalizer and the basic equalizer are shown later in connection with the bearer alignment procedures.

The equalizer allocation for telephony and television is shown in Fig. 5. Description of the allocation of equalizers in the System (Fig. 5) should be considered together with the general equalization plan, as shown in Fig. 1. The short-term deviations, i.e., the cable attenuation variations with temperatures, are equalized in every unattended repeater station (not shown in the diagram).

The minor attended stations have, in addition to their basic equalization unit, a system equalizer in order to compensate for the design (or systematic) deviations of the fixed equalizers. There are two types of system equalizers:

(i) 7-section type, for less than eight repeater sections;
(ii) 10-section type, for more than eight repeater sections.

The allocation of the system equalizers is planned to compensate the total systematic errors of the line, although some major sections may be under or over compensated.

The equalization of the random variations, the residues of the system equalization and the errors caused by maladjustment are equalized in the so-called "Type 100 stations" which are equipped with fine equalizers. The fine equalizers are designed and tested individually for each coaxial tube during the installation. They mop-up all the remaining discrepancies in the equalizing of the telephony bearer.

The automatic equalizers are placed in the "Type 200" stations in addition to the fine equalizers. Besides Sydney,

---

* Mr. Krastev is Assistant Chief Engineer, Line Telephony Dept., Telecommunication Company of Australia. See Vol. 14, No. 1, page 83.

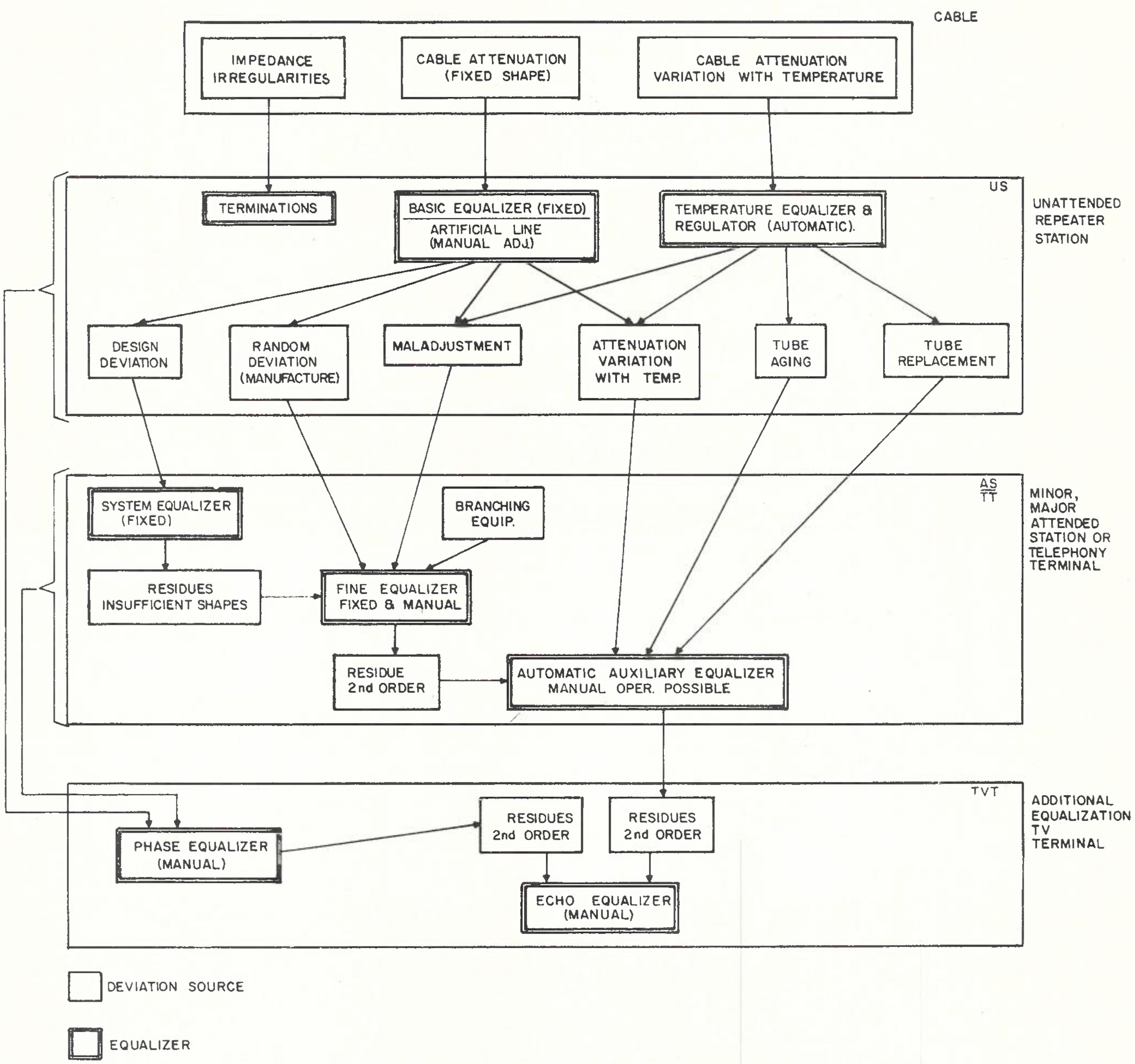


Fig. 1.—Equalization Plan of V960/STR120 Coaxial System.

Canberra and Melbourne, Wagga and Albury are the "Type 200" stations on the route. The automatic equalizers compensate for the long-term variations due to the ambient temperature and tube aging. The function of the automatic equalizer will be described in some detail under the heading Fine Equalization and Regulation.

Additional phase and amplitude equalization for the television transmission (Fig. 5) is incorporated in each terminal. The phase equalizer reduces the line phase error from some 15 to 30 periods to a phase deviation of a few degrees in the 500 kc/s-6000 kc/s band. The group time delay target is 0.1 μsec.

The echo equalizer in each terminal is a manually controlled device. It compensates for any random and second order amplitude or phase deviations so that the television transmission objective can be maintained.

PRE-TESTING OF THE LINE EQUIPMENT

It is a generally accepted requirement that the reliability of the line equipment ought to be a great deal better than that of the terminal equipment.

The following considerations outline the reasons for a further increase of the line reliability by conscientious and exhaustive equipment pre-testing in the field:—

(i) The line equipment is either in the transmission path of the coaxial system or it influences directly its characteristics. Therefore, any fault would jeopardize the performance of the whole transmission band, e.g., **all** telephone, telegraph, programme or television channels.

(ii) Most stations on route are not attended (87%) and automatic facilities for a changeover to a standby bearer are not provided.

(iii) A faulty plug-in unit of the line equipment may be replaced, but in most cases it will take time to rectify and so may cause an interruption of the traffic.

(iv) The manual patching of the whole line or parts of it to a standby bearer (if any available) may cause the loss of the telephone branching facilities in the intermediate stations.

(v) Some line faults may produce misalignment of the bearer without affecting the traffic initially.

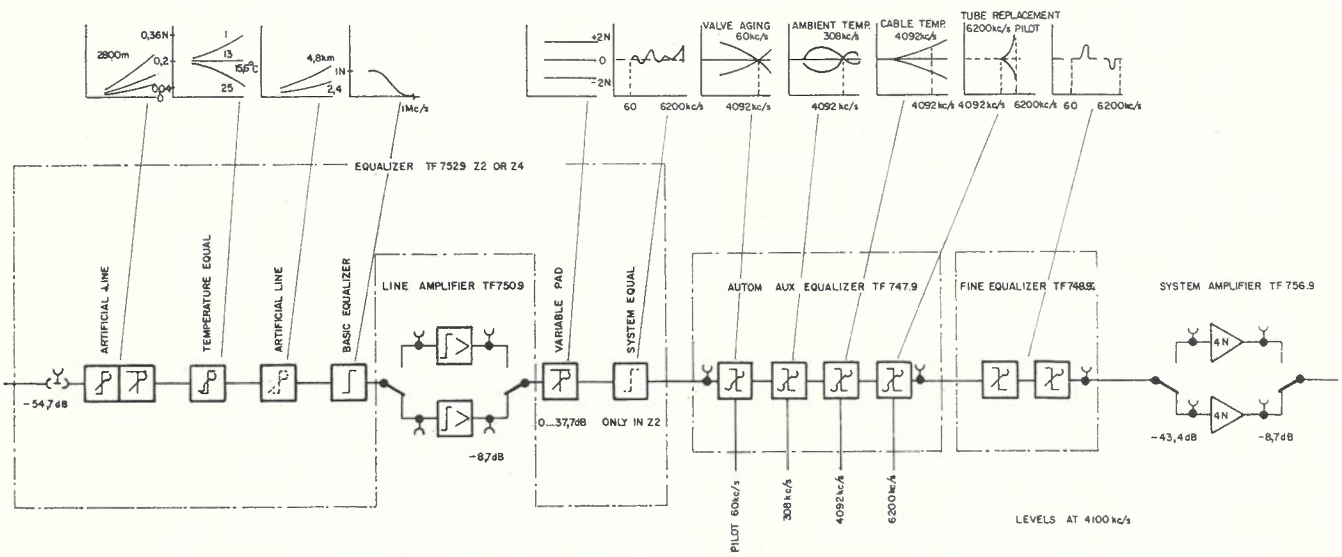


Fig. 2.—Functions of the Equalizers in the Coaxial System.

The location and correction of such faults is difficult and it would require permanent specialized coaxial staff in Sydney, Canberra and Melbourne.

In order to diminish the possibilities of a major breakdown and to avoid a great amount of inconvenience, the line equipment was extensively pre-tested before it was distributed along the line and taken into service. The testing was split into:

(a) Operational tests; and,
(b) Contact fault location.

In most instances the two methods overlapped and some final adjustments were made during the operational tests.

Prior to the unit pre-testing, the line amplifier tubes D3a were checked for conformity with the 2nd harmonic distortion specification of the manufacturer. Some 40% of the first tube deliveries were found to be unsatisfactory and they were subsequently replaced by the suppliers. The tubes used in the pilot receiver and the first two stages of the line amplifier (E28OF) were tested in a tube tester. Approximately 10% of all tubes were found unserviceable. The most common fault appeared to be a grid-to-cathode short circuit. After a preheating period the line amplifier gain and response were tested by connecting the amplifier in series with a standard repeater section simulator. The latter consists of an artificial cable, 9.5 km, with simulation of two power separation filters and the basic equalizer. A frequency sweep of 0.1-7 Mc/s was applied. The line amplifier was passed as satisfactory if the total response was flat within 0.25 db and the shapes did not deviate from the statistical average.

The line and system amplifiers were percussion tested twice with a low (approximately 100 kc/s) and a high frequency signal (3.5 Mc/s). The pilot receivers were pre-heated before the operational tests. The balance of the "high" and "low" pilot operation and the threshold sensitivity were adjusted and the alarm limits were recorded. The percussion tests of the pilot receivers were conducted with their relevant pilot frequencies (up to 4092 kc/s). A special contact fault locator was used for this purpose.

Special attention was devoted to the temperature equalizer, because each unit

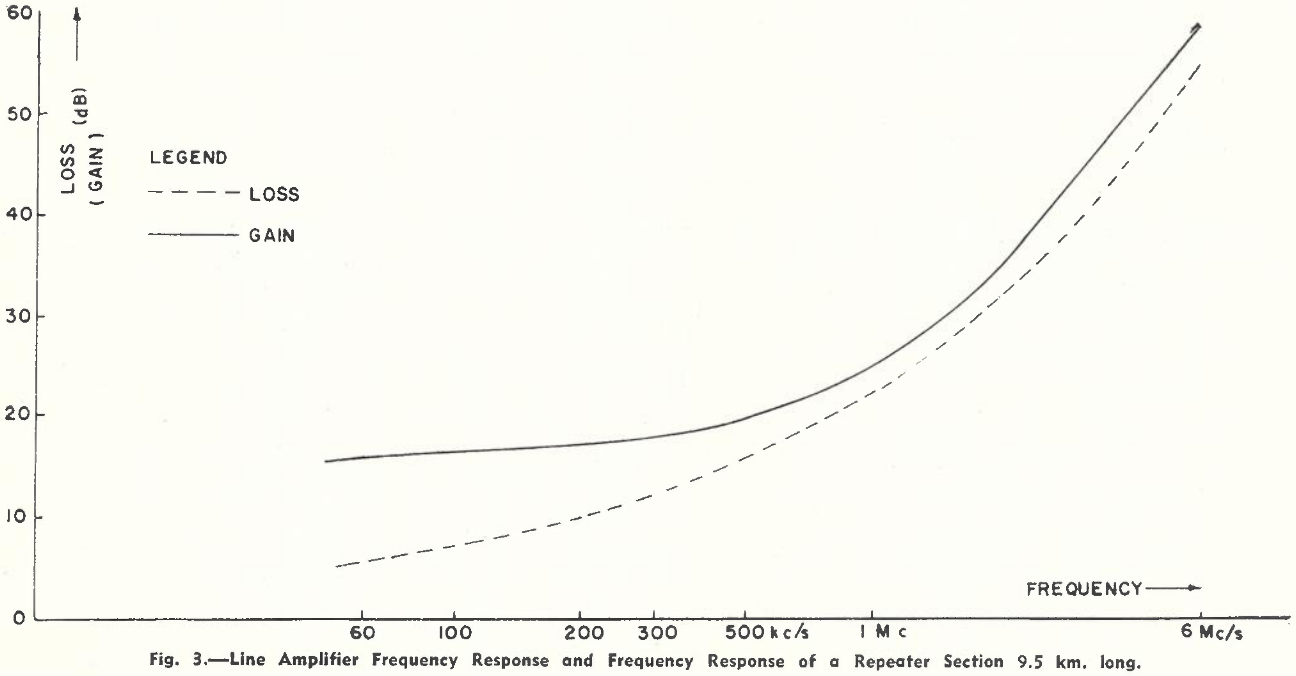


Fig. 3.—Line Amplifier Frequency Response and Frequency Response of a Repeater Section 9.5 km. long.

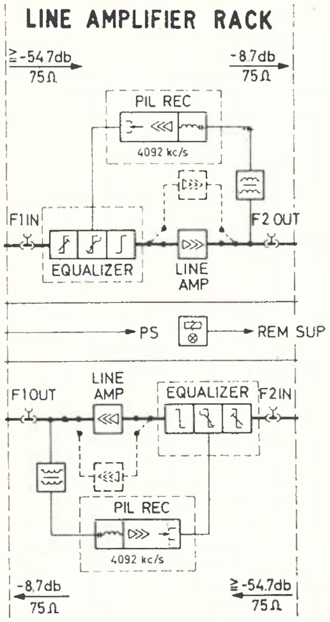


Fig. 4.—Line Amplifier Bay — Unattended Station. Block Schematic.

is individually allocated to a repeater station. The artificial line network of the temperature equalizer was adjusted and soldered to a theoretical line build-up value before the unit was tested. The functional tests were made in one of the line amplifier bays. A double percussion testing was conducted on each position of the equalization network.

The percussion tests were most successful, as could be judged from the very small percentage of faults after the commissioning of the bearer. The percussion testing is a severe test and its main advantage lies in its effectiveness of fault prevention. It is considered that, if the percussion testing were combined with heating and cooling cycles, an aging and stabilization of the characteristics of the transmission equipment would produce a reliability of the highest order. The percussion procedures have shown that despite the very careful and thorough testing in the factory, some percentage of faults cannot be detected and additional testing during installation was of paramount importance.

It is well known that the crystallization of the poorly soldered joints and other chemical processes take some time to become effective. The temperature and mechanical changes during transportation (such as, climatic conditions and vibration in a ship's hold and road transport), tend to accelerate the process of deterioration of the dry joints, the internal fracture in resistors or the oxidation of unsoldered wire ends. Therefore, it was not surprising that the percussion technique was applied with a remarkable success. Further application of the percussion testing on the line equipment in service may produce quite different aspects in the bearer maintenance and reliability.

Prior to the equipping of the line, the following tests were conducted in every station:

(i) Continuity check of the coaxial and the power wiring station.
(ii) Check of the signalling wiring and the alarm functions.
(iii) Check of the order wire facilities.
(iv) High tension insulation test (2000 V) of the coaxial tubes.
(v) Continuity tests of the coaxial tubes.
(vi) Percussion testing of the cable potheads and the inter-bay wiring without the power feeding.
(vii) Check of the "Cable Safe" device.
(viii) Check and adjustment of the power feeding transformers, settings and links.

The "cold" (i.e., without power-feeding) percussion tests served the purpose of detecting dry soldering joints in the transmission path before the high feeding voltage produced a "welding" effect. Here, perhaps, must be emphasized that despite the numerous tests and precautions, all cable faults could not be eliminated and in the first half year of operation some further cable faults were discovered. They consisted mainly of dry soldering joints of the outer coaxial conductor and injected very disturbing noise or caused distortion of the frequency response. This points to the necessity of a yearly routine percussion testing of the bearer. For this purpose one major section could be patched out at a time.

ALIGNMENT OF THE BEARER

The alignment of the bearer comprises mainly the following operations:

(i) Power feeding and testing of the equipment in the stations under normal operational conditions.
(ii) Adjustment of the artificial line build-up network, the temperature equalizers and the pilot receivers.
(iii) Tests of the alarms, signalling and the order wire facilities.
(iv) Percussion tests of the line equipment in operation.

Prior to the power feeding of a major section, the P.F. (power feeding) bay in the relevant attended station was thoroughly tested on a dummy load. The adjustments of the transformer and the switching panels in the P.F. bay of each unattended station were set according to the position of each station from the feeding station and the total length

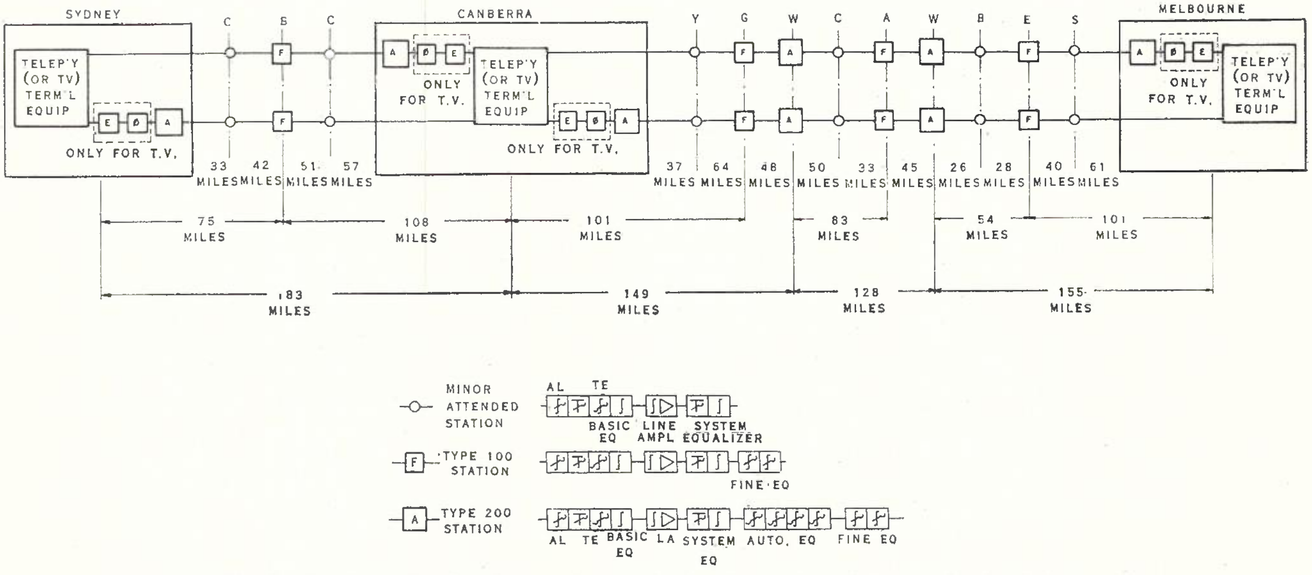


Fig. 5.—Equalizer Allocation for Telephony and Television. Sydney-Melbourne Coaxial System.

of the major section. In general, the feeding voltage should not fall below 700V and boosting transformers are provided for the major sections exceeding seven repeaters. The power consumption of each repeater is approx. 140 VA.

The P.F. adjustments in the unattended repeater consist of setting the transformer taps and the fine adjustment of the secondary voltage to 240 V. Our field experience showed that it is more advantageous to adjust not to a nominal value (i.e., 240 V AC) but to an AC voltage (of the same order), which would enable both line amplifiers to operate as closely as possible to their nominal anode voltage of 180 V DC, thus maintaining uniform operating conditions throughout the system. The power feeding conditions along the route could not be anticipated exactly. Therefore, after the initial power feeding, the installation personnel had to go at least twice to every repeater station and check exactly the loading conditions and re-adjust the fine settings of the feeding transformers. The power feeding alignment had to start with the last fed unattended station so that the consequent adjustments did not effect the settings of the other stations.

Another adjustment was to set the power feeding equipment on the unattended station according to the direction of the power feeding.

The proper equalization alignment covered the building-up of the repeater cable length by means of the artificial cable network, the setting of the temperature equalizer to the correct cable temperature and the calibration of the pilot receivers to the nominal pilot level. For this purpose frequency response tests were taken between an attended station to each unattended station in sequence, starting from the nearest one. The send level was fixed to 8.0 dbm and selected frequencies were used to suit the requirements. A frequency in the proximity of the line pilot (4092 kc/s) was used as reference.

In the unattended station the signal was measured by a passive wide band diode voltmeter and the artificial line was adjusted by soldering wire links in order to obtain a frequency response slope deviation of less than ± 0.3 db. The frequency response of the artificial cable network in terms of cable lengths is shown in Fig. 6.

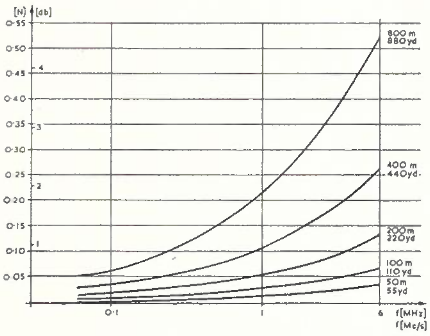


Fig. 6.—Frequency Response of the Artificial Line.

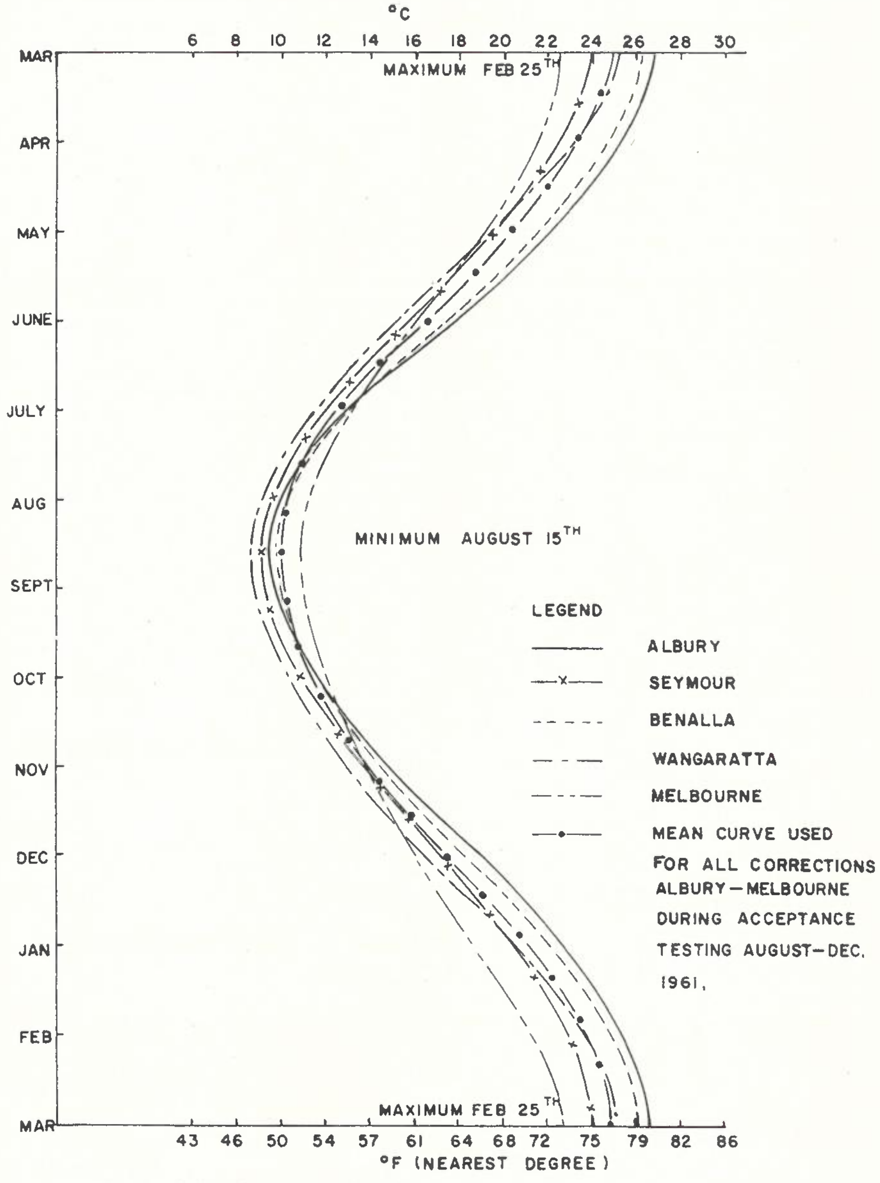


Fig. 7.—Sydney-Melbourne Coaxial Cable—Predicted Cable Temperatures.

The setting of the temperature equalizer unit was fixed by the cable temperature during the tests. Many methods were devised for the measurement of the cable temperature, but the most practical one was to drill a hole approximately 1½ inches in diameter to four feet depth and to sink a thermometer for a direct measurement. In no major section more than three drillings were necessary. The direct measurements came within ± 2°C. of the temperature calculated from the cable resistance measurements and the computed figures by the Postmaster-General's Department as shown in Fig. 7.

The position of the temperature equalizer was computed in the following fashion. For each major section of the coaxial line an annual average cable temperature was calculated from the available minimum and maximum figures and Pos. 13 of the temperature equalizer was nominated to correspond to this temperature. Any measured deviation from the average annual temperature could then be translated directly in terms of position number of the manual control of the temperature equalizer.

The frequency response of the temperature equalizer is shown in Fig. 8. During the alignment the reference level was set exactly to + 8.0 dbm. Then the line pilot was transmitted from the attended station at —18.7 dbm. The pilot level was indicated by the pilot receiver, which was then re-adjusted to read zero.

This calibration procedure takes care of all tolerances in the pilot decoupling path and it is sufficiently accurate, provided the signal-to-pilot-ratio in the sending station is maintained in very close tolerances. The equalization run usually was repeated several times for

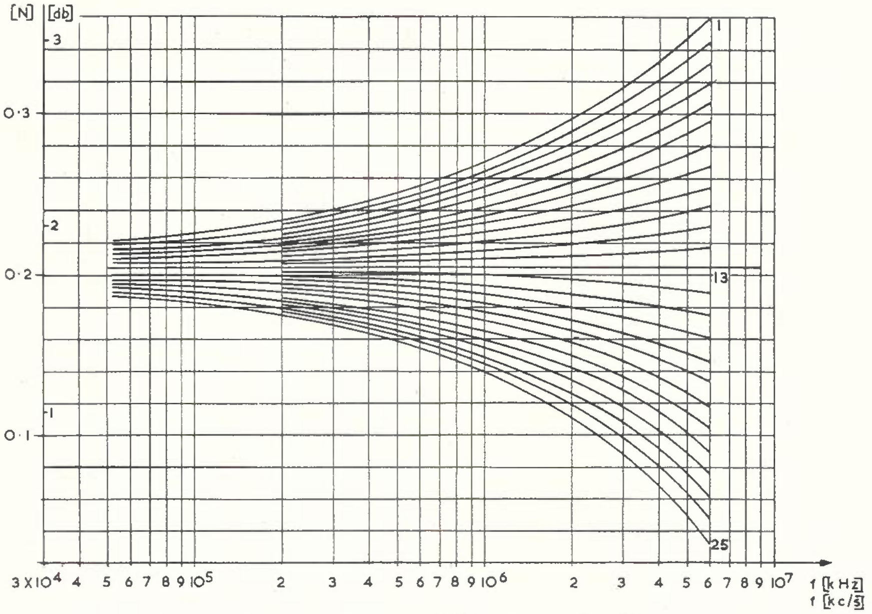


Fig. 8.—Frequency Response of the Temperature Equalizer.

each transmitting direction until the most satisfactory results were obtained.

Further tests in the repeater included the changeover facilities for the line amplifier, tests of the alarms and their remote signalling, as well as the functions of the short haul order wire. These tests are outside the scope of this paper. During the alignment, the motors of the temperature equalizers were switched off; thus no regulation could occur until the whole section was completed.

After the temperature equalization in the unattended repeaters was completed, each major section was tested from terminal to terminal. The frequency response deviations of the line were compensated further by the system equalizer. The latter is mounted as a sub-assembly in the temperature equalizer shelf. There are two types of system equalizers, for seven and ten sections, and they were applied according to the length of the major section between two attended repeaters. The frequency response of the system equalizer is shown in Fig. 9.

Every major section was tested in addition for crosstalk and intermodulation noise. The crosstalk attenuation between the transmitting and receiving directions had to be less than —95 dbm per station. The crosstalk was measured selectively by terminating the far end of the line. The coaxial system met this requirement for telephony with a safe margin.

All frequency responses during the installation were measured "flat" (that is, without weighting). The final terminal-to-terminal tests, however, were conducted at the pilot decoupling points because the whole telephone band is transmitted with pre-emphasis as shown in Fig. 10. The transmission band is de-emphasized later in the receiving terminal. The television pre-emphasis and de-emphasis curves are shown in Fig. 11. .

The shaping of the transmission band improves considerably the signal-to-noise-ratio as well as the attenuation of the unwanted intermodulation products. The noise measurements were conducted by loading the line with a uniform spectrum of white noise over the whole telephony band except the three slots (narrow band-stop filters). The intermodulation products and the basic noise were then measured in the slots which have approximately the bandwidth of a speech channel. The total noise of the line was considerably less than the recommended C.C.I.T.T. figure of 3 pW per kilometer. The crosstalk and the intermodulation noise measurements were regarded as "final" tests because they provided some of the most important criteria of the transmission system.

After the transmission tests, each major section was percussion-tested in a loop which amounted to an over-all testing of all units in the transmission path. Then the motors of the temperature equalizers were released and the section was regarded as fully operational.

FINE EQUALIZATION AND REGULATION

Fine Equalization

In general the fine equalization of the coaxial bearer has the objective to reduce further the amplitude response deviation to approximately ± 1.0 db. In particular, the fine equalizer compensates for residual discrepancies, random errors, manufacturing tolerances, design variations, maladjustments as well as some left-over systematic deviations.

For the television transmission, the requirements for closer tolerances call for further equalization and a versatile mop-up equalizer is provided. A phase equalizer takes care that the phase deviations are compensated to within 100 nanoseconds.

The fine equalizer must be a flexible and adaptable unit. It should provide many possibilities for the injection of different equalization shapes. Therefore, this equalizer of the coaxial system is manually set and assembled. Each shape is calculated and tested on the spot to meet a particular requirement. The manufacturers supplied for this purpose a complete assortment of all possible coils, condensers and resistors so that the equalization networks could be assembled with highly reliable components.

The compensatory range of the fine equalizer is approximately 3 db. These

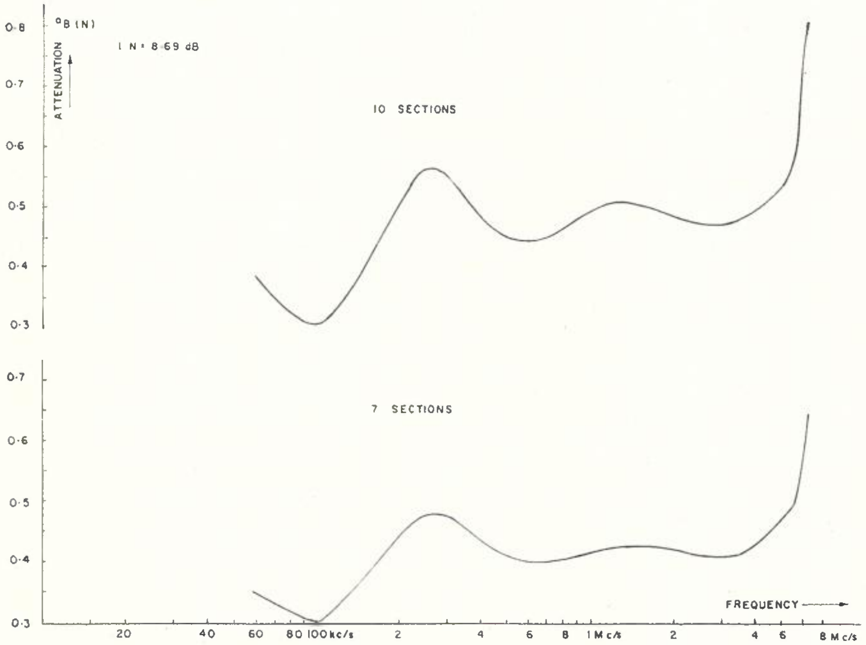


Fig. 9.—Frequency Response of the System Equalizers.

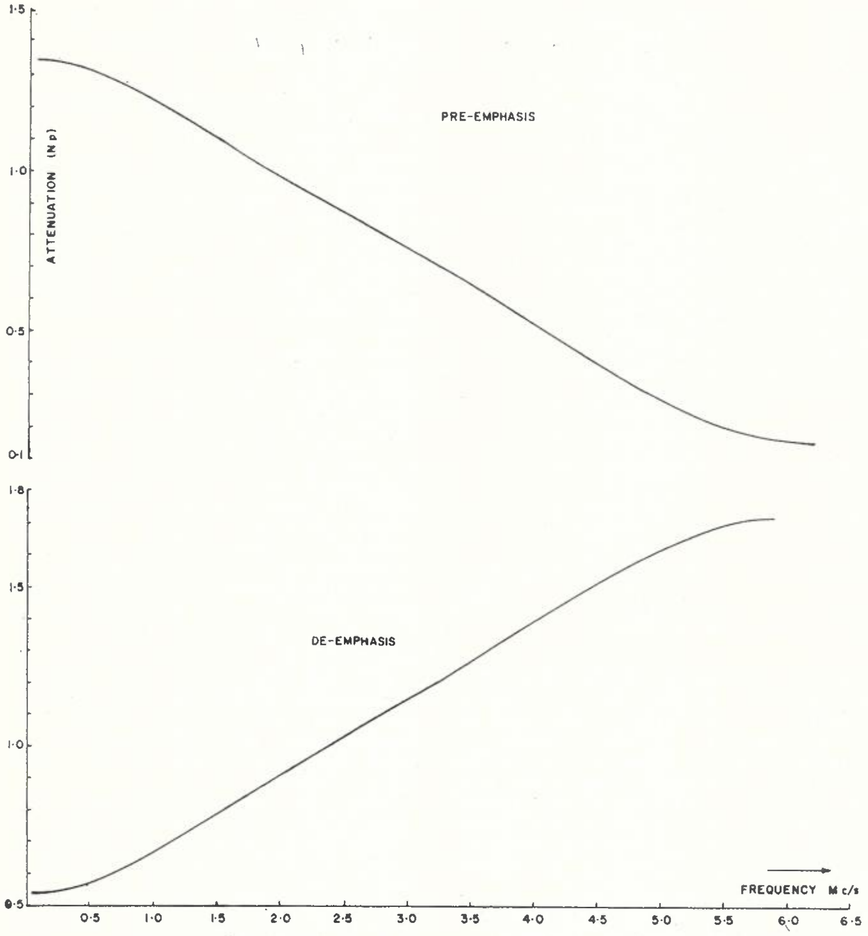


Fig. 10.—Pre- and De-emphasis for Telephony.

are installed at so-called "Type 200" stations, approximately 100 miles apart. The fine equalizer consists of two major sub-assemblies: the basic fine equalizer with insertion loss and a set of four transistorized plug-in boxes with an insertion loss equivalent to a bridged —T-network of optimum design.

The basic equalizer contains three compartments in series. Altogether there are provisions for the assembly of eight (8) two-pole equalization networks. For better matching, pads of 1 Neper (8.7 db) are inserted between the equalization compartments. If a section is not in use, it should be short-circuited.

The two-pole networks produce attenuation maxima or minima shapes which could be inserted anywhere in the band. If two networks are used in one compartment, their resonant frequencies must be far apart or interference may occur. An equalization circuit may be realized in the series or shunt paths, but some limitations due to the sizes and the values of the components would determine what network should be used. The charts supplied by the manufacturers plot the equalization shapes as functions of the fractional detuning Δf with the $\frac{L}{C}$ ratio as paramater.

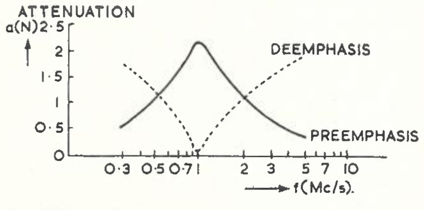


Fig. 11.—Television Pre-emphasis and De-emphasis.

The transistorized fine equalization boxes are used when the insertion loss of the basic fine equalizer is excessive. The insertion loss of each plug-in unit is that of a four-pole equalizer of optimum design. Only a series two-pole network could be used in the transistorized circuit and the amplitude may be selected in four steps by a switch mounted on the front panel. The transistor amplifier maintains a constant input impedance equal to the line impedance (75 ohms). This is due to the characteristics of the amplifier which has a high input impedance, zero output impedance and a gain of unity. The circuit is shown in Fig. 12 and it could be easily shown that the input impedance is independent of the equalization network impedance Zeq. and equal to 75 ohms.

The attenuation of the transistorized circuit equals that of the bridged T-network, that is:

$$\propto = \ln \left| 1 + \frac{Zeq}{2} \right|$$

The transistorised plug-in units can be removed from the fine equalizer shelf in traffic as long as their switches are set to zero.

Regulation

The common and mostly used regulator in the coaxial system is the temperature equalizer (TE). The temperature equalizer characteristics are adjustable according to the level variation of the line pilot, 4092 kc/s. The pilot levels are sensed by the pilot receiver at the output of each repeater station. Any deviation beyond the preset limits (± 0.5 db) would apply "Earth" to the motor drive of the temperature equalizer. The equalization network is a Bode-type equalizer where the terminating resistors are switched over in steps until the pilot level is increased (or decreased) to the permissible limits (approximately ± 0.3 db). Then the motor is switched off.

The range of the temperature regulation is ± 12°C. and the level variation is in the order of ± 1.4 db at the highest frequency of the transmission band, 6.2 Mc/s. The detail regulation curves for each switch position are shown in Fig. 8.

During the alignment of the bearer the motor drive could be cut off and the required equalization shape set by the manual control.

In the "200-type" and the terminal stations the automatic auxiliary equalizer introduces further equalization and regulation (Fig. 13). This unit accommodates four variable equalization networks. The equalization shapes are controlled by the line pilots and the variations are introduced by a thermistor in the series equalization network of a modified Bode-type equalizer.

The control currents for the thermistor are supplied by the electronic pilot receivers which check the levels of the 60 kc/s, 308 kc/s, 4092 kc/s and 6.2 Mc/s line pilots. The limits for the pilot regulation are identical to those used for the 4092 kc/s pilot. The thermistor regulation, however, is a great deal faster than the motor drive.

The automatic regulation of the automatic auxiliary equalizer could be switched off and the individual equalization shapes may be set by hand. Another important feature is that a failure of any one of the line pilots would cause automatically a changeover to the manual operation. Therefore, it is essential to check at regular intervals whether the manual settings of the automatic equalizer are matching the

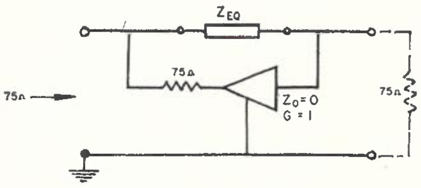
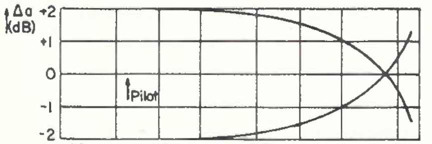
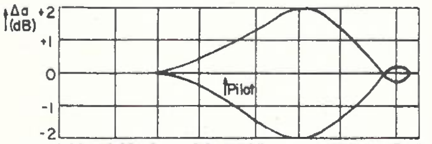


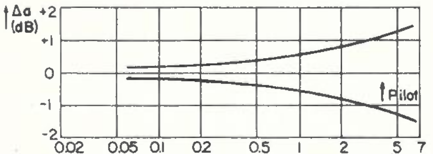
Fig. 12.—Transistorized Fine Equalizer.



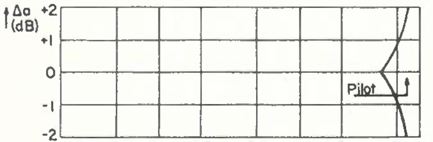
VALVE AGING EQUALIZER.



AMBIENT TEMP. EQUALIZER



CABLE TEMP. EQUALIZER



VALVE REPLACEMENT EQUALIZER

Fig. 13.—Regulation Characteristics of the Automatic Equalizers.

automatically regulated response of the bearer. Fig. 13 shows the shape and range of regulation of each section of the automatic auxiliary equalizer.

It can be seen that the 60 kc/s pilot regulation introduces a slope which compensates for the valve aging in the system. The slopes may vary by ± 2 db and they would effect the levels of the pilots 308 kc/s and 6.2 Mc/s. The cable temperature pilot 4092 kc/s is not influenced by the valve aging equalization. In order to avoid interference, none of the last three pilot controlled slopes may effect the 60 kc/s pilot level.

The 308 kc/s pilot controls the ambient temperature slope, i.e., the amplitude distortion introduced by the ambient temperature in various repeater stations on the route (600 miles). The ambient temperature equalizers avoid any interference with the other pilots.

The regulation introduced by the 4092 kc/s pilot is identical to that produced by the motor driven equalizer. The cable temperature slopes vary in a comparatively short time (approximately a week) and they control the short-term performance of the bearer.

The valve replacement amplitude errors are compensated by the deviations introduced in the high frequency end of the transmission band and they are supervised by the 6.2 Mc/s pilot. The valve replacement shapes are long-term deviations and they have no influence on the other pilot levels.

LINE EQUALIZATION FOR TELEVISION TRANSMISSION

Television transmission sets much stricter equalization objectives than the telephony traffic. In addition, the phase deviations of the bearer must be equalized to within a few degrees, especially around the carrier and the upper part of the vestigial side band. In terms of group time delay, it would mean that this should not vary more than 100 nanoseconds throughout the whole transmission band.

An amplitude response of ± 0.5 db is regarded as satisfactory although closer tolerance is desirable. The main problem consists of maintaining the above tolerance. Because the stability of the bearer cannot be improved beyond a certain point, further flexible equalization means are required to assure the high quality requirements of the television transmission. This is achieved by an additional mop-up equalizer.

Phase Equalizer

The phase distortion, in terms of group time delay, of the bearer Canberra-Melbourne, is shown in Fig. 14. The maximum deviation exceeds 5 μsec. and it should be noted that the slope (the gradient) of the curve is very steep in the lower frequency range. This necessitates the use of many sharp phase equalizing networks (bell shapes) placed at discrete intervals along the imaginary and real frequency axes. The stability of their frequency allocation and delay amplitudes must be of the highest possible order. The losses of the networks must be kept to a minimum, and have to be equalized.

Special mathematical investigations into the theory of the approximations made it possible to apply modern computation techniques to the design of the phase equalizer and the total ripple was reduced to below 2% of the maximum deviation.

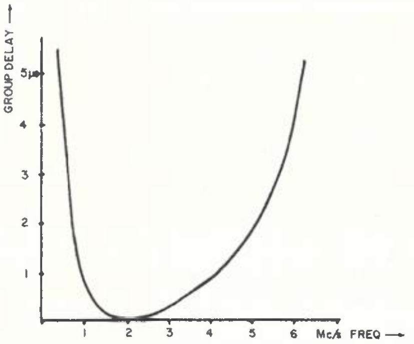


Fig. 14.—Group Time Delay of the Coaxial Bearer, Canberra-Melbourne.

The phase equalizer consists of 30 all-pass equalizing sections of the types shown in Fig. 15. Five sections are provided for the amplitude equalization and nine pads isolate the groups of the delay sections in order to reduce the mutual interference. All sections are in tandem.

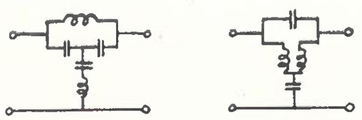


Fig. 15.—Phase Equalizing Networks.

The phase equalizer is a fixed preset unit and there are no provisions for further adjustments in service. Any mop-up equalization can be made by the echo equalizer. The insertion loss of the phase equalizer is 20 db.

6.2 Echo Equalizer

The final mop-up equalizer with a large scope of application and adaptability is the echo equalizer. It consists of two delay lines as shown in Fig. 16. Both delay lines provide facilities for tapping the advanced or retarded echoes by means of balanced potentiometers. The echoes are generated by the main signal which passes firstly through the advanced echoes delay line and then is amplified by a flat amplifier. For the delayed echoes, a part of the signal is fed through T_R delay line which is terminated by its characteristic impedance (75 ohms).

The equalizing echoes are selected and their polarity and amplitude is adjusted as required. Then they are combined, amplified and injected into the main transmission path in order to cancel the distortion shapes.

For the easy understanding of the operation of the echo equalizer one should consider the time function of the main signal. Any transmission function could be described by either its frequency or time response which are equivalent in every respect. Because in the television technique we consider the transmission of wave forms, the representation of the transmission function in the time domain is customary.

The phase and the amplitude distortion of a time function may be presented as echo pairs of even and odd symmetry around the main signal, as was first pointed out by H. A. Wheeler in his theory of paired echoes (3). The theory is based on the Fourier integral and it is accurate within a distortion of 8.7 db and one radian (57 deg.).

The echo equalizer can compensate for the distortion of the non-minimum as well as the minimum phase networks. The echoes which are spaced at discrete time intervals, $T = \frac{1}{2f_c}$, (where f_c is the cut-off frequency of the transmission band) may be selected and varied in amplitude and polarity. The range of the advanced echoes is approximately 1 μsec. (12 × 0.082 μsec.). The retarded echoes cover a 2.2 μsec. range (27 echoes, 82 nanosec. each).

The distant retarded echoes (more than 1.5 μsec.) could be most unpleasant on the TV viewer. Therefore, special measures are taken in the echo equalizer to avoid second order effects by introducing a feedback loop for the injection of the retarded echoes.

The main scope of the echo equalizer is to compensate for the distortion of the minimum phase networks with retarded echoes (i.e., amplitude correction), although it is able to

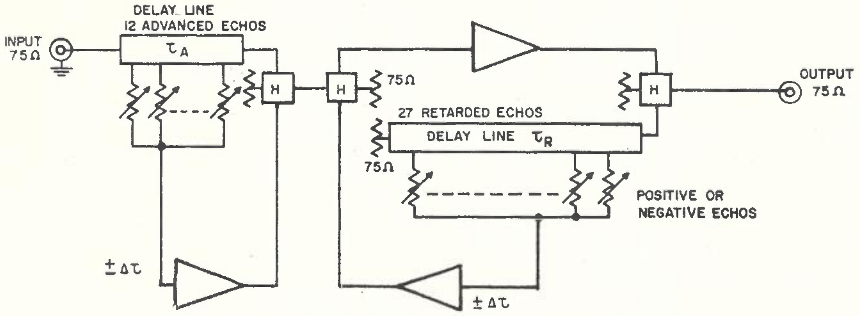


Fig. 16.—Echo Equalizer, Block Schematic.

provide phase equalization as well. However, the phase equalization adjustments are not intended as a routine procedure.

Practical field experience has shown that skilled field personnel can reduce amplitude deviations of ± 3 db to within ± 0.5 db throughout the band without any difficulties in a comparatively short period (30 min.). The adjustments are made by observing the sweep frequency response in the band 0.1-7 Mc/s.

CONCLUSION

Some technical and design aspects of the equalization of a wide band coaxial bearer have been described briefly. The design concept considers automatic compensation and regulation of the short-term, that is, cable temperature variations, in each unattended station. The systematic errors are equalized in every attended station and a "tailor-made" fine equalizer caters for the random amplitude deviations. A fast-acting automatic regulator, controlled by the line pilots, is provided to compensate for the shapes introduced by the ambient temperature variations, valve aging and tube replacement.

ACKNOWLEDGEMENTS

The author wishes to thank the manufacturers, Messrs. Felten and Guilleaume Fernmeldeanlagen G.m.b.H. and N. V. Philips' Telecommunicatie Industrie for the information contained in this article. The permission of the Management of Telecommunication Company of Australia to publish this paper is gratefully acknowledged.

REFERENCES

1. J. R. Walklate, "Design of Transmission Equipment"; The Telecommunication Journal of Aust., Vol. 13, No. 3, page 235.
2. P. Krastev, "Sydney-Melbourne Coaxial Television Transmission—Part I"; The Telecommunication Journal of Aust., Vol. 14, No. 1, page 29.
3. H. A. Wheeler, "The Interpretation of Amplitude and Phase Distortion in Terms of Paired Echoes"; Proc. I.R.E., June, 1939.

PROPOSED CHANGES IN JOURNAL NUMBERING

Most international technical journals conform with the numbering practice suggested in British Standard 2509, 1959, whereby one complete volume is published in each calendar year. This procedure has some administrative advantages over the present system and in view of the increasing overseas subscription list, the Council of Control of the Society has decided that commencing with the February issue in 1965, the Journal will comprise three issues per volume. The February, 1965, issue will be Vol. 15, No. 1, and to provide for the change from the existing numbering system, Vol. 14 will end with No. 5 in October, 1964.

To offset increased costs of overseas postage (the weight of the Journal has increased threefold over the past five years) overseas subscriptions will be increased by 3 shillings per year to 13 shillings, Australian currency, post free, as from Volume 15, No. 1. Annual subscription rates for addresses in Australia or in Australian Territories will remain unchanged at 10 shillings, post free. Subscribers who have paid advance subscriptions will be credited in full; for example, a subscriber who has already paid for Vol. 14, Nos. 4-6 (old style) will receive a credit of 3/4d. (one-third of 10/-) in respect of Vol. 14, No. 6, which will become Vol. 15, No. 1. To ensure receipt of Vol. 15 Nos. 1-3, he need pay only 6/8d.

This issue contains a subscription renewal form. Subscribers may renew at this time either for Vol. 14, Nos. 4 and 5 only at 4/- each (single copy rate), or for Vol. 14, Nos. 4 and 5, and Vol. 15, Nos. 1 to 3 at 16/8d. (Australia) or £1 Australian currency (overseas). Vol. 14, No. 5 will contain another subscription renewal slip for Vol. 15, No. 1-3, for those who wish to defer ordering these numbers.

Henceforth, membership renewals (which apply only to residents of Australia) will be attended to exclusively by State Committees of the Society; membership fees will not be accounted for on Journal subscription forms.

AIR LINE TELEPHONE FACILITIES FOR T.A.A., SYDNEY

A. B. WILSON, and T. J. KILDEA***

INTRODUCTION

The normally highly competitive nature of Air Lines' business is increased in Australia due to the fact that all air-traffic between capital cities is shared between two companies. As these organisations provide a very similar standard of service from the point of view of speed, comfort and economy, the inducement to travel on a particular line may, apart from personal choice, very well depend on the general efficiency and speed with which booking of seats and general information to the customer can be provided. As the great majority of bookings and enquiries are made by telephone, the Air Lines telephone system becomes a very important factor in any plans either Company may have to increase its percentage of the air traffic offering. Therefore, when T.A.A. decided to erect a new Reservations Room and Booking Hall in Sydney, the telephone facilities constituted a major item in the programme.

FACILITIES

The following facilities were required at the date of cutover:

1. A new 300 line P.A.B.X.
2. A minimum of 82 telephone units mounted on laminated plastic topped Reservations Tables.
3. Each unit to be equipped with finding and gating facilities.
4. The whole group to be formed into a number of minor groups—each minor group to be accessible from:
   (a) A P.A.B.X. level.
   (b) A jack strip on the P.A.B.X. manual cabinets.
5. Each desk unit to have:
   (a) Answer/hold/release on the level line.
   (b) Answer/hold/release/dial on individual P.A.B.X. extensions.
   (c) Call and speak to the monitor.
   (d) Busy P.A.B.X. extensions.
   (e) Order wire to manual cabinets.
   (f) Recall manual operator on a level call for purposes of call transfer.
6. A monitor's cabinet with facilities to:
   (a) Observe and/or speak or signal any desk unit in the system.
   (b) Indicate the number of desk units staffed.
   (c) Observe the number of calls awaiting to be answered on any minor group.
   (d) Count the number of calls answered or calls abandoned before being answered on any minor group.
   (e) Re-route traffic between Phone Sales, Agents, Interline and Manifest groups.

GENERAL

The old T.A.A. Building had a frontage to Phillip Street with a vacant allotment at the rear which had a frontage to Elizabeth Street.

The new building is in fact an annex erected on the vacant allotment and keyed into the Phillip Street building; this annex consists of a basement, ground and two upper floors, the ground floor being the new Booking Hall (Fig. 1) with the P.A.B.X. and Reservations Rooms on the 1st floor and general offices on the 2nd floor. The new scheme now permits air line buses to drive in from Phillip Street, collect passengers and luggage within the shelter of the building and thence proceed via Elizabeth Street.

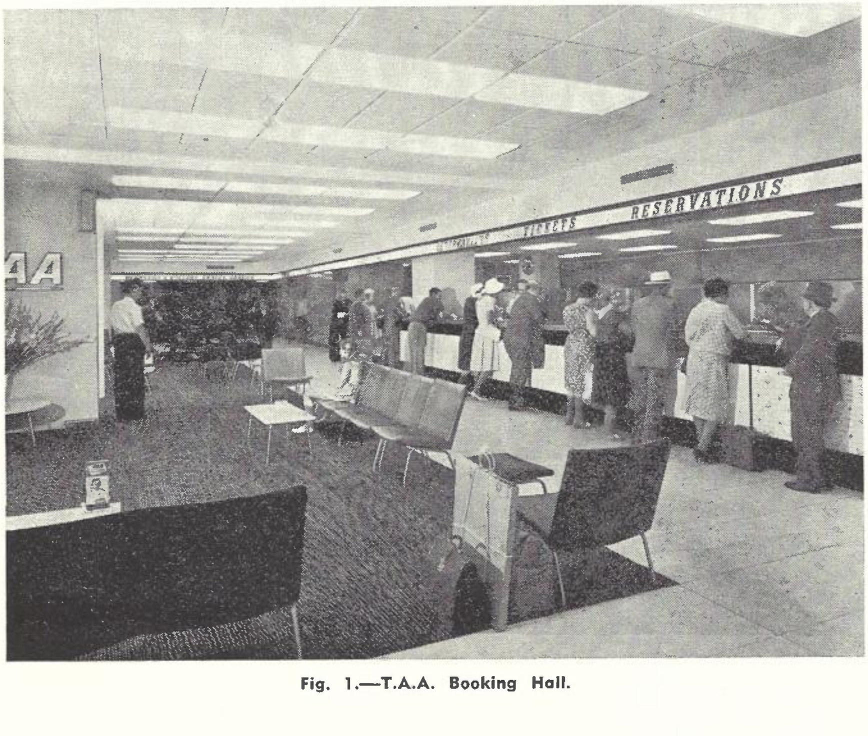


Fig. 1.—T.A.A. Booking Hall.

To make sufficient time available for telephone equipment installation, the building programme was carried out in steps as follows:—

December, 1961: Foundation excavation and the erection of structural steel together with the pouring of the 1st and 2nd floor slabs.

January, 1962: Erection of the P.A.B.X. room walls on the 1st floor slab; the 2nd floor slab becoming, of course, the roof and ceiling of the P.A.B.X. room. To ensure complete curing of the floor and ceiling cement rendering in the shortest possible time, "High Early Strength" cement was used which gave a cure period of 48 hours against two weeks for normal cement.

February, 1962: First floor area encompassing the Reservations Room to be available for telephone installation from the end of February to cutover date, July 2, 1962.

Due to a period of inclement weather and other building difficulties, the cutover was postponed for three weeks but nevertheless the whole programme was carried out in accordance to plan.

RESERVATIONS ROOM

The Reservations Room has dimensions of 40 x 80 feet, the whole east wall being occupied by a Flight Board which displays up-to-date information on aircraft movement, seating vacancies, etc. Fig. 2 shows a plan of the room wherein it can be seen that the two largest minor groups, i.e., Phone Sales and Agents are accommodated on long tables, the remaining groups on circular type tables, the centre of these circular tables being devoted to rotatable card index systems. The Phone Sales Table is situated directly in front of the Flight Board, and Agents and the remaining minor groups are placed on a 3 feet high false floor, thus ensuring that all Personnel can observe the Flight Board.

A cupboard at each end of the Phones Sales Table and one at the right-hand end of the Agents' table contain the I.D.F.'s for cabling purposes. All tables have been covered in a dove grey laminated plastic. The circular tables have tapered steel legs finished in black semi-flat enamel and fitted with brass ferrules of ¾ inch diameter.

THE DESK UNIT

The desk unit which has dimensions of 9 inch width, 5 inch height and 7 inch depth, is fabricated from sheet steel and finished in grey hammertone. It is equipped with five standard switchboard keys together with lamps and dial as shown in Fig. 3. The front panel is of greater dimensions than the body, thus allowing the unit to be dropped into an

---

* Mr. Wilson is Engineer Class 2, P.A.B.X. Installation, Sydney. See Vol. 12, No. 6, page 465.

** Mr. Kildea is Supervising Technician, P.A.B.X. Installation, Sydney.

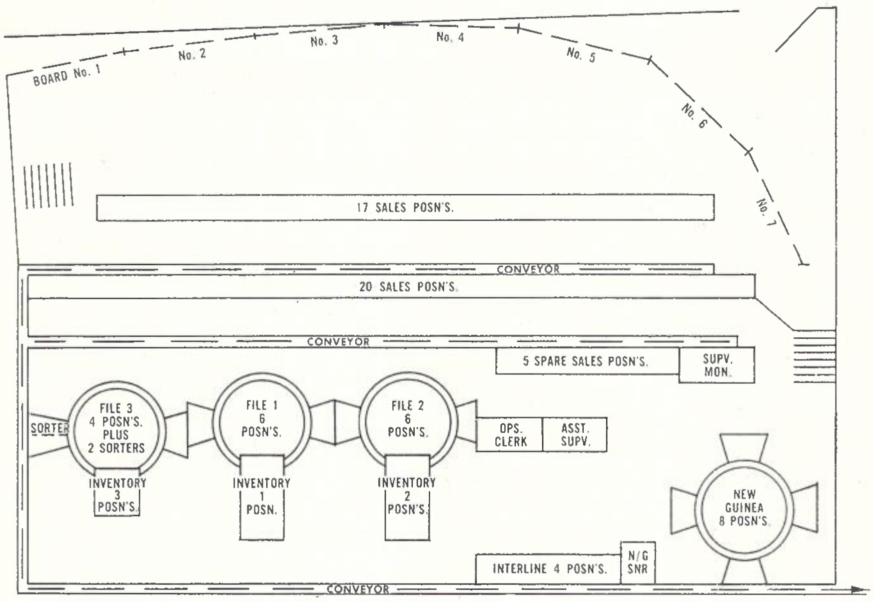


Fig. 2.—Reservations Control Room.

opening and secured to the table surface by means of four chromed wood screws. Apart from the fittings attached to the front panel, the body of the unit also contains four 3000 type relays, operator's cct., night alarm buzzer, etc., and was rendered dust proof by being totally enclosed by a metal cover.

It was anticipated from the beginning that work within the Reservations Room would be rather difficult because of:—

(a) The short interval between date of availability and cutover date (six weeks).

(b) A sprayed acoustic ceiling making for very dirty and dusty conditions and so preventing the installation of any equipment until all building work had ceased within this area (building work was completed two weeks before cutover).

(c) The large amount of work involved, i.e., the installation and testing of some 80 desk units and 70 telephones together with a monitor's cabinet.

It was, therefore, decided to terminate the desk units in sockets, cable the room during building activity and terminate the cables in the corresponding plugs. This can also be noted in Fig. 3, a Painton 32 point plug and socket being used for this purpose.

Consequently, it was possible to install all desk units in one day and thus leave the remainder of the two weeks for general testing and fault location. The plug socket termination also permits the rapid replacement of a faulty unit (two spare units being held in the P.A.B.X. room). A plug and socket terminated cord has also been provided thus enabling a unit to be inspected whilst still in circuit—this can be seen in Fig. 3. The desk units fitted to the circular tables are shown in Fig. 4.

MONITOR'S UNIT

The monitor's unit is situated at the left-hand end of the Agents' table, (Fig. 5). It is of similar construction and finish as the desk units and has dimensions 30 inch width, 10 inch height, 12 inch depth, the front panel being sloped at an angle of 45° to allow the monitor an unrestricted view of the Flight Board. The panel on the left of the unit can accommodate a maximum of 100 lamps behind translucent strips, each lamp indicating a staffed position. The display in Fig. 5 shows that six positions are staffed on the Phones Sales Table.

The monitor has key digit access to all desk units, the digit keys can be seen in Fig. 5 and are designated from 1 to 0. The keys arranged in groups of three in the centre are the traffic re-routing keys; the display in Fig. 5 indicates that a proportion of Agents' traffic has been re-routed to Phone Sales positions.

The moving coil meters at the right indicate the number of calls that are awaiting answer and have been calibrated from 1 to 10; the display indicates that two calls are awaiting answer at File 1 positions. For purposes of recording the total number of

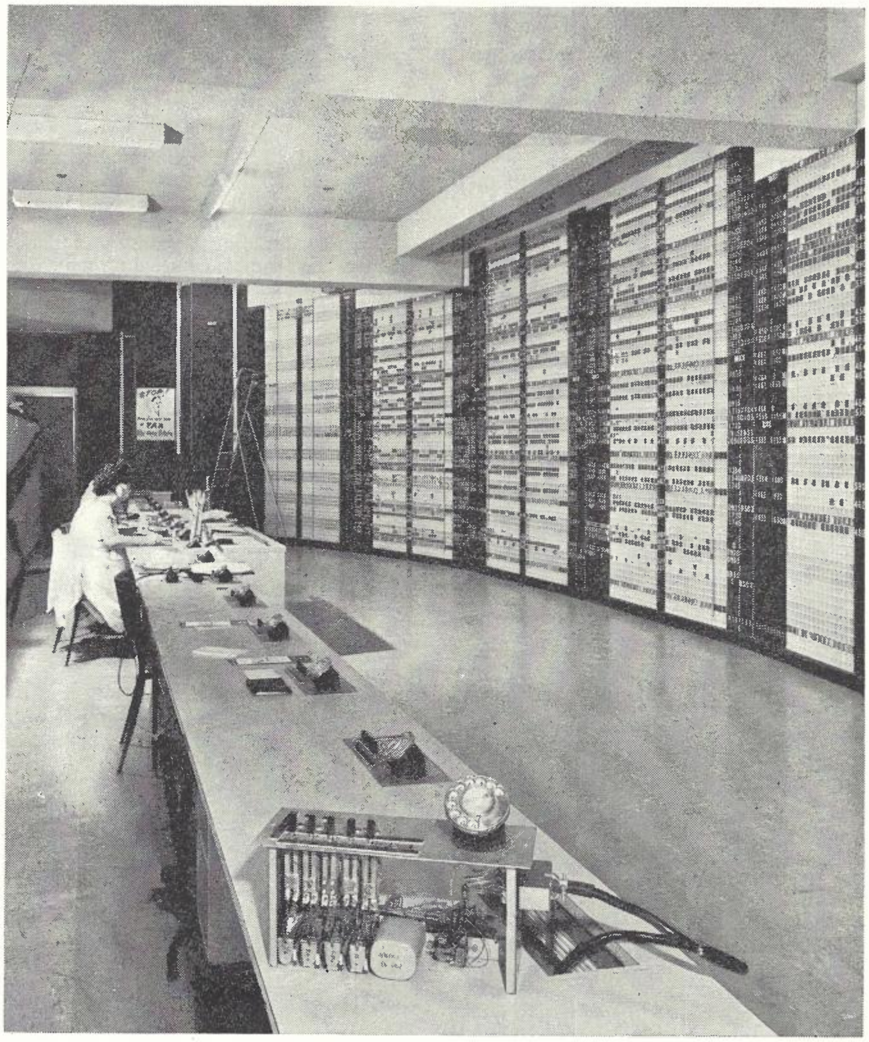


Fig. 3.—Desk Units in Reservations Control Room.

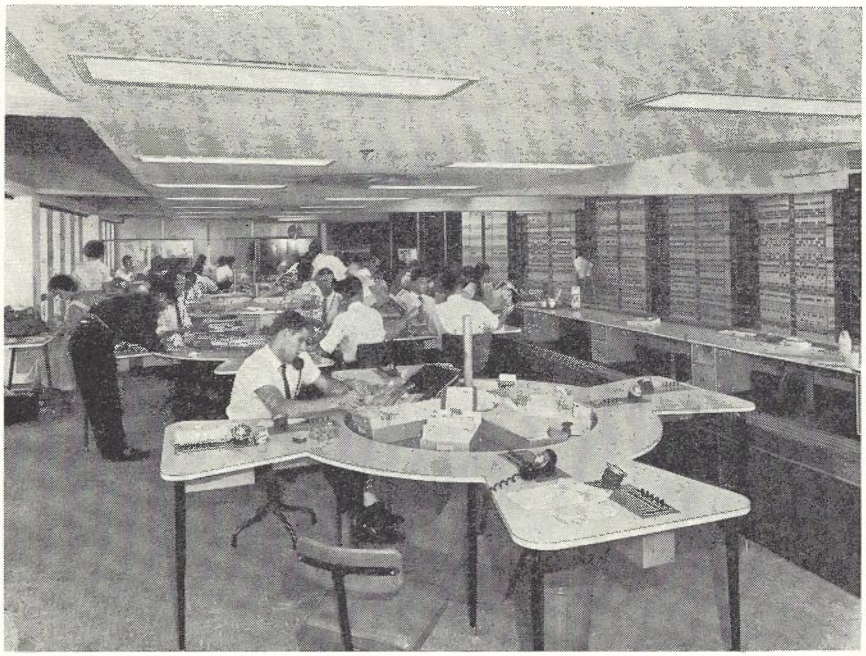


Fig. 4.—Desk Units on Circular Tables.

calls answered and calls that were abandoned before answer, 100A type telephone meters were used. These meters are mounted in a metal cabinet and installed to the immediate left of the monitor's unit.

CABLING

The heavy bulk of cabling between the P.A.B.X. equipment and the Reservations Room positions was centralised on a 7-Bay T.C.F., 10 feet 6 inches high, utilising 20 x 8 point terminating strips, the T.C.F. being installed in the P.A.B.X. Room. PVC cables of varying size extended from the T.C.F. via normal P.A.B.X. equipment cable ducts to a position underneath the false floor in the Reservations Room and thence to the I.D.F.'s recessed at each end of the Phone Sales Tables, the cabling to the individual units being run in small wooden ducts underneath the tables.

Cabling to the circular tables was made difficult because of the necessity to cable through the slender tubular table legs. This was overcome, however, by removing these legs from the tables that were to carry cables, drilling out the leg ferrules, reaming out the side of the leg at table height and then positioning the legs over holes that had been drilled in the false floor and fitted with short length of $\frac{5}{8}''$ conduit. The success of this procedure depended on close collaboration with the table manufacturers and has subsequently proved to be completely successful.

CIRCUIT DETAILS

Gating: A three-stage gating system was employed, one gating relay set per group, a total of nine relay sets being required.

Finders: The desk unit finders consist of 50 Pt. B.P.O. type uniselectors and an associated relay set, i.e., one uniselector and one relay set per position—87 positions being equipped.

Traffic re-routing: Because the largest sub-group in the system has a maximum of 21 incoming lines (some of the smaller sub-groups only having 8 lines), it became possible to utilise the spare contacts on the 50 Pt. uniselector finders for the traffic re-routing facility. The spare negative and positive bank contacts of the finders were connected in multiple throughout the system; the corresponding private contacts, however, were open-circuited and back busied via the contacts of traffic re-routing relays. The traffic re-routing procedure being as follows—assuming that it is required to re-route Agents' Traffic through to Phone Sales, Incoming traffic for Agents also appears at Phone Sales finders but the corresponding private contacts being back busied will present a busy condition. To re-route this traffic, the monitor operates the appropriate re-route relay by depressing the key designated "Phone Sales" in the Agents' row of traffic re-route keys, the busy condition is removed and now Agents' traffic is automatically picked up at Phone Sales positions. A lamp is aglow in the key handle to indicate the re-route pattern that has been set up.

Line Free Lamp: Instead of the normal busy lamp condition being employed on the manual switchboard jack field a Free Line Circuit was installed. This circuit consists of a uniselector which is stepped on via the contacts of a relay, one such relay being mounted in every incoming line relay set, as an incoming line is answered; this relay operates and steps the uniselector to the next free line, this being indicated by the line free lamp being aglow immediately below the jack pt. This facility has the advantage of:—

(a) Reducing busy lamp current by 80%.

(b) Reducing switchboard operators' eye fatigue and increasing their operating speed.

Key Digit Access to Desk Positions: Key digit access to desk positions was provided by means of two 50 Pt. B.P.O. type uniselectors, the desk positions being designated from 01 to 99. The depression of the digit keys operated relays whose contacts formed a contact tree to mark the appropriate bank contact, the uniselector self drive circuit being set up simultaneously.

CONCLUSION

Since its inception, the new Reservations Room telephone system, which is capable of handling 3,000 calls per day, has greatly reduced the "waiting answer time" with a consequent 80% reduction in abandoned calls. The facility of being able to record these weaknesses in the system enables the management to:—

(a) Plan future staff requirements.

(b) Move existing staff to areas of activity where their effort will be more effective.

(c) Maintain a high level of economic efficiency by the continuous presentation of an optimum work load to the Reservation Room staff.

Two similar installations are in progress, the crossbar switch being utilised on these occasions and it is anticipated that there will be a continuous demand for this type of facility.

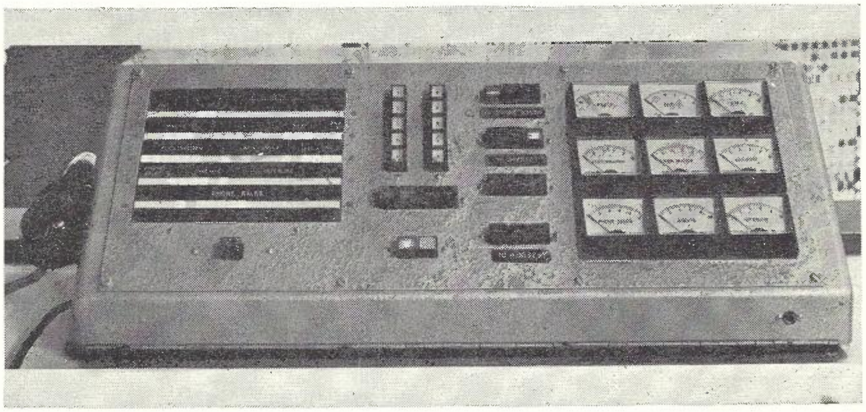


Fig. 5.—Monitor Unit.

A STANDARD PATTERN FOR WIRING SUBSCRIBERS' PREMISES

A. C. WISE*

INTRODUCTION

This article is not intended to be a complete treatise on all the aspects of subscribers' telephone equipment installation, nor even of simple service installations. However, it is proposed to discuss an important phase of development in the wiring of buildings for telephone service. The author believes that the recent introduction of the Colorfone (1) (A.P.O. type 801 telephone) and associated plug and socket has made possible realisation of an ideal pattern of wiring for telephone service. He further believes that the adoption and development of this pattern will give rise to over-all economies in the provision and maintenance of services. Installations which are efficient and aesthetically pleasing will follow naturally and field staff should find cause for pride in performing work which shows obvious forethought. Furthermore, subscribers will undoubtedly find these installations more satisfactory.

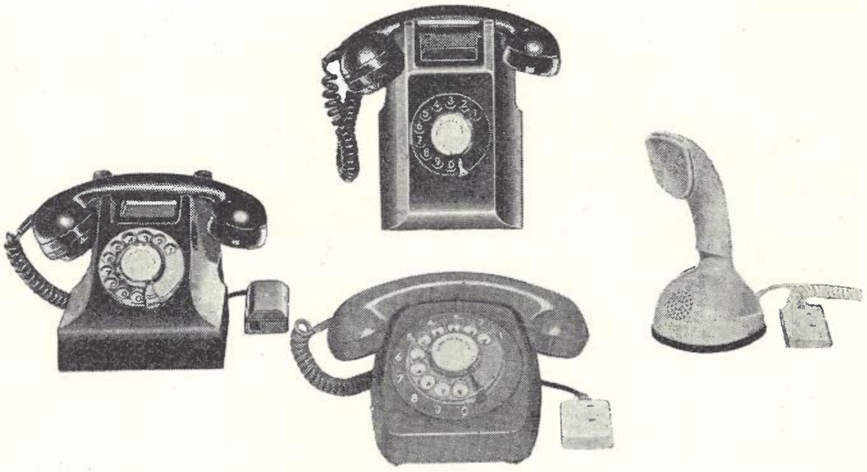


Fig. 1.—Most Widely Used Telephones in the Department.

Simple Telephone Facilities: Increasing numbers of requests for second and third telephones on services are indicative of the growing awareness by Australian telephone subscribers of the various facilities that are available. In many instances intercommunication is not required between the telephones, the only requirement being that they should be available when required to answer or originate exchange calls. Generally in these cases the absence of provision for local secrecy between the telephones is acceptable to the subscribers.

One or two of these telephones are often required to serve at several locations within the premises. Long flexible cords are unsightly, expensive to maintain and can be hazardous to people as well as the telephone instruments. The more worth-while alternative is multiple telephone outlets to which the telephones may be carried and plugged in for use as required.

The Postmaster-General's Department satisfies these requirements with Standard Telephone Facilities. Normal telephones in fixed locations within the one building and sharing the same exchange number are referred to as parallel telephones, whereas the arrangement of multiple outlets and plug-in telephones is a portable telephone service. A parallel portable service is one with a fixed telephone and also a number of multiple outlets, into any of which another telephone may be connected.

For practical reasons the Department has a limit of three speaking points for each exchange line; thus on an exchange service three instruments may be connected in parallel whilst as an extension from the P.B.X. only two instruments may be connected in parallel. In addition, provision is allowed for only two instruments on a service to be portable telephones but they may have access to as many as six socket outlets.

These arrangements with the telephone instruments now available, including the recently introduced Colorfone (1) and Ericofon (2), offer the single exchange line residential or small business customer a range of facilities generally suitable to his needs. Fig. 1 shows the most widely used types of telephone now installed by the Department The new ranges of coloured telephones have been introduced with a plug and socket connection for all applications. This innovation is intended primarily to facilitate both installation and maintenance of instruments, but also allows subscribers the opportunity in many cases to re-arrange their telephones by unplugging and and interchanging them.

ELEMENTS OF THE CONNECTION PROBLEM

The telephone is essentially a two-wire terminating device for signalling and transmission purposes and it could be expected that a pair of wires simply paralleled to any number of telephones, to be used only one at a time, should give satisfactory performance.

However, although this is correct for transmission purposes it is not so for the other basic function, signalling. It is necessary to originate a call, which in automatic areas requires dialling, and to indicate an incoming call. In practice it has been found necessary to provide additional interconnecting wires to properly control these functions when there is more than one telephone on a service.

During dialling it is essential to prevent the build up of excessive induced voltages which can result in costly plant failures. This is achieved in the telephone by connecting a spark quench, consisting of a resistor and a capacitor, across the dial impulsing springs. The capacitor reduces the peak voltage but it also shapes the impulses which are used directly in step-by-step systems to position the switches. An incorrect value for the spark quench capacitor will distort the impulses beyond the safe operating margin for the switches thus contributing to "wrong number" or "no progress" calls.

The calling signal from an exchange is a low frequency AC voltage which usually operates an AC sensitive bell in the telephone. The bell is an electromagnetic device which requires a certain minimum current for its satisfactory operation. The impedance of most telephone bells is such that they will receive this minimum current if connected in parallel, but their operating margin will be greater if they are connected in series. The series connection is essential where other call indicating devices, such as large bells and relay operated devices, with very different impedance values, are required.

The answer condition for the calling signal is a DC loop. The bell circuit must, therefore, include a capacitor to allow the ring current to pass but to block DC. If two or three telephones are connected on a two-wire basis, these capacitors will all be in circuit and during dialling from one instrument the other telephone capacitors and bells will cause impulse distortion and bell tinkling. A simple remedy for this is a three-wire interconnecting circuit which places the bells in parallel but connects only one capacitor to the service to perform the functions of spark quench and loop blocking for all telephones.

However, to eliminate all the difficulties associated with signalling, the series connection of bells is necessary, and for this reason is preferred as the standard method guaranteeing most satisfactory

---

* Mr. Wise is Engineer Class 2, Telephone Equipment Section, Headquarters. See page 251.

performance in the widest range of applications. In many cases a fourth interconnecting wire between the telephones is required to achieve this standard.

Concepts for a Wiring Pattern: Having established that three or four wires will be required to interconnect multiple telephone outlet points on a service, it is desirable to consider the economics of treating the first-in telephone installation as the commencement of a future wiring pattern to serve multiple points which may not be sought initially. Cable is relatively cheap compared to cabling, especially recabling, which is expensive. Therefore, if the telephone is installed in a location where recabling will be difficult, four-wire cable should be provided from the point of entry or from an accessible wiring point.

The wiring of a service with multiple outlet points should be such that very little re-arrangement and certainly no recabling is necessary when instruments are changed. Whenever technically possible the subscriber should be able to freely interchange different instrument types between outlet points. An instrument housing a capacitor which serves other telephones must, of course, be permanently connected to the wiring.

A wiring pattern must be flexible to allow for extension and facility changes to be carried out easily. For example, a residence may initially have a single telephone in the entrance hall and at a later date a second parallel telephone is added in the kitchen. Subsequently this could be changed to a parallel/portable service with multiple points in bedrooms, lounge and workshop.

Plug and Socket: Plugs and sockets have been offered as a standard feature for portable services for many years. Coincidental with the design of the Colorfone in 1961-62 and the inclusion in it of circuit flexibility for additional facilities, a new plug and socket was developed. Appraisal of the possible applications of the Colorfone, which are typical of most modern versatile telephones, showed that up to six simultaneous connections may be required between the instrument and the wiring. Therefore, a six connection plug and socket combination was adopted. (Fig. 2.)

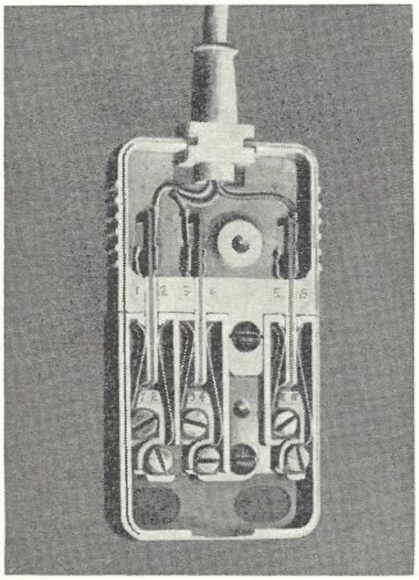


Fig. 2.—Standard Plug and Socket.

Where telephone connections are completed by plugs that are "free" in their sockets (i.e., portable services or to permit interchanging) and series circuitry is used for bells and other alarm equipment on the service, the continuity of the series circuit must be retained when the telephone is unplugged. This condition is best achieved by an integral make contact, within the socket, which replaces the series connected telephone bell as the plug is withdrawn. This contact is a feature of the new A.P.O. 610 type socket.

Single telephone installations, of course, predominate and to cater for the easy connection of additional alarm equipment to these, a metal link has been included between two of the connection elements of the socket to complete the telephone bell circuit. When additional alarm equipment is required this link is removed and replaced with the wiring to the alarm which will then be connected in series with the telephone bell. This arrangement removes the need to open the instrument case or to alter the cord connections.

The complementary unit to the type 610 socket is the type 603 plug. Like the socket this plug is easily accessible for the installer, but whereas the former has screw terminals for cable conductors, the plug has terminal lugs to receive the push-on connectors of the cord conductors. These permit very easy cord changing or conductor repositioning. The front of the plug has, in addition to the connection pins, a moulded tongue which guides the lug into the socket and is used, when necessary, to make the plug "captive" by passing one of the socket mounting screws through it.

The 603 plug and 610 socket is fitted to all new telephones and supersedes the 20/4 terminal block previously used for 300 and 400 type telephones. New installations of portable services, including those with 400 type telephones, are being installed with the new plugs and sockets. Existing portable services should have the old pattern sockets changed for the new six pin type whenever a Colorfone or Ericofon is first introduced to those services.

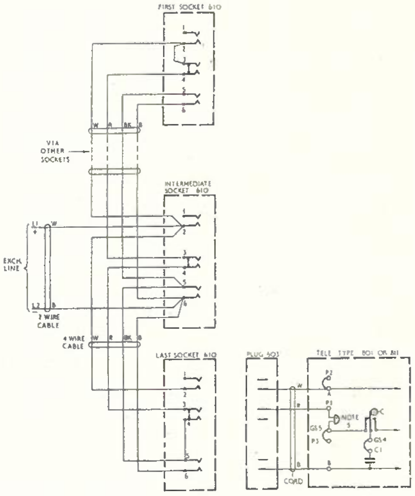


Fig. 3.—The Basic Wiring Pattern for a Portable Service.

Telephone Line Cords: Different types of flexible line cords interconnect the new plug and the various types of telephone instruments. All have push-on connectors for the conductors at the plug end, but only the Colorfone cords have these connectors at the instrument end. Other types of line cords have spade type conductor terminations to fit the screw terminals in the 400 type telephones and Ericofons.

Six conductor cords, which make full use of the plug capacity, are available for Colorfones and 400 type telephones. The conductors are identified by the colour of their insulation. Table 1 shows the colour identification code, plug pin number allocation, and normal circuit function of the conductors of a six-way line cord.

Six conductors in the cord are a maximum requirement, the need for which does not occur often. Therefore, to avoid stocking a range of cords in all sizes and types, two sizes only have been standardised. These are the six conductor size and a three conductor size. The three conductor cord caters for most situations and is fitted to all table telephones in the factory.

The three conductor cord has a white, a blue and a red coloured conductor. The allocation of these colours is normally the same as for the same three colours in Table 1. White and blue are always the line connections, L1 and L2 respectively, but the red conductor may be moved around within the plug

TABLE 1: SIX CONDUCTOR LINE CORD COLOUR CODE

Conductor Colour	Plug Pin No.	Normal Function
Green	1	Earth connection
White	2	A, L1 or + line
Red	3	Bell circuit in
Orange	4	Bell circuit out
Black	5	Capacitor common
Blue	6	B, L2 or — line

and telephone to perform the function in place of any one of the other colours, e.g., parallel telephones, with bells in parallel and sharing the one capacitor, need only three conductor cords and in this case the red conductor replaces the function normally allocated to the black conductor in a six conductor cord.

Cables: Two, three and four-wire PVC insulated and sheathed cables have been employed for many years for cabling simple telephone facilities. The colour coding and wire allocations have varied from time to time. However, in 1962 the wire colour coding of these cables was standardised to prepare for the uniform pattern of connections which is now being realised. This code and the normal wire allocations are shown in Table 2.

TABLE 2: COLOUR CODING AND WIRE ALLOCATION FOR SMALL CABLES

Cable Size			Wire Allocation		
2-wire	3-wire	4-wire	Designation	Single Service	Two Services
White	White	White	A	L1	L1 1st Pair
Blue	Blue	Blue	B	L2	L2
	Red	Red	C	Bell	L1 2nd Pair
		Black	D	Capacitor	L2

The trend of development of wiring patterns for simple services, especially for interconnecting outlet points, is toward an increasing requirement for four-wire cable whereas previously much use has been made of the two and three-wire size cables. The cost difference of the additional wire or wires in the cable is insignificant compared with cost of cabling and then recabling with a larger cable when additional facilities are required. Therefore, four-wire cable has been established as the standard cable for interconnecting outlet points on telephone services. Two-wire cable still has application for wiring miscellaneous apparatus such as alarm equipment and possibly for lead-in line connections. Three wire cable may still be used for leading-in duplex services, wiring to recall press-button extension telephones and similar applications. However, it is anticipated that the reduced demand for these sizes could result in them being uneconomical to stock and they may be discontinued.

Future experience may show a need for a five or six-wire cable to cater for those simple service installations where an earth circuit, for press-button duplex or P.B.X. operator recall is required in addition to telephone interconnection, or for those exchange multi-outlet services where normal four-wire cabling is uneconomical because of unusual routing. However, at the present time the anticipated usage for these purposes does not warrant such a cable size and it might be more dependent for its introduction upon the wiring requirements of the more elaborate intercommunication telephone facilities now under consideration by the Department.

BASIC WIRING PATTERN

Having discussed the elements of a pattern of wiring, i.e., the types of telephones, the plug and socket features, the line cord conductor allocations, and the interconnecting cable appropriations, it remains only to demonstrate some typical examples of the actual pattern itself. The Colorfone has been designed with the built-in features which make the basic pattern possible. Therefore, it is used to illustrate the new wiring method.

Fig. 3 shows the basic pattern of a portable service wired with four-wire cable and having a number of type 610 socket outlets. A single telephone type 801 or 811 (Auto or CB manual Colorfone) with the three conductor cord, connected in the same way as for a straight line service, may be connected to any one of these outlets.

The designations "first" and "last" socket have no special significance except that they are at the ends of the cable route and that in the former case there is a link between terminals 2 and 3, and in the latter there is a wire strap between terminals 4 and 5. At the intermediate sockets the links are removed and no other straps have been inserted. The line connection may be made to any of the sockets.

It should be noted that there is no auxiliary apparatus wired into the circuit, although any type of alarm equipment may be. In this simple case when the telephone is unplugged the line is open circuit or unterminated. This is now accepted as standard practice on all types of simple service unless the subscriber requests that a telephone or bell set be permanently connected.

The line circuit is extended through white and blue wires in the cables to terminals 2 and 6 respectively of all sockets, so that at any socket where the telephone may be plugged in, it is further extended through the white and blue cord conductors into the instrument. The bell circuit commences from the link between terminals 2 and 3 of the "first" socket and passes via the red wires in the cables, through the socket make contacts 3 and 4, until at the socket where the contact is open due to the telephone being plugged in, it passes via the red cord conductor to the instrument and is completed via the bell and capacitor.

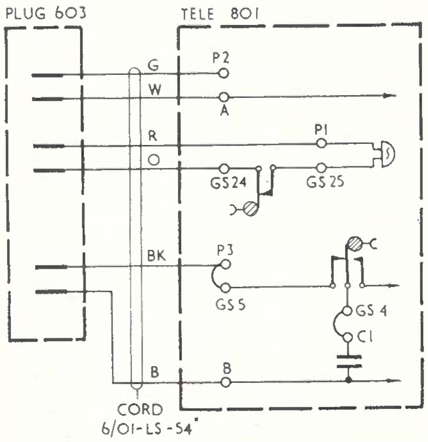


Fig. 4.—Portable Colorfone with 6 Conductor Cord.

A single 400 type portable telephone can, with the appropriate cord and plug, be associated with this wiring pattern in exactly the same way as a Colorfone.

A Second Portable Telephone: A subscriber with a portable Colorfone may be supplied with a second portable Colorfone without any alterations to the permanent wiring of the sockets. All that is required is that both Colorfones be fitted with six conductor cords in lieu of the normal three conductor cord. A technician can replace these cords in a matter of minutes. Fig. 4 shows the cord connection for this arrangement.

It will be seen that if two Colorfones, connected as shown in Fig. 4, are associated with the pattern of socket wiring, shown in Fig. 3, that the line connections to each instrument through the white and blue conductors is the same as described above, but the connection of the bell circuit is somewhat different. In this case when both telephones are plugged in, the bells are in series and the line capacitors are in parallel.

Whilst one Colorfone is in use an

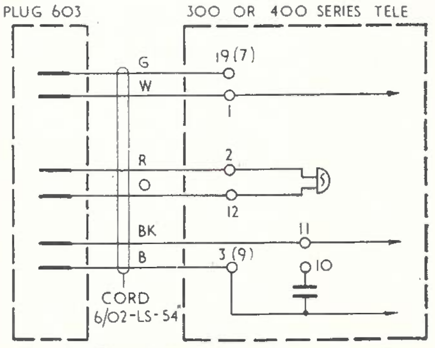


Fig. 5.—Second Portable 500 Type Telephone.

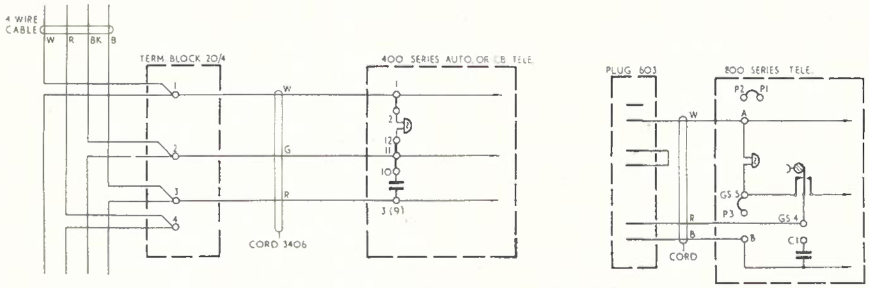


Fig. 6.—Typical Connections for Parallel Telephones.

auxiliary break gravity switch contact open circuits both bells and the capacitor of the other Colorfone. Each Colorfone uses its own line capacitor for dial spark quench and transmission circuit functions. The Colorfones may be plugged in singly at any socket or together in any combination of sockets without mutual interference.

Additions To and Variations of the Pattern: Special additions to the wiring pattern are required for portable services equipped with instruments which do not have the internal terminal capacity or the switching facilities of the Colorfone. In these cases it is not possible to parallel the line capacitors, to serve in the bell circuit, and then to separate them to perform dial spark quench and transmission functions.

This problem is overcome by connecting a 2mF capacitor available in standard bellsets, between terminals 5 and 6 of any socket and mounting it in some inconspicuous but suitable location. The telephone capacitors are then disconnected. The cord connections to the instruments are arranged in a manner similar to that shown typically in Fig. 5 for the 400 type telephone. If a Colorfone is associated on a portable service with another type of telephone the link between terminals P3 and GS5, as shown in Fig. 4, is removed.

Some economies in cord provision are achieved when one of the telephones on a service is fixed or "captive" and no additional alarm equipment is required. These are the parallel or parellel-portable services where the telephone bells can be operated in parallel and with only one capacitor in the fixed telephone serving the other telephones. If a fixed telephone is a 400 type the terminal blocks are retained and the normal three conductor cord re-allocated within the telephone. In other respects the pattern of wiring shown in Fig. 3 is retained and the other telephones are re-terminated as shown typically for a 400 type telephone and a Colorfone in Fig. 6.

The basic wiring pattern will require variation for telephones not having the versatility of the Colorfone. For instance, the Ericofon is equipped with a buzzer to indicate incoming calls, and for optimum operation in association with the bells of other telephones it should be connected in series with them.

Variations of the basic wiring pattern for the Ericofon in association with the Colorfone are shown in Figs. 7 and 8. The combinations of a fixed Ericofon with one or two portable Colorfones, or of a single fixed Colorfone in association with a single portable Ericofon, include the buzzers and bells in series circuits and can be expected to give satisfactory service under all normal exchange line conditions in Departmental networks.

However, the Ericofon normally has only a three conductor cord and does not have the internal terminal capacity to accommodate the five conductors to cater for the standard wiring pattern. To obtain the best arrangement with this limitation it is necessary to resort to parallel connection of the buzzer with other bells in some cases. An Ericofon when connected as shown in Fig. 9 and associated with the Standard Wiring Pattern with fixed capacitor will perform satisfactorily in most circumstances.

PRACTICAL ASPECTS

The uniform application of a standard pattern for wiring multi-outlet telephone services is an ideal, and yet, on examination it appears as an economic proposition for all new installations. It can be seen that even in the variations from the standard pattern, the elements are there so that it may be restored with only slight alterations to the wiring on two or three terminals of a few sockets.

The pattern allows the easy addition or cancellation of outlet sockets and in most cases permits the addition, change or interchange of instruments with very little effort.

The sequence of wire and cord

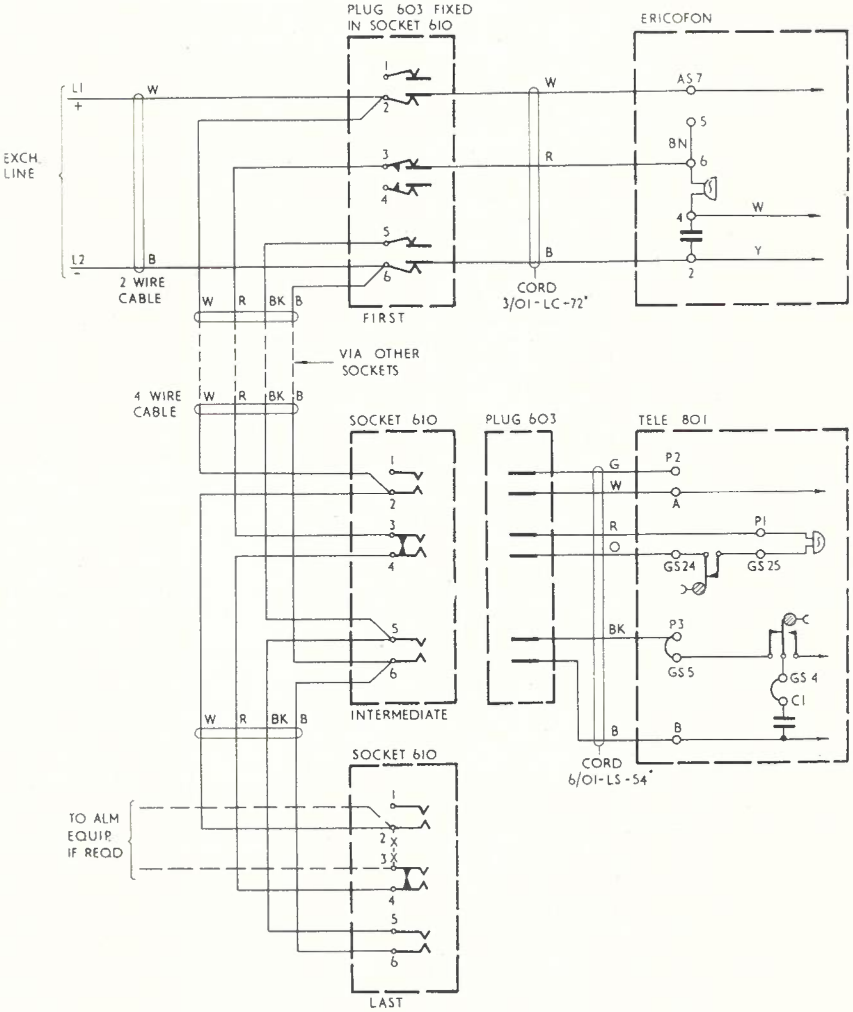


Fig. 7.—Fixed Ericofon with One or Two Non-Captive Colorfones.

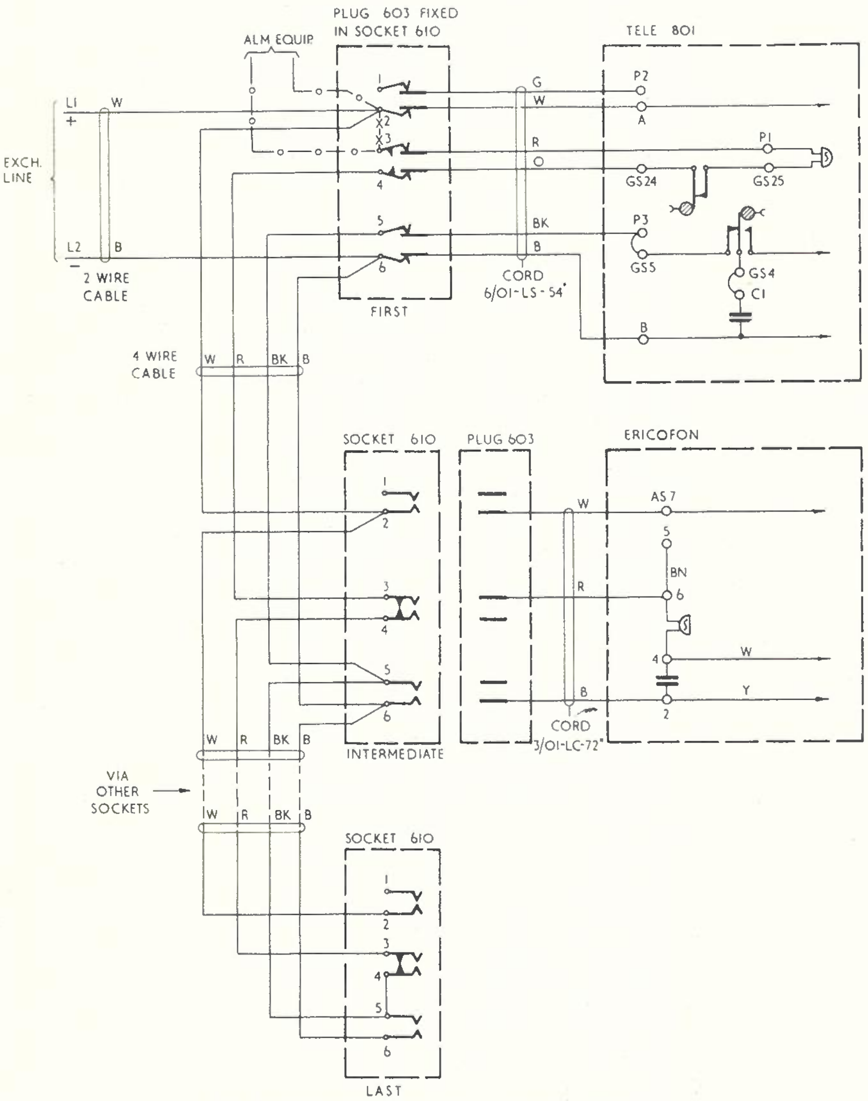


Fig. 8.—Fixed Colorfone with a Portable Ericofon.

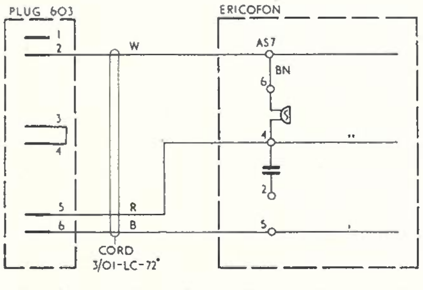


Fig. 9.—Ericofon Connection with Parallel Buzzer.

conductor colour coding is easily assimilated by installers and servicemen.

Cabling is usually the major part of the installation effort in subscribers' premises. Recabling is to be avoided as far as practicable both to reduce costs and to minimise disturbance and possible defacement of subscriber's premises. Therefore, only as a last resort is existing three-wire cable to be replaced with four-wire to make the pattern conform to the standard. Most arrangements can be made to work satisfactorily with three-wire cable, but they cannot then be easily extended.

The new wiring pattern together with the new plug and socket provides a flexibility which not only reduces overall costs of labour and material but also makes possible an installation most likely to gain the approval of the subscriber and to give the satisfaction of a job well done to the field staff who carry out the work.

A standard pattern makes it practicable for builders, architects and others responsible for new buildings where telephone facilities will be required, now or in the future, to have telephone cabling installed during construction with confidence that for the most common services no further cabling will be required. This is called "wiring in advance". For the simple type of telephone facilities referred to in this article, the only work required at the building stage is to provide a continuous run of four-wire cable past those points where a telephone outlet might be sought in the future and a connecting cable from this run to the point of entry for the exchange line.

When telephone facilities are required, the lead-in cable is connected to the advance wiring which may be detected and exposed at the actual location selected for the outlet or outlets. This wiring is brought to the socket-mounting surface through a small hole which will usually be covered by the mounted socket, and a small length of the cable sheath is removed. With the wires exposed they may all be terminated on the socket terminals and only the red wire need be cut, this simplifies the terminating operation.

CONCLUSION

The logical development of the basic wiring pattern, its flexibility and potential to facilitate advance wiring of buildings have been discussed in the foregoing. The handbook of instructions issued to the Department's subscribers' equipment installation technicians includes sections on the provision of 801 type and Ericofon telephones in various combinations. The patterns of wiring illustrated in these sections are derived from the basic pattern described in this article.

REFERENCES

1. R. J. Kolbe, "801 Telephone"; Telecommunication Journal of Aust., Vol. 13, No. 6, page 434.

2. "A New Telephone for Australia", Telecommunication Journal of Aust., Vol. 14, No. 1, page 39.

3. M. J. Power, "Sub-station Installation"; Telecommunication Journal of Aust., Vol. 12, No. 6, page 451.

TECHNICAL NEWS ITEMS

EPOXY RESIN FIELD PACK

The Department has now adopted the method of encapsulation to seal joints in its buried plastic cable network (1). The whole of the jointing area in both plastic to plastic and plastic to P.I.L.C. cable joints is encapsulated with epoxy resin which is mixed and poured into a prepared mould by the cable jointer in the field. This operation is made possible by the successful development within the Department's Research Laboratories of a suitable field pack of epoxy resin.

Epoxy resins are unique in that they combine excellent insulating, sealing and mechanical properties all of which are requirements for effecting an adequate underground joint seal. It was recognised early that they could be extremely useful in helping to overcome the problem of sealing underground joints in plastic cable and developmental work has proceeded accordingly for the last five years.

Field Problems in Use of Epoxy Resin: Hazards attached to the use of epoxy resin under conditions met in every-day field practice include:

(i) The proportions of the components—resin and curing agent—must be accurately predetermined, preferably by weight. The weighing out of ingredients in the field is completely impracticable for every-day use.

(ii) The chemicals used, being very reactive at room temperature, are toxic. They can cause dermatitis by contact with the skin and, therefore, must be used so that a "no touch" principle is employed.

(iii) The ingredients must be thoroughly mixed before pouring to ensure satisfactory curing.

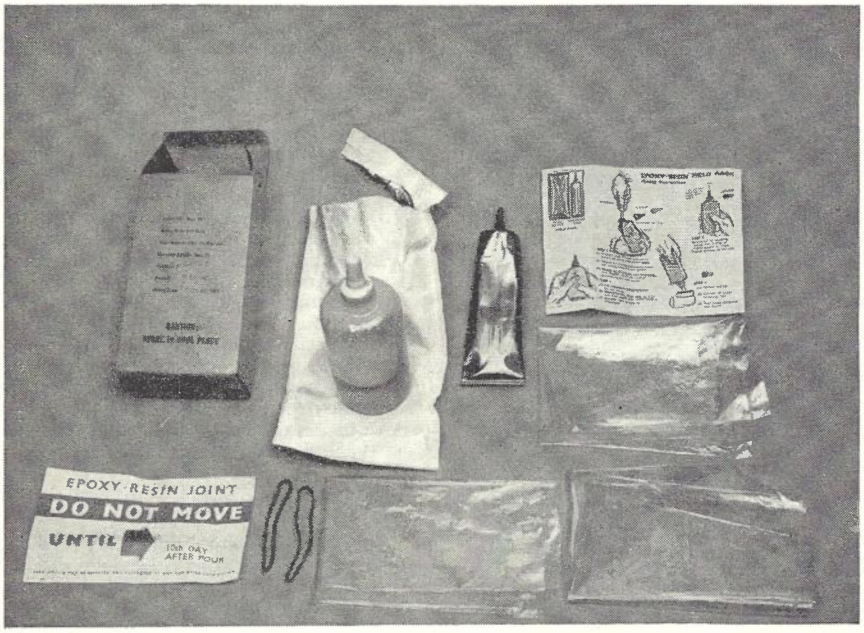
(iv) Unless chemicals of the correct formulation are used a satisfactory cure will not be achieved in a reasonable time over the wide range of ambient temperatures encountered in Australia.

(v) Correct formulation is also essential to ensure that the exotherm—the peak temperature attained in the compound from the heat developed during the chemical reaction—does not exceed the melting point of polythene conductor insulation.

(vi) The volume to be poured at one time in a joint must be limited so as to control the exotherm.

These difficulties were overcome in the Departmental field pack which was developed in 1961 and was then satisfactorily subjected to field trials to ensure that the cable jointers could perform the required operations.

Initial Field Pack: This pack consisted of two polythene bottles containing the components in preweighed quantities so that each pack was a unit of 180 grams. The bottles were packed together in a cardboard carton. The larger of the two bottles contained the epoxy resin and was thin walled because it was also used for mixing the ingredients. The smaller bottle contained the curing agent. This was thicker walled, made of high density polythene to limit the permeation of chemical vapours through the bottle wall. Both bottles had dispenser type screw-on nozzles. To use the resin, the curing agent was poured into the larger bottle, air was expelled from the larger bottle by squeezing and the ingredients were then mixed by kneading the bottle between the fingers and rolling between the palms of the hands. The thin wall facilitated this operation and also permitted visual inspection to check the completeness of the mixing by observing whether the liquid was of uniform colour. The epoxy resin itself was honey coloured whereas the curing agent was dark. The mixture was then poured through the nozzle into the jointing mould where the cure would take place. A warning label, included in the pack, was attached to the joint. This gave the date of the pour and warned that the joint must not be moved for ten days thereafter. Another label in the pack gave mixing instructions and listed safety precautions to be observed.



The Pack and Contents consisting of Thin Wall Polythene Bottle containing resin, Tube containing curing agent, Three Plastic Bags, Two Rubber Bands, Instructions, and Label for Joint.

The chemicals in this pack were:

(i) In large thin-walled bottle—
epoxy resin with an epoxide equivalent approximately 190 and viscosity at 25° C of 10,000-150,000 cp—
100 parts by weight.

(ii) In small bottle—
reactive modifier (Thiokol LP8)—
60 parts by weight.
curing agent (Hardener D.M.P. 30)—
4 parts by weight.
or 2.5 parts by weight.

There were two types of pack—the A pack contained 4 parts of D.M.P. 30 and the B pack contained 2.5 parts of D.M.P. 30. The A pack was used where not more than one unit was required to fill the mould. The B pack was used where two units were required—the smaller quantity of D.M.P. 30 limited the exotherm to a safe mark.

Whereas this pack met requirements successfully, the following problems remained:—

(i) The existence of two types of packs, A and B, caused some confusion to jointers.

(ii) Thiokol is an imported material and it became obvious, due to supply difficulties, that an all Australian content was desirable.

(iii) Curing of the compound in low winter temperatures in the southern and inland areas was not completed within a reasonable time unless properly controlled preheating of the pack was carried out. This proved difficult to organise.

(iv) The pack was not pleasant to handle because of the obnoxious smell emanating from the Thiokol.

(v) The base epoxy resin would crystallise in storage in cold weather necessitating heating to reliquefy it before use.

New Field Pack: To overcome these problems a new formulation is now being supplied. The properties of the ingredients has meant varying the pack so that it now consists of a thin-walled polythene bottle as before and a tinned lead tube with a long spout. The tube is like a toothpaste tube and contains the curing agent which will not remain stable in storage if packed in a plastic bottle.

The new formulation is:—

(i) In thin-walled polythene bottle—
epoxy resin (Epichlcohydrin—Bisphenol A)—105 gms.

reactive diluent (Cardura E—an epoxidised synthetic fatty acid)— —19 gms.

The two combined give an epoxide equivalent of 230-275 and a viscosity at 25°C of 105-125 poises.

(ii) In tinned lead tube—

Curing agent (Polymid 75—a Polyamine-Polamide Resin)

This ingredient is dyed red to facilitate mixing —56 gms.

The thin-walled bottle is packed in a foil-lined, sealed paper bag to limit the permeation of the Cardura E through the bottle walls. Also included in the new pack are three thin polythene bags. Two are worn on the hands when mixing and are held at the wrist by rubber bands. The third is used to return the used pack to the depot to be destroyed.

The new pack is superior in the following points:

(i) The same mix is used whether a half or double bottle quantity is required.

(ii) The compound will cure in reasonable time in ambient temperatures ranging from 40° to 120°F.

(iii) The heat evolved during reaction is much less than in previous formulations.

(iv) The ingredients are cheaper and of lower density than those used previously. There is a gain of approximately 10% in volume for the same mass.

(v) The ingredients are less toxic, more pleasant to handle and easier to remove if accidentally spilt.

(vi) Being an additive hardener system it will have better physical properties than the previous catalysised mix.

(vii) Proportions of ingredients are not so critical and are much easier to check.

(viii) The base resin will not crystallise in cold weather.

(ix) The contents of the pack are all products of Australian manufacture.

Several hundred thousand packs have now been delivered to the field. Jointers have proved adept at handling them and no problems have arisen due to their toxic nature. The packs are proving very satisfactory for their purpose.—R.T.

REFERENCE

1. W. H. Walker, "Some Aspects of External Telephone Plant in Australia"; Telecommunication Journal of Aust., Vol. 14, No. 2, page 109.

TRIAL INSTALLATION OF 4,000 PAIR/2½ LB. PLASTIC CABLE

A trial installation is about to commence in Sydney of a type of underground cable which is novel in many aspects. The cable, manufactured in Japan, consists of approximately 1,000 yards of 4,000 pair/2½ lb. unit quad cable using foamed polythene insulation and a polythene sheath.

Cables using 2½ lb. conductors have been developed by the Nippon Telegraph and Telephone Public Corporation, (N.T.T.P.C.), Japan (1) (2), over recent years. Extended transmission and signalling limits allow lighter conductors to be used, and maximum use is obtained from duct and tunnel space. Extensive trials with this type of cable have been proceeding in Japan since 1961 with good results, and accordingly in 1962 when the N.T.T.P.C. decided to considerably extend the use of this type of cable in Japan, the Postmaster-General's Department decided to proceed with a trial.

Makeup of Cable: The N.T.T.P.C. have developed a new manufacturing technique for insulating the fine 2½ lb. conductors with foamed polythene, as it was considered that the use of paper insulation or normally extruded solid polythene was impracticable and uneconomic. In the new insulation process, conductors are passed through a coating tank containing polythene dissolved in a solvent. The coated conductors then pass through drying and bubble forming furnaces which result in a thin polythene coating containing minute bubbles confined to the inside of the insulation. This technique results in a decreased dielectric constant of the insulation, and a smooth polythene outer coating generally free from imperfections. The coating thickness on 2½ lb. conductor cable is 3.1 mils.

Insulated wires are formed into star quads, with the quads then formed in concentric layers into units comprising 200 pairs nominal, 204 pairs actual. Twenty units are then laid up to form a complete core of the 4,000 pair cable. A simple colour code using only three colours, red, white and blue, allows identification of all pairs and hence rotation jointing is possible. The sheath is of conventional alpeth construction using a corrugated 8 mil. aluminium tape applied over the cable core followed by a polythene sheath. The outer diameter of the cable is 2.8".

Cable Installation: Installation of the cable will also see the use of new techniques for wire jointing and sheath sealing. Although wire jointing can be performed satisfactorily by conventional methods, the N.T.T.P.C. have developed a battery operated "splice gun" (Fig. 1) for the purpose. The action is as follows:—

(i) The two conductors to be jointed are inserted into the jaws of the gun without twisting and without stripping the insulation.

(ii) Operation of one trigger actuates an electric motor which twists the conductors together for a set number of turns.

(iii) Operation of the second trigger applies battery potential to the twisted conductors which burns off the insulation, cuts off surplus conductor and welds the two conductor tips together.

An open ended polythene jointing sleeve is then placed over the wire joint.—W.F.C.

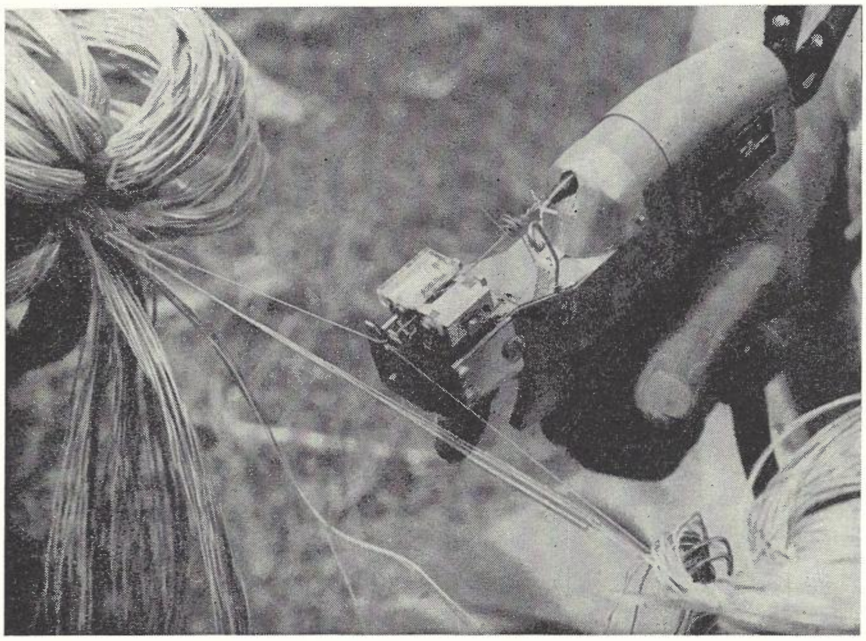


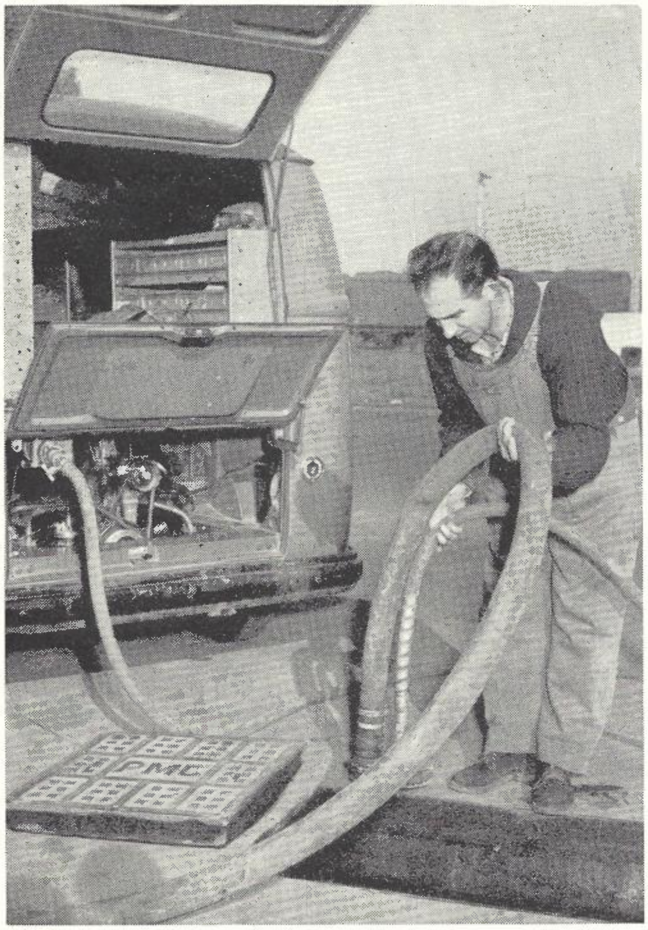
Fig.1. —"Splice Gun" for Jointing 2½ lb. PEF Insulated Conductors.

REFERENCES

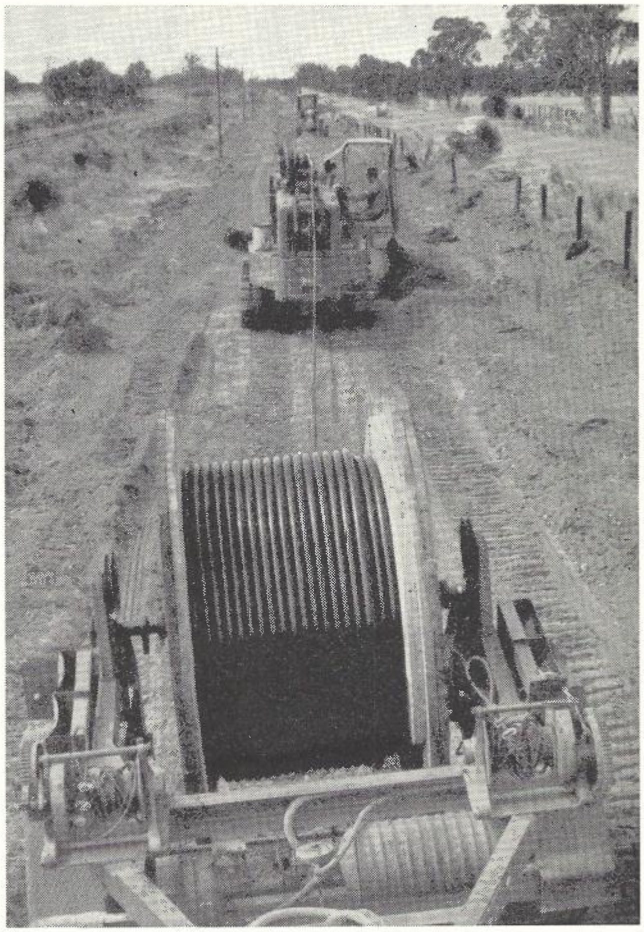
1. M. Rokunohe, "Foamed Polythene Insulated City Cable"; Review of The Electrical Communication Laboratory, Vol. 9, Nos. 11-12, page 733.

2. Y. Toriyama, "Foamed Polythene Insulated Local Cable"; Japan Telecommunications Review, 1963, page 30.

RANDOM ITEMS OF INTEREST

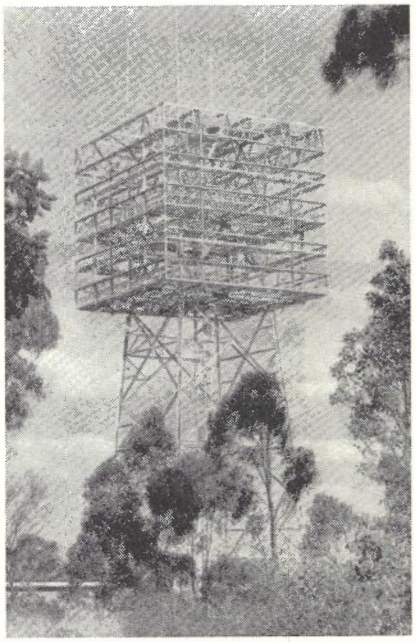


A submersible self-priming pump, driven off the jointer's van engine.



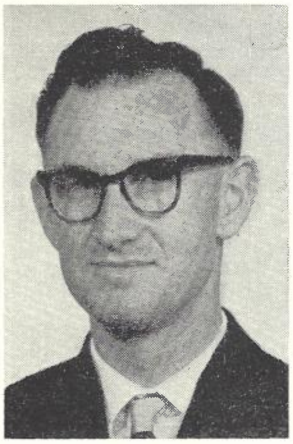
A typical coaxial cable laying operation in easy soil.

The new C.D.C. 160A Computer at the Research Laboratories.

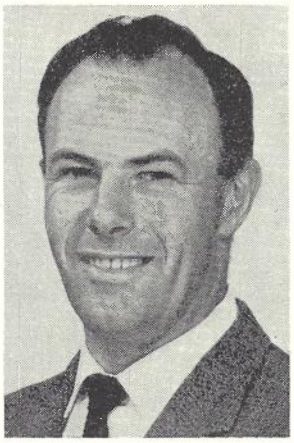


An aerial mounting structure at a radio-telephone terminal.

OUR CONTRIBUTORS



N. A. S. WOOD



A. C. WRIGHT

J. RUBAS

W. M. McMURRAY

N. A. S. WOOD, author of the article, "Introduction of Common Control Switching Equipment in Australia", and co-author of the article "Programming the Introduction of Crossbar Equipment", entered the Postmaster-General's Department as a Junior Mechanic in New South Wales in 1937. After war service with the A.I.F. Corps of Signals from 1940 to 1946 he qualified as Technician and Senior Technician, taking up duty in 1948 as Technical Assistant to the Divisional Engineer, Planning, New South Wales. He qualifield as engineer in 1952 and after a total of six years experience in Planning and three years in Metropolitan Exchange Installation he was promoted to Headquarters as Divisional Engineer, Network Planning, in the Telephone Equipment Section. Mr. Wood was closely associated with the investigation of switching systems prior to the adoption by the Department of the L M Ericsson Crossbar Systems in 1959. In 1960 he represented the Telephone Equipment Section in the group which accompanied Mr. F. P. O'Grady, then Deputy Director-General, to Stockholm for facility and interworking design discussions with the L M Ericsson Company. On return from overseas Mr. Wood was appointed Sectional Engineer, Installation Standards and since that time has been actively engaged with programming and implementation phases of the introduction of crossbar equipment into local manufacture and into the Department's installation works programmes. As Sectional Engineer, Installation Standards, he is also concerned with the standards of provision of subscribers' equipment in the field. Mr. Wood is an Associate Member of the Institution of Engineers, Australia.

A. C. WRIGHT, co-author of the article, "Programming the Introduction of Crossbar Equipment", is a Sectional Engineer in the Telephone Equipment Section at Headquarters. He commenced his service in the Postmaster-General's Department as a Junior Mechanic in 1939 and qualified as Senior Technician (Telephones and Radio) and in 1948 qualified as Engineer. His subsequent experience has been on exchange installation in the Melbourne metropolitan area and exchange and long line equipment installation in the country areas of Victoria before being appointed in 1956 as Divisional Engineer in the field of exchange equipment design. He was appointed to his present position in the Works Programme Section in 1960 and is concerned with the over-all level of the Switching Equipment Sections of the capital works programmes and the provision of the necessary equipment to implement the programmes. Mr. Wright is an Associate Member of the Institution of Engineers, Australia.

★

J. RUBAS, author of the article, "Dimensioning of Crossbar Equipment", joined the Postmaster-General's Department in 1953 and was appointed Engineer Grade 1 in 1957. He worked in the Victorian Metropolitan Branch as Junction Control Engineer until early 1959, when he was promoted to Group Engineer, Central Office. At Headquarters, Mr. Rubas has been engaged chiefly on traffic engineering work. He was the Secretary of the Traffic Engineering Committee from 1959 to 1962, and was intimately associated with the preparation and issue of the new series of Traffic Engineering Instructions. In 1962, Mr. Rubas was appointed Divisional Engineer, Traffic (Operations) in the Fundamental Planning Studies Section of the newly established Headquarters Planning Branch. There he has been working on traffic engineering problems posed by the introduction of crossbar equipment into Australian networks. He is currently investigating crossbar interconnecting schemes with the help of a computer simulation programme.

Mr. Rubas has a Diploma in Radio Engineering from the Royal Melbourne Technical College and is a Graduate Member of the Institution of Engineers, Australia.

★

W. M. McMURRAY, author of the article, "Petersham ARF.102 Crossbar Exchange Installation", commenced as Junior Mechanic in Melbourne in 1936. Following completion of training in 1940, he served as Technician on automatic exchange installation and maintenance until 1943.

For three years from 1943 to 1946 as a Senior Technician he carried out transmission field measurements with the Transmission Planning Division. He was promoted to Acting Engineer in the same division in 1946 and qualified in 1947, remaining in this position until 1949 when he was transferred as Group Engineer to Regional Works and Services in the Outer Metropolitan Division. He occupied this position for four years until 1953 when he was promoted to Divisional Engineer in charge of the Grafton Division, N.S.W.

After four years' service in this area he was transferred for a six months' term to Central Office to write Engineering Instructions on Lines Practices. He returned to N.S.W. in 1958 and after a period of nine months as Divisional Engineer, Primary Works, in Sydney he was transferred to the position he now occupies, Divisional Engineer, Metropolitan Equipment Installation.

D. W. ARCHER

D. G. KENNER

R. A. KIRKMAN

A. C. WISE

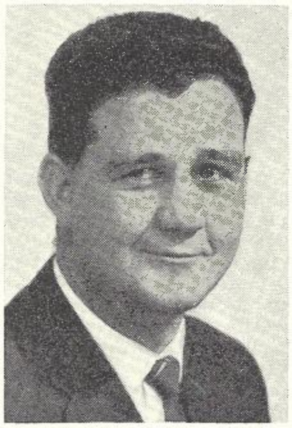
D. W. ARCHER, author of the article "Pilot ARF 102 Crossbar Exchange—Petersham," joined the Postmaster-General's Department as a Junior Mechanic in 1941 and subsequently qualified as Technician (Telephones) and Senior Technician (Telephones). After eight years at the New South Wales Technicians' Training School as a Technical Instructor and Senior Technical Instructor he qualified as Engineer in 1954 and after 18 months in Metropolitan Sub-station Installation, No. 1 Division, as a Grade 1 and Group Engineer, transferred to Metropolitan Installation No. 3 Division. Since 1955 Mr. Archer has been associated with the installation of 2000 type equipment and the Sefton (N.S.W.) Crossbar Exchange. He was the N.S.W. representative on the Toowoomba Crossbar Installation and became resident Group Engineer on the Petersham Pilot Crossbar Installation.

★

P. J. O'NEILL, author of the article, "Provision of Rural Telephone Facilities under Unusual Conditions", joined the Postmaster-General's Department as a Cadet Engineer in 1953. He obtained his B.E. degree with 2nd Class Honours from the University of New South Wales in 1956 and completed his cadetship in 1957. Mr. O'Neill was employed from 1957 to 1960 as an Engineer Grade 1 and acting group engineer in the Traffic Engineering Division, Sydney. Whilst in that position he was associated with the development of a permanently installed resistor type traffic recorder which has since been adopted as standard for new country automatic exchanges. His final task whilst engaged on traffic engineering was the collection of basic traffic figures and the estimation of all trunking requirements for the crossbar exchanges proposed to provide S.T.D. to and from Sydney, Canberra and Newcastle. In 1961, Mr. O'Neill transferred to Armidale to gain country experience and was subsequently appointed Engineer Class 2, Armidale (his present position). The project described in his paper is one of the larger ones that has been supervised by him as district engineer in charge of the Western area of the Division. Mr. O'Neill is a Graduate Member of the Institution of Engineers, Australia.

★

D. G. KENNER, author of the article "Training for Crossbar", joined the Postmaster-General's Department in Melbourne in 1937 as Junior Mechanic and subsequently qualified as Technician and Senior Technican. After some years of experience on exchange and sub-station installation and maintenance, he joined the staff of Melbourne Technicians' School in 1946 as a Technical Instructor. He served at the Melbourne School for a period of 13 years during which he was appointed as Technical Instructor Grade 2 and Senior Technical Instructor Grade 2. In 1959, he joined Headquarters Training Section as a writer of Course of Technical Instruction Books on crossbar equipment and was subsequently appointed Senior Technical Instructor Grade 3. In this capacity he has pioneered the development and writing of crossbar training courses in the Department.



P. J. O'NEILL

R. A. KIRKMAN, author of the article, "Perth Civil Aviation Tape Relay Centre," was appointed Cadet Engineer, Postmaster-General's Department, Western Australia, in 1948. He completed a degree in Electrical Engineering in 1951 and his first Engineering appointment was in the Telephone Equipment Section, where he was engaged in Planning duties. He was next employed in Metropolitan Equipment Service and this was followed by a number of years on Telephone Equipment Installation. In 1957 he was transferred to the Telegraph Section as Group Engineer, TRESS and he was appointed Divisional Engineer, Telegraphs and Trunk Services, in 1958. Mr. Kirkman is an Associate Member of the Institution of Engineers, Australia.

★

A. C. WISE, author of the article, "A Standard Pattern for Wiring Subscribers' Premises for Telephone Services", joined the Postmaster-General's Department in Tasmania as a Technician-in-Training in 1947 and trained as a Telecommunications Technician in the fields of telephony, long line equipment and telegraphy. Having successfully completed the training course in 1951, he was employed in Hobart on exchange installation, long line equipment and trunk exchange maintenance, P.A.B.X. and subscribers' equipment maintenance and installation as a Technician, Senior Technician and Supervising Technician before transferring to the Technicians' School as an instructor in 1953. He was promoted Senior Technical Instructor in 1956 and in 1958 he transferred to the Telephone Equipment Section, Headquarters, as a Senior Technical Officer to investigate technical suggestions received by the Improvements Board. Mr. Wise qualified for promotion as Engineer, P.M.G. Department, in 1960. In 1961 he was promoted Group Engineer and became concerned with developing installation standards for subscribers' equipment and P.A.B.X.'s.

ANSWERS TO EXAMINATION QUESTIONS

Examination No. 5043—7th July, 1962, and subsequent dates

To gain part of the qualifications for promotion or transfer as Senior Technician (Telecommunications), Telephones, Postmaster-General's Department.

TELEPHONY AND LONG LINE EQUIPMENT

SECTION 1 (TELEPHONY)

Answers by W. R. PRYDE

QUESTION 1.

(a) Draw a schematic diagram showing the speech path and private wire circuit conditions from the CALLING to the CALLED telephone on a call from a 2000 type main exchange to one of its branch exchanges, also 2000 type. Assume a six-digit network.

Designate switches and relay sets in the train and show the wipers, relays, retards, capacitors and rectifier in the speech path in the "call answered" condition.

Contacts in the speech path need not be shown.

Show sufficient detail in the private wire circuit to indicate how the call is held.

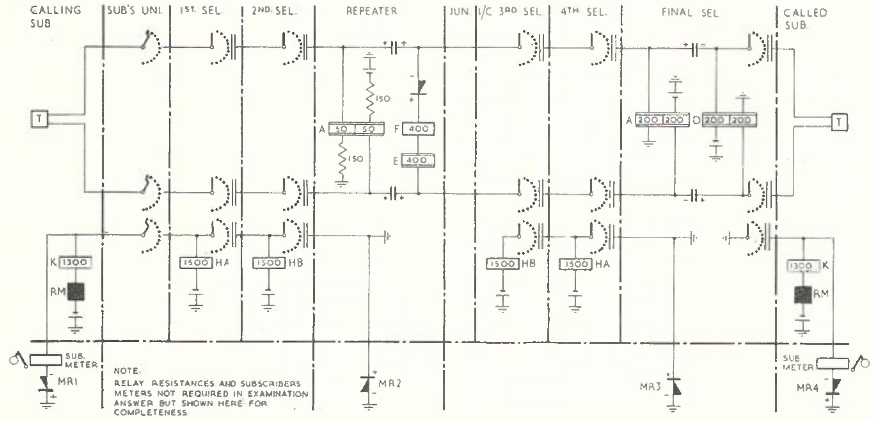
(b) Explain briefly what happens to the connection if—

(i) The CALLING party but not the CALLED party clears;

(ii) The CALLED party but not the CALLING party clears.

ANSWER 1.

(a)



NOTE.
RELAY RESISTANCES AND SUBSCRIBERS METERS NOT REQUIRED IN EXAMINATION ANSWER BUT SHOWN HERE FOR COMPLETENESS.

(b) (i) When the **calling party** clears, the earth on the P-wire is removed for the duration of the "blink" period and is re-applied to the P-wire until the final selector restores to normal. The D relay in the final is held operated by the called party and the C.S.H. alarm operates. The "blink" period is provided to allow the selectors holding on the P-wire to release.

(ii) When the **called party** clears, the D relay in the final selector restores and the C.S.H. alarm is operated. The selector train to the final selector is held by the calling party.

QUESTION 2.

(a) Draw the trunking diagram of a 200-line R.A.X. comprising one "C" unit and three "D" units.

In your diagram show relay sets for alarm extension and party lines.

(b) How is a permanent loop on a R.A.X. service prevented from holding common equipment indefinitely?

ANSWER 2.

(a) The question can be suitably answered by drawing the sketch shown in Telephony 5, Paper 8, Page 12, Figure 7, but leaving out details of equipment quantities and excluding public telephones and charge-over trunk line relay set.

(b) A permanent loop goes into line lock-out on the subscribers' line circuit.

QUESTION 3.

(a) Show, by simple schematic diagram, the speech path condition of the two cords used in a sleeve-control exchange to connect the following. (Details of relay and key contacts are NOT required).

(i) Trunk line to a local subscriber.

(ii) A trunk line to another trunk line.

(b) State briefly how 2VF signals, such as ring forward and answer signal, pass from an incoming 2VF relay set to an outgoing 2VF relay set when these relay sets are connected via—

(i) A sleeve-control manual switchboard cord circuit;

(ii) A transit selector.

(c) When four-wire amplified trunks with 2VF signalling are switched together via a motor-uniselector, a "tail-eating" or "tail-chasing" connection is usually established.

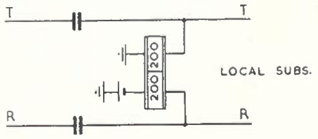
Show by a simple diagram the essential features of the connection between the hybrid coils of the two trunk lines so switched.

Details such as relay contacts, capacitors, retards and control leads, etc., are not required but clearly designate relay sets and switch wipers. The hybrid coils can be indicated by a square marked HYB.

ANSWER 3.

(a)

(i)

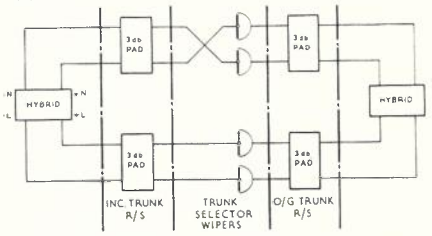


(ii)

(b) (i) The VF signals are relayed from the incoming to outgoing relay sets as DC signals over the T and R of the cord circuit.

(ii) The VF signals pass straight through from the incoming to outgoing trunk relay set unhindered and without conversion.

(c)



QUESTION 4.

(a) You are in charge of technicians engaged on sub-station installation work. List the aspects you would ask them to keep in mind in the course of their duties to ensure that a good impression is made on the public.

(b) On what order forms and authority can sub-station installation work be undertaken?

ANSWER 4.

(a) (i) No entry into the premises should be made unless the owner gives his consent.

(ii) Use a minimum number of men on the job or do the job as quickly as possible.

(iii) Have all equipment and apparatus available before proceeding to the job.

(iv) Keep tool kit tidy and in good order. Replace broken tools.

(v) Leave premises clean and tidy at the completion of the job or at the end of each day.

(vi) Wires and furnishings must not be dirtied or defaced.

(vii) Avoid temporary and incomplete work on small jobs.

(viii) Do not leave Departmental apparatus on the premises for lengthy periods after the completion of the job.

(ix) Forms and documents used in the subscribers' premises should be clean and tidy.

(x) Workmanship should be of a high standard and be neat and tidy in execution.

(xi) Keep personal appearance neat and refrain from using slang terms when speaking.
(xii) Be helpful to the subscriber and comply with his wishes where possible.
(xiii) Explain the use of the service to the subscriber and how he may lodge a complaint if the service is not working satisfactorily.

(b) (i) Telephone order.
(ii) Minor or Major works authorities —Recoverable works order.
(iii) Tel. 40 and similar (on the job alteration requested by the subscriber and confirmed by Telecom. Div.).
(iv) Service order docket (rewiring or replacement of defective apparatus).

QUESTION 5.

(a) List the functions of the Anti-Side Tone Induction Coil in a telephone.

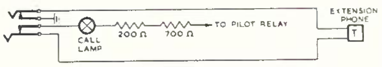
(b) Show by simple schematic diagrams the following circuit conditions for a standard lamp signalling C.B. P.B.X. switchboard. (Details of relay and key contacts are NOT required.)
(i) Extension calling the switchboard.
(ii) The speech path for an extension-to-extension call.
(iii) The speech path for an exchange-to-extension call.
(iv) Operator dialling an exchange call.

ANSWER 5.

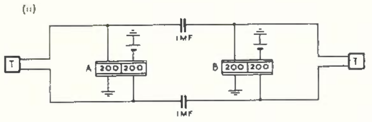
(a) (i) Match transmitter to line when sending.
(ii) Match receiver to line when receiving.
(iii) Reduce side tone level in the receiver to acceptable value when speaking.

(b)

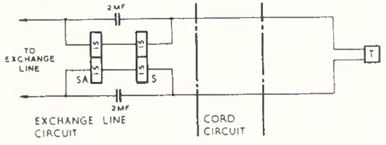
(i)



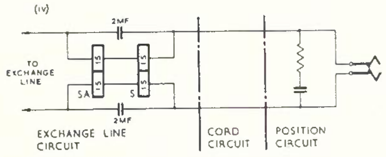
(ii)



(iii)



(iv)



QUESTION 6.

(a) List, in correct order, the adjustments and checks which are required on a red label relay. (Details of tolerances and adjustment values are NOT required.)

(b) What are—
"Test values" and "Re-adjust current values" as applied to red label relays?

(c) What do the following symbols mean on a relay label?—(5) 3N1

(d) What is —
(i) Relay "armature climbing"?
(ii) A simple cure for "armature climbing"?

(e) For what special purpose are platinum contacts used on a 3000 type relay and how are they easily identified?

(f) What two mechanical adjustments can be made on a slow release 3000 type relay to increase its release lag?

ANSWER 6.

(a) (i) Springs straight.
(ii) Springs tension correctly.
(iii) Residual screw projection.
(iv) Armature stroke.
(v) Contact clearance and overlap spring lift buffer block.
(vi) Current tests applied (Note that (i) and (ii) can be done after (iii) and (iv) but (iii) must be done always before (iv).)

(b) (i) The "test" current value is applied to the relay to determine if "re-adjustment" is necessary.
(ii) The re-adjust current test is used for checking the relay after it has been re-adjusted (Note lever spring tensions are adjusted to comply with the current test but in no circumstances should the lever spring tension be less than 10 grams).

(c) (i) The residual is 5 mil but it has more **restricted tolerances** than normal.
(ii) There are three nickel iron sleeves on soft iron relay core.

(d) (i) Armature climbing refers to the armature of an impulsing relay moving off its knife edge while repeating pulses.
(ii) This fault can be cured by using an armature retaining screw having a heavier spring tension (these screws were identified by a red paint on the end of the screw, however, 3000 type relays supplied in the last couple of years have had heavier retaining screws as standard equipment.)

(e) (i) Platinum is used for contacts which make or break high current circuits (approximately 1 to 1½ amps).
(ii) Platinum contacts are identified by two V shaped nicks at the end of a relay spring. (Note one nick indicates Paladium contact material, only found in rare use in pre-2000 type equipment in the A.P.O.)

QUESTION 7.

(a) Four typical difficulties encountered in an exchange are listed below. Assume that you are advising a technician what is the most likely fault he will find, and against each state what you would tell him to look for. (A typical answer would be "no ring-tone on a final selector on 43 20 board".)
(i) A subscriber in the 51 main exchange calls 51 3421 and gets 51 3521.
(ii) A subscriber in the 51 main exchange calls 53 9429 and gets 53 3942.
(iii) A subscriber in the 62 exchange calls 62 2961 but gets 2 2961.
(iv) A main exchange subscriber complains that he frequently cannot break dial tone.

(b) What is the service effect of an open-circuit positive or negative trunk encountered by—
(i) A non-homing uniselector.
(ii) A homing uniselector.
(iii) A 2000 type group selector.
(iv) An SE group selector.

(c) A group selector has failed to release on the completion of a call. What will be the effect on traffic if the selector is—
(i) A local selector.
(ii) An incoming selector.

ANSWER 7.

(a) (i) A fourth selector in the 53 stage group over stepping one step.
(ii) An incoming third selector in the 53 branch exchange held-up on level 3.
(iii) A local first selector or DSR in the 62 exchange dropping-out on level 6.
(iv) A local first selector failing to move off normal.

(b) (i) The uniselector steps on the outlet and its L and K relays chatter —call is no progress.
(ii) Uniselector passes over outlet—call is O.K.
(iii) The selector drops-out and no progress or wrong number results.
(iv) The selector steps over the outlet and the call is O.K.

(c) (i) No effect on traffic as the switch busies itself.
(ii) No progress or wrong number calls result when the proceeding repeater is received. It will not be busy to traffic.

QUESTION 8.

You have just taken charge of a new installation staff which is about to commence installing and placing in service some additional local group selector racks and switches.

(a) List the main precautions you would take throughout the work to reduce the dust hazard to working equipment. Do not include precautions which should already be taken by the maintenance staff.

(b) List the important precautions and instructions to staff that are necessary throughout the work to keep interruptions to service to a minimum.

(c) List the tests and checks on switches that should be carried out prior to commencement of regrading.

(d) What final over-all tests should be made on completion of the work on the grading?

ANSWER 8.

(a) (i) Unpack equipment outside switch room.
(ii) Do not store equipment in switchroom.

- (iii) Clean up rubbish at the end of each day.
- (iv) Do not make a workshop of the switchroom.
- (v) Do not leave covers off switches.
- (vi) Encourage staff to wear lint-free clothing or dust coats.
- (vii) Discourage smoking in the switchroom.
- (viii) Clean cable runways before working on them.
- (ix) Place dust sheets over existing equipment.
- (x) Clean equipment before bringing it into the switchroom (I.P.I. General C5010 refers).

(b)
- (i) Avoid working on trunks during heavy traffic.
- (ii) Ensure non-working outlets are busied out (SE50 selectors will step over open circuit trunks).
- (iii) Staff to avoid contacting tags on working circuits with loose busy wire, etc.
- (iv) Staff to be careful when working near common services distributions such as bus bars, dial tone supply, etc.
- (v) At the end of each day check all outlets on which work has been done.
- (vi) Staff to check working circuits for no conversation before removing it from traffic. (Use test set 26 to pre-busy circuits).

(c)
- (i) Check wiper and wiper-to-bank adjustments.
- (ii) Functional tests of selectors.
- (iii) Outlet testing from banks of new switches.
- (iv) Check release alarm in switches.

(d)
- (i) Test of outlets from all grading groups.
- (ii) Identify all outlets to see that the grading is as per grading diagram.
- (iii) Check with the test set 17 or an outlet tester that trunks are not commoned or crossed.

Contributions and Letters to the Editors

may be addressed to:

the State Secretaries or the General Secretary at the following addresses:—

The State Secretary,
Telecommunication Society of Australia,
Box 6026, G.P.O., Sydney, N.S.W.
Box 1802Q, Elizabeth St. P.O., Melbourne, Vic.
Box 1489V, G.P.O. Brisbane, Qld.
Box 1069J, G.P.O. Adelaide, S.A.
Box T1804, G.P.O., Perth, W.A.
Box 246C, G.P.O. Hobart, Tas.

The General Secretary,
Telecommunication Society of Australia,
Box 4050, G.P.O. Melbourne,
Victoria, Australia.

Agent in New Zealand: E. C. Cheyne, c/o Engineer-in-Chief, G.P.O., Welllington, C.1.

Agent in Europe: P. S. Bethell, B.Sc., Dip.P.A. Australia House, Strand, London, W.C.2, England.

ADVERTISING

All Enquiries to:

Ruskin Publishing Pty. Ltd.
39 Leveson Street,
North Melbourne, Victoria.
Telephone: 30 1207

Revenue

The total net advertising revenue is paid to the Telecommunication Society of Australia whose policy is to use such funds for improvements to this Journal.

Contract Rate

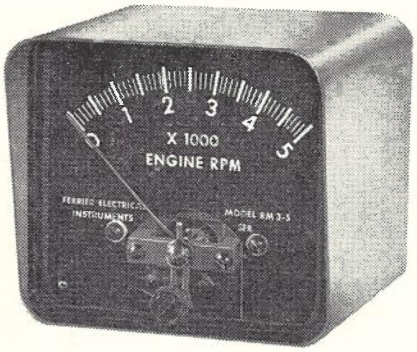
Space used in any three consecutive issues.
Full Page, black and white, £42 per issue.
Half Page, black and white, £26 per issue.
(horizontal only.)

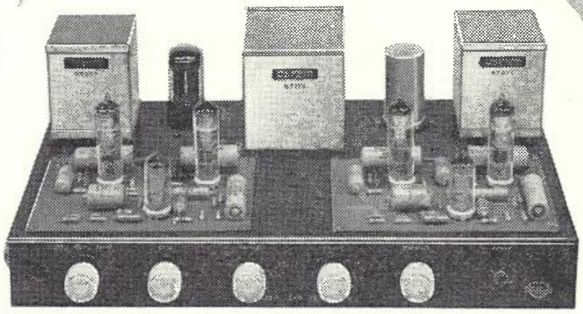
Casual Rate

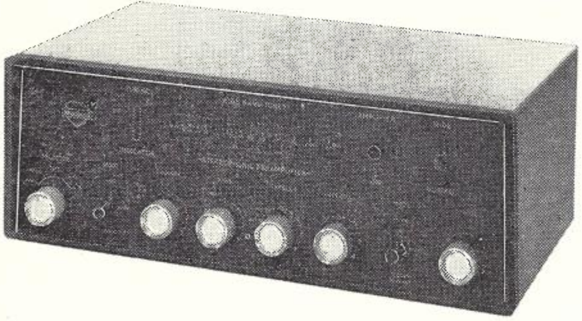
Contract rate, plus 10%.

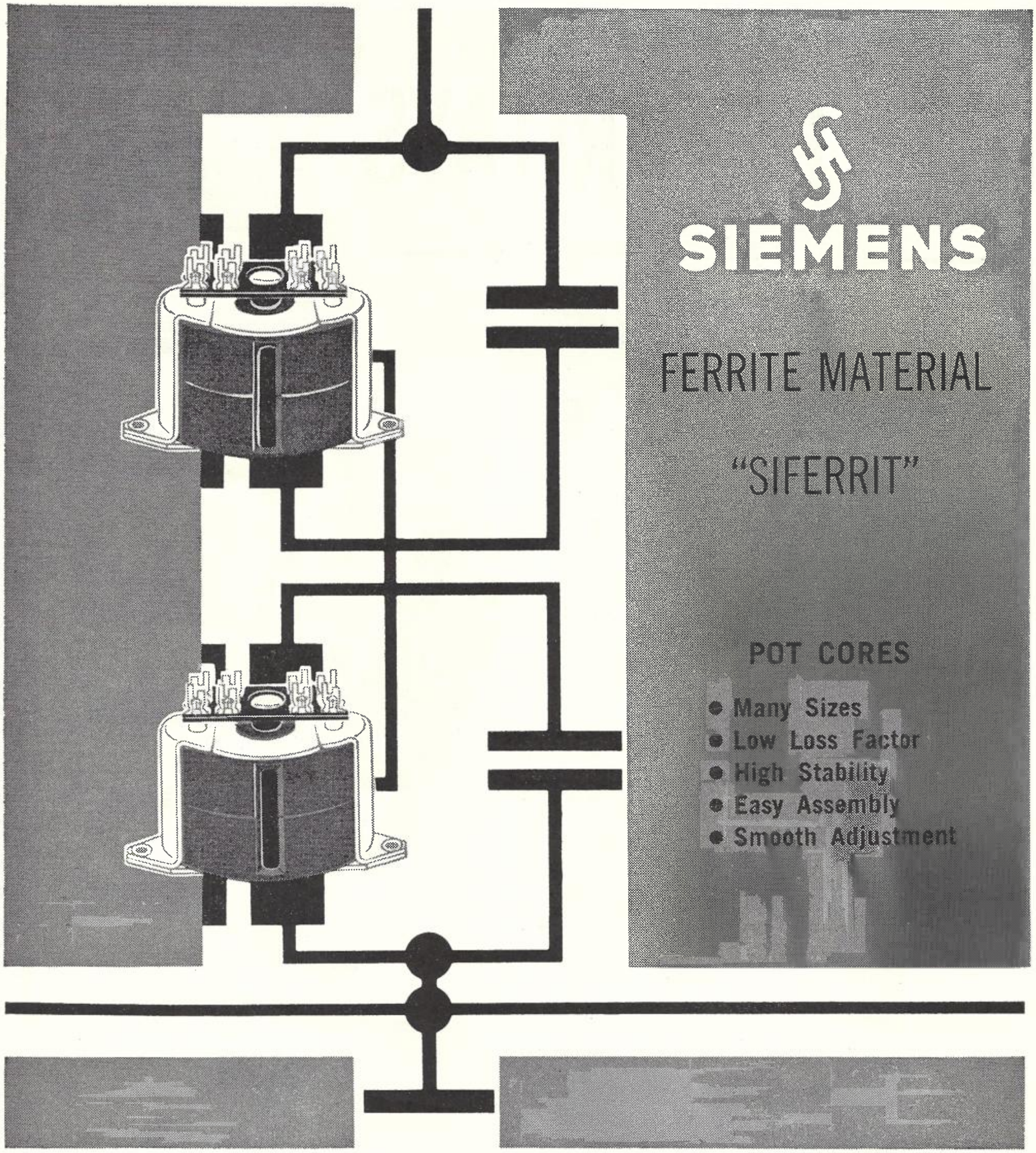
Copy Deadline

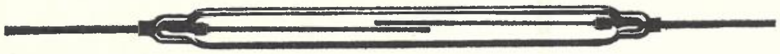
1st January, 1st May, 1st September.
Published three times each year.

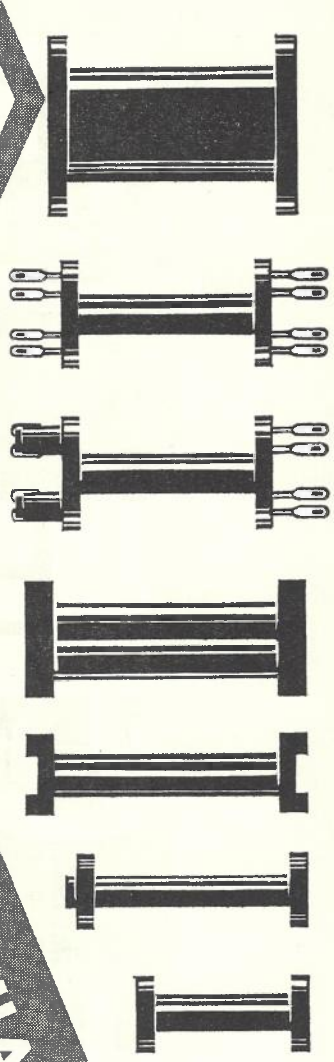

0
1
2
3
4
5
X 1000
ENGINE RPM
FERRIED ELECTRICAL INSTRUMENTS
MODEL RM 3-5

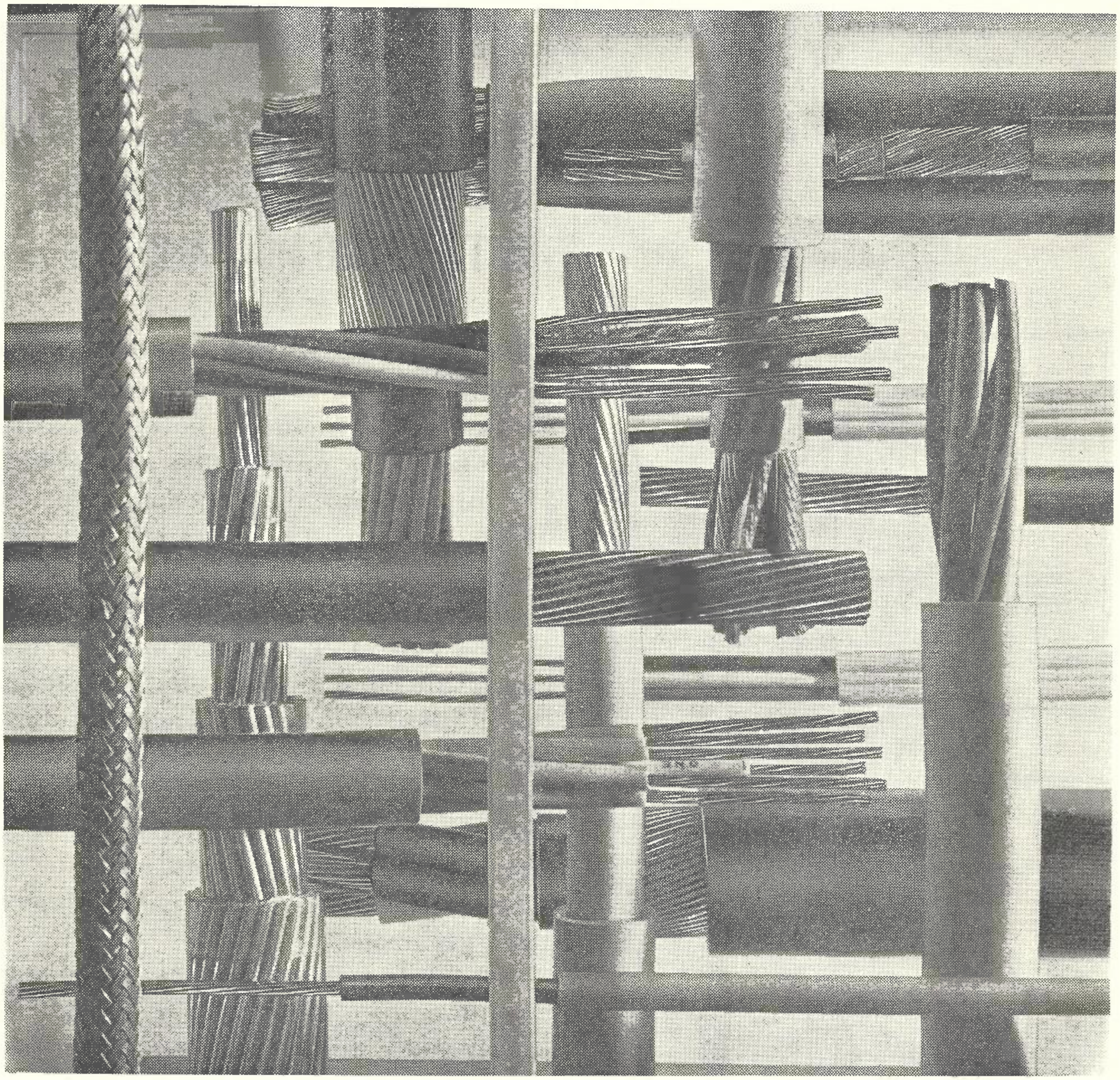


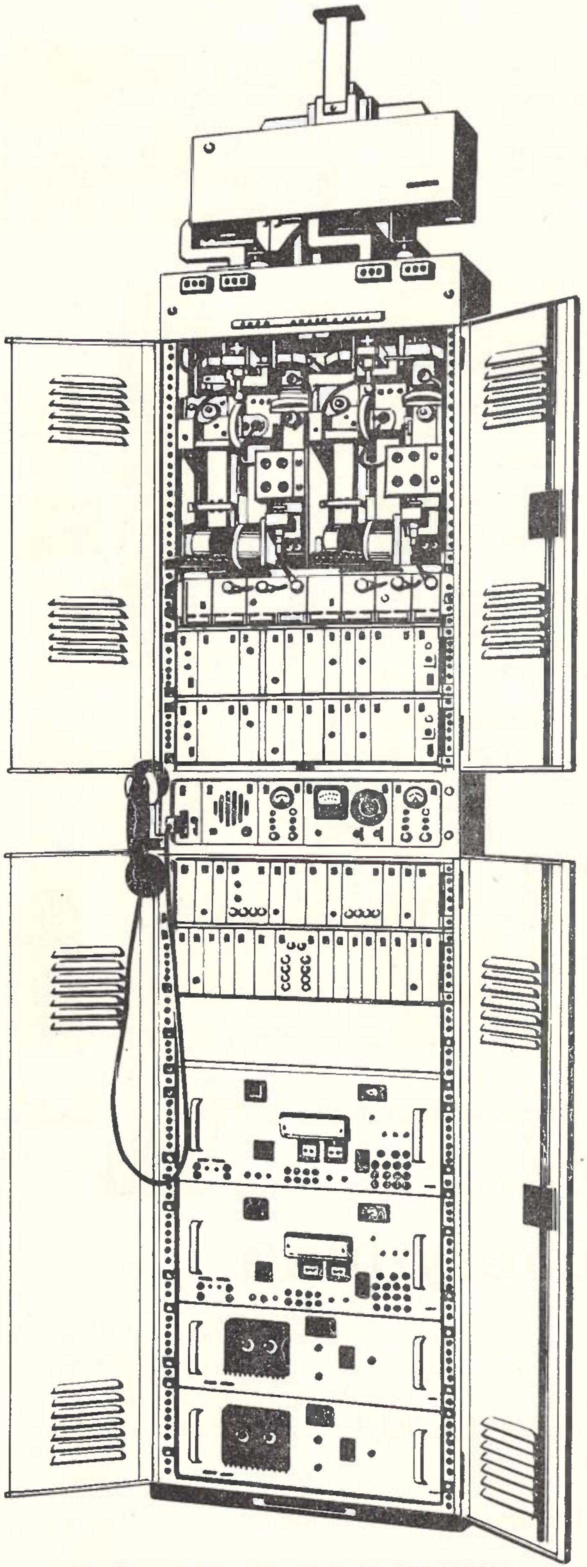



SIEMENS
FERRITE MATERIAL
"SIFERRIT"
POT CORES
Many Sizes
Low Loss Factor
High Stability
Easy Assembly
Smooth Adjustment



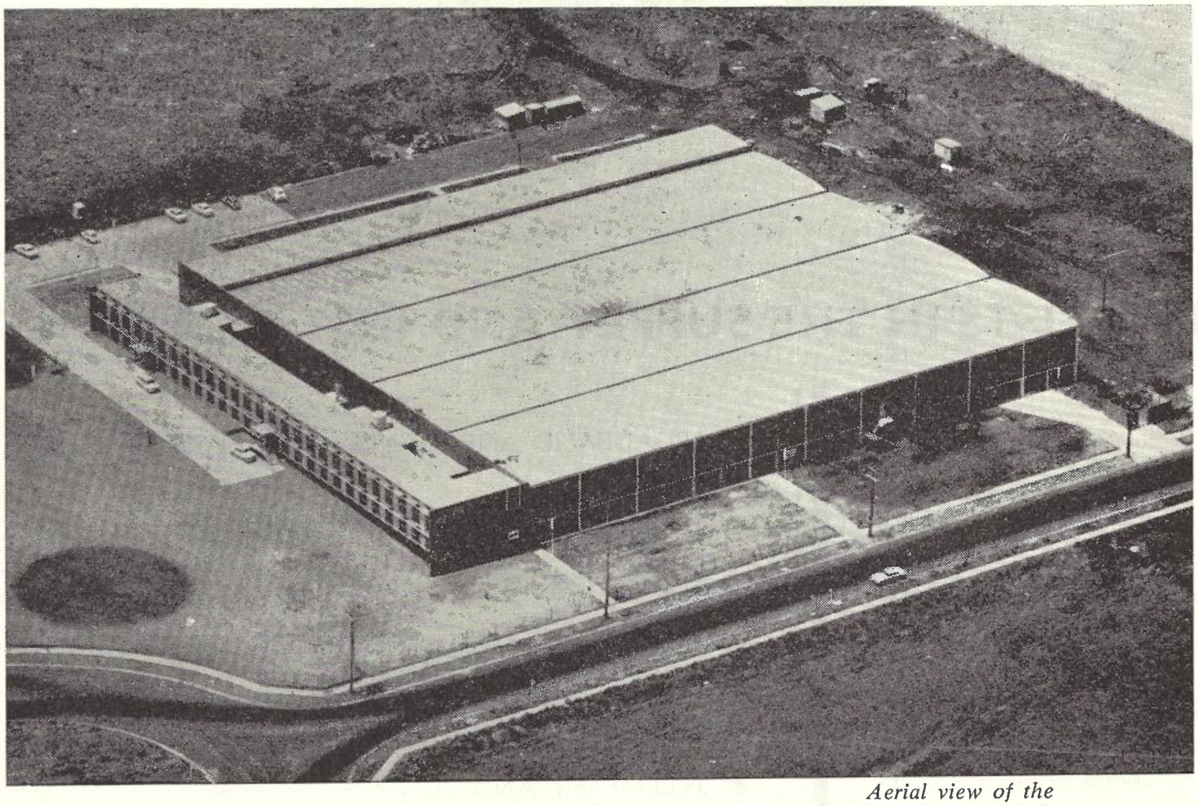






FK-71-T TYPE RADIO EQUIPMENT

NEW FACTORY ESTABLISHED . . .



Aerial view of the Broadmeadows plant

With the official opening of the new factory at Broadmeadows, Victoria, on 6th December, 1963, L M Ericsson Pty. Ltd. expanded into large-scale Australian production of Crossbar switching equipment for public and private exchanges. Backed by the technical resources and the 88 years' experience of L M Ericsson in Sweden, this plant is a major contribution to the development of the telecommunication industry in Australia.

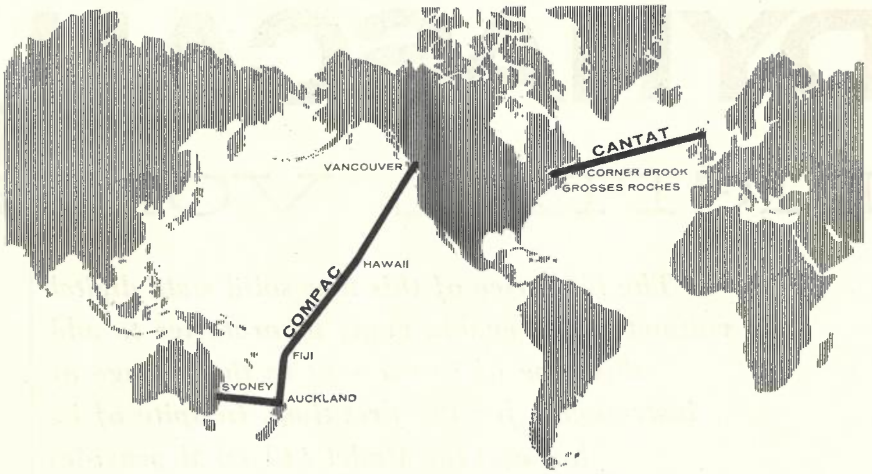
L M Ericsson, a world-wide organization with about 42,000 employees, operates in more than 80 countries through associated Companies or agents. World headquarters in Stockholm, Sweden.

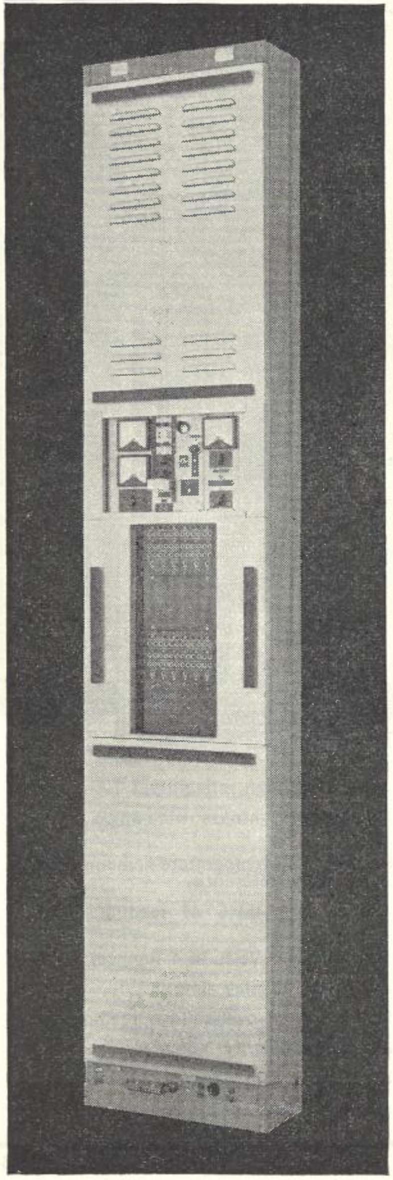
L M ERICSSON PTY. LTD.

20 COLLINS STREET,
MELBOURNE, VIC.

182 BLUE'S POINT RD.,
NORTH SYDNEY, N.S.W.

AEI with world-wide experience in communications and well-known for its contribution to the success of CANTAT B and COMPAC in the Commonwealth Cable Link, introduces a further addition to its range of carrier transmission equipment.





AEI

Transistorised FMVFT

TYPE CT 24A

For the provision of teleprinter or data transmission circuits.

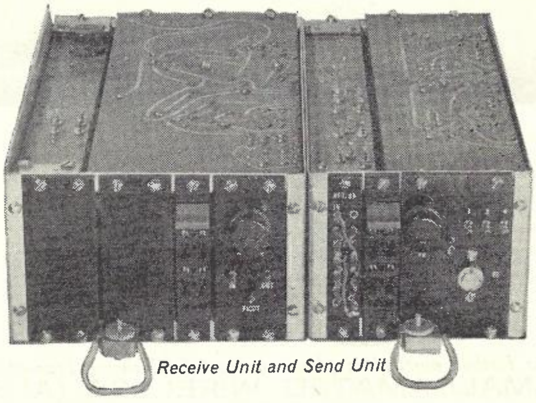
Minimum space . . . Minimum maintenance . . .
Minimum power consumption . . .

- ✳ CCITT standards of performance
- ✳ 24 channels per rackside
- ✳ 50 baud nominal, with operation up to 80 bauds
- ✳ Plug-in units
- ✳ Pilot facility 300 c/s or 3300 c/s
- ✳ Optional in-built test equipment comprising:—a) Telegraph test set
  - b) Level measuring set
  - c) Frequency check unit
- ✳ Completely self contained with all power supplies.

24 frequency modulated channels are provided in the nominal frequency band 420-3180 c/s with 120 c/s separation between adjacent channels. These are built up from 4 sub-groups of 6 channels each in the frequency band 1140-1740 c/s.

Compactly assembled plug-in units use printed circuit wiring boards with small encapsulated filter and transformer units. Equipment is protected by bay covers, but test equipment and jackfields are directly accessible at centre of rack.

Details of the latest AEI Carrier Telephone and Telegraph Equipment supplied on request.



Receive Unit and Send Unit

AEI

Associated Electrical Industries Ltd
TRANSMISSION DEPARTMENT
Telecommunications Division Woolwich London SE18 England

AEI Engineering Pty. Ltd.
93 Clarence St., Sydney, N.S.W. 555 Bourke St., Melbourne, Victoria

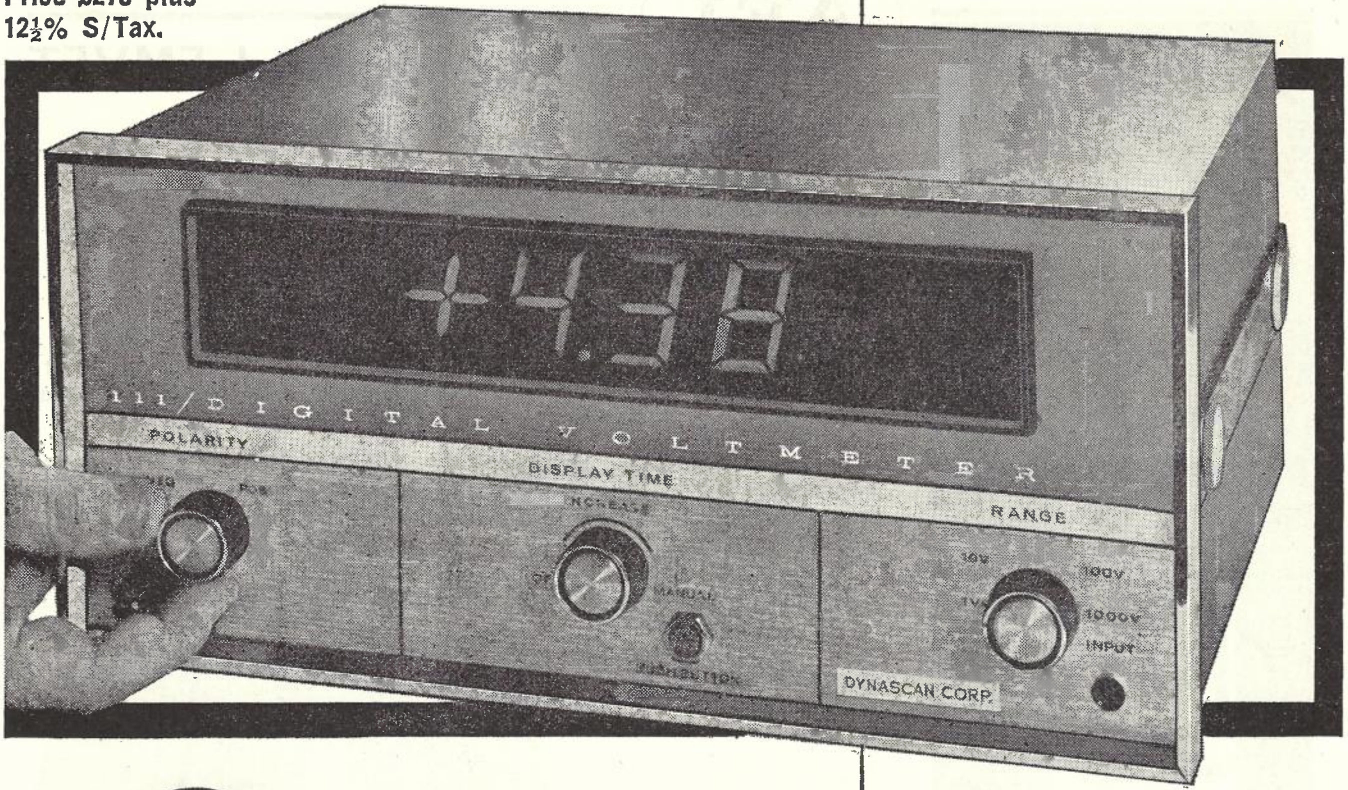
DYNASCAN

SOLID STATE

DIGITAL VOLTMETER

The low price of this new solid state digital voltmeter will enable many laboratories to add this type of instrument to their range of instruments for the first time. In spite of its low cost the Model 111 DVM provides laboratory standard type accuracy.

Price £270 plus
12½% S/Tax.



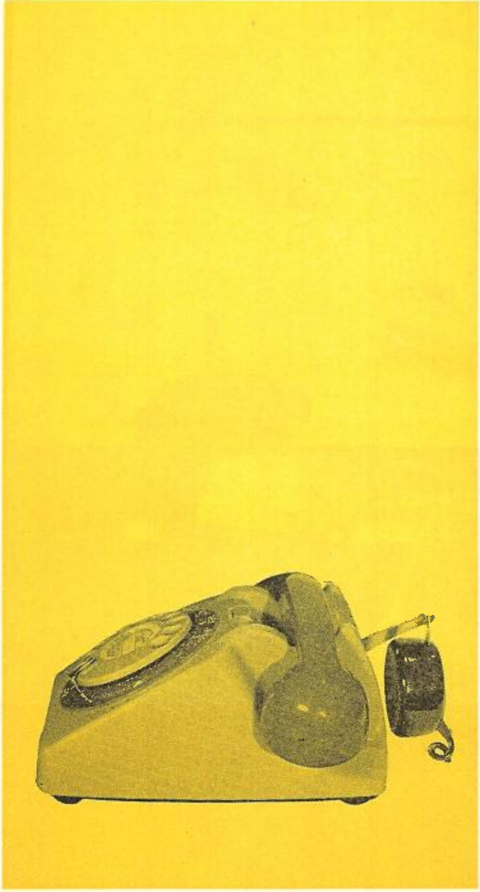
- Solid state high reliability.
- New high-brightness wide-angle read-out.
- Highly stable temperature-compensated zener diode reference.
- Accuracy ± 0.1% of reading, ± 1 Count.
- Reads 0-1,000 Volts in 4 Ranges.
- Adjustable display time.
- No erroneous over-voltage reading.
- Automatic polarity indicator.
- High input impedance.
- All-electronic.

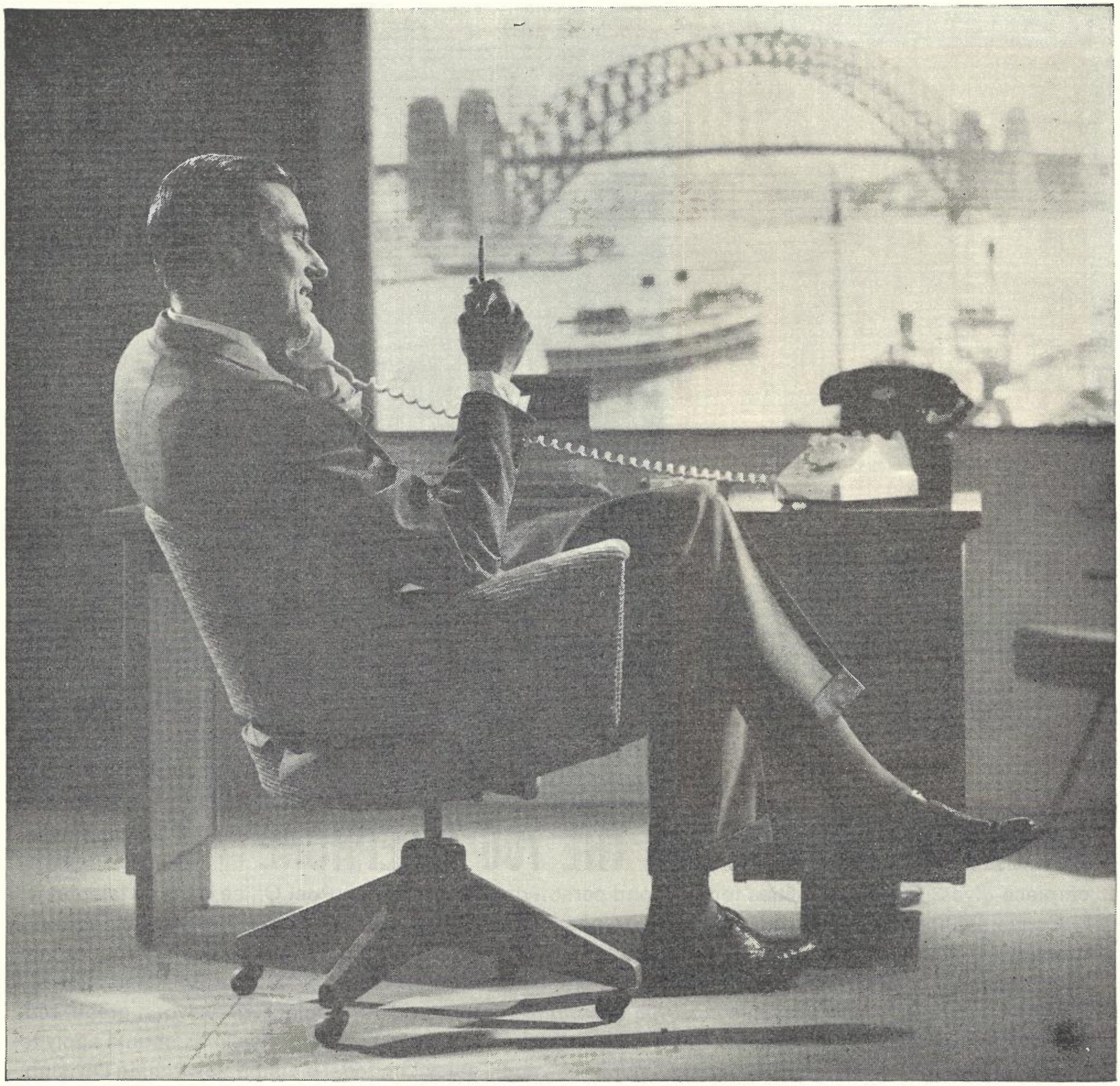
For further particulars please contact Engineering Products Divison.
AMALGAMATED WIRELESS (AUSTRALASIA) LTD.
HEAD OFFICE: 47 YORK STREET, SYDNEY. 2 0233

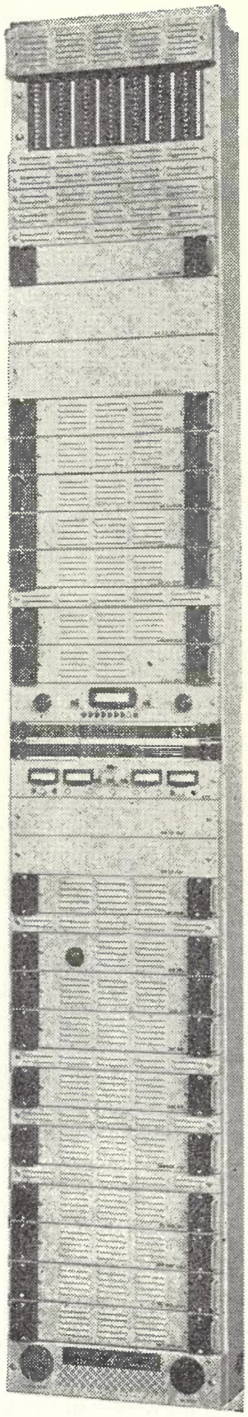
MELBOURNE	BRISBANE	PERTH	HOBART	LAUNCESTON	WELLINGTON, N.Z.
67 9161	4 1631	28 3426	3 3836	2 1804	43 191

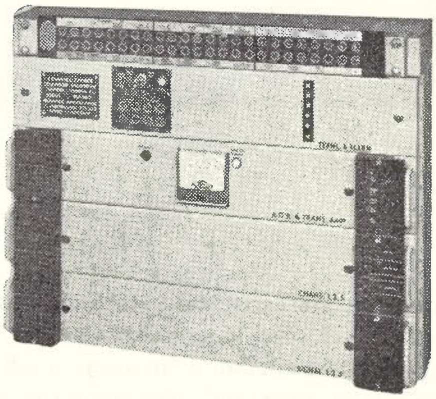
ADELAIDE: Newton McLaren Ltd., LA 0111.

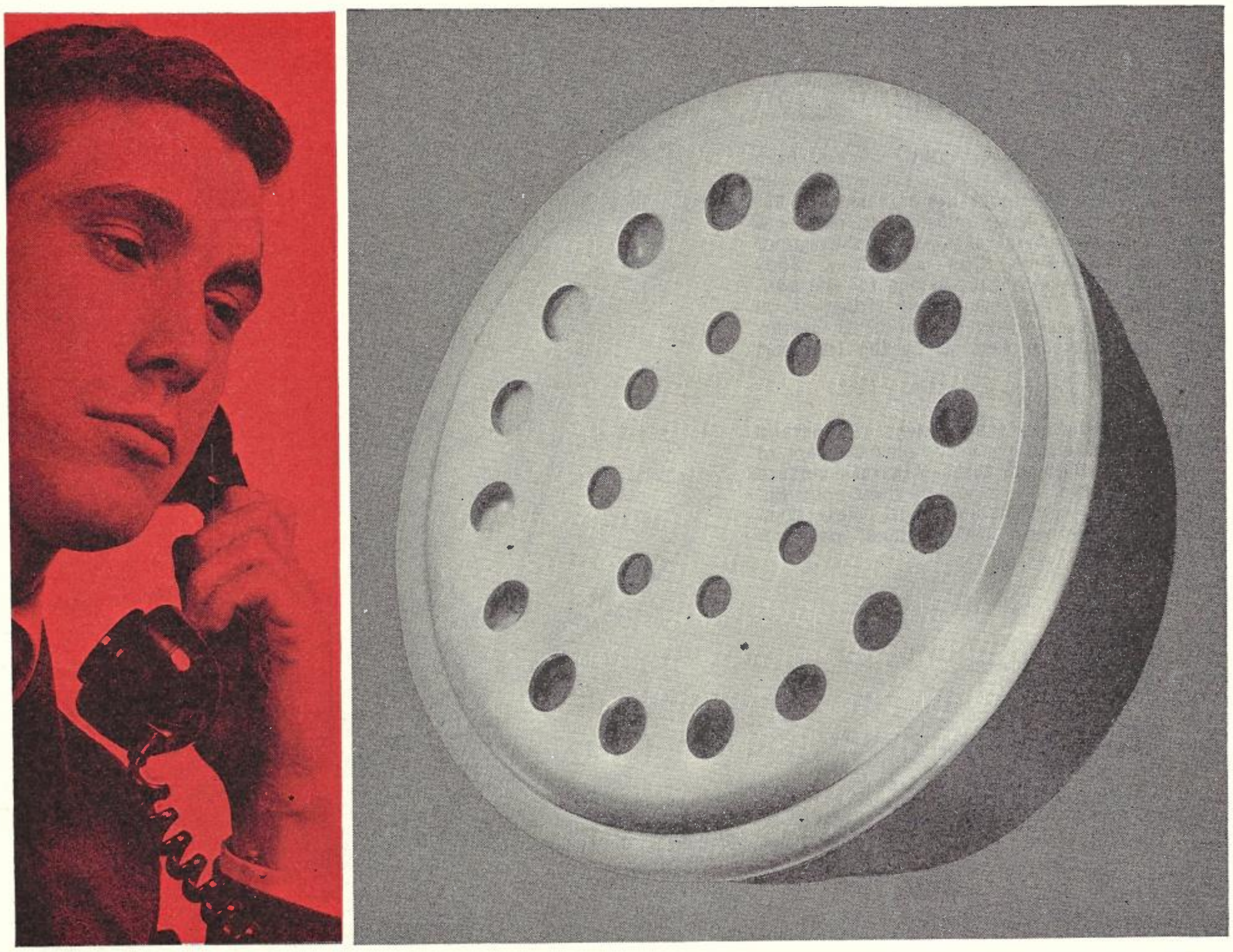
EP36-63











safe, sure communication

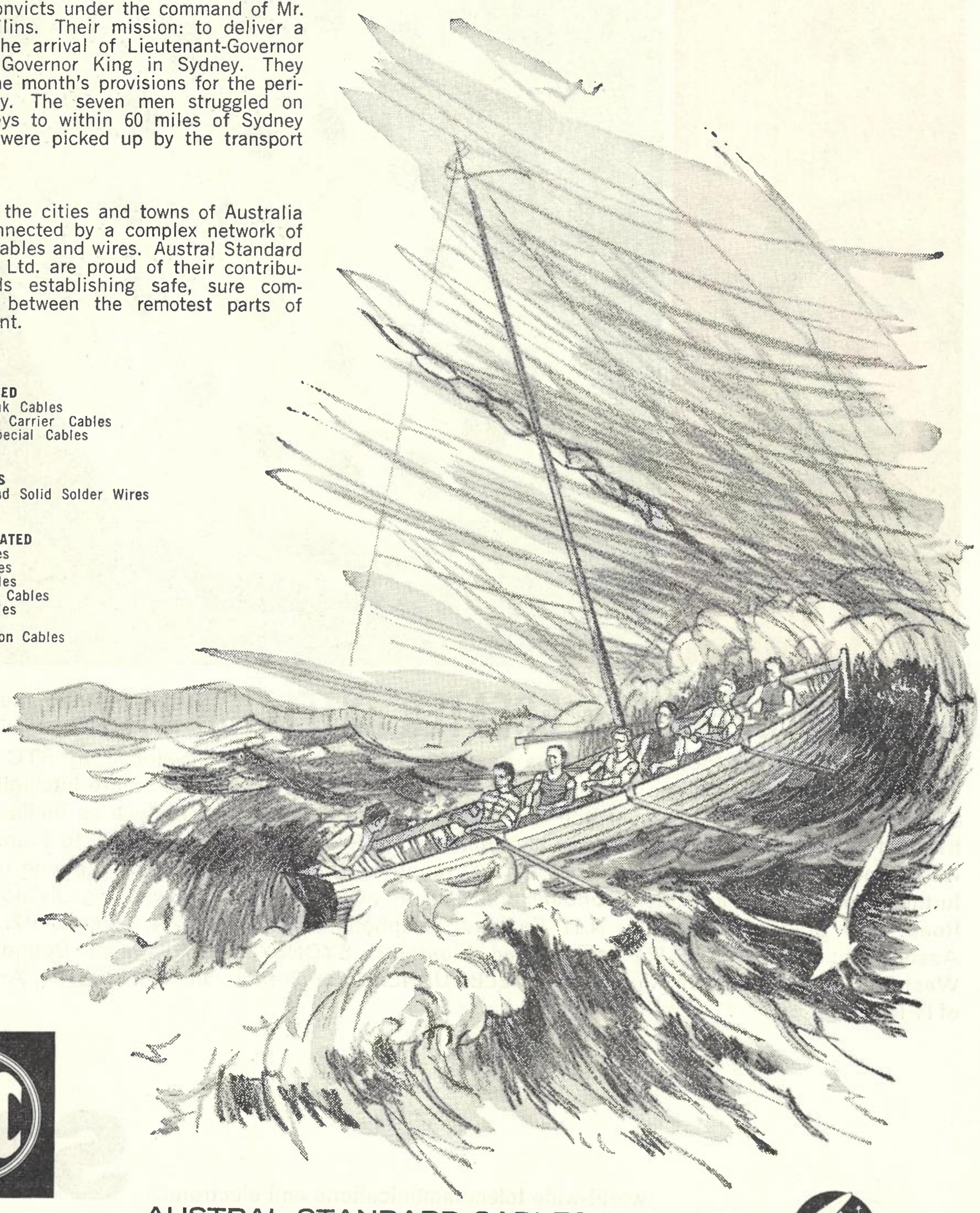
In 1803, a fragile six-oar cutter set sail from the tiny Port Phillip Bay settlement. Its crew: six convicts under the command of Mr. William Collins. Their mission: to deliver a report on the arrival of Lieutenant-Governor Collins to Governor King in Sydney. They had only one month's provisions for the perilous journey. The seven men struggled on for nine days to within 60 miles of Sydney when they were picked up by the transport "Ocean".

In 1963, all the cities and towns of Australia are interconnected by a complex network of telephone cables and wires. Austral Standard Cables Pty. Ltd. are proud of their contribution towards establishing safe, sure communication between the remotest parts of the Continent.

PAPER INSULATED
Local and Trunk Cables
Multi Channel Carrier Cables
Control and Special Cables
Coaxial Cables

LEAD PRODUCTS
Resin Cored and Solid Solder Wires
Lead Tube

PLASTIC INSULATED
Equipment Wires
Telephone Cables
Interphone Cables
High Frequency Cables
TV Lead-in Cables
Video Cables
Rural Distribution Cables
Coaxial Cables

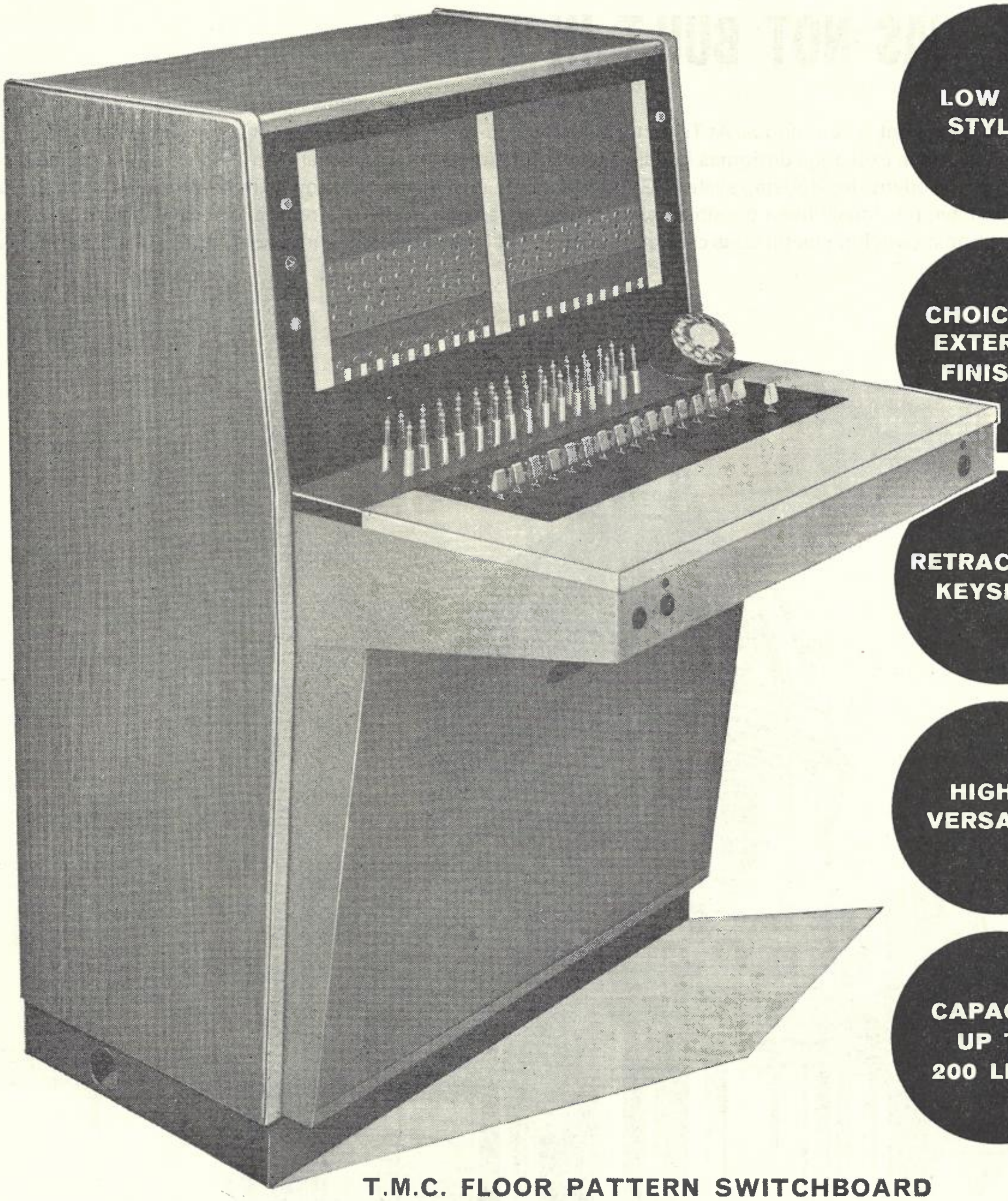


ASC
CABLES

AUSTRAL STANDARD CABLES PTY. LTD.
Makers of Australia's Telephone Cables
Works at: MAIDSTONE, VICTORIA and LIVERPOOL, N.S.W.

AUSTRALIAN MADE

8840




POSTMASTER-GENERAL'S DEPT.
EMI
PHILIPS
DH
PYE
STC
KRIESLER
HEALING
B.G.E.
AWA
TAA
For electronic components

SILICON
CONTROLLED RECTIFIERS

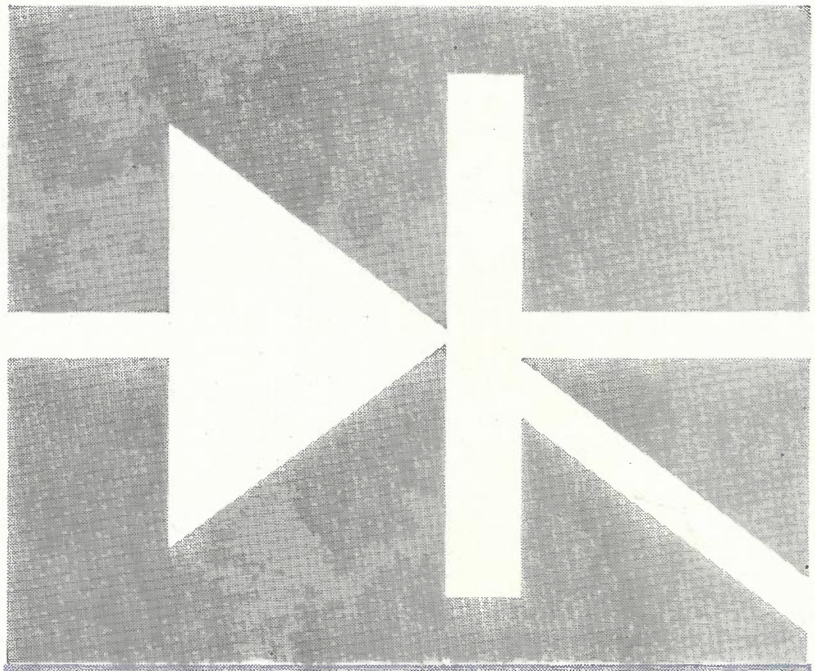
Now available in a wide range . . . and in

PRODUCTION QUANTITIES

Solid state control at low cost.

No maintenance an important feature

STC's range of "2SF" codings are pnpn-type silicon controlled rectifiers for use in power control or switching applications. The reverse characteristic is similar to a pn silicon rectifier, and the forward characteristic is such that it will block below the peak forward voltage if no gate signal is applied. When a gate signal is applied, it switches to the conducting state and presents a very low forward voltage drop similar to a silicon rectifier.



Silicon Controlled Rectifiers are available in the following ranges and voltages identified by each coding.

Rating	P.I.V. Coding	25	50	100	150	200	250	300	400
300 m.a.		—	2SF101	2SF102	2SF103	2SF104	2SF105	2SF105	2SF108
6.5 A.		2SF20	2SF11	2SF12	2SF13	2SF14	2SF15	2SF16	2SF18
11 A.		2SF30	2SF21	2SF22	2SF23	2SF24	2SF25	2SF26	2SF28
19 A.		2SF40	2SF31	2SF32	2SF33	2SF34	2SF35	2SF36	2SF38
55 A.		—	2SF111	2SF112	2SF113	2SF114	2SF115	2SF116	2SF118
80 A.		—	2SF120	2SF122	2SF123	2SF124	2SF125	2SF126	2SF128
300 A. Available shortly									

FEATURES OF STC SILICON CONTROLLED RECTIFIERS

- ★ **Low forward voltage drop during conducting state.**
- ★ **Low leakage current in both forward and reverse directions at high temperature.**
- ★ **Large power control with small gate power.**
- ★ **Wide range of allowable operating temperatures.**
- ★ **Quick response.**
- ★ **Stable operation and long life.**
- ★ **Compact, light weight.**

The Industrial Products Division of STC can supply either the device or the complete equipment incorporating Silicon Controlled Rectifiers. In addition, engineering advice is available to assist in applying the wide range of S.C.R.'s offering. Its research facilities are at present engaged in the development of a complete range of equipment using Silicon Controlled Rectifiers for inverter/converter equipment up to 25 kVA, both 3 phase and single phase.

For further information on STC Silicon Controlled Rectifiers contact Industrial Products Division

Standard Telephones and Cables Pty. Limited

SYDNEY • MELBOURNE • BRISBANE • CANBERRA

Distributors:

S.A.: Unbehaun and Johnstone Ltd., 54 North Terrace West, Adelaide. **W.A.:** M. J. Bateman Pty. Ltd., 12 Milligan Street, Perth. **TAS.:** W. & G. Genders Pty. Ltd., Hobart, Launceston, Burnie, Devonport. **Newcastle:** Newcastle Automatic Signals Pty. Ltd., 116 Lawson Street, Hamilton.

S162

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