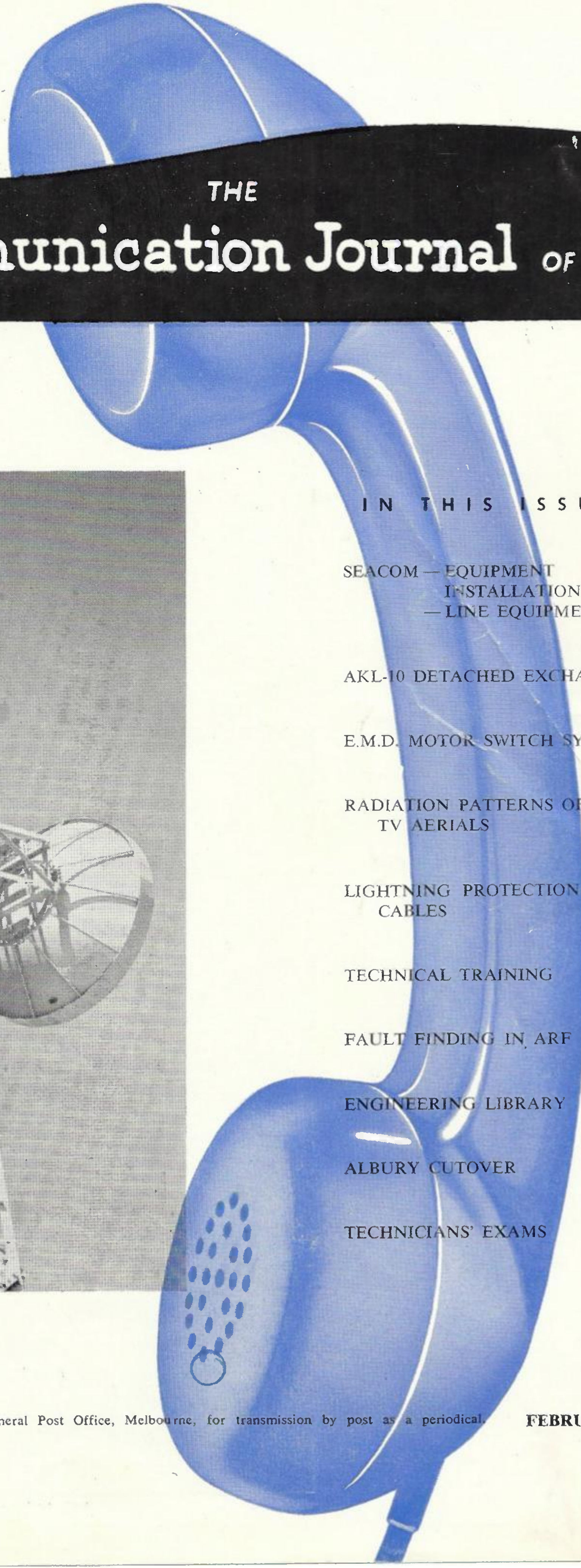
THE

Telecommunication Journal OF AUSTRALIA



IN THIS ISSUE

VOL. 16, No. 1 Registered at the General Post Office, Melbourne, for transmission by post as a periodical. **FEBRUARY, 1966**

WHERE SOUNDS ARE RARELY HEARD

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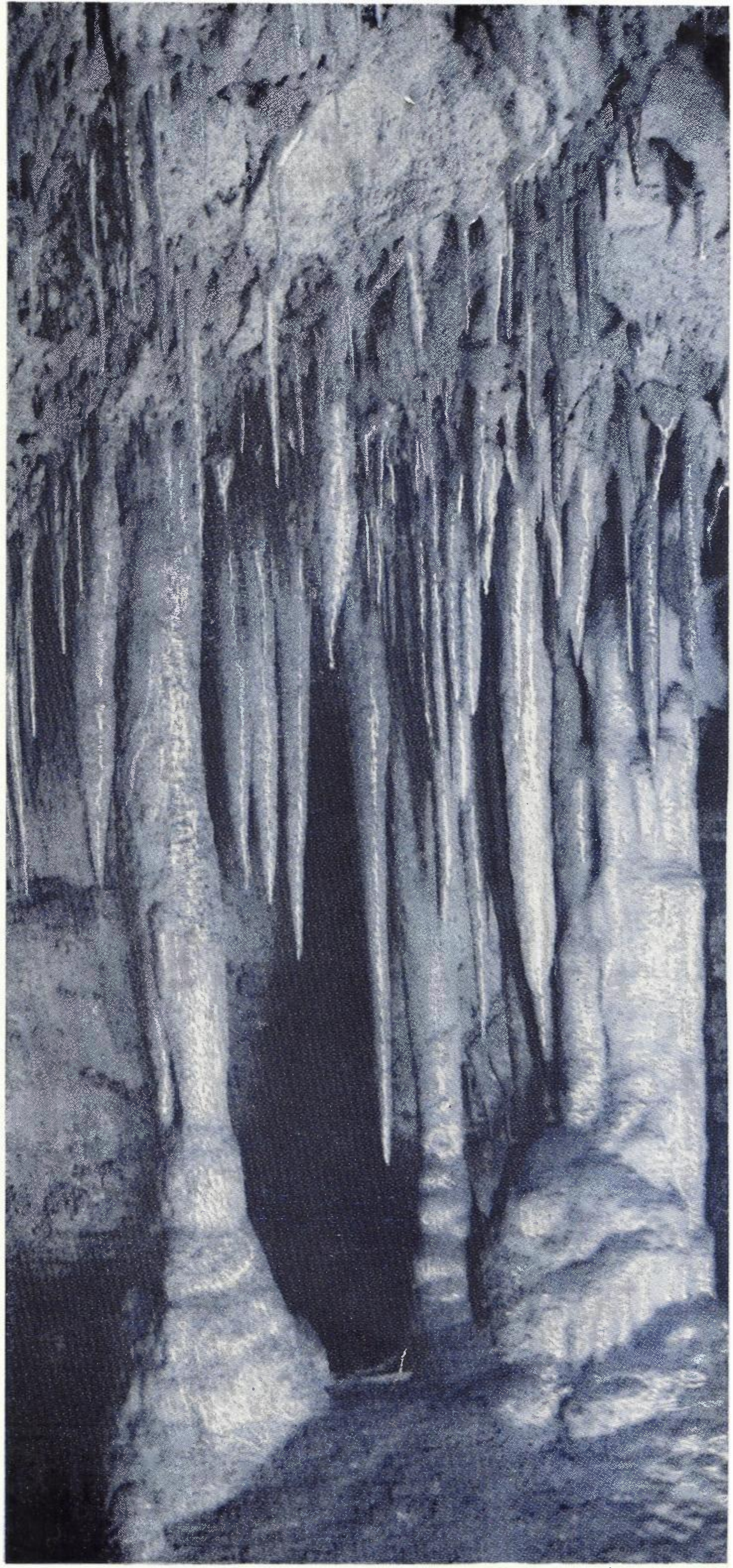

"Photo by courtesy of New South Wales Dept. of Tourist Activiti

The
TELECOMMUNICATION JOURNAL
of Australia

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CONTENTS

The Journal is issued three times a year (in February, June and October) by the Telecommunication Society of Australia. Commencing with Volume 15, each volume comprises three numbers issued in one calendar year.

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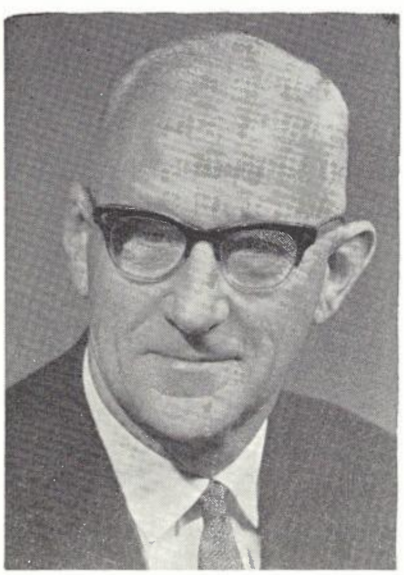
*For addresses see page 91

DIRECTOR - GENERAL — NEW APPOINTMENT

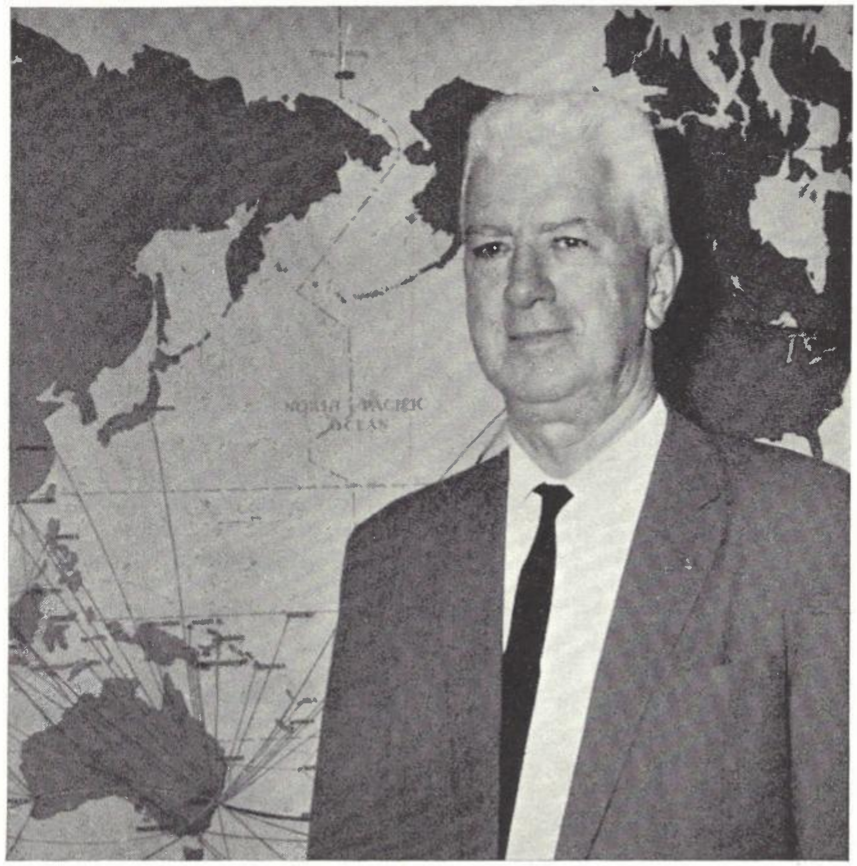
F. P. O'Grady, C.B.E., retired from the position of Director-General, Posts and Telegraphs, on 8th December 1965, after a career of many outstanding achievements. The Society owes much to his efforts and interest and takes this opportunity to record its appreciation and to wish him well in his retirement.

Mr. O'Grady has always been in the forefront of new developments and throughout his career, he has achieved a reputation for making notable contributions in all fields of telecommunications and in particular the fields of transmission and signalling. His last seven years at Headquarters as Deputy Director-General and Director-General served as a fitting climax to a career of this character. During this period, Mr. O'Grady guided the Department through a period of rapid technical development coupled with continuing heavy pressure of demand for new service and took a key part in the development of the National Telephone Plan, the introduction of a nation-wide network of broadband, coaxial and microwave systems, the national television network, and the introduction of register controlled crossbar switching equipment and Subscriber Trunk Dialling. In addition, he has emphasised the importance of engineering and scientific research within the Department in the development of the national communications system and has taken a close interest in the developments in the field of satellite communications and their significance for the future.

A Member of the Institution of Engineers and a Fellow of the Institution of Radio and Electronics Engineers, he was given the honour of moving the vote of thanks to His Royal Highness, The Duke of Edinburgh, on the occasion of the first Dunrossil lecture in 1965.



Mr. F. P. O'GRADY, C.B.E.



Mr. T. A. HOUSLEY, C.B.E.

Mr. O'Grady's knowledge, understanding and patience have endeared him to his Post Office associates at all levels. Although he is now enjoying a well earned retirement, the Society hopes that he will be available for many years to give members the benefit of his advice and guidance.

The Society welcomes the appointment of Mr. T. A. Housley, C.B.E., as the new Director-General, Posts and Telegraphs. Mr. Housley, formerly General Manager of the Overseas Telecommunications Commission (Aust.), has also taken an interest in the Society's affairs. A leading figure in international communications, he was the Convenor of the Pacific Cable Management Committee, which undertook the provision of the COMPAC cable now in operation, and the SEACOM cable which is being installed. He has also been the Australian representative on the Interim Communication Satellite Committee and a member of many delegations affecting Australia's communication interests.

Mr. Housley, whose earlier service was with the Post Office and the Department of Civil Aviation, is a Bachelor of Science and a Member of the Institution of Engineers. He joined the Department in 1926 and as Engineer and Divisional Engineer he was associated with extensive radio and general telecommunications installations in Queensland, New Guinea and the Pacific Islands. During the war period 1939-45, he controlled large works in these areas and organised radio installations for the Navy. In 1946 he transferred to the Department of Civil Aviation and in 1951 was appointed to the O.T.C.

The Board of Editors congratulates Mr. Housley on his appointment and on behalf of the Telecommunication Society of Australia, offers him full support in the work that lies ahead.

SEACOM: SITE DEVELOPMENT AND EQUIPMENT INSTALLATION ASPECTS

*V. J. Griffin, A.M.I.E. Aust., S.M.I.R.E.E. Aust.**

INTRODUCTION

This paper is the fifth, and a continuation, of the series dealing with the establishment of the Brisbane to Cairns microwave radio system which will provide a high capacity bearer for interstate trunk circuits, a TV bearer and an important link in the SEACOM Cable Project. The previous papers have dealt with the Overall Planning Aspects (Ref. 1), Transmission Performance Assessments (Ref. 2), Route Survey (Ref. 3) and Equipment Design (Ref. 4).

The physical aspects involved in the establishment of the radio bearer are dealt with in this paper, viz., the construction of roads and buildings and the installation of equipment. At the time of preparation of this paper in November 1965, all equipment had been installed, line-up and testing had been carried out to Mackay and was proceeding towards completion of the overall radio bearer by 28th February, 1966. A TV programme relay was introduced to service over the first section from Brisbane to Maryborough on 8th October 1965, when the National Television Station, ABWQ6, was opened at Mt. Goonaneman in the Maryborough district.

* Mr. Griffin is Engineer Class 3, Radio Section, Queensland. See Vol. 15, No. 2, page 161.

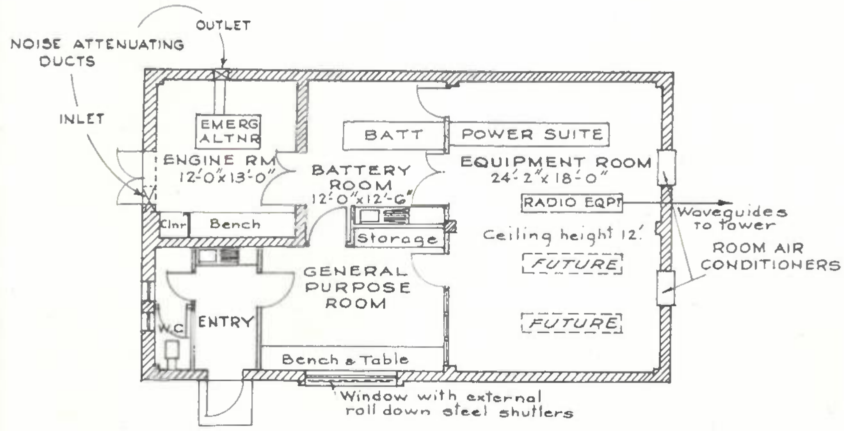


Fig. 2 — Floor Plan of Repeater Station.

ROADS

New road construction was required to 20 of the 30 stations north of Brisbane and improvements were required at a further two stations. The Commonwealth Department of Works and, in some cases, Consulting Engineers at a number of the provincial centres, designed the roads in accordance with specifications laid down by the Works Department. The Commonwealth Department of the Interior carried out a considerable amount of field survey work. The broader aspects of the road specifications were based upon the requirements of the Postmaster-General's Department with regard to traffic usage and reliability of access, modified as required to achieve acceptable road costs. For example, there are a number of areas along the main northern highway and along some secondary roads leading to various sites where traffic may be halted for hours or even days during periods of heavy and sustained rainfall. The new road construction provides a reliability of access at least in keeping with such existing and inescapable situations. However, the system maintenance proposals, which will be the subject of a subsequent paper, allow for staffing of such stations as required during the wet season to avoid even limited periods of isolation.

The mountain type road construction was carried out at 20 sites to a total distance of approximately 30 miles. The roads comprise a pavement 8 ft. in width having 4 ft. outer and 2 ft. inner shoulders. They were designed to achieve a ruling grade of 1 in 8, and a limiting grade of 1 in 6 was accepted for short straight sections. The pavement was covered with gravel to a depth of 6 inches and sealed to prevent longitudinal scouring. The design was commenced in July 1962 and proceeded quickly through to the tender and contract stage. Construction was first commenced in September 1963 and continued at such a rate that by Sep-

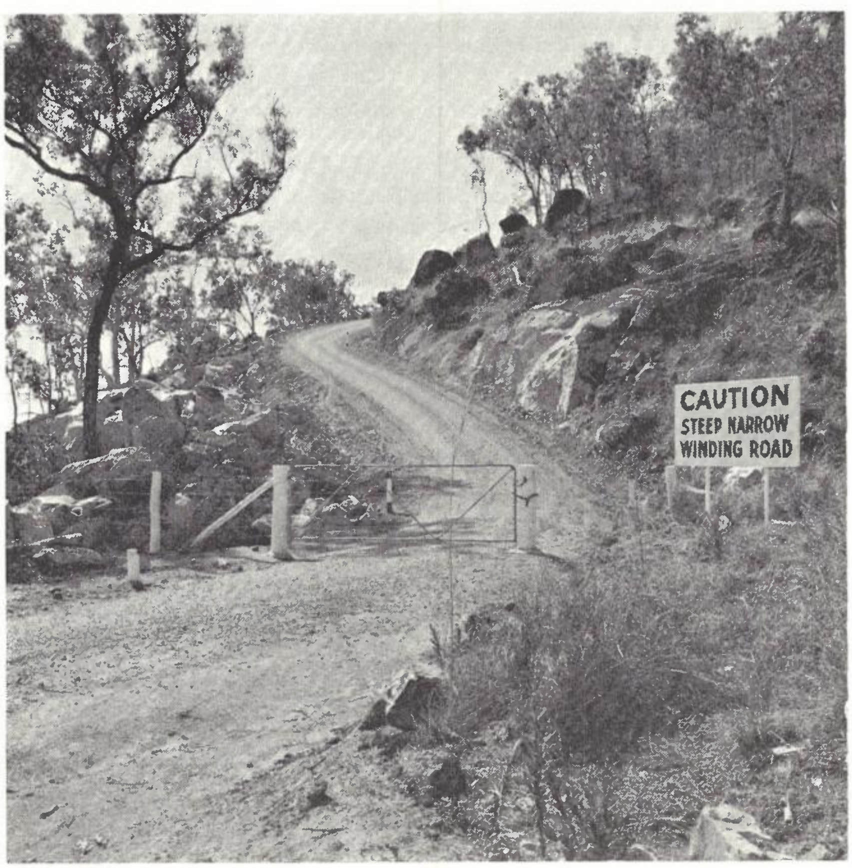


Fig. 1 — Entry to a Mountain Road.

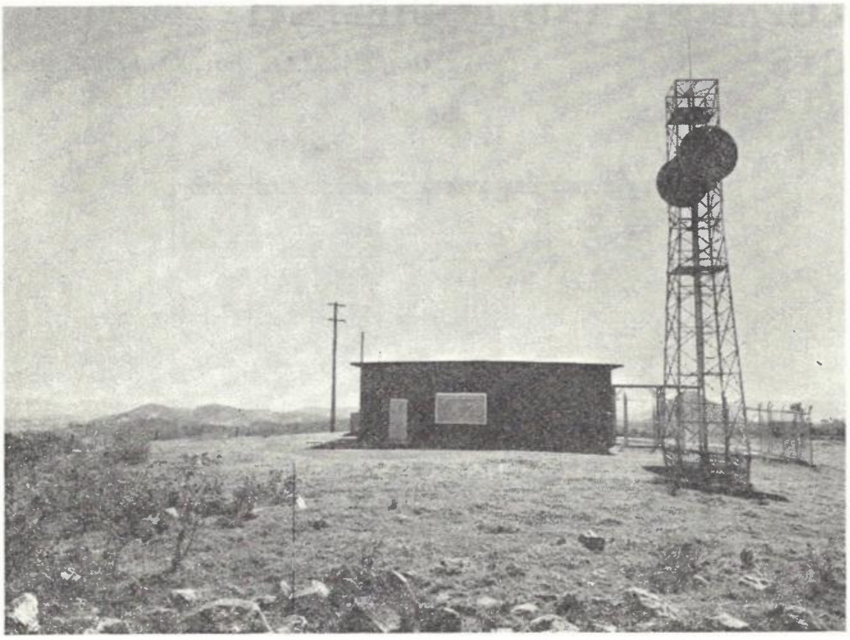


Fig. 3 — Typical Repeater Station.

tember 1964, 17 of the 20 new roads had been completed. Construction was carried out by the Commonwealth Department of Works, Shire Councils and Private Contractors. A typical access road is shown in Fig. 1.

BUILDINGS

An equipment building existed at Mt. Gravatt, the Brisbane radio terminal and 30 new buildings have been erected over the route to Cairns. Of these, 25 are unattended repeater stations, and 5 are to be staffed terminal stations, those at Maryborough, Rockhampton, Mackay Townsville being demodulating terminals. All buildings were designed by the Commonwealth Works Department to meet the requirements of the Postmaster-General's Department, and the former Department supervised construction which was carried out by various contractors.

Figs. 2 and 3 show the floor plan and the general appearance of the repeater type station. The building has a floor area of approximately 1,170 sq. ft., is rectangular in shape and measures 45 ft. by 26 ft. This building, of cavity brick construction, with a continuous galvanised sheet steel roof decking, has been designed as a maximum security structure having full protection to all windows and with steel sheeted external doors. Three R.S.J.'s provide the main roof support and steel rods are used to anchor each of these to the building walls at three points, to a depth of 16 brick courses. The roofing is fixed to steel purlins which are bolted to the R.S.J.'s. Fibreglass thermal insulating bats are laid upon the ceiling panels which are supported by a suspended aluminium grid. Accommodation has been arranged for an equipment room in which the power suite and radio equipment are installed, a battery room, a standby diesel-alternator room, a general purpose area, a lobby and toilet facilities. Work benches and storage cupboards have been provided as built-in units. Two 2 H.P. air conditioning units are wall mounted in the equipment room. The heat dissipation from the initially installed equipment is 1.4 KW and, although one unit is sufficient to maintain a suitable environment, the second has been provided as an on site spare unit. A picture window of fixed clear georgian wired glass in the general purpose area is protected by an external lockable steel roller blind. The air lock to the toilet area serves as a shower recess when staff are required to live at the station. Water supply is provided by a 1,000 gallon storage tank which is filled from the roof catchment.

With the exception of a few locations where the repeater stations are located in urban areas, the site boundaries are unfenced, but a man proof fence abutting the building encloses the tower. Overall site areas are approximately 6 chains by 5 chains, the whole of the area being cleared of timber and bush to minimise bush fire danger and damage from falling trees during cyclonic conditions. All repeater buildings are being fitted with an alarm system to advise of entry of unauthorised persons. This alarm will be raised locally, and also remotely over the radio supervisory system.

Figs. 4 and 5 show a typical floor plan and appearance of a demodulating terminal station. These will be staffed stations and amenity and office accommodation has also been provided. Owing to varying site conditions it was not practicable to provide an identical building for all terminal stations, but each has similar accommodation totalling approximately 2,000 sq. ft. this being arranged to suit individual site characteristics with all internal appointments of a standard design. Three 2 H.P. room air conditioning units, including one spare unit, are mounted in the equipment room. Although all terminal stations are located within residential development, emphasis has been placed on security and all windows have been fitted with georgian wired glass, and additional internal security bars have been fitted to rear windows. Unathor-

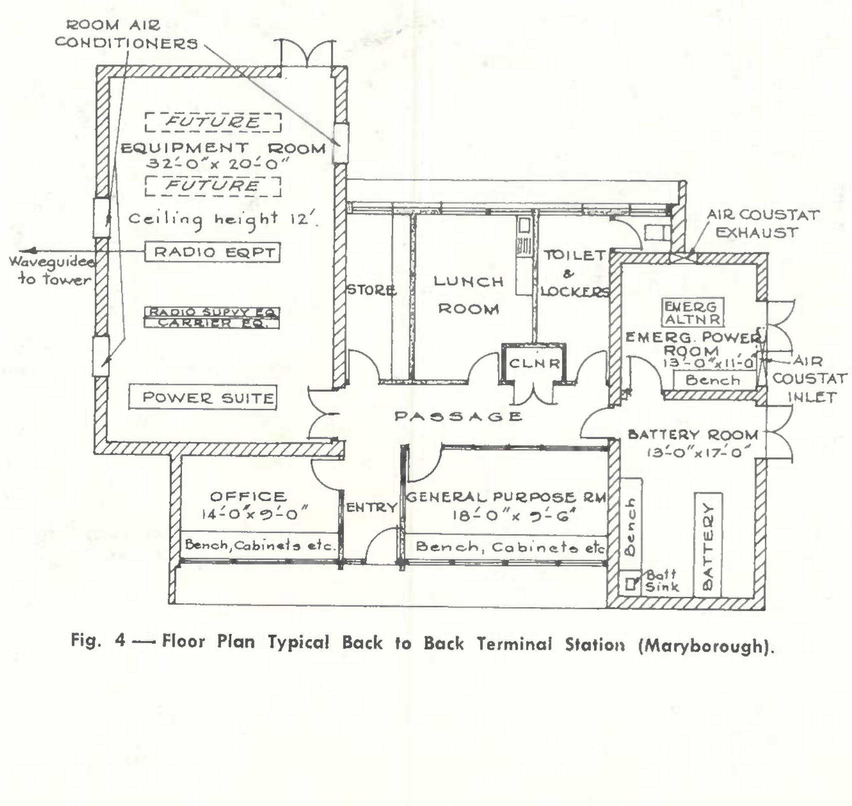


Fig. 4 — Floor Plan Typical Back to Back Terminal Station (Maryborough).

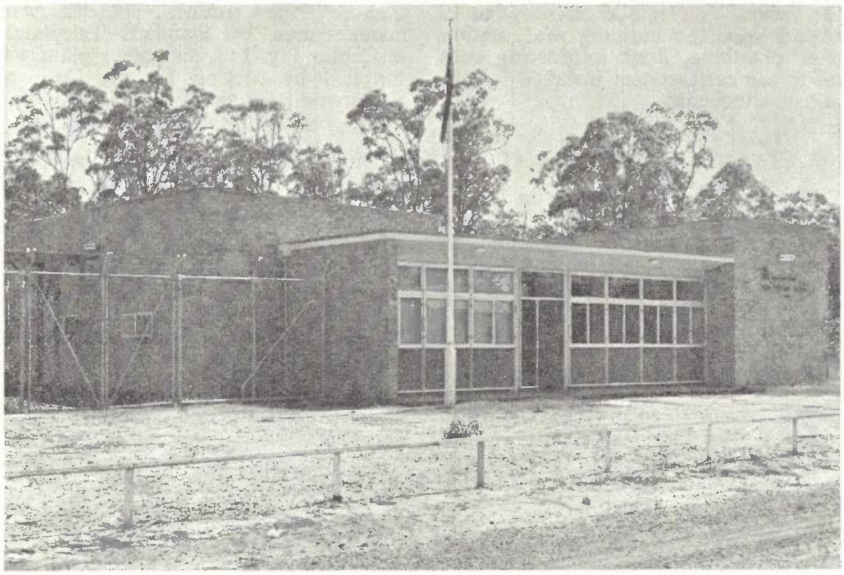


Fig. 5 — Maryborough Demodulating Station.

near the surface, to stiff clay at the lower limit of the test bores. The standing water level at Cairns was 5 feet and at Halifax 8 feet 6 inches. Departmental Inspectors were on site at all times during the excavation and piling work.

Rock blasting was employed extensively and special care was necessary at 17 sites where the buildings had already been erected. In such cases, limited charges to a maximum of 2½ ozs. of gelignite were laid in quantities of 20 to 30 at a time and detonated in succession by safety fuses. This type of blasting was carried out generally to within 10 to 15 feet of the building wall, but in one case limited charges were used successfully to within 5 feet of the building wall. Full safety precautions were observed in laying and detonating the charges viz., blasting mats, warning signs and loud sounding hooters. In urban areas, nearby residents were visited personally before excavation commenced and hand held traffic signs were also employed. The extent of the ex-

ised entry and fire alarms have been installed at each terminal station.

Design and construction work proceeded at an urgent pace and no significant delays were experienced in gaining access for equipment installation. This result was achieved in spite of the fact that erection of so many buildings was dependent upon new road construction. In addition, heavy rainfall was experienced in the nothern sections, one section in particular receiving 125 inches within four months.

TOWERS

The supply and erection of the 30 towers was carried out by Electric Power Transmission Pty. Ltd. as subcontractor to Standard Telephones and Cables Pty. Ltd. who were the prime contractor to the Postmaster-General's Department for the supply and installation of towers, power plant and radio equipment. Tower work commenced in July 1964 and a number of teams were employed on the different phases viz., excavation, concrete foundations, erection of superstructure and aerial mounting. The size, number and disposition of these teams varied from time to time and were determined by the subcontractor to suit his overall target date and to satisfy the needs of other sub-contractors who were concerned with the installation of other items such as waveguides and radio equipment.

At 28 stations a total of 6,366 cubic yards of soil was excavated in preparing for tower foundations, whilst at 25 of these, rock was encounted in varying quantities to a total of 4,705 cubic yards. At the other two stations, heavy duty piles, six per tower leg at Cairns and five per leg at Halifax, were driven to a depth of 55 feet to secure suitable tower foundations. Test bores had been carried out at these sites to a depth of 70 feet and the strata showed only a gradual improvement from very soft clay

Fig. 6 — Mounting Aerial Systems.

cavation varied with tower height and loading, but the order of excavation for each tower leg was 11 ft. x 11 ft. x 15 ft. 6 ins. deep with an undercut of 1 ft. around the bottom of the excavation. A backbone was used to remove the spoil.

Ready-mix concrete was used in the foundations at 21 sites and retarders were employed when ready-mix was carried over long distances, the limit on pouring time in such cases being 1½ hours. Departmental Inspectors were also present at all times during the foundation work to carry out slump tests and take specimens for compression tests. The average compression strength required for the concrete was 1,500 lbs./sq. inch at 7 days and 2,400 lbs./sq. inch at 28 days. Specimens were tested by the Queensland Department of Main Roads. Ramming was employed at approximately 6 inch intervals during back-filling and, because of the extent of rock encountered at many sites, it was often necessary to carry a considerable quantity of soil to site to achieve an acceptable result during this operation.

Tower erection was carried out by three teams. The first checked and laid out the steel work, the second carried out the erection and mounted the aerials, whilst a third team, accompanied by a Departmental Inspector, attended to the finer points to complete the structure. Fig 6 shows work in progress on mounting aerials at Ocean View. The waveguide installation then followed, this work being carried out by staff of Electric Power Transmission Pty. Ltd. under the control of an Engineer from Standard Telephones and Cables Pty. Ltd.

STATION EARTH-SYSTEM

The station earth-system was incorporated in the tower foundations. A total of 16 mild steel galvanised rods, ¾ inch diameter, were installed around the perimeter of each foundation hole and driven into the bed to a depth of at least 2 feet. Where the foundation bed was rock, the rods were grouted into the rock using a slurry of Bentonite Gypsum and water, prior to pouring the concrete. The rods which were of the order of 17 feet in length reach to approximately 1½ feet from the surface where they are drawn together and bonded with a 2 x ⅛ inch mild steel galvanised strap which is in turn bonded to the tower leg immediately above ground level. The earth-systems in each of the four foundations are bonded together below ground level. The effectiveness of this earthing system may be gauged from the Maryborough installation. This station is located in flat terrain approximately 100 feet above mean sea level. The total excavations amounted to 246 cubic yards of which 131 cubic yards was classified as rock. The earth resistance three months after installation was measured as 0.6 ohms. The waveguides have been bonded to the vertical waveguide runway at the lower bend leading to the equipment. In addition bonding has been carried out from the base of the vertical waveguide runway to a tower leg, to the building roof, station water plumbing, floor reinforcing rods and to the earth-system installed for the mains switchboard.

STATION POWER PLANT

This equipment comprises a power suite, a battery installation, and a normally stationary diesel alternator set. The power suite 13 ft. in length, 6 ft. in height and 2 ft. deep consists of four cubicles, viz mains terminating, standby set control, and two rectifier cubicles. Figs. 2, 4 and 9 show the layout and appearance of this equipment. It is usual for the mains terminating cubicle to be provided by the Commonwealth Works Department but on this project a fully integrated power suite was supplied and installed by the contractor. The rectifier cubicles were manufactured by Standard Telephones & Cables Pty. Ltd. and other plant was supplied by McColl Electric Co. who also carried out the installation work as a sub-contractor to S.T.C. Pty. Ltd.

The battery installation comprises two banks of 23 lead acid cells both banks normally operating in parallel connection. Cells are of 500 A.H. capacity except at Brisbane where 200 A.H. cells are employed. The Brisbane terminal and all repeater stations are equipped with 100 amp rectifiers whilse rectifiers of 200 amp rating are installed at the demodulating stations.

At the Brisbane radio telephone terminal a normally stationary diesel alternator set was already available. The other installations comprise an air cooled diesel and a three phase 15 kva alter-

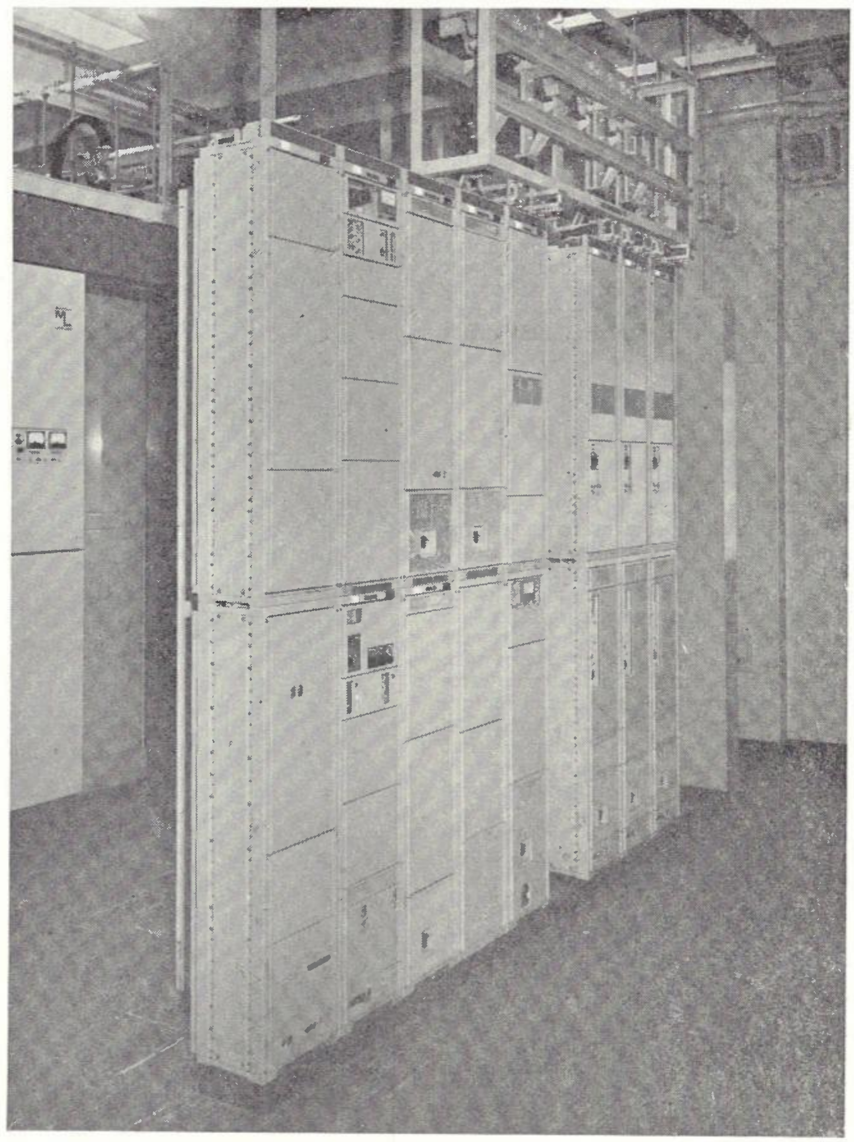


Fig. 7 — Radio Equipment, Brisbane Terminal.

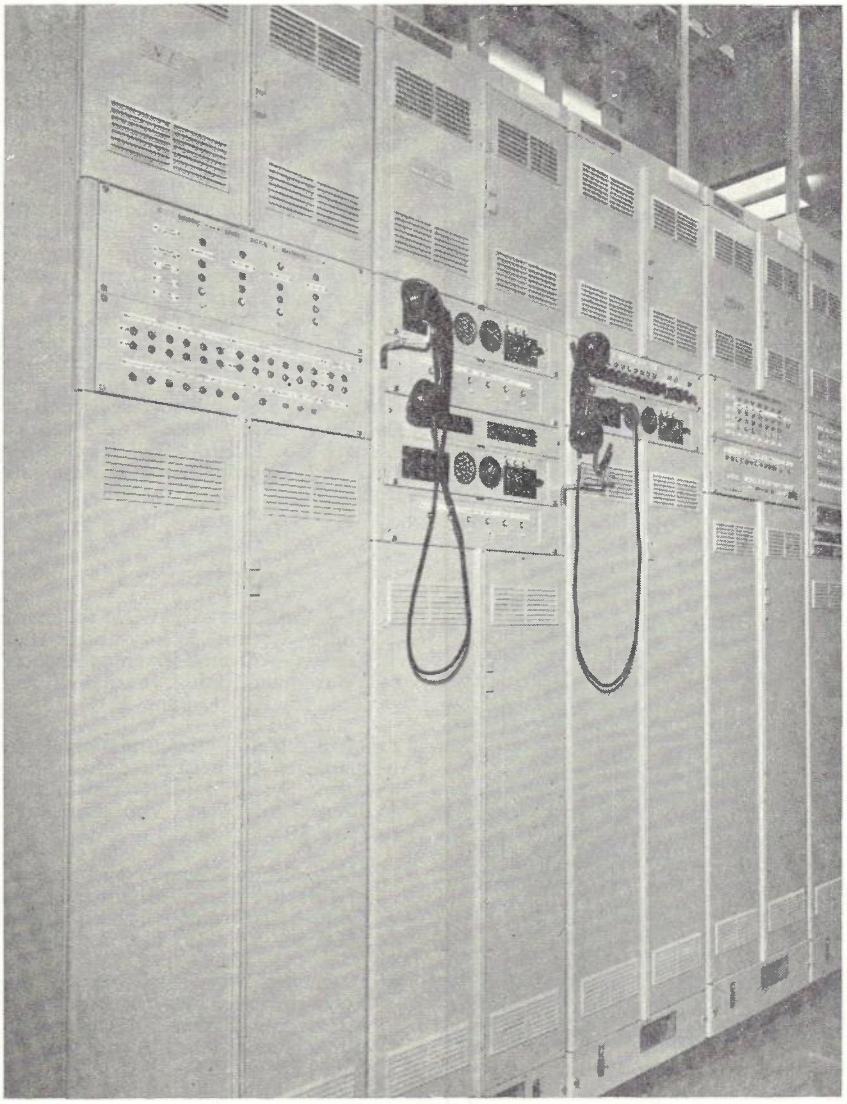


Fig. 8 — Supervisory Equipment, Brisbane Terminal.

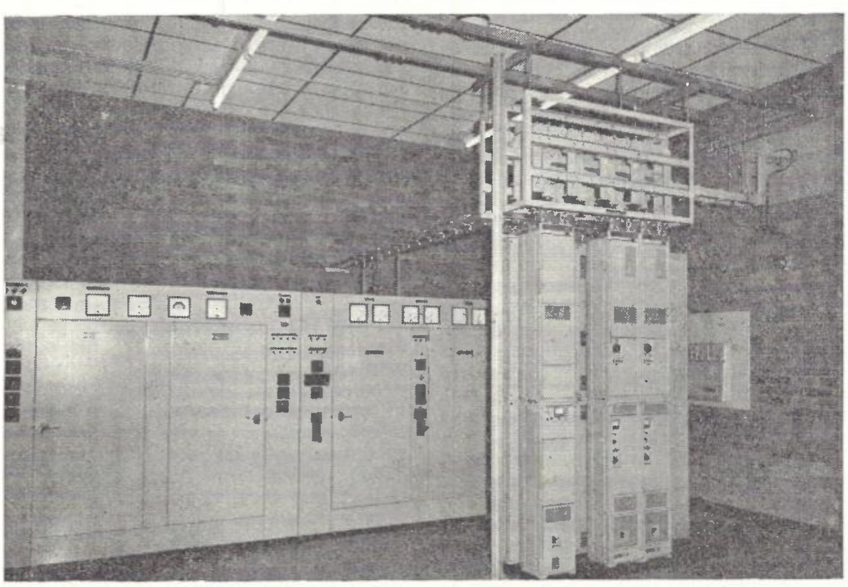


Fig. 9 — Equipment Installation, Repeater Station.

nator for each repeater station and an air cooled diesel and a 30 kva alternator at the Maryborough, Rockhampton, Mackay, Townsville and Cairns terminal stations. The diesel starter battery is a nickel cadmium type associated with a float charge rectifier. A diesel fuel tank of 50 gallon capacity is filled by a hand pump from the 250 gallon bulk storage tank at all except three stations where, due to possibility of isolation in the wet season, a 500 gallon bulk storage tank and an automatic refuelling pump are installed. Noise attenuating ducts have been provided in the inlet and outlet air flow apertures of the diesel alternator room at 12 stations which are located in or near residential locations. At the more isolated stations security grills have been fitted in these apertures. Weather protection cowls are fitted to these apertures at all stations.

A very satisfactory power equipment layout has been achieved at the repeater stations where the main items of power plant, although located in three adjoining rooms, are installed in line and coupled by a single straight wiring duct. Installation of the power plant was commenced in September 1964 and continued at a rate which ensured completion well in advance of any radio equipment installation work.

RADIO EQUIPMENT

A previous paper (Ref. 4) has dealt with the design features, including the form of construction and size of the radio equipment, and the installation aspects can best be seen by referring to Figs. 7 to 10.

Figs. 7 and 8 show the radio and supervisory equipment installed at the Brisbane terminal. The bays are installed in a back to back manner with a separation of 4 inches and occupy a total floor area of 8 feet 6 inches by 1 foot 10 inches.

A repeater station installation may be seen in Figs. 9 and 10. Two horizontal tie bars are installed between the walls of the room and provide head support for the equipment. These bars are coupled by means of two angle pieces from which two vertical angle iron supports are installed to the floor. The cable runway is also used as a lateral brace for the equipment. The equipment at a repeater station occupies a floor area of 5 feet by 1 foot 10 inches which includes a test cord bay and space for a southbound TV bearer, not initially equipped.

Three teams have completed the installation of radio equipment at 32 stations, including the Mt. Goonaneman Television Station, within a period of six months. Each team consisted of four men including personnel of Standard Telephones & Cables Pty. Ltd., the Nippon Electric Co Ltd. and the Nippon Telecommunication Consulting Co. Ltd.

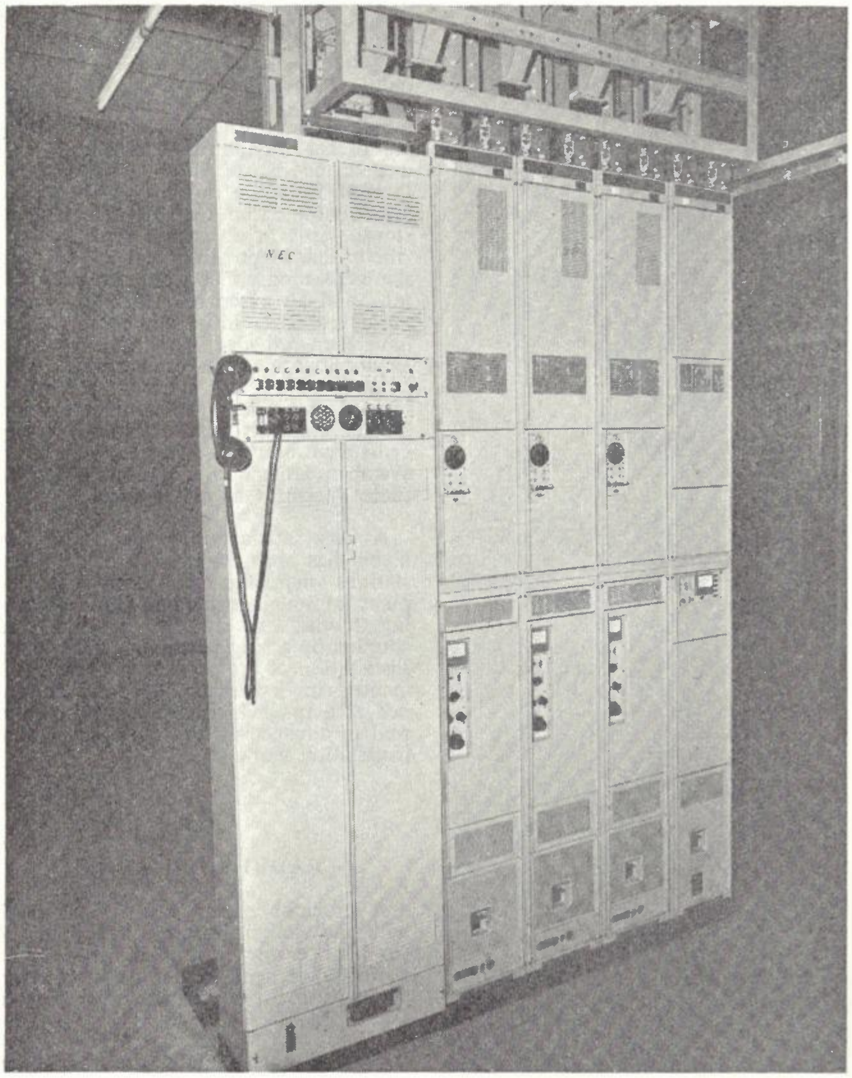


Fig. 10 — Radio and Supervisory Equipment at Repeater Station.

CONCLUSION

The installation phase of the 960 mile Brisbane-Cairns microwave radio route was completed in November 1965 and radio equipment line up and testing is proceeding towards an overall completion date in February 1966.

The project has been carried out to a strict timetable and the Postmaster-General's Department, as the requiring authority, has been strongly supported by the Commonwealth Departments of Works and Interior in the road and building construction phases. The supply and installation of all equipment has been the responsibility of Standard Telephones & Cables Pty. Ltd. as prime contractor, and sub-contractors to the Company have included the Nippon Electric Co. Ltd., McColl Electric Pty. Ltd. and Electric Power Transmission Pty. Ltd.

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TECHNICAL NEWS ITEM

EXPANSION OF SUBSCRIBER TRUNK DIALLING FACILITIES IN AUSTRALIA

Since the first automatic telephone exchange in Australia was placed in service in Geelong in 1912, the automatic setting up of telephone calls directly by subscribers has gradually superseded manual operators and manual equipment. This change, which is a universal one, has been caused by the urge for better, faster, and lower cost telephone service. At present approximately 80% of all local services in the Commonwealth are automatic. The application of automatic methods to trunk operation led to single operator or semi-automatic working, in which a trunk call is established right through to the wanted automatic subscriber by the originating trunk operator. By 1960 80% of trunk traffic was completed by single telephonist control.

Subscriber Trunk Dialling takes the final step in telephone automation by substituting automatic switching and charging equipment, for the originating trunk operator, thus enabling automatic subscribers to complete trunk calls to one another directly. Most countries of the world are moving as fast as possible towards full S.T.D. operation. For example, Great Britain hopes to handle 98% of its trunk calls with S.T.D. by 1970, Sweden hopes to achieve 100% S.T.D. operation by 1967, and North America 95% operation by 1970.

During 1965 there has been a notable expansion of S.T.D. facilities in this country. Twenty-five thousand subscribers in four Sydney inner city exchanges now have S.T.D. access to Melbourne, Brisbane, Canberra, Wollongong and Albury. Thirteen country centres in New South Wales have S.T.D. to the Sydney network and several also have access to other nearby centres.

Twenty-seven thousand subscribers in seven Melbourne inner city exchanges have S.T.D. access to Sydney, Albury, Canberra and many Victorian country areas. Eleven Victorian centres have S.T.D. access to the Melbourne network. A number of minor S.T.D. routes have been established in other States.

Special access equipment must be provided in a telephone network to give the subscribers S.T.D. service. This access equipment automatically analyses the number dialled to determine the appropriate charging rate for the call. When the called number answers it applies metering pulses to the calling subscribers meter at the appropriate rate for the duration of the call. The equipment also detects certain types of fault conditions and advises the caller to "try again" when these are encountered.

The current S.T.D. installations use Australian designed line relay sets for signalling over the junctions and trunks between the originating exchange and the distant local network. This equipment has been developed for use in step exchanges. With the introduction of crossbar equipment a new type of trunk exchange known as the ARM exchange will be used for switching S.T.D. traffic from local crossbar exchange and local step exchanges.

The Post Office will spend approximately £40m. on special S.T.D. access equipment and S.T.D. trunk exchanges over the next ten years to meet the objective of 66% of trunk calls dialled S.T.D. by 1975.

SEACOM: BROADBAND LINE AND TERMINAL EQUIPMENT FOR THE BRISBANE–CAIRNS ROUTE

*W. D. McKenzie, A.M.I.E. Aust.**

INTRODUCTION

The overall planning aspects of the Sydney-Cairns land section of the SEACOM submarine telephone cable system outlined in a paper by C. J. Griffiths (Ref. 1) included an estimate of the trunk circuit requirements between the major centres of the Brisbane-Cairns route based on a 1964 survey and referred to the more stringent noise specifications for this section to meet requirements of the SEACOM supergroups. The proposed limitation of the system loading to 600 channels between Brisbane and Maryborough and 300 channels in the Maryborough to Cairns section and the future developmental capabilities of the route were also discussed.

The transmission aspects of the Brisbane-Cairns microwave radio route were described in a subsequent paper by M. Strohfeldt (Ref. 2) and in the same issue of the *Journal* V. J. Griffin dealt with its survey and selection (Ref. 3).

The object of this paper is to describe the broadband line and terminal equipment that is being installed at Brisbane, Maryborough, Rockhampton, Mackay, Townsville and Cairns to connect the baseband output of the radio system to the associated long line equipment offices and its subsequent translation to supergroups, groups and channels. The extension of the SEACOM supergroups from the long line equipment office to the Overseas Telecommunications Commission office at Cairns is also described.

*Mr. McKenzie is Engineer Class 3, Long Line Equipment Installation, Queensland.

CIRCUIT PROVISION

Only a proportion of the channels provided by a broadband system need be extended from terminal to terminal. Others can be used between either terminal and one or more intermediate offices, between intermediate offices or connected to spur routes usually as a basic group to a 12-channel open wire system. Fig. 1 shows the proposed initial provision of supergroups, groups, and programme channels for the Brisbane-Cairns system. The normal spacing between adjacent supergroups is 8 Kc/s. but it is 12 Kc/s. between Supergroups 1 and 2 also between 2 and 3. This increased spacing and the comparatively low baseband frequency allocations of 60-300 Kc/s and 312-552 Kc/s for Supergroups 1 and 2 respectively, facilitate the design of stop filters which can be inserted in the through paths between the input and output hybrids in the radio building and thus prevent their onward transmission except via the coaxial tails to the long line equipment office. This enables Supergroups 1 and 2 to be replenished with the following important advantages:—

(i) up to 120 channels could be provided, if required, on each of the following sections:—
Brisbane-Maryborough
Maryborough-Rockhampton
Rockhampton-Mackay
Mackay-Townsville
Townsville-Cairns

(ii) Supergroup 2 uses the basic frequency band of 312-552 Kc/s. and therefore does not require any supergroup carrier supply at the long line equipment office.

Supergroups 1 and 2 will provide circuits between Brisbane-Rockhampton and the intermediate offices between Rockhampton and Cairns. Supergroups 3 and 4 are reserved for the ultimate SEACOM requirements.

Initially Supergroup 4 will provide the Brisbane-Cairns section of the SEACOM E link between the O.T.C. offices at Paddington and Cairns to handle international traffic via the COMPAC and SEACOM cables. It will be extended from the Cairns long line equipment office to the O.T.C. building as an 80-channel supergroup of 312-552 Kc/s. for subsequent amplification, translation and transmission over the SEACOM cable. Fig. 2 shows the proposed arrangements at Cairns in simplified form. Until about 1970 when the additional SEACOM circuits will be required Supergroup 3 will be available for patching purposes in the event of any interruption to the SEACOM supergroup but

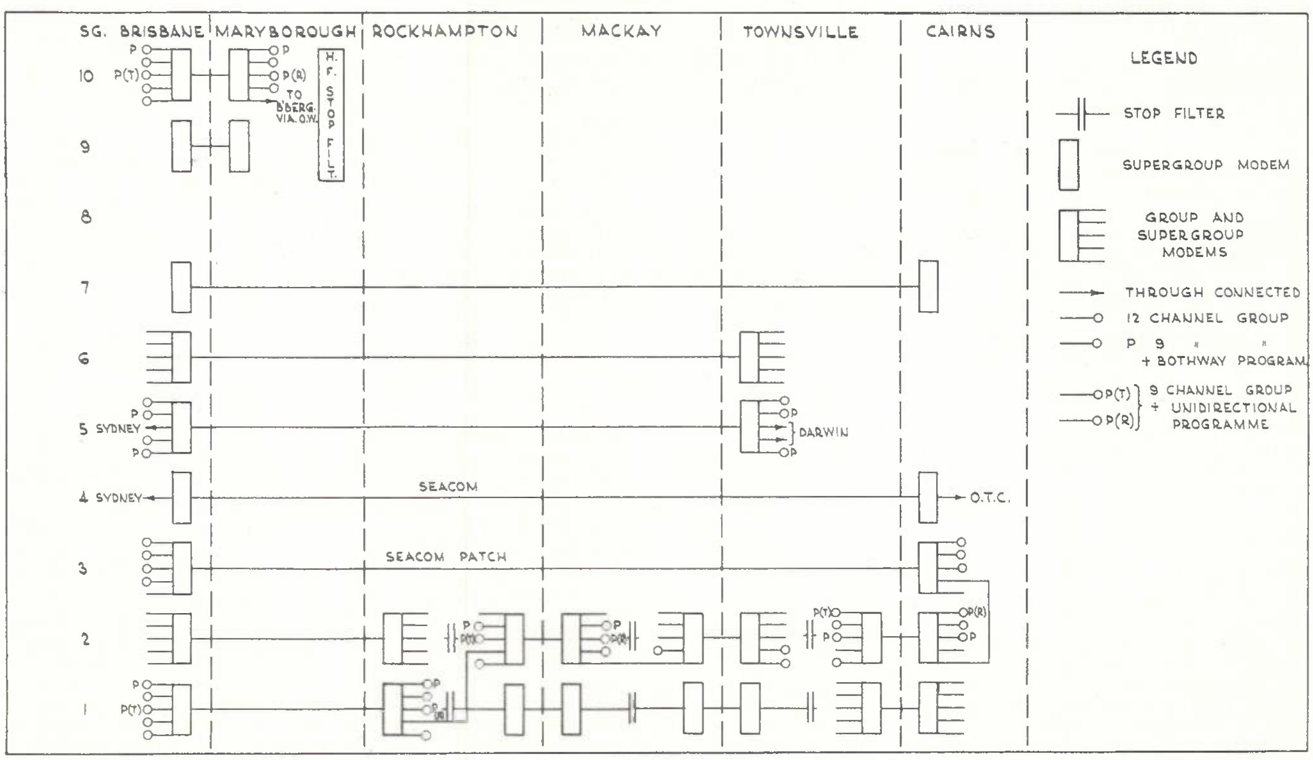


Fig. 1 — Channel Provision.

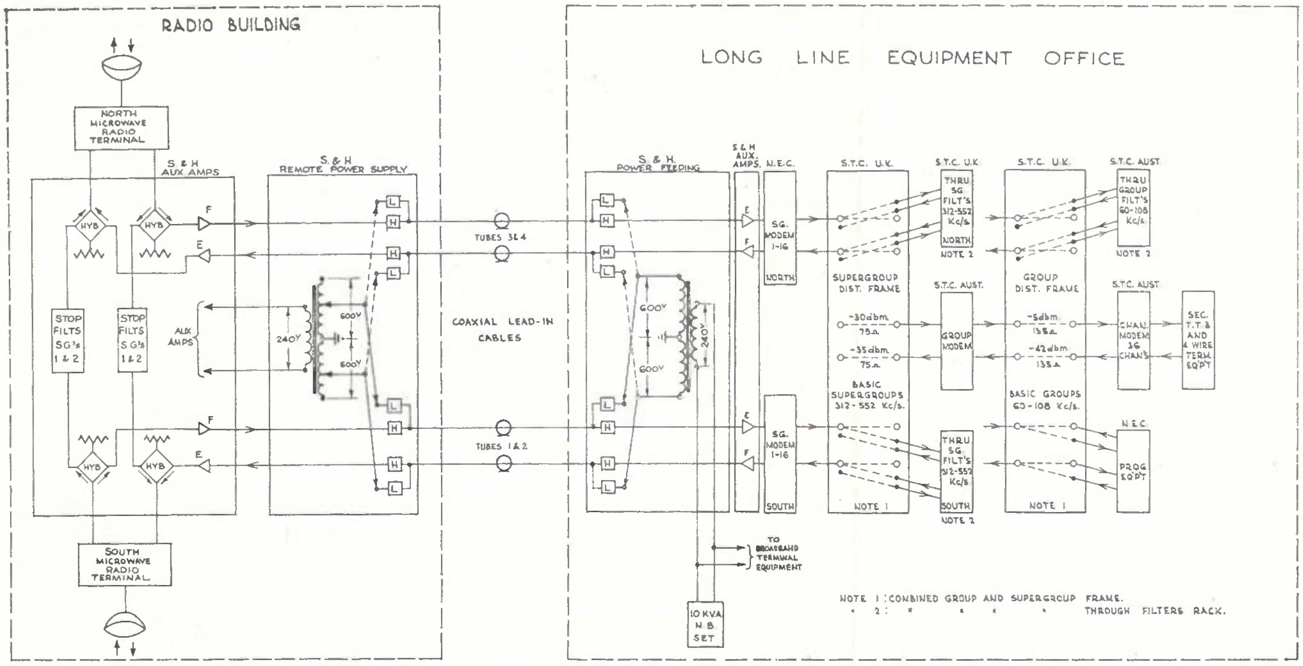


Fig. 3 — Simplified Schematic — Maryborough, Rockhampton, Mackay and Townsville.

will normally be used to provide Brisbane-Cairns circuits with one group connected at Cairns to Supergroup 2 to provide 12 Brisbane-Townsville circuits. Supergroups 5 and 10 will provide direct circuits between Brisbane-Townsville and Brisbane-Maryborough respectively. Two of the groups in Supergroup 5 will be extended to Darwin by 12-channel open wire systems at a later date.

COAXIAL LEAD-IN-CABLES

The need to meet line of sight requirements between adjacent repeater stations resulted in the location of attended radio buildings at Mt. Gravatt, Maryborough, Rockhampton, Mackay, Townsville and Cairns at distances ranging from 1.5 to 8 miles from the existing long line equipment offices.

The eight mile coaxial cable link between Brisbane and Mt. Gravatt via a repeater at Holland Park caters for several broadband systems and a description of the cable provision and allocation is beyond the scope of this paper. In all other cases composite cables each containing eight Type 375 coaxial tubes, eight 20 lb. interstice quads, and 24 20-lb. quads laid up as a core in the centre of the cable are used to interconnect the radio buildings with the long line equipment offices. Because of the short distance involved in the one mile 55 chains section between the Cairns long line equipment office and O.T.C. building, compensation for the cable attenuation and equalisation over the transmitted range of 312-552 Kc/s. will be effected by means of simple pre-emphasis networks with a flat amplifier at the transmitting end in each direction of transmission.

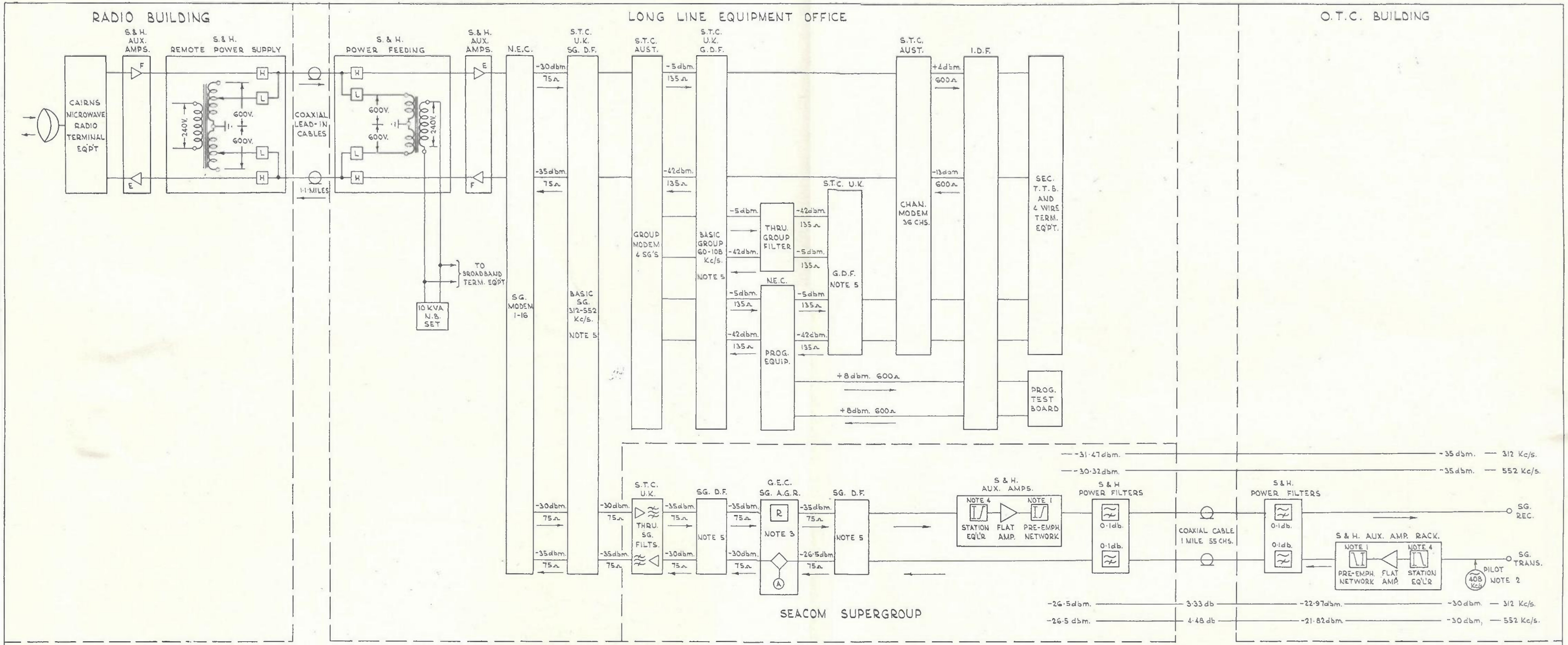
In all other applications the coaxial lead-in cable will be built out electrically to a nominal section length of 5.8 miles at a mean cable temperature of 15°C with a permissible deviation in mean cable temperature of ±12°C. This arrangement provides standardisation and ensures that the equalising amplifiers and associated building-out networks are operated under optimum design conditions. Referring specifically to the four intermediate demodulating stations, the radio signals in the 4,000 Mc/s range are translated to a baseband of 60-2540 Kc/s. at Maryborough and 60-1548 Kc/s. at Rockhampton, Mackay and Townsville. The separate unidirectional paths for the south and north bound directions of transmission are further divided by means of branching hybrids on the amplifier rack. One path is fed via the radio equipment and translated back to the 4,000 Mc/s. range for onward transmission. The other path is extended to the long line equipment office via the coaxial tails as shown in Fig. 3.

The coaxial tubes in the composite cable are extended from pothead joints at the radio building and the long line equipment office by means of single tube, air spaced, lead covered coaxial cables and terminated in Siemens and Halske High Frequency Angle Terminations mounted in ducts above the appropriate equipment racks. The connection from the angle termination to the rack is provided by a short length of semi-flexible, solid dielectric P.V.C. covered coaxial cable.

Each coaxial tube provided for the Brisbane-Cairns broadband system has its outer conductor insulated from earth. This is necessary to enable any tube to be used for the transmission of television directly on the cable at video frequencies. This insulation is provided in the composite cable but would be nullified if the angle terminations were used without modification. To prevent this the termination coupling nut supplied with termination is replaced by a modified nut which is grooved to accommodate a nylon insulating ring and a bronze wire circlip. The bakelite split ring supplied with the termination is replaced by a polystyrene ring. A perspex plate and wax impregnated piece of pressphan is used to insulate the modified angle termination from the metal duct. The 32 quads at each end of the composite cable are extended from the pot-head joint to two 38 pair cable termination boxes mounted on a voice frequency termination rack. These are used for speaker circuits, alarms, supervision etc.

LINE EQUIPMENT

The line equipment for a broadband system which operates on a radio bearer differs appreciably from that used for a coaxial cable bearer. In the latter case several line pilots are used to maintain the overall gain/frequency characteristic within very close limits and to compensate for changes of temperature in the cable, ageing of valves etc. The microwave radio bearer will be regulated within very close limits by the radio system, hence line pilots are not required. The line equipment for the Brisbane-Cairns system was supplied by Messrs. Siemens and Halske Pty. Ltd. The designations, dimensions, locations and functions of the various racks are outlined in Table 1.



NOTE 1: PRE-EMPHASIS NETWORK WILL BE SUPPLIED BY P.M.G. RESEARCH LABORATORIES.
" 2: 408 Kc/s. PILOT IS INJECTED BY O.T.C.
" 3: FOR SCHEMATIC OF SG. A.G.R. RACK SEE FIG. 4.
" 4: A 3db FIXED PAD MAY BE USED IN LIEU OF STATION EQUALISER.
" 5: SG. D.F. AND G.D.F. ARE ON COMBINED FRAME.

Fig. 2 — Simplified Schematic — Cairns Radio, Long Line Equipment and O.T.C.

TABLE 1

Designations	Dimensions			Locations	Functions
	Height	Width	Depth		
Auxiliary Amplifier	8 ft. $6\frac{3}{8}$ ins.	1 ft. $11\frac{5}{8}$ ins.	$8\frac{3}{4}$ ins.	Radio and L.L.E. buildings also O.T.C. building at Cairns.	The rack used in the radio building accommodates up to six line amplifiers plus associated branching hybrids, stop filters etc. Those used in the long line equipment offices and the Cairns O.T.C. building accommodate up to 10 line amplifiers.
Power Feeding	8 ft. $6\frac{3}{8}$ ins.	1 ft. $11\frac{5}{8}$ ins.	$8\frac{3}{4}$ ins.	Long Line equipment office only.	This rack provides terminations for four coaxial tubes and accommodates the associated power filters and a 240v. to 600-0-600v. step-up transformer for power feeding over the coaxial tails to the radio building.
Remote Power Supply	5 ft. 1-/16 ins.	1 ft. $11\frac{5}{8}$ ins.	$8\frac{3}{4}$ ins.	Radio building only.	This rack provides terminations for four coaxial tubes and accommodates the associated power filters and a step down transformer to restore the no-break power to 240 volts.
Power Filters	8 ft. $6\frac{3}{8}$ ins.	1 ft. $11\frac{5}{8}$ ins.	$8\frac{3}{4}$ ins.	Radio and L.L.E. buildings also O.T.C. building at Cairns.	This rack provides termination for up to 12 coaxial tubes and associated power filters. It is used for any telephony tubes which are not connected to the power feeding or remote power supply racks.

The abovementioned racks have been extended by means of 1 in. x 1 in. x 3/16 in. angle iron frames to a height of 9 ft. in the radio building and at O.T.C. Cairns and to 10 ft. 6 ins. in the long line equipment offices. Their functions are generally similar to those of the line equipment provided for the Melbourne-Morwell coaxial cable system which was described in a paper by Messrs L. A. White, R. K. Edwards, I. L. McMillan and J. R. Walklate (Ref. 4). Brief descriptions of their operation are however, included in this paper. When the baseband is applied to an auxiliary amplifier rack in the same office and when only the level has to be adjusted, a Type F flat amplifier is used. It has a fixed gain of 39.1 db. and its input is preceded by a station line equaliser and an attenuator which is adjustable between 0.9 and 37.6 db. The output is connected to a similar attenuator so that the specified level may be transmitted. The flat amplifier has three stages with feedback applied over all three; each stage is equipped with parallel valves for greater reliability of service.

When the baseband is applied to an auxiliary amplifier rack after transmission over a coaxial lead-in cable and its associated building-out network a Type E equalising amplifier is used. The building-out network has five adjustable sections equivalent to artificial lines of 0.25, 0.5, 1.0, 2.0 and 2.0 miles respectively. These simulate the losses at different frequencies of varying lengths of coaxial lead-in cable so that it can be adjusted to within ± 0.125 mile of the design length of 5.8 miles. The equalising amplifier has a sloping gain/frequency characteristic which matches the attenuation/frequency response of the built out cable section. The sloping/gain characteristic is obtained from fixed equalisers and a variable equaliser. The amplifier has four stages each with parallel valve operation to ensure a high degree of reliability from service interruption. The variable equaliser network, which is in the pre-stage section, includes a thermistor element which enables the gain to be adjusted within specified limits. This control corrects for the changes in attenuation due to changes of cable temperature and also provides fine adjustment to the correct gain after the building-out network has been adjusted. The mean amplifier gain varies from about 7 db. at 60 Kc/s. to 48 db. at 4 Mc/s. The amplifier output is connected to an attenuator which is adjustable between 0.9 and 37.6 db. so that the output level may be adjusted to the specified value.

The primary function of the power filters is to separate the signal baseband from the 50 c/s. power fed over the cable and they are designed to operate with potentials up to 1,000 volts and a maximum current of 3 amps. The attenuation provided by the high pass section to the power frequency of 50 c/s. is at least 95 db. These filters protect the equipment from longitudinal voltages that may be induced in the coaxial cable due to power line faults or lightning strikes and also maintain standard conditions for cable equalisation and termination. For these reasons they are provided at each end of the coaxial tubes irrespective of whether or not they are used for power feeding purposes.

TERMINAL EQUIPMENT

In this section is described the broadband terminal equipment required to translate the baseband from the radio system to supergroups, groups, telephone and programme channels. Descriptions of conventional long line equipment such as secondary test boards, four wire terminating sets, I.D.F's etc. have not been included. Fig. 4 shows a simplified schematic for both directions of transmission from the coaxial lead-in cable to the line, supergroup, group and channel equipment, thence via the four wire terminating equipment to the secondary test board.

Supergroup Equipment

The supergroup modem equipment supplied by the Nippon Electric Company (N.E.C.) Japan is described hereunder. It accommodates up to 16 transistorised supergroup modems on a single 10 ft. 6 in. x 1 ft. $8\frac{1}{2}$ in. x $8\frac{1}{2}$ in. rack and the D.C. potential of 24 volts is obtained from a power unit which is connected to the 240 volt 50 c/s. output of the no-break power plant.

The translation of basic supergroups into various basebands is shown in Table 2.

TABLE 2

Supergroup Numbers	Baseband Frequency Range	Application
1-16	60-4,028 Kc/s.	Fully equipped N.E.C. rack where 960 channels are required.
1-10	60-2,540 Kc/s.	Brisbane-Maryborough.
1-6	60-1,548 Kc/s.	Brisbane-Maryborough (part) — Cairns.

A 612 Kc/s. carrier supply is used for Supergroup 1 and the basic supergroup of 312-552 Kc/s. is transmitted as Supergroup 2 without further modulation. Carrier frequencies ranging from 1,116 Kc/s. to 4340 Kc/s. at intervals of 248 Kc/s. are used to modulate Supergroups 3-16. After modulation they are connected through band pass filters after which four supergroups are connected in parallel to each of the four input paths of two hybrid coil circuits as follows:—

(i) Supergroups 1, 5, 9 and 13
(ii) Supergroups 3, 7, 11 and 15
Connected to one hybrid coil.
(iii) Supergroups 2, 6, 10 and 14
(iv) Supergroups 4, 8, 12 and 16
Connected to a second hybrid coil.

The outputs of the two abovementioned hybrid coils are then combined by a further hybrid coil and the resultant baseband has its level adjusted to —45 dbm. into 75 ohms by a transmitting amplifier and is then connected to the line equipment for transmission over the coaxial lead-in cable to the radio building.

In the receive direction the incoming baseband from the radio building is transmitted over the coaxial lead-in cable to the line equipment racks in the long line equipment office. The level is adjusted to —20 dbm. into 75 ohms and is then connected to the supergroup modem rack. A similar arrangement of hybrid coils to that used in the transmit path separates the incoming baseband into four separate arms and the various individual supergroups are selected by the appropriate band pass filters and demodulated to the basic range of 312-552 Kc/s. They are cabled to the supergroup distribution frame at a level of —30 dbm. into 75 ohms and may be through connected to supergroups of other systems or translated to the required range of groups, channels etc.

Automatic regulation of selected supergroups is provided by means of 408 Kc/s. generating and regulating equipment. Initially this is restricted to the supergroups which are connected together to provide the overall SEACOM E link. The 408 Kc/s. pilots are injected at the group mod out points in the O.T.C. buildings at Paddington and Cairns. They are monitored and connected to alarm panels in the associated long line equipment offices at City South and Cairns and are transmitted directly from end to end.

Automatic regulating equipment, as shown in simplified schematic form in portion of Fig. 4, is connected to the supergroup modem output points in the long line equipment offices at Brisbane and Cairns for the northbound direction of transmission and at Brisbane and City South for the southbound direction.

Group Equipment

Each group modem translates five basic groups of 60-108 Kc/s. into a 60 channel basic supergroup of 312-552 Kc/s. Group modulators with carrier frequencies of 420, 468, 516, 564 and 612 Kc/s. and a group combining coil panel are used to translate and combine the five groups together and an auxiliary transmitting amplifier is used to obtain the required output level. This process is reversed in the receive direction. The nominal input and output levels and impedances are —42 dbm. into 135 ohms and —35 dbm. into 75 ohms in the transmit direction and —30 dbm. into 75 ohms and —5 dbm. into 135 ohms in the receive direction.

The group modem equipment is manufactured by Standard Telephones and Cables Ltd., Australia. Each rack is 10 ft. 6 in. high x 1 ft. 8½ in wide x 8½ in. deep and it accommodates the equipment for four supergroups.

Channel Equipment

A channel modem unit provides the frequency translating and combining facilities for one basic group of 12 voice frequency channels for both directions of transmission. In the transmit direction, these channels are modulated with carrier frequencies ranging from 64 to 108 Kc/s. at intervals of 4 Kc/s. and the lower sidebands are selected by crystal band pass filters and combined for subsequent transmission as a basic group 60-108 Kc/s. The input level is —13 dbm. into 600 ohms and the output level —42 dbm. into 135 ohms. A group pilot of 84.08 Kc/s. can be injected into the group combining unit for reference or regulating purposes as required.

In the receive direction the incoming basic group level of—5 dbm. into 135 ohms is connected via a pilot stop filter and combining unit to crystal band pass filters similar to those used in the transmit direction. The selected frequency bands are demodulated with carrier frequencies of 64 to 108 Kc/s., individually amplified and connected through low pass filters to provide an adjusted output of +4 dbm. into 600 ohms and in the voice frequency range 300-3,400 c/s.

Each channel modem provides facilities for out of band signalling of 3,825 c/s. The transmit signal is actuated by D.C. and the receive frequency is converted to D.C. by a signalling receiver which is connected permanently across the channel. Adequate safeguards are provided to prevent false operation.

The channel modem equipment for the Brisbane-Cairns broadband system is manufactured by Standard Telephone and Cables Ltd., Australia, and is completely transistorised. The rack is 10 ft. 6 in. high x 1 ft. 8½ in. wide x 8½ in. deep and it accommodates 36 channel modems.

Programme Equipment

A high quality 50-10,000 c/s. programme channel is obtained from equipment which replaces Channels 4, 5, and 6 in a 12-channel basic group of 60-108 Kc/s. A maximum of three programme channels may be used in any supergroup so that system peak power loading conditions will not be exceeded.

The programme equipment for the Brisbane-Cairns broadband system was supplied by the Nippon Electric Company and is completely transistorised. Three bothway programme terminals can be mounted on a 9 ft. high x 1 ft. 8½ in. wide x 8½ in. deep rack. Each terminal includes transmit equipment, receive equipment and a common carrier supply, as shown in simplified schematic form in Fig. 5.

In the transmit direction the audio programme from the broadcasting studio is connected via an attenuator, equaliser and amplifier into a two phase (single sideband) modulator which is coupled together by hybrid coils at the input and output respectively. The function of the hybrids and associated networks is to phase shift the carrier and the audio inputs by 90° and then after modulation, one sideband is suppressed and the other is transmitted. The audio programme signals are modulated by a 96 Kc/s. carrier frequency and then connected through an equaliser and amplifier to a combined band stop and band pass filter. The band stop filter attenuates the upper sideband frequencies between 96.15 and 96.4 Kc/s. to reduce interference from the signalling frequency of Channel 3 and the band pass filter selects the lower sideband of 86-95.95 Kc/s. This band is connected via an attenuator and branching hybrid coil where the programme and telephony bands are combined and then connected to another attenuator and transformer in the common programme—telephony path and thence to the group distribution frame. The telephony band in the ranges 60-84 Kc/s. (Channels 7-12) and 96-108 Kc/s. (Channels 1-3) is connected from the channel modems via the group distribution frame through a transformer, amplifier, 95.85-96.05 Kc/s. band stop filter and attenuator to the branching hybrid coil and then combined with programme channel for onward transmission as a basic group of 60-108 Kc/s.

Similar methods and equipment are used in the receive direction of transmission. The combined programme and speech channels in the incoming band

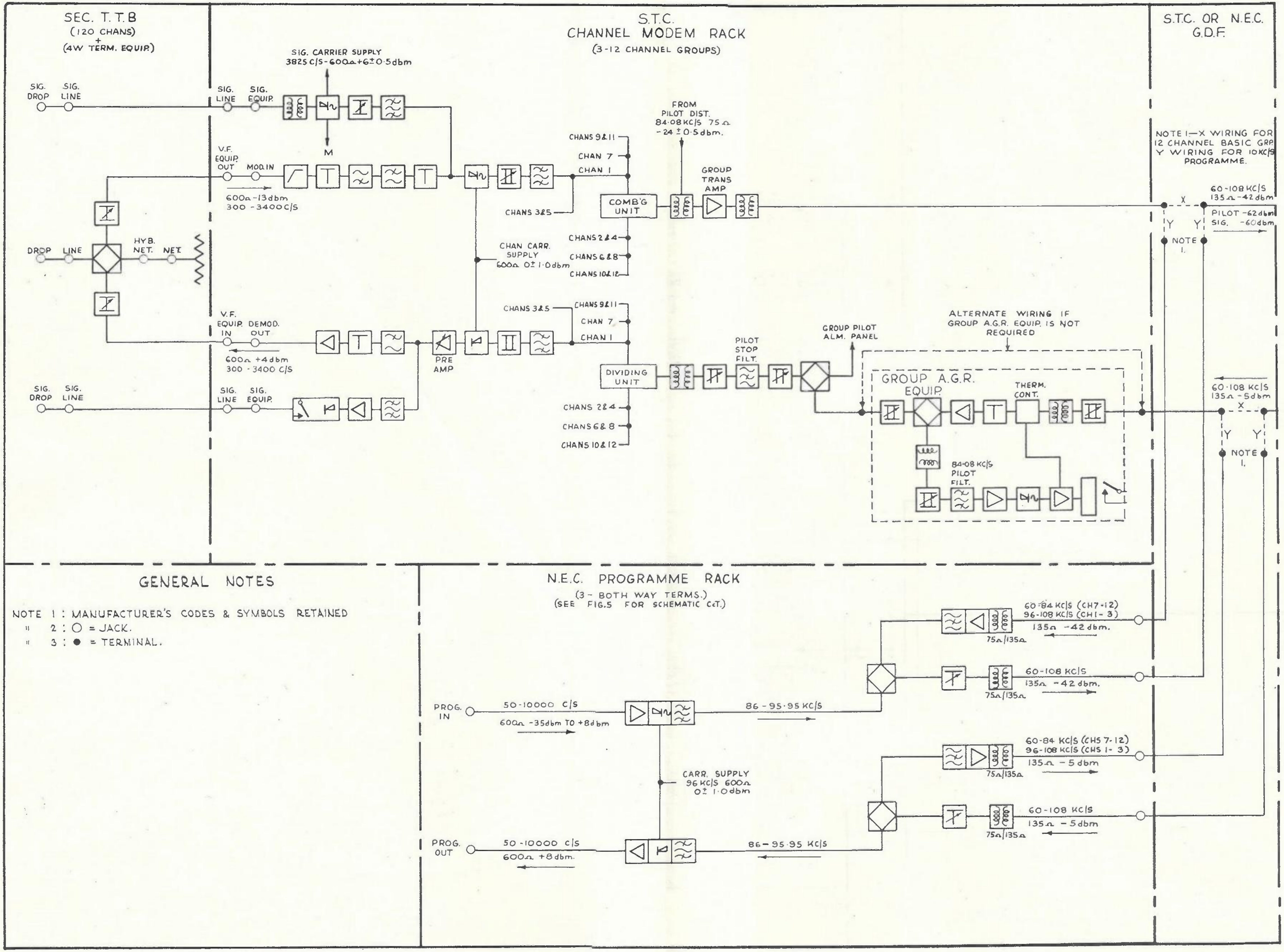


Fig. 4 — Simplified Schematic — Long Line Equipment Office

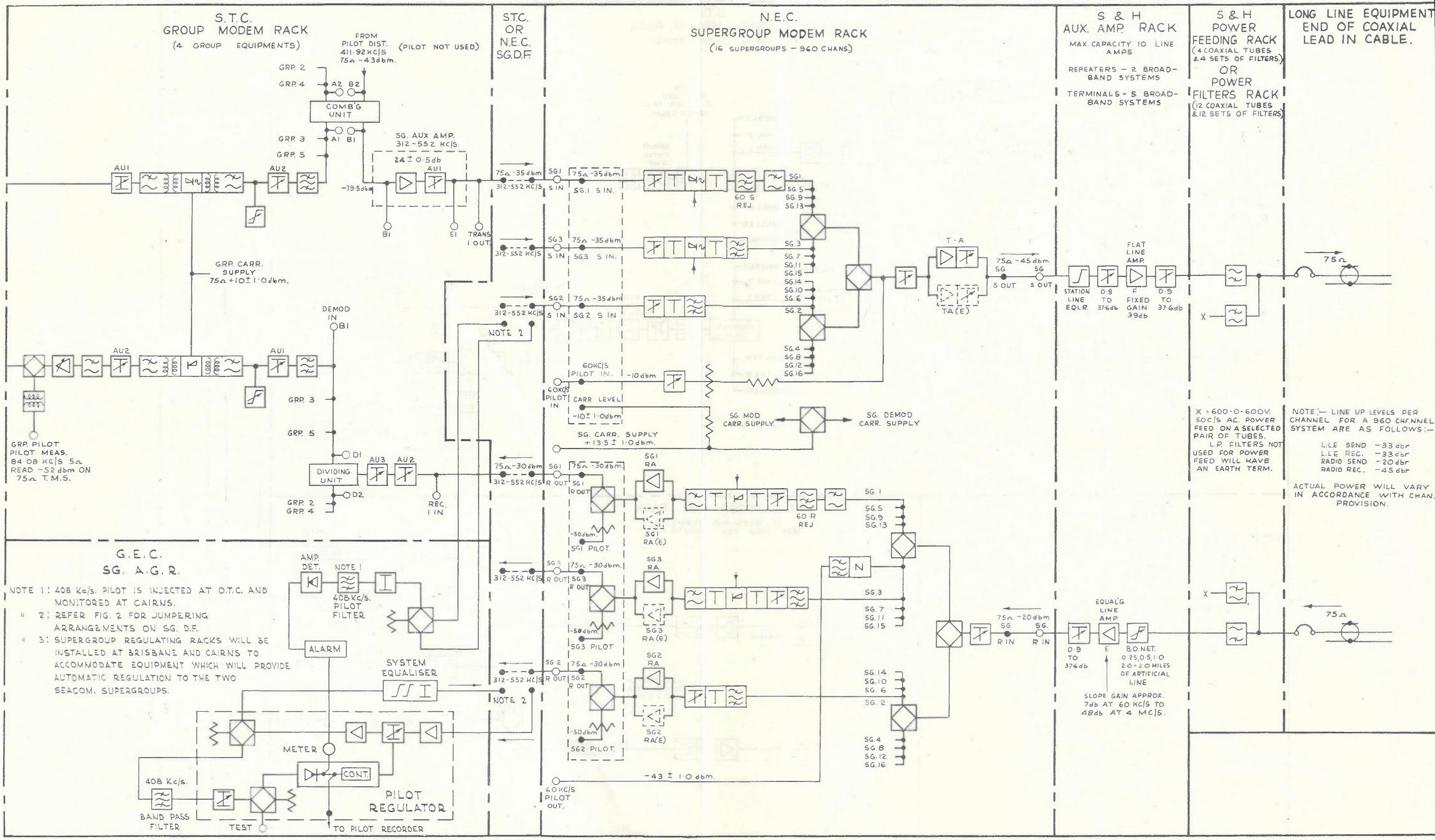


Fig. 4 (continued) — Simplified Schematic — Long Line Equipment Office.

of 60-108 Kc/s. are connected from the group modem through the group distribution frame and thence through a transformer and attenuator in the common path to a branching hybrid coil which separates the telephony and programme circuits into two paths.

The programme channel is connected via an attenuator to a combined band pass and band stop filter. The pass filter selects the required band of 86-95.95 Kc/s. and the stop filter attenuates the adjacent frequencies in the range of 96.15-96.4 Kc/s. The 86-95.95 Kc/s. band is then connected through an amplifier and equaliser to a two phase demodulator to which a carrier frequency of 96 Kc/s. is applied and the resultant audio band of 50-10,000 c/s. is connected via a low pass filter, audio amplifier, attenuator and equaliser for onward transmission to the broadcasting studio.

The telephony band in the ranges 60-84 Kc/s. (Channels 7-12) and 96-108 Kc/s. (Channels 1-3) is taken from the branching hybrid coil through an attenuator to a 95.85-96.05 Kc/s. band stop filter which has the same function as the similar filter in the transmit path and thence via an amplifier and transformer to the group distribution frame for onward transmission to the channel modem equipment.

The 95.85-96.05 Kc/s. band stop filters in the transmit and receive telephony paths are complementary to the 96.15-96.4 Kc/s. filters in the transmit and receive programme paths and their combined effect is to prevent any interference between the programme channel and the telephony channels.

The permissible variation in the overall frequency response of a programme channel is from +1.0 to —2.0 db. relative to the 800 c/s. response in the 50-10,000 c/s. range.

Six bothway and four unidirectional programme channels will be derived initially from selected groups in Supergroups 1, 2, 5 and 10 of the Brisbane-Cairns broadband system.

Carrier Supply Equipment

The carrier frequency generating equipment is manufactured by Standard Telephones and Cables Ltd., London. Equipment already installed for the Brisbane-Lismore coaxial cable system is used at Brisbane and similar equipment is being installed at Maryborough, Rockhampton, Mackay, Townsville and Cairns.

Five racks each 10 ft. 6 in. high x 1 ft. 8½ in. wide x 8½ in. deep are required at each of the abovementioned offices to generate the various carrier frequencies and to accomodate associated equipment such as power supplies, distribution panels, changeover facilities etc.

The rack designations, with the accepted abbreviations shown in brackets, are listed hereunder:—

(i) 124 Kc/s. master oscillator and channel carrier frequency generating equipment (M.O.C.C.S.)

(ii) Group and supergroup carrier frequency generating equipment. (G.S.G.C.S.)

(iii) Supergroup carrier supply amplifier equipment (S.G.C.S.A.)

(iv) Carrier frequency distribution — 2 racks (C.S. Dist.)

A simpified schematic of the broadband carrier supplies is shown in Fig. 6 and the more important frequencies provided by the M.O.C.C.S. are listed hereunder:—

(i) Carrier frequencies ranging from 64-108 Kc/s. at intervals of 4 Kc/s. for the translation of voice frequency channels to and from the basic group of 60-108 Kc/s.

(ii) A frequency of 3,825 c/s. for use with the out of band signalling system.

(iii) 12 Kc/s. and 124 Kc/s. supplies to the G.S.G.C.S. rack for connection to harmonic generators used to provide group and supergroup carrier frequencies.

The rack is equipped with two 124 Kc/s. master oscillators, two sets of frequency dividers producing outputs of 60, 12 and 4 Kc/s. and two 4 Kc/s. harmonic generators. Both sets are running continuously with one supplying the load and the other on standby under the control of a switching panel so that the standby set is automatically switched into circuit should there be any failure of the set which is normally on load.

The channel carrier supply amplifiers are not duplicated as the single stage consists of two halves of a double triode valve connected in parallel so that failure other than a short circuit between electrodes in one half results in a small change in carrier output and not complete failure.

Two separate 3,825 c/s. oscillators, with automatic change-over facilities, are provided for out of band signalling.

The two 124 Kc/s. crystal controlled master oscillators are identical, the crystals being contained in temperature controlled oven to provide a frequency stability of ±2 parts in 10 million per month. The output of each 124 Kc/s. oscillator is taken to a 124/60 Kc/s. divider panel which produces two outputs at 60 Kc/s.

The 140 ohm output is passed via the harmonic generator change-over circuits to the 60 Kc/s. OUT terminals in the rack and can be used as a frequency comparison pilot injected in the supergroup modem stage.

The 600 ohm output is fed directly to the 60/4 Kc/s divider panel. This panel produces two outputs at 4 Kc/s. and also a 12 Kc/s. output which is used in the harmonic generator circuits in the associated G.S.G.C.S. rack. One of the 4 Kc/s. outputs is fed back to the preceeding 124 Kc/s. divider where it is used for locking and dividing purposes while the other is passed to the 4 Kc/s. harmonic generator panel which produces the odd and even harmonics of 4 Kc/s. including all the frequencies required for channel carrier supplies.

After passing through the switching panel the harmonic output from the set in use is connected through a compensating network which provides impedance matching for the following filters and also acts as a band pass filter to restrict the transmitted frequency range to a 64-108 Kc/s. Each channel filter selects the required frequency and connects the output to a hybrid coil which provides a choice by means of suitable strappings, of two paths, one of which can be equipped with a channel carrier supply amplifier.

The G.S.G.C.S. rack provides the frequencies required for the following purposes:—

(i) Group modulation of five basic groups to form one basic supergroup and, in the reverse direction, demodulation of the basic supergroup into its component groups.

(ii) Supergroup modulation of the basic supergroup for transmission as a baseband of up to 16 supergroups over the coaxial lead-in cable to the ratio building and, in the reverse direction, separation of the incoming baseband into its component supergroups and subsequent demodulation to the basic supergroup.

The 12 Kc/s. frequency from the M.O.C.C.S. rack is applied to two identical sets of harmonic generators equipped with automatic change-over facilities. They generate odd harmonics up to at least the 51st, that is, 612 Kc/s. These output harmonics are connected to a bank of five filters which select the appropriate group carrier frequencies of 420, 468, 516, 564 and 612 Kc/s.

The 612 Kc/s. frequency is also used for Supergroup 1 and a hybrid coil is used to obtain the additional supply. These two outputs plus the single outputs from the other four filters are connected to separate carrier supply amplifiers so that each frequency may be transmitted to the C.S. Dist. rack at the correct output level.

The 124 Kc/s. frequency from the M.O.C.C.S. rack is applied to two identical sets of harmonic generators equipped with automatic change-over facilities. They generate odd harmonics up to at least the 21st, that is, 2,604 Kc/s. These harmonics are connected to a frequency doubler which doubles the incoming fundamental and harmonics. A combination of amplifiers, equalisers etc., is used to select the frequencies for Supergroups 3-16. As mentioned above, the 612 Kc/s. carrier frequency used for Supergroup 1 is also one of the group carriers and no carrier is required for Supergroup 2 which is transmitted to line without further modulation.

The carrier frequencies used for modulation and the resultant sidebands are shown in Table 3.

TABLE 3

Supergroup No.	Carrier Frequency In Kc/s.	Frequency Range of Resultant Sideband in Kc/s.
1	612	60-300
2	—	312-552
3	1,116	564-804
4	1,364	812-1,052
5	1,612	1,060-1,300
6	1,860	1,308-1,548
7	2,108	1,556-1,796
8	2,356	1,804-2,044
9	2,604	2,052-2,292
10	2,852	2,300-2,540
11	3,100	2,548-2,788
12	3,348	2,796-3,036
13	3,596	3,044-3,284
14	3,844	3,292-3,532
15	4,092	3,540-3,780
16	4,340	3,788-4,028

The S.G.C.S.A. rack selects and amplifies carrier frequencies for Supergroups 3 to 16 and they are then connected to the C.S. Dist. rack at the specified frequency and input level. The amplifiers are not duplicated as each has two valves in parallel in the first stage and three in parallel in the second stage.

The C.S. Dist. rack distributes the carrier, pilot and signalling frequencies to the broadband terminal equipment racks. Dummy load resistors are removed from the various panels as additional terminal equipment is installed. The C.S. Dist. rack also accommodates the duplicate 84.08 Kc/s. group pilot frequency generators and their associated changeover panel. The 84 Kc/s. frequency used for Channel 7 is modulated by a separate 80 c/s. oscillator to provide the required frequency of 84.08 Kc/s. This is amplified to a level of +8.5± 1.0 dbm into 75 ohms for subsequent distribution as required via individual outlets to 12-channel modem groups at a level of—24±1.0 dbm. into 75 ohms.

Distribution Frames

A broadband system incorporates facilities for the interconnection of equipment at the 12-channel basic group and 60-channel basic supergroup stages by means of distribution frames which are installed in the long line equipment offices. These facilities are provided by rectangular frames of pressed steel members which are equipped with terminal blocks, coaxial sockets, etc. Each frame is double sided and has the same external dimensions as two racks back to back.

Reference to Fig. 4 will clarify the following description. A group distribution frame is used to re-route the basic groups in each direction on a four wire basis. It provides flexibility not only within the broadband system itself, but also to other carrier systems. The basic group of 60-108 Kc/s. can be connected directly to the group terminal of an open wire or cable 12-channel carrier system without translation to voice frequencies. Through group filters and attenuators are normally used to adjust the receive level of—5 dbm. into 135 ohms to the transmit level of —42 into 135 ohms. Cabling is taken directly to the terminal strips and not through the normal rack to panel links. Separate portions of the frame are used for terminations which have different transmission levels and similar arrangements provide segregation between channel modem and group modem cabling. Interconnection is achieved by the use of one pair shielded jumper wires.

A supergroup distribution frame is used to re-route the basic supergroups in each direction of transmission. It enables through routing of a complete supergroup to be carried out without the necessity for group and channel translating equipment.

The transmission levels at the S.G.D.F. are — 30 dbm. into 75 ohms in the receive direction and—35 dbm. into 75 ohms in the transmit direction thus requiring a loss of 5 db. in the through supergroup filter and associated amplifier.

All cabling on a supergroup distribution frame is terminated on a coaxial junction box, the receive side cabling being terminated on the upper half and transmit side cabling terminated on the lower half of the frame. All output cabling is terminated on one side of the frame and all input cable is terminated on the other side. The frame also provides for the termination of through supergroup filter rack cabling with terminations as outlined above. Interconnection of the various equipment is achieved by the use of shielded coaxial jumpers.

The coaxial junction box used on this frame provides for the termination of the external cable and the interconnecting jumper and it also incorporates a coaxial socket for test access and patching purposes. When used for the latter application it is necessary to remove links in the supergroup modem equipment.

Separate group and supergroup distribution frames are installed only in the larger offices, e.g., Brisbane, where extensive interconnection of groups and supergroups is required. These conditions are not applicable to Maryborough, Rockhampton, Mackay, Townsville and Cairns and the distribution facilities in each of these offices are provided by a combined group and supergroup distribution frame, which has similar facilities to those of the two separate frames, but with reduced capacities.

Through Group and Supergroup Filters

When groups are re-routed on a distribution frame, crystal lattice type through group filters are used to remove fringes which are left near the upper and lower extremities of the 60-108 Kc/s. basic groups after they have been demodulated from an incoming basic supergroup. Normally when groups are demodulated to voice frequency channels these fringes are of no consequence because they are removed by the channel band pass filters. If, however, these unwanted modulation products are not removed before connection to another system (or within the same system), they may cause interference to adjacent groups and, in due course, will be demodulated to appear as noise on adjacent channels. The loss in the pass band is adjusted by pads to a uniform value to compensate for the level difference between the output of the group demodulator (—5 dbm. into 135 ohms) and the input to the following group modulator (—42 dbm. into 135 ohms).

Similar arrangements are provided for re-routing of basic supergroups. Through supergroup filters have a pass band of 312-552 Kc/s., and their function is to provide adequate suppression to frequencies in adjacent supergroups. Reasons for the proposed use of these filters to minimise interference to the 3 Kc/s. spaced channels on the SEACOM supergroups were explained in the paper by C. J. Griffiths (Ref. 1).

The filters and their associated amplifiers are adjusted to provide an overall loss of 5 db. to compensate for the level difference between the output of the supergroup demodulator (—30 dbm. into 75 ohms) and the input to the following supergroup modulator (—35 dbm. into 75 ohms). Except for the larger offices (e.g., Brisbane) group and through supergroup filters are installed on a common rack.

POWER SUPPLIES

The terminal equipment in a modern broadband system is designed to operate from a regulated 240 volt A.C. supply which is connected to power units in each active rack. These units transform and rectify the input supply to provide the A.C. and D.C. potentials which differ from those used for older types of long line equipment and thus preclude the use of the 24 volt and 130 volt station batteries. Special measures are taken to minimise interruptions to the A.C. supply to these power units because of the very large number of channels that would be affected. Even though some of the racks may be transistorised and connected to the station busbars a failure of the A.C. mains could render the whole system inoperative unless continuity of supply from some other sources is arranged. The reason for this is that common equipment such as carrier supplies, line amplifiers, etc., is valve operated. Although the commercial A.C. mains are inherently reliable interruptions do take place and the regulation may vary outside permissible limits for

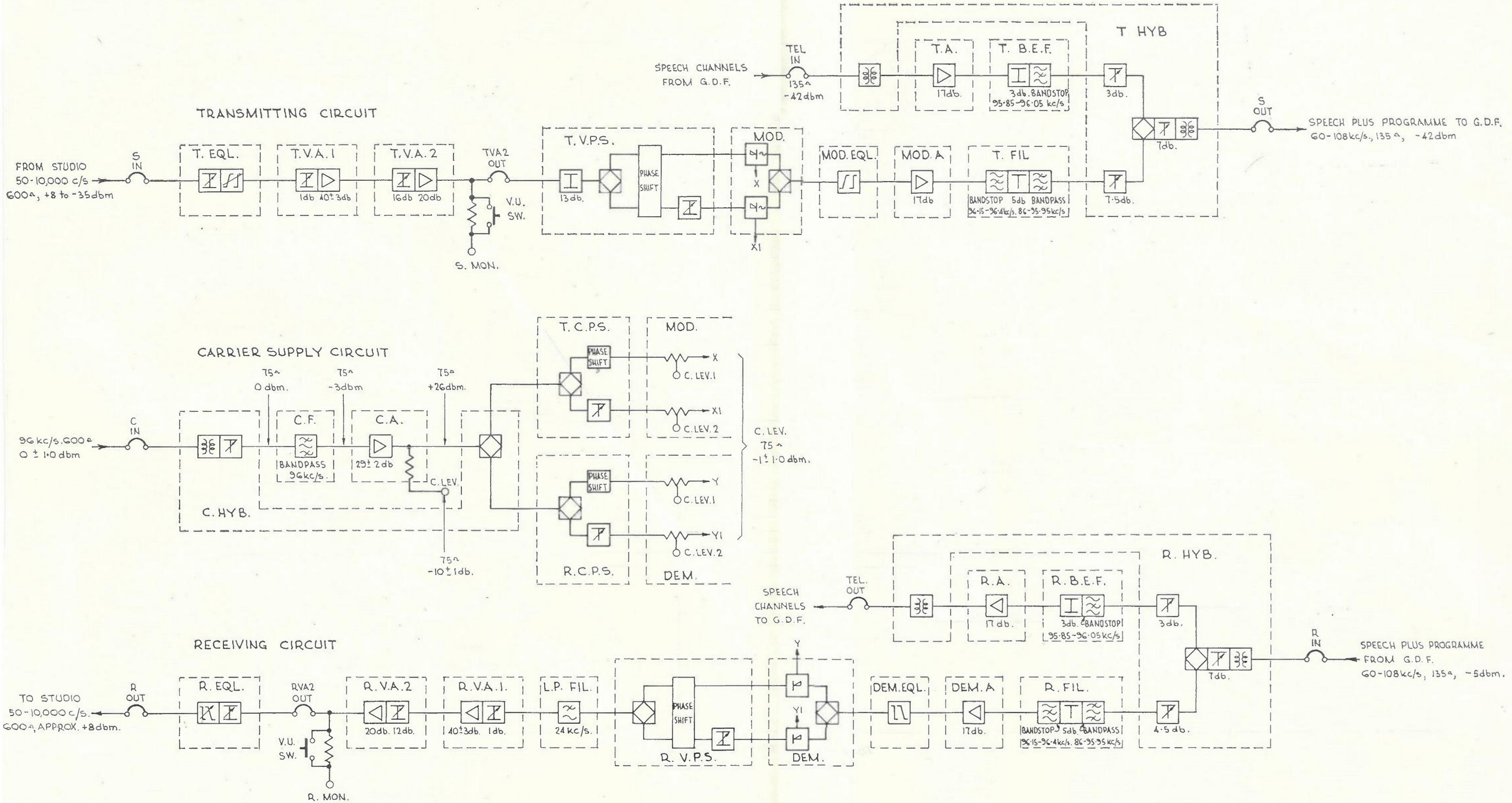


Fig. 5 — Simplified Schematic — Programme Terminal Equipment.

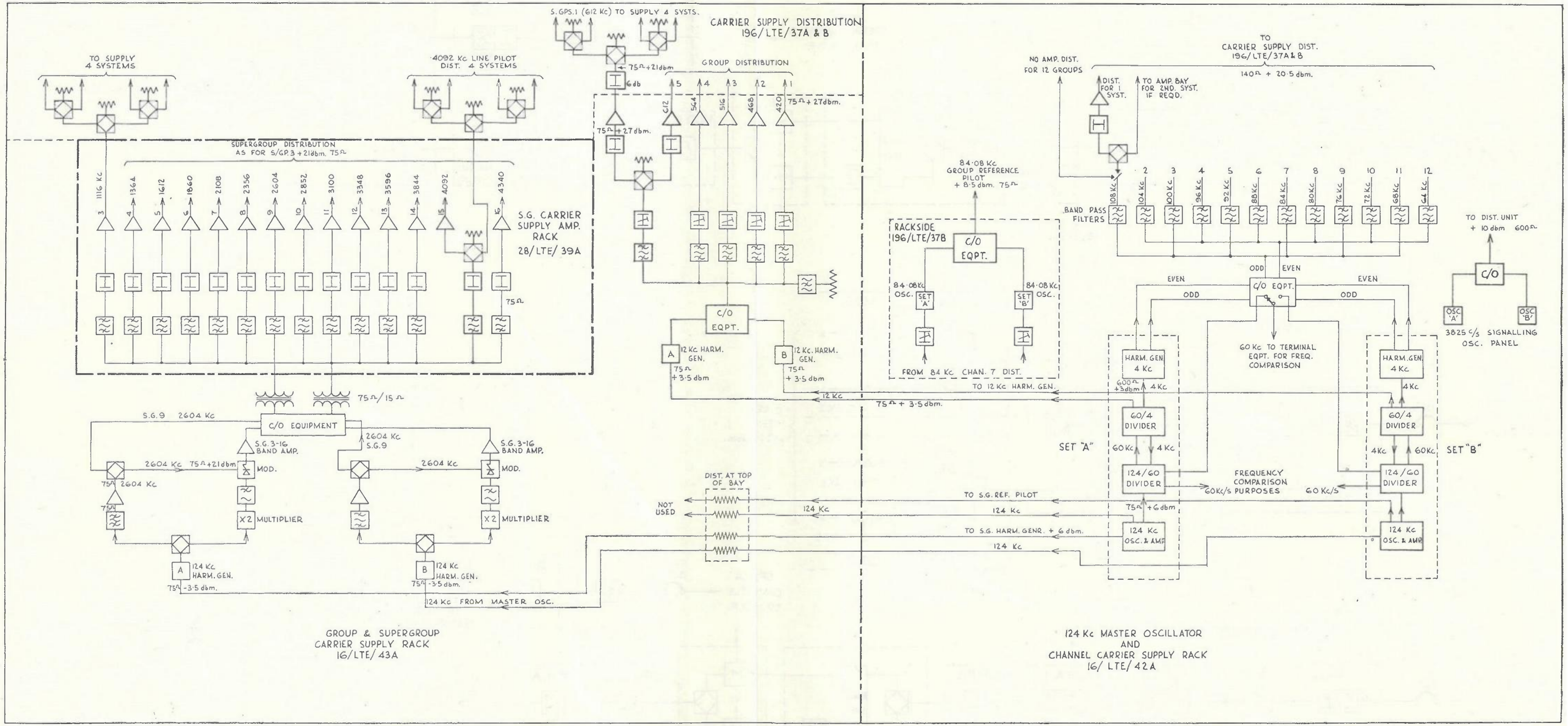


Fig. 6 — Simplified Schematic — Carrier Supplies.

optimum performance of broadband equipment.

No-break Supplies

Continuity of the A.C. supply to the broadband equipment is ensured by the use of no-break power plant. There are several alternative methods available, but the only ones adopted for general use by the Australian Post Office have been "The three machine all electric no-break set" as used for recent broadband installations and the "Two machine all electric no-break set" which has comparable functions, but with an appreciable simplification of the rotating machines and associated control equipment and, in particular, the elimination of switching.

The following description, based on the simplified schematic shown in Fig. 7 refers to the 10 KVA. two machine no-break nower plant manufactured by McColl Electric Works Pty. Ltd., and installed at Maryborough, Rockhampton, Mackay, Townsville and Cairns. A statically controlled two machine no-break power plant comprises a control cubicle, a two machine motor/alternator unit and a motor battery. The control cubicle accommodates the necessary transformers, rectifiers, battery chargers, control equipment, bypass and isolating switches etc., for the satisfactory control and operation of the plant.

The input power of 380/440 volt, three phase, 50 c/s. from the commercial mains or a normally stationary diesel engine alternator is applied to the primary of the main stepdown transformer TFRI. The secondary of this transformer is connected to a silicon three phase bridge rectifier network designated MRR and usually referred to as the "run" rectifier. Assuming normal mains input voltage the D.C. potential of 150 volt from the output of this rectifier is fed through a starting resistance to a D.C. motor which is directly coupled to an alternator. The motor/alternator unit has only two bearings and is mounted on a common frame. The alternator supplies an output of 415 volts, three phase, 50 c/s. which is controlled within very close voltage limits by a high speed automatic voltage regulator. The three phase are distributed to various broadband equipment racks to provide inputs of 240 volt, single phase, 50 c/s., or any phase may be stepped up for transmission over two tubes in the coaxial lead-in cable to the radio building.

Two 60 cell 200 A.H. batteries, normally connected in parallel, are floated at 2.25 volt per cell to provide the 135 volt motor battery supply, which is connected through a blocking rectifier BR to the D.C. motor. Under normal operating conditions with input power obtained from the commercial mains or the N.S. set, this rectifier, which is rated to carry the full load current of the D.C. motor, is non-conducting (i.e. high resistance) because the output of the mains transformer/run rectifier combination is at a higher potential (approxiamately 150 volt) than the motor battery voltage (135 volt). The power required to drive the two machines is therefore obtained from the 150 volt D.C. supply and not from the motor battery.

Should the mains fail (this includes total failure, failure of one or more phases or a reduction in the input voltage so that the potential of the rectifier output falls below the motor battery potential) rectifier BR conducts (i.e. it has low resistance) and the machine is driven from the motor battery without any switching operation, and, therefore, without interruption to the broadband terminal equipment load.

The motor series field includes a "run" series coil which is in circuit irrespective of which form of motor drive is applied. When the potential from the mains transformer/run rectifier output falls below that of the motor battery, rectifier BR conducts and a "reverse" series field coil, which only functions under conditions of motor battery drive is introduced. This additional coil opposes the "run" series coil and weakens the series field of the motor so that it maintains approximately the same speed with a reduced driving voltage.

The position of the brushes in the D.C. motor is arranged to cater for the slight speed change which may occur during transfer of drive from the 150 volt D.C. supply to the motor battery supply. The D.C. motor includes a speed potentiometer RF3 in its shunt field circuit to provide the necessary adjustment for load variations between no-load and full load.

Apart from the excellent speed regulation of the machines the action of the automatic voltage regulator A.V.R. is extremely fast and the overall effect is that any variations in output voltage are of a transitory nature and are corrected without delay.

When the mains supply is restored (or the N.S. set started) the output potential of the run rectifier MRR again exceeds that of the battery on the D.C. motor side of rectifier BR which resumes its blocking function so that the machine is driven from the mains transformer/run rectifier combination.

The motor battery is maintained at its float potential of 135 volt by the contacts of a float charge relay FC, connected in series with a five ohm resistor across rectifier BR. Relay FC, which is controlled by a single stage transistor amplifier, is energised and the rectifier by-pass path is open circuited when the battery potential reaches 136 volt. It is de-energised and the 150 volt D.C. sup-

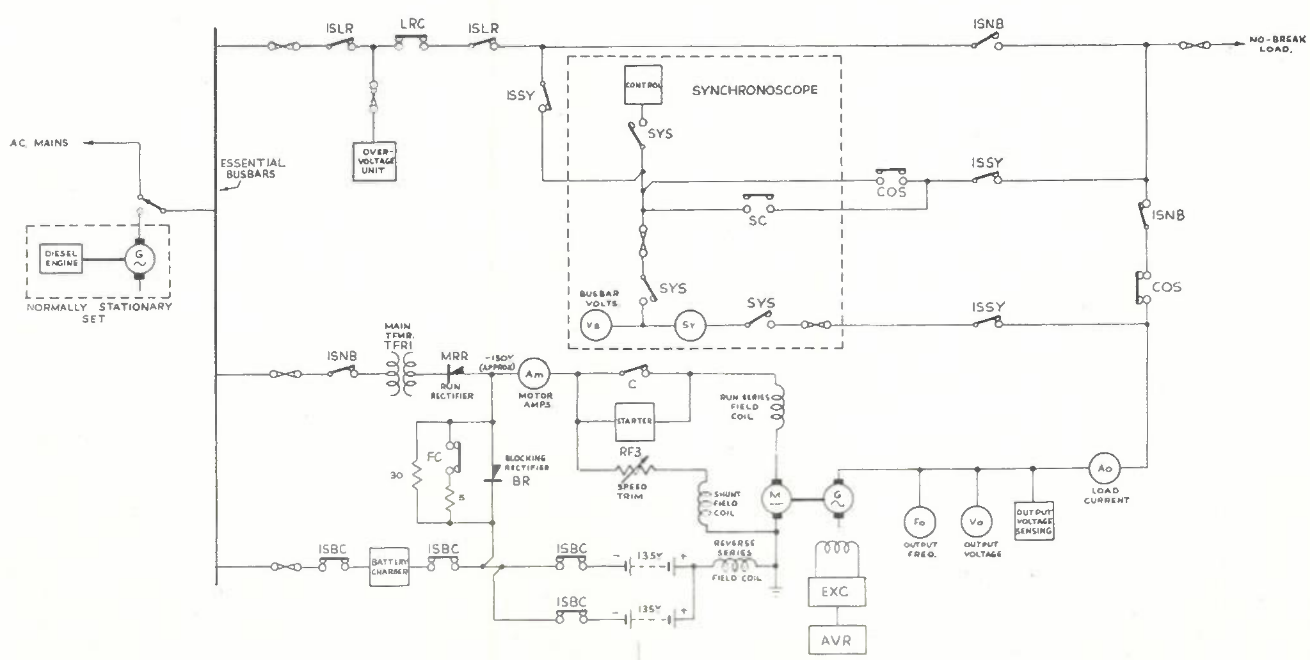


Fig. 7 — Simplified Schematic — 10 KVA No-break Power Plant.

ply is again connected through its contacts and the five ohm resistor to float charge the battery when the potential falls to 134 volt.

A 30 ohm resistor, which is not controlled by a relay, is permanently connected across rectifier BR to provide a small bleed current from the 150 volt D.C. potential to offset any leakage losses in the motor battery.

A separate auto/manual rectifier is used to charge the motor battery following any partial discharge and also to give a periodical gassing charge under manual control to either one of the two batteries whilst the other is available for normal use. In practice the input power for the operation of the no-break plant is obtained from the N.S. set in the event of mains failure. Should the N.S. set fail to start, an alarm is raised and the motor battery can drive the machines for a period of up to three hours until the potential falls to approximately 105 volt (1.75 volt per cell).

Whenever the mains fail or vary outside permissible limits, the control circuitry transmits a start signal after a short pre-determined delay to the N.S. set which starts automatically from a seperate 24 volt battery. The reason for providing this delay is that the supply may be interrupted for a very short period and the driving power can be provided by the motor battery instead of the N.S. set. The start signal is, therefore, connected to a pneumatic timer which is normally adjusted for a delay of 30 seconds, but may be varied by turning a screw on the top of the unit to provide any delay between 0 and 2.5 minutes to meet requirements at a particular station.

Once started the N.S. set continues to run for a pre-determined period of not less than 30 minutes. Should the mains supply be restored within this period it replaces the N.S. set input to the no-break set, but the N.S. set continues to run on no load for the specified period unless manually shut down.

The facilities provided by the statically controlled 10 KVA two machine no-break power plant are not described in this paper as they are listed in the relevant handbook under the following sub-headings:—

(i) No-break Compartment and Machine.
(ii) Synchronising Compartment.
(iii) Battery Charging Compartment.
(iv) Isolating Compartment.

From an installation viewpoint, the two machine no-break power plant consists of a control cubicle, the integrated machine and a motor battery.

The control cubicle is 7 ft. wide x 6 ft. high x 2 ft. 6 in. deep and is mounted on 2 in. wooden plinths on a level surface. Cabling is run overhead in metal ducts. The integrated machine is 5 ft. 5 in. long x 1 ft. 9 in. wide x 2 ft. 4 in. high and it weighs 16 cwt. It is not bolted to the floor, but rests on miscolite pads attached to a flat and level floor surface with a suitable adhesive. The motor batteries are accommodated in three double sided steel cabinets, each of which is 4 ft. 6 in. long x 1 ft. 9 in. deep x 6 ft. 0 in. high.

Arrangements at Brisbane

The power arrangements for the Brisbane terminal differ somewhat from those described above. Long line equipment is installed in the Central Auto Exchange building and no-break power is obtained from a 40 KVA three machine set which was provided initially for the Lismore coaxial cable system and for "TRESS". Channel modem equipment in this office is operated from the 24 volt secondary battery busbars. The new Edison engineering building is nearing completion and it will be used to accommodate all broadband and long line terminal equipment in Brisbane. In the meantime the Brisbane terminal of the Cairns system is installed in the existing C.A.E. building. Broadband equipment supplied after 1966/67 will be completely transistorised and will operate from the 24 volt busbars. However, some of the existing and proposed equipment that will be transferred to the new building is valve operated and its no-break power will be obtained from duplicate 15 KVA sets. These are similar to the 10 KVA sets provided for the country offices and, apart from slightly increased physical dimensions, the same description is applicable. The 240 volt 50 c/s regulated A.C. supply required for the operation of the power units on the auxiliary amplifier racks in the radio buildings at Maryborough, Rockhampton, Mackay, Townsville and Cairns is obtained from the 10 KVA no-break power plant installed in the associated long line equipment offices. A 240 volt 50 c/s feed from one of the three output phases of the no-break set is connected to a transformer on the power feeding rack and stepped up to 600v-0-600v for transmission via power filters over the inner conductors of Tubes Nos. 1 and 2 in the coaxial lead-in cable. The high voltage is used to avoid excessive transmission losses and prevent over-heating of the cable.

Tubes 1, 2, 3 and 4 are terminated above the remote power supply rack in the radio building and the 50 c/s high voltage power is separated from the telephony baseband by power filters and connected to an auto. transformer with subsidiary winding. The auto. transformer includes tapped connections so that the incoming voltage may be restored to 600v-0-600v to compensate for any power transmission loss over the built out cable section. The secondary winding supplies the 240 volts 50 c/s input to the power units on the auxiliary amplifier rack. These arrangements are shown in Figs. 2 and 3. The initial installation of power feeding equipment can supply an equipment load in the radio building of approximately 700 volt amps which will cater for up to three broadband systems.

Personnel Safety Measures

Adequate safety measures protect personnel who are required to work on the cable. The officer concerned (usually the fault lineman) visits the long line equipment office and requests disconnection of power from the cable. It can be switched off at the power feeding rack by an interlocking switch fitted with a key which cannot be removed until the power switch is turned to "OFF". The power cannot be turned on again until this key is re-inserted in the lock. The station attendant hands the key to the lines officer who then places it in a special box provided for this purpose and locks the box with his own padlock. A separate padlock is used for each officer who proposes to work on the cable at the same time, and the power cannot be restored to the cable until all padlocks have been removed. These precautions ensure that the high voltage cannot be accidentally reconnected to the cable until field operations have been completed. They are very important because any cable fault could require remedial action from the lines staff and, say, the cable protection staff. When the work has been completed the staff concerned return to the long line equipment office, unlock the padlocks and return the power key to the station attendant who re-inserts it in the lock, turns the switch and restores the power feed over the cable.

Whenever the power feeding circuit is interrupted a relay set in the radio equipment room automatically changes the input to the auxiliary amplifier rack from power feed to regulated local mains supply. Under normal power feeding conditions a lamp indicates that power is being transmitted over the cable.

CONCLUSION

This paper describes the line and broadband terminal equipment that is being installed on the Brisbane-Cairns section of the SEACOM route but does not include signalling methods, order wires, alarms, supervision, testing instruments, equipment layout, cabling arrangements or installation procedures. The radio bearer is scheduled for completion by the end of February, 1966, and it is planned to provide the trunk channels during 1966.

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THE L.M. ERICSSON AKL—10 DETACHED EXCHANGE

*J. J. Andrews, B.E.E., Grad.I.E.Aust.**

INTRODUCTION

General

The AKL-10 Detached Exchange performs functions similar to those of a normal line concentrator. That is, it enables a group of subscribers in a restricted geographical area to be connected to an exchange using fewer cable pairs than would normally be required. This article outlines the installation of the system in Brisbane, and contains a broad discussion of its operation and principal features.

Line concentrators and detached exchanges are two closely related methods of reducing line plant costs at the penalty of increasing equipment costs. Both depend on the fundamental principle that only a relatively small proportion of connected subscribers will be making or receiving calls at any given time. If a number of subscribers are grouped within a reasonably compact area situated some distance from the nearest exchange, and with insufficient spare line plant available between the area and the exchange, a line concentrator is one possible solution to the problem of providing service. By this means a common group of junctions can be used between the area and the exchange. The reduction in required cable pairs is normally of the order of 50%-80%.

A line concentrator or detached exchange has three distinct functional sections:—

(a) A distant unit (concentrator) to allot individual lines to the common group of junctions.

(b) A unit to retranslate the allotted position to individual lines for metering and identification purposes.

(c) A system for signalling between the two units.

A conventional concentrator uses the already existing subscribers exchange equipment (e.g. subscribers line circuit, uniselector and final selector multiple in step-by-step or LR/BR relays and SLA switch multiple in crossbar). Hence the subscribers connected to the unit may be allotted any number within the existing numbering range of the parent exchange.

Facilities

All normal facilities can be provided for subscribers connected to the Detached Exchange with the exception of special observations and full interception. The only difference noticeable to the subscriber is a slightly longer interval between lifting the receiver and obtaining Dial Tone.

It is not desirable to connect P.B.X. lines to a concentrator because they are normally of a higher than average calling rate. However both directory and auxiliary lines may be connected if desired in the same way as for a normal 200 line group. Public Telephones may not be connected to the AKL-10.

All subscribers may be class marked in the normal way in relay set K.A.N.

The Chapel Hill — Jindalee Installation

The first unit of this type to be brought into service in Australia was installed to serve subscribers in the new Brisbane suburb of Jindalee, which is part of a larger development known as Centenary Estates. The area is expected

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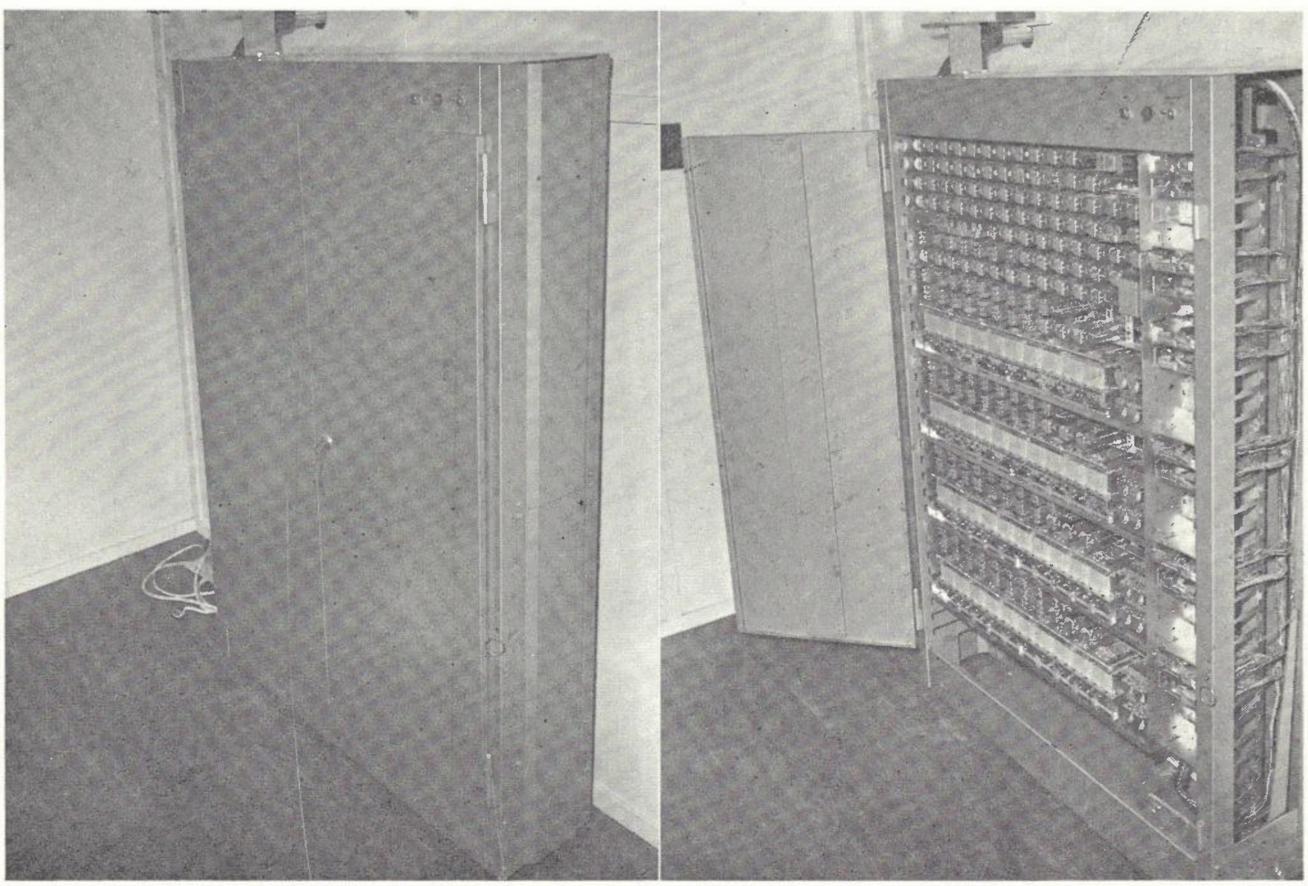

Fig. 1 — Detached End Rack. Left: Covers in place. Right: Covers removed.

to be served ultimately by its own exchange, but as the development has just commenced, and the anticipated site of Centenary Exchange has not yet been surveyed, an interim arrangement was desired. The closest existing exchange (approx. two miles) with adequate capacity to serve the area is Chapel Hill (ARF 102 Crossbar). It is anticipated that the preferred route for junction cables to the ultimate Centenary Exchange will not be via Chapel Hill, and so a new cable from there to Jindalee would not be an economical proposition. As the existing cable to Chapel Hill had sufficient spare pairs available (after transferring a number of subscribers to the AKL), it was decided to instal an AKL-10 Detached Exchange.

The remote end unit is housed in a hut normally used for ARK 511 exchanges, which is situated in close proximity to the principal cable distribution pillar for the area. As power was available on the site, and was required in the hut in any case, the charge over idle trunks facility was disconnected and a separate small rectifier installed.

The batteries could be installed in the base of the remote end cabinet. However, NIFE cells gas continuously on charge and since adequate space was available in the hut a small battery cabinet was used to ensure complete protection against risk of battery gas explosions.

DETAILED DESCRIPTION

Removal of SLA Switches

The AKL-10 Detached Exchange, which is compatible with ARF crossbar exchanges, in effect removes the SLA switches in a particular 200 group from the parent exchange and places them in a remote location. The junctions may be regarded as the links between the SLB and SLA switches. The position in the parent exchange normally occupied by the SLA/B rack is instead taken up by the AKL Parent End Rack.

The effects of this are twofold:—

(i) Most of the subscribers' line equipment in the parent is not required. This cost is thus saved.

(ii) The Detached Exchange is limited to numbers within a certain numbering range. As a result, in a 1,000 line group, one-fifth of the SR and SLB capacity, one-fifth of the cost of the SL marker, and a certain fraction of the cost of the Register Finder stage can be applied only to subscribers in the Detached Exchange. If the area in which the unit is situated does not grow rapidly enough to achieve full occupancy within a reasonable time, then since the spare capacity in this thousand line subscribers stage cannot be applied to the remainder of the exchange service area, the cost of this unusable capacity must also be debited to the detached exchange. This factor must be considered in determining the economics of the system.

Principal Features and Mechanical Construction

The AKL-10 Detached Exchange may be built up to serve 50, 100, 150 or 200 subscribers. It is housed in a steel cabinet (Fig. 1) which rests on the floor and is hinged to a wall. The cabinet is fitted with lockable, removable doors. It contains an Identifier relay set, a Code Sender relay set and one to four Code Switch relay sets. The battery may also be fitted in this cabinet.

The parent end rack (Fig. 2) occupies the position of an SLA/B rack in the ARF exchange. Three SLB switches are fitted on the bottom of the rack, the remainder being occupied by signalling and control relay sets and one to four code switches. The parent rack may serve four detached exchanges of 50 line capacity, one of 200 lines, or various combinations between these two limits.

Junction Requirements

50 lines	10 junction pairs + 7 signalling pairs
100 lines	20 junction pairs + 7 signalling pairs
150 lines	30* junction pairs
200 lines	40* junction pairs

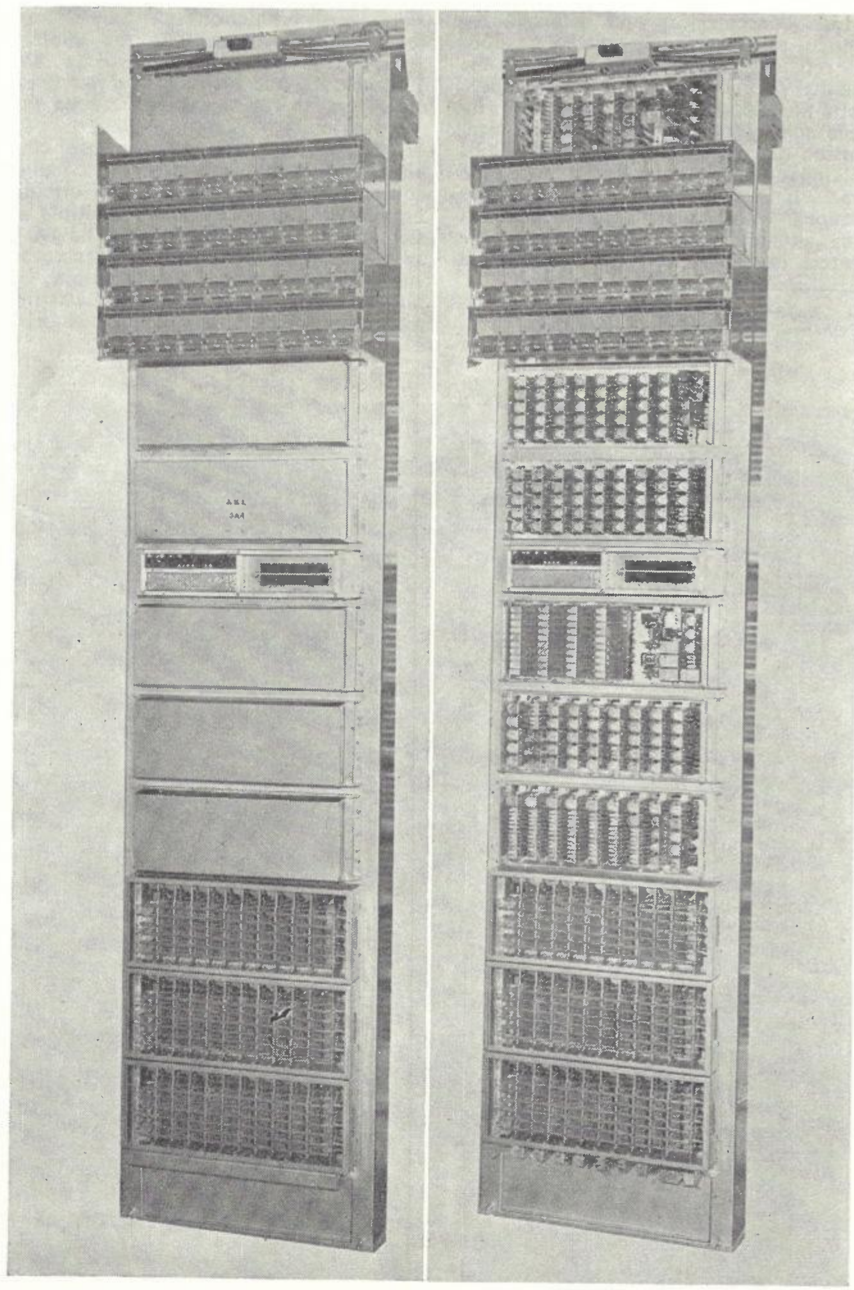

Fig. 2 — Parent End Rack. Left: Covers in place. Right: Covers removed.

* In the 150 and 200 line units, signalling takes place over idle junction lines connected to the home position contacts of verticals 3-9. Thus separate signalling pairs are not required. (See under "Signalling Channels"). One pair out of each of these groups must always remain free for signalling, hence 33 pairs are the maximum available as junctions in a 200 line unit, and 23 in a 150 line unit.

The Code Switch

The AKL-10 detached exchange is designed around a new type of crossbar switch — the Code Switch. In developing this selector, the manufacturers aimed for small size and low current consumption combined with ease of fabrication. A new type of contact unit was developed (Fig. 3). The moving

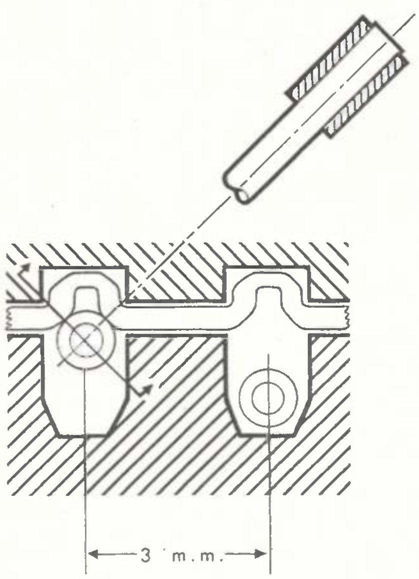

Fig. 3 — Code Switch Contact Unit.

contact is a small cylinder which fits over one end of a spring wire. The wire is moved by a lifting comb into a "V" shaped slot in a horizontal strip of contact material which performs the same function as the vertical contact bars in a crossbar switch. The cylinder contacts both sides of the "V", giving a twin contact unit which comparative tests have shown to be less susceptible to dust than normal twin relay contacts.

The contacts are arranged in 17 vertical columns of 12 contacts each, with 3 mm. spacing between contacts, giving a basic unit capable of switching 16 x 12 wire circuits. By level switching (analogous to HA/HB switching in a conventional crossbar switch) the unit may be used to provide 30 x 6 wire, 42 x 4 wire or 52 x 3 wire outlets. Ten of these basic units are combined with the selecting mechanisms into one code switch. Fifty outlets of three wires each are required in the AKL-10 system, the other two outlets being used for special functions (see Figs. 4 and 5).

Mechanism

The selecting system for the vertical lifting combs is a "binary code system". Six code elements are necessary to provide the required number of combinations for 52 outlets. The code elements are bars running the full length of the switch. They are provided with notches, the six bars being notched in such a way that only two clear notches are available to the selecting fingers when an outlet

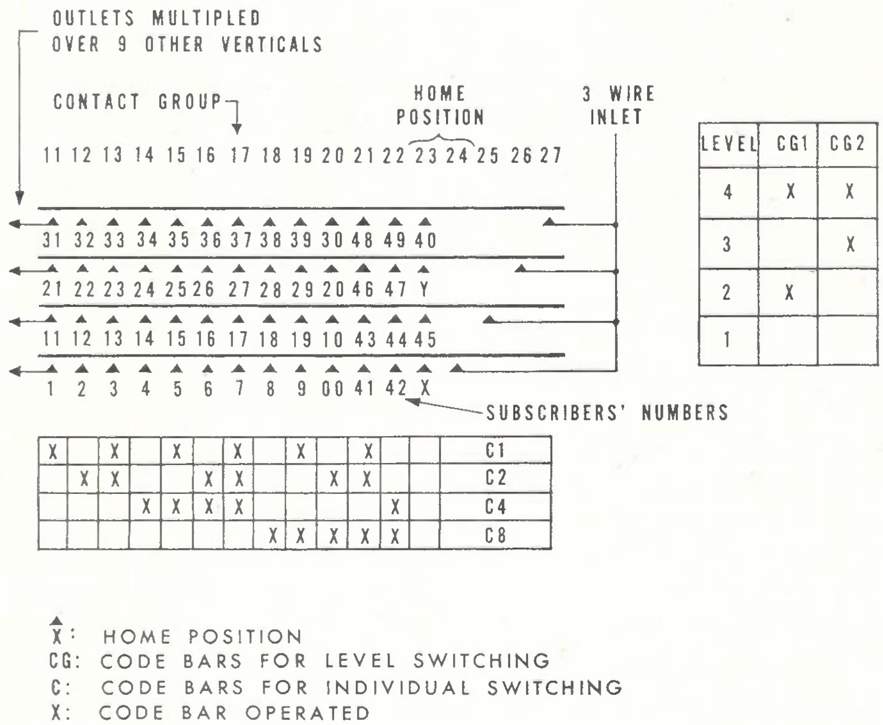

Fig. 4 — Outlets from Code Switch.

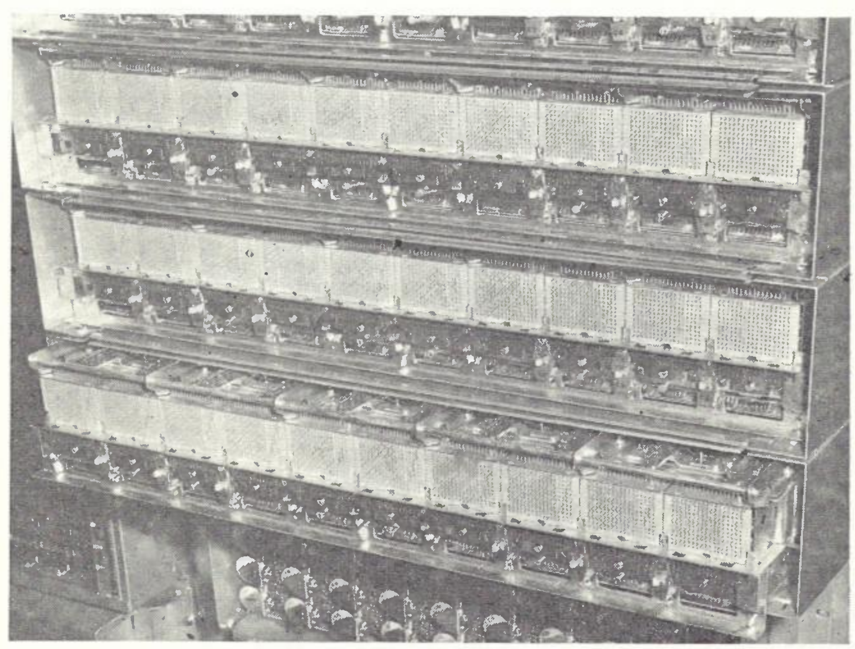

Fig. 5 — General View of Code Switch.

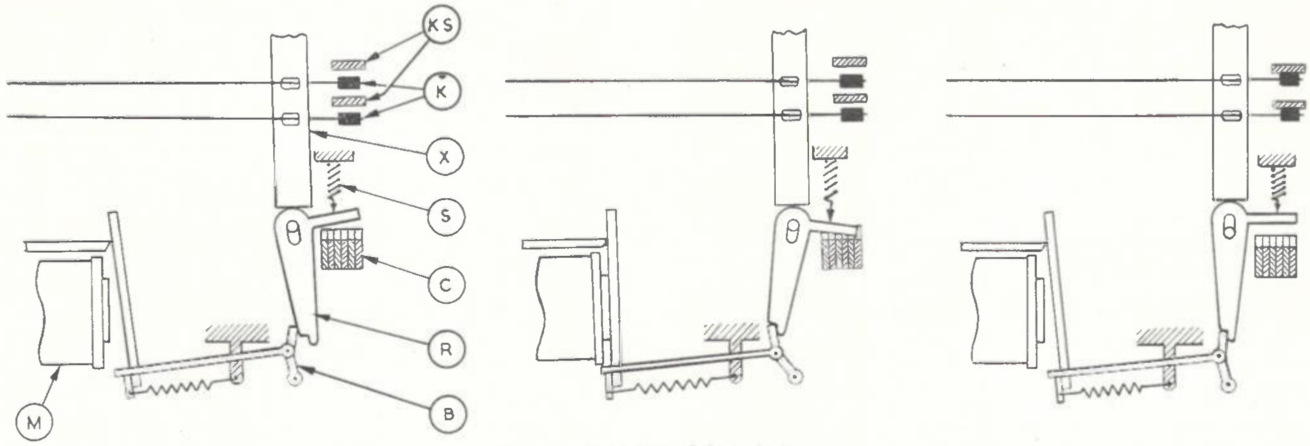

Fig. 6 — Operation of Code Switch.

is being selected. Fig. 6 illustrates the operation of the selecting mechanism. The appropriate code bars (C) are operated, followed by one of the ten vertical magnets. Each vertical magnet (M) can actuate 17 selecting fingers (R) (one for each lifting comb) consisting of "L" shaped rockers pivoted on a common shaft, the rockers being individually spring loaded (S) so as to move down against the teeth of the code bars. The fingers are normally kept from engaging the code bars by the lifting bar (B). When this bar (B) is operated by the vertical magnet, the rockers (R) are allowed to move so that one end contacts the code bars. Fifteen of the rockers are stopped against the code bars, but two (one level rocker and one outlet rocker) slip into notches. This allows the "tail" of the rocker to engage in the lifting bar (B). When the vertical magnet is released, the lifting bar (B) forces the rocker arm (R) upwards. The top of the rocker arm pushes the lifting comb (X) upwards, thus forcing the contacts (K) against the contact strip (KS). The code bar magnets are subsequently released and thus the connection is held with no magnets operated.

The notches in the code bars are arranged in such a way that if the vertical magnet is operated with all code bars normal, rocker arms 13 and 14 are engaged, and when the vertical magnet is released, the corresponding contact units are made. This serves as a "home" position. If desired, an additional contact unit is fitted above these two lifting combs to provide for additional circuit functions.

The internal multiple of the switch is made up of flat contact strips machine soldered to the wire spring contact units. Because of the compact nature of the multiple, and the necessity of connecting approximately 200 wires in a space only 51 mm x 36 mm, conventional terminating tags are impracticable. Instead, the connecting wires are soldered to a small plug unit (similar in construction to the strapping blocks in the "KAN" relay set in ARF.102) which mates with extensions of the contact wires.

Trunking

A trunking diagram is shown in Fig. 7. It will be noted that there are only

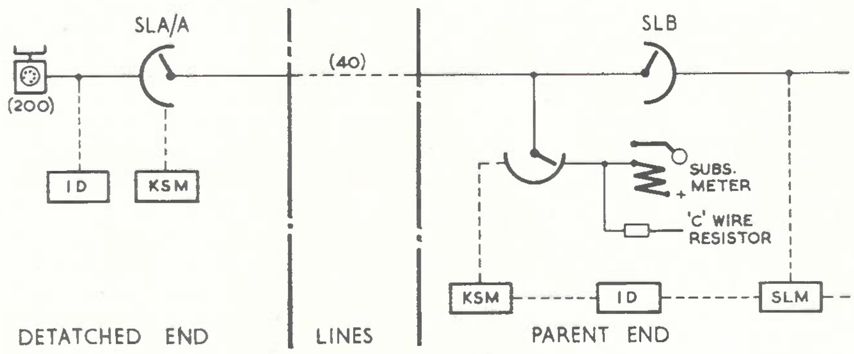

Fig. 7 — Trunking Diagram.

40 links available between the SLB and the SLA switches and furthermore (see "Signalling") seven of these links are effectively not available because of signalling requirements. It is stated, however, that the traffic handling capacity is not significantly less than for an ARF M = 6 subscriber stage. In an ARF M = 6 stage, each subscriber can obtain access to only six SLA-SLB links. However, in the AKL system, because of the larger multiple capacity of the code switch, each subscriber is multiplied over ten basic switching units (verticals) and hence has access to ten SLA-SLB links. It is this factor which allows the use of the smaller number of links and makes the AKL-10 Detached Exchange attractive in terms of cable savings.

Links from SLB to SLA are normal 5 wire circuits. The code switches in the parent end unit switch the "c" and "r" wires (to testing resistor — in lieu of LR relay coil, and to subscriber's meter respectively). The "d" wire from SLB is used to hold a junction line relay operated. The third switching position is used only by the "home" contacts to connect one leg of the junction to the signalling relays. The "a" and "b" wires are connected to junctions by the junction line relay and are switched by the code switch in the Detached unit. A local "c" wire is also switched at the detached end.

Signalling Channels

In a 50 line unit, 10 pairs are required as junctions plus seven for signalling. In the 200 line unit, however, only 40 pairs are required, the signalling pairs being taken from the free junction pairs as indicated in Table 1. For

TABLE 1: ALLOCATION OF SIGNALLING CHANNELS

Vertical	1	2	3	4	5	6	7	8	9	10
Code Switch	Junction Pair No.									
1	1	2	3	4	5	6	7	8	9	10
2	11	12	13	14	15	16	17	18	19	20
3	21	22	23	24	25	26	27	28	29	30
4	31	32	33	34	35	36	37	38	39	40
Signalling Channel No.	1	*	1	2	3	4	5	6	7	7

* Test Lines

example, signal channel 1 may use pairs 3, 13, 23 and 33. If all of these are free, they are used in parallel as a signalling channel and any three of them are still available for use as a junction. However, should only one of these pairs be free, it is marked artificially busy and cannot be used as a junction. By this means flexibility is retained and a minimum number of junction pairs are required. This system is, however, not without its hazards. Should any one of the 36 pairs which may be used for signalling become short circuited, reversed or earthed, the complete detached exchange will be put out of service.

Signalling

When a subscriber initiates an outgoing call, identification at the detached end commences. Identification is carried out in two stages — one of the 16 horizontal rows (4 rows in each of 4 switches) is determined firstly, ("A" identification), followed by one of the 13 vertical columns ("B" identification). When indentification is completed, the parent unit is called, and if free, sends back a "proceed" signal. The "A" identification signal is transmitted forward by connecting negative polarity to the "a" leg of between one and four of five signalling channels. (Table 2). This information is received and stored at the parent end. The same information is then returned by negative polarity on the "b" leg of the signalling channels. At the detached end this is compared with the original signal. If the two sets of information are identical, the system proceeds to send the "B" identification which is stored and compared in the same way. The "B" identification is also stored at the Detached end. If at any time the sent and received signals do not correspond, a lock up condition occurs until cleared by time throw-out and an alarm is given.

The store relays at the parent end present to the SL marker a condition identical to that caused by the operation of a normal LR relay. The SLM proceeds with identification and selection in the normal way, except that the availability of the SLB switch and vertical is indicated by relays in the parent end rack and not by SLA vertical off-normals. Because the grouping plan for an AKL unit is different from that of an ARF stage, the horizontal to be operated in SLB is determined by the AKL unit and not by the SLM alone. When the SLB vertical has been chosen, the SLA (code switch) vertical is also determined. At this stage, a signal is sent to the detached end (and returned and compared as before) to indicate the chosen level and code switch. Following this, a signal is sent (and verified) to indicate the chosen vertical in the code switch. From the previously stored "B" identification, the outlet number is known. All the required information is now available. A switch setting signal is now sent. This causes the operation of the correct code bars, followed by the vertical magnet at both parent and detached ends. The vertical magnets then release, followed by the code bar magnets. On receipt of the verification signal, the forward signal ceases, causing the revertive signal to cease. A junction line relay corresponding to the chosen junction is operated and the calling subscriber receives dial tone from the Register. The AKL equipment is then free for use by another call.

An incoming call is set up in a similar manner, with the exception of course that the called subscriber's identity is transmitted forward to the detached exchange.

At the end of the call, a restoration identifier is called in to determine which vertical has just become free. This is indicated by the release of the junction line relay which was held on the "d" wire from the SR. The identity of the vertical and the code switch is transmitted to the distant end and the vertical magnets at both ends operated with all code bars normal. As described previously, this will allow the "home" position contacts to operate.

TABLE 2: SIGNALLING OF "A" IDENTIFICATION

	Identification Relays	Signalling Relays				
		S1	S2	S3	S4	S5
Switch 1	A1			X		
	2	X		X		
	3		X	X		
	4	X	X	X		
Switch 2	5				X	
	6	X			X	
	7		X		X	
	8	X	X		X	
Switch 3	9			X		X
	10	X		X		X
	11		X	X		X
	12	X	X	X		X
Switch 4	13				X	X
	14	X			X	X
	15		X		X	X
	16	X	X		X	X

SUPPLEMENTARY EQUIPMENT

M.D.F.

This frame (Fig. 8) is unconventional in several ways:—

(i) The density of terminations is very high (250 line side terminations and 240 exchange side terminations are accommodated in a cabinet only 20 in high x 19 in. wide x 7 in. deep, and it could easily accommodate twice this number).

(ii) No soldering is required on jumper wires.

(iii) No protection is provided.

(i) and (ii) are achieved by using a flat terminal unit identical with that used in the KAN relay set in ARF. Each terminal strip accommodates ten wires. Jumpering is by means of a special twin jumper wire which is stripped for approximately 1¼ in. from each end and inserted in the contacts strips of the terminal unit. It is gripped firmly by these strips and being stronger and more springy than tinned copper there would appear to be no danger of bad connections.

As the housing estate in which the unit is installed is served completely by underground cable and normal protection can be provided at the exchange end of the junctions if required, it was not considered necessary to provide any protection at the detached exchange. It is this factor which contributes most to the reduction in size of the M.D.F.

Battery

The battery provided with the unit has nickel cadmium cells using an alkaline electrolyte. As no feeding bridge or holding magnet current is required, the battery can be of small size and is meant to be housed in the bottom of the equipment cabinet. The equipment is designed for charging over idle junction lines by provision of a booster rectifier in series with the main exchange battery at the parent end. This was not desired in this particular installation and a separate 3 amp. rectifier was installed.

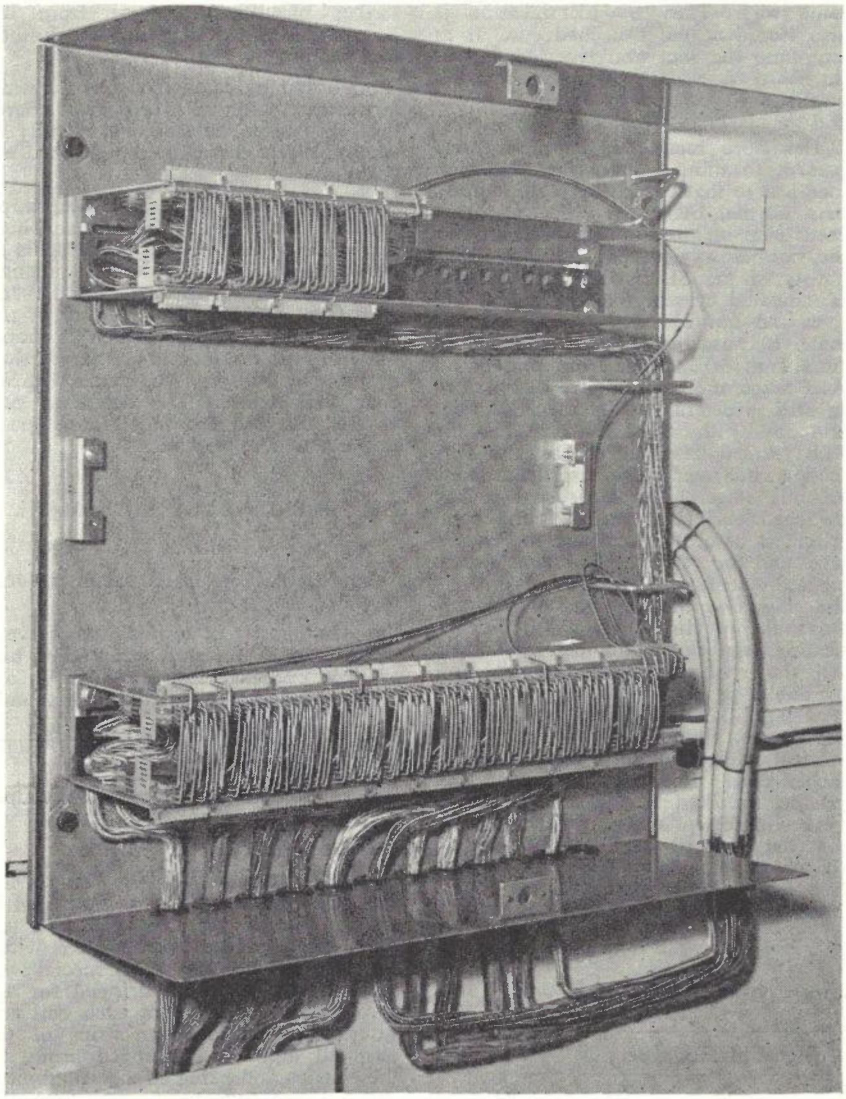

Fig. 8 — Detached End — Main Distributing Frame.

Test Lines

Four test lines can be provided from the parent rack to numbers in the detached exchange by making use of idle junction lines strapped to subscribers' numbers via the "home" position of the switch.

CONCLUSION

The unit at Jindalee has given completely trouble free operation in the three months since its installation. However it is the writer's opinion, based on experience during the testing out of the unit, that a cable fault on the junction lines could result in faults which would very seriously degrade the service and be very difficult to diagnose. The provision of completely independent signalling pairs might be desirable if the area is prone to line plant faults and pairs are available.

The AKL-10 Detached Exchange represents for this country a new approach to the problem of providing service where insufficient line plant is available, or line costs are high. There is no evidence to show that the system is not satisfactory and provided its limitations are considered together with its advantages there would seem to be no reason why the use of Detached Exchanges should not be extended.

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2. B. P. Dew and J. D. Mather, "G feller Line Concentrator Unit"; The Telecommunication Journal of Aust. Volume 14, No. 5/6, October 1964, page 408.
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CHANGES IN BOARD OF EDITORS

The Telecommunication Society wishes to announce important changes in the Board of Editors. Mr. R. C. Melgaard and Mr. D. P. Bradley have resigned and Mr. K. B. Smith, Mr. G. Moot and Mr. C. Freeland have been appointed as Editors of the Journal.

Mr. Melgaard who joined the Board of Editors in June 1959 has been a most enthusiastic and energetic member of the Board. His interests in telephone equipment brought a particularly heavy editorial load, not only because of the large number of readers he represented but also because of the rapid technical changes which occurred in his field of interest. A particular tribute to the effectiveness of Mr. Melgaard's period as Editor is the coverage the Journal has given to the many technical implications of the change to crossbar switching equipment. Mr. Melgaard has been appointed to the Australian Post Office Representative's office in London and will continue to serve the Journal as its Agent in Europe.

Mr. Bradley was appointed to the Board of Editors in February 1961. For nearly five years he has energetically represented the external plant area of the Journal's activities and largely through his efforts readers have been provided with an adequate record of external plant engineering practices and developments. Mr. Bradley has proved a capable Editor with a broad view of the Journal's role and objectives. He has been appointed Engineer Class 5, Mechanical and Electrical Services and has kindly agreed to continue his association with the Journal as a Sub-Editor. The Society is indebted to both Mr. Melgaard and Mr. Bradley for their excellent and willing service to the Journal over a number of years. In recognition of their contributions to the general development and improvement of the Journal, the Council of Control has been pleased to appoint them as Honorary Life Subscribers to the Journal. The Board of Editors takes this opportunity to express appreciation for a job well done and to extend to each, best wishes in their new appointments.

The Society has been fortunate in obtaining the services of Messrs. K. B. Smith, G. Moot and C. Freeland, who have agreed to appointments as Editors of the Journal. Mr. Smith has been a Sub-Editor for many years; as Engineer Class 5, Subscribers Equipment, Telegraphs and Power he is in an excellent position to make a contribution to an important area of the Journal's activities. Mr. Moot is Engineer Class 4, Exchange Equipment and his appointment to cover the vital exchange equipment field is very welcome. Mr. Freeland, Engineer Class 3, Lines Section, has had several years experience in external plant engineering; his appointment should enable the Journal to continue providing an adequate record of external plant developments.

FAULT FINDING IN ARF 102 CROSSBAR EQUIPMENT

B. W. Hyde*

INTRODUCTION

The purpose of this article is to briefly compare fault finding in step by step and crossbar exchanges and to illustrate various methods of isolating and locating some typical faults in the ARF 102 system.

Faults occurring in step by step exchanges which affect service are usually indicated and isolated in a reasonably short time with the aid of the following:—

Equipment Alarms.
Subscribers Complaints and Complaints Analysis Recording and Graphing Organisation C.A.R.G.O. (1).
Rapid Tests.
Traffic Route Tester.

These faults are seldom major in comparison to crossbar faults as usually one switch only is affected, resulting in minor loss of service to subscribers, and generally, these faulty switches are quickly repaired. The similarity of equipment stages in step by step exchanges simplify its general circuitry, as the first, second, third and fourth selectors are identical, and all stages except the uniselectors follow a similar mechanical operation.

Six general factors lead to the relative complexity of ARF 102 crossbar equipment from a study point of view:

Common Control.
Relay Principle of Switching.
Grouping Plans.
M.F.C. Compelled Signalling.
Alternate Routing.
Circuitry.

Due to these factors considerable knowledge and practical experience is needed to be competent in the initial and final location of faults in this equipment.

Each marker is equipped with numerous relays (e.g., SLM rack 468, GIVM rack 280, IGVM rack 702) and although some functions in different stages can be classified as similar, different methods are often used to achieve the same results. Two examples of this are the identification and the route testing (i.e., GVB outlet selection) in the IGV and GIV markers. Identification of the 160 inlets in the IGV marker is by the use of 16-X and 10-Y reed relays whereas the GIV marker identifies each group of 80 inlets using 6-A and 14-B general purpose relays. Route testing is carried out by cold cathode tubes in the GIVM but by transistorised circuits in the IGVM.

If one of the marker stages of a crossbar exchange fails, major loss of service to subscribers is highly probable and finding the fault causing the failure can take considerable time. However, minor faults in crossbar such as a faulty S.R., do not cause a great deal of trouble to the individual subscriber because of the use of call distributors, whereby each call is given the opportunity of seizing a different piece of equipment; thus the traffic is evenly distributed throughout the exchange.

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FAULT INDICATION AND LOCATION

The main indicators available in crossbar working are:—

Service Alarms.
Traffic Route Tester (T.R.T.).
Subscribers Complaints and C.A.R.G.O.
Exchange Alarms.
Permanent Meters.
Observation and Fault Finding Register (RKR).
Route Alarm.
The Sound of the Equipment.

Fault location in crossbar systems can be broken into two categories:

Initial location: i.e., the location of the faulty marker or unit of equipment. This requires a knowledge of:—

(a) The appropriate exchange trunking diagram.
(b) Grouping Plans.
(c) Local knowledge (e.g., where the equipment is mounted).

Final location: i.e., the location of the actual fault within the marker or unit of equipment. This requires a detailed knowledge of the circuitry and functions of that marker or unit. When investigating a fault it is advisable to approach it systematically (i.e., examine all conditions) and record all details. e.g., when tracing from a T.R.T., enter all information of the trace in a prepared book or form. This will be a valuable record if the fault is not apparent on the first examination.

EXAMPLES OF TECHNIQUES

To illustrate fault finding methods the following examples explain the approach and isolation of some typical faults experienced in crossbar systems using the various indicators.

Service Alarms

The first type of fault was indicated by outgoing SLM and RSM-L service alarms occurring at the same time and at not too frequent intervals, i.e., twice in one day, three times another day. When the fault meters were connected to the SL and RSM-L groups causing the alarm it was noted that over a period of time in a particular thousand group both markers were being time thrown out. It was noted also that one RSM-L directly connected to this same thousand group, was timing out.

As forty SR's are connected to an RSM-L it was decided to isolate the SR's and see if the time throwouts were affected. Also traffic was concentrated into this group by blocking of other SR's associated with this thousand group. SR's one to twenty were blocked and the fault meters noted. After a period of time it was noticed that time throwouts were still occurring so SR's twenty-one to forty were blocked and one to twenty restored to service. This time throwouts ceased. Further isolation of SR's was continued until the fault appeared in a certain group of five and no matter which SR of this five was let into service the SLM and RSM-L time throwouts increased.

The reason for blocking SR's in multiples of five is because five SR's are tied to five SLB verticals of one SLB switch which is tied to two SLA switches each in different SLA racks. If a fault is in the SLA stage it will affect the five verticals of the SLB switch and thus all five SR's tied to this SLB switch.

The two SLA switches were blocked in turn with the five SR's back in service until the one causing the alarm was identified. A test of the operate circuits of the vertical magnets was carried out from the rack connecting relay contacts and one was found to be not operating, and on testing directly at the coil it proved to be open circuit.

The reason for this fault bringing up service alarms was that the calling subscriber using this vertical of the SLA could be identified, the RSM-L and REG-L could be called but due to the SLA vertical not operating, the "c" wire could not link the subs LR/BR relay to R1 relay in the REG-L. When BR operates it releases the SLM which releases the RSM-L but in this case the SLM and RSM-L had to be force released. Whilst not major, this fault illustrated the fact that although a service alarm indicated the fault, the markers involved were not faulty in themselves.

A fault causing time throwouts in any of the common control equipment is quickly brought to notice by a service alarm and indication of the faulty marker or code receiver is isolated by means of the fault counters. The next fault illustrates this fact.

An SLM incoming service alarm occurred. When the fault counters were connected to this group it was noticed that one SLM was timing out excessively (TIM); also the timeouts were occurring after SLM vertical selection and before SLC selection (F1M2). There were two SLM's in this thousand group, one SLM was faulty and the other was working correctly. The faulty SLM was blocked until a period of lighter traffic, to enable an investigation to be made of the fault condition.

From the sequence diagram (circuit aid chart) and circuits it was seen that with one E relay only operated, EB relay operated which completed the SLC selection. The cover was removed from the ZQ relay set and the EB relay observed. This relay was not operating. From the circuit, the operate path of EB relay was traced and found to be open circuit at EA relay contacts.

Traffic Route Tester (T.R.T.)

Due to a low "Grade of Service" local T.R.T. run, it was decided to use the T.R.T. on fault trace. The faulty calls were traced and recorded in the T.R.T. book, noting also the following conditions of the Register-L relays. (The register is prevented from time releasing by a signal from the KAN on T.R.T. lines).

(a) All digits had been stored OK.
(b) The K.S.R. had been called (KS1 was operated).
(c) The relay indicating that the first digit had been sent was operated — (P2).
(d) No number length signal had been received from the 1GV marker.

At the 1GV stage the GVA vertical only was operated.

The T.R.T. was reset and the above process repeated. When the next faulty connection was traced a different condition from the above occurred but was again recorded and the T.R.T. reset. After a few traces of faulty connections of this kind it was found that a similar condition to the first trace had occurred with a different SLA switch and REG-L but the same SLB, SR and 1GVA inlet. An analysis of the recorded results showed that the SLB must have been correct because a REG-L was seized and the correct digits stored and therefore the fault must lie between the SR and 1GV marker.

The automatic exchange tester (A.E.T.) was connected to the 1GV inlet, and found to test correctly. The AET or SR tester was then connected to the SR and on testing it was found that when any REG-L was called it stored all digits correctly but with the same relay conditions as previously encountered when tracing from the T.R.T. It was also noted that when repeated calls were being attempted from this SR a service alarm from the 1GV stage occurred. From these indications it appeared that the fault was between the SR and 1GV inlet and that although the 1GV marker was being called no forward signal of MFC was being received.

Continuity of the "a" and "b" wires was checked between the SR and 1GV inlet and the fault was found to be a dry joint on the "a" wire at the gaffeltags on the 1GVA/B rack. The reason for the 1GVA vertical being operated was that when a time throwout occurs at the GV or SL incoming stages the vertical magnet of the inlet is operated to release the marker.

It should be noted that if the T.R.T. test lines were not strapped in the KAN for a "no time throwout" category, the SR's and REG-L's disconnect "time throwout" keys would need to be operated, to enable a trace to be carried out. It can be readily understood that call tracing can be difficult on other than test lines due to the equipment being designed to release faulty calls.

Subscribers Complaints

The Complaints Analysis, Recording and Graphing Organisation (CARGO) reported that they were getting complaints of no progress from local subscribers to a particular exchange. The T.R.T. was set to this exchange and it was found that approximately 30% of calls failed. As this appeared to be the only exchange affected it was presumed that the fault was at or forward of the 1GV stage.

A faulty connection established by the TRT was traced to a particular 1GVA inlet and then the AET was connected to this inlet. Failures occurred, but intermittently a call would succeed. A random test of other inlets over the four 1GVA/B racks was made and the fault appeared to be restricted to racks one and two. It was observed that when the faulty connection took place the GVA was switched but the GVB vertical and HA springs were operated without a horizontal.

As the GVA can switch to two GVB switches, one on rack one and the other on rack two, making a total of twenty GVB verticals, plastic picks were placed between vertical off normal (VON) springs of 19 verticals which, in effect, busies these verticals. This was done to observe a connection from the AET using the remaining vertical, to watch the horizontal operation. When a failure occurred it was noted that the horizontal did not operate. A check of the horizontal magnet operate circuit was made and found to be correct so it was decided to see if the route relay mounted on the first rack was operating. This relay was operating intermittently and a check of its circuitry found a dry joint on the relay tags.

No service alarms would be given with this fault as the route relays operate in pairs, one on rack one and the other on rack two, each one having a different function. Rack two route relay completed the marker operation circuits.

Exchange Alarms

The exchange alarms are usually self indicating but there is a fault detected by an FLS alarm of a GIV marker worthy of note. When this fault occurs it means that the 200 volt positive high tension has failed, the GVA inlets are automatically blocked and incoming junctions to these inlets are lost. The cause of this trouble is usually due to one of the two cold cathode tubes associated with this circuit (V. 22 and 23) failing.

Permanent Meters

A high percentage of time throwouts on all CD-Code receivers of all thousand groups had occurred since cutover. The fault appeared to be something common to all CD-Code receivers and the first approach was to test all GIV connections looking for an open circuit "a" or "b" wire condition between the GIV/A inlet and GIV/B outlet, thus calling in the CD-Code receivers, which were not able to receive the forward signal. Using the AET all inlets and outlets were tested and found to be functioning correctly. This left the three GIV markers as the only common pieces of equipment likely to cause the fault.

It was decided to test the GIV markers in a time of very light traffic. An audible indication was required to tell at what instant the two CD-code receivers' time throwout relays restored, so a bell was connected by means of Ericsson armature attachments to these relays (K2) so that when a K2 relay restored the bell would ring. Each GIV marker was then tested from GVA inlets with the AET and on a group of inlets associated with one marker the bell rang. This indicated a time throwout in the CD-code receivers, at the same instant as the call was being handled by the GIV M, although as far as the AET was concerned the call was successful. One of these inlets was patched to the multiple jacks and the AET moved to a position where the GIV M concerned could be observed. With the covers removed it was seen that when a call reached the testing of outlets stage, more than one cold cathode tube would strike and if the relay (TK1) that completed the test circuits for these tubes was prevented from operating the tubes still struck.

The 200 volt positive potential supply to these tubes was tested (with a cathode ray oscilloscope) and it was seen that voltage peaks were occurring instead of a steady 200 volt potential, allowing the tubes to strike as soon as the relay (TK2) which completes this circuit operated. A test was made of the two smoothing condensers of this circuit and they were found to be open circuit.

This fault did not interfere with service calls but was sending false calls to the two CD-code receivers, one call being chosen when the cold cathode tube test circuit was completed to one CD-code receiver and the other call being released, causing a time throwout condition.

A number of open circuit subscribers meter conditions were indicated by the RKR permanent meters. The RKR hold and trace key was operated which gives an alarm and a lamp display when a fault condition is encountered.

An alarm was given indicating an open circuit subscribers' meter condition and the connection to the REG-K was traced through the RS-L, SR, SLB and SLA to the subscriber's number and recorded, also the subscriber's meter reading was recorded. Continuity of the subscriber's "r" wire was checked through the stages with an ohm meter and the open circuit condition appeared to be between the subscriber's meter and SLA vertical. The subscriber's meter was tested and found to be correct and on checking at the SLA gaffeltags at the SLA rack a dry joint was found.

Sound of Equipment

There is a definite "rhythm of flow" of the relays operating in the markers and some faults in the equipment can be indicated before an audible alarm is given.

The SLM of a thousand group was heard to be continuously seized and released and when the AB and AXN relay set covers were removed to see if identification was taking place it was seen that the A identification was correct but no B relays were operating. The A relay indicated the subscriber's hundred group and units digit whilst the 1AN relay indicated what rack the call was coming from. At the rack, with the aid of circuits and head receiver the subscriber's tens digit was identified (the tens digit appear on contacts of the AV relay). The B relay circuit for this subscriber was then checked and found to be open circuit. FUM1 indicates this condition but this lead from the SLM's is not connected to a service alarm at present.

Lampset and Sequence Diagrams (Circuit Aid Charts)

Faults of an intermittent nature are very difficult and sometimes tedious to isolate and the lampset, Fig. 1 is a valuable aid when these types of faults occur. Sequence diagrams have been prepared for all major relay sets and markers and in conjunction with the lampset, fault finding of these conditions is simplified. If a faulty call occurs, the lampset will

Fig. 1

stop and indicate by lamp display, the last relay to operate successfully. Between this lamp and the next one, there are possibly a number of relays in the marker that should have operated, and by the use of Ericsson armature attachments these relays can be wired to the lampset and indication will then be given of the of circuits and head receiver this circuit can be tested and the fault cleared.

Relay Set Interchanging

The possibility of losing a fault by disturbing a dry joint, short circuit etc., only for it to re-appear again at a more inopportune moment is the main deterrent of this procedure, and it is advisable generally that relay set interchanging should only be used when the fault has been isolated to a particular relay set, or it is required to determine whether the fault is in the rack wiring or the relay set. However, in some circumstances it may be necessary to use this procedure to restore some service to an exchange or section thereof. For example where two SLM's are provided in one thousand group only, one of these can exact relay that is faulty. With the aid be moved to a faulty thousand group position and the faulty SLM blocked out of service.

CONCLUSION

The faults used to illustrate this article have been reasonably straightforward, as the "Indicators" gave a direct line of approach to the fault conditions and the test equipment was readily available, but in service, faults sometimes occur that require considerable research and circuit knowledge.

Due to different exchange equipment requirements, some exchanges will only be equipped with single GV stages. In the event of a failure at this stage, it must be understood that the exchange could be "off the air" for a period of time and unless staff is available with considerable knowledge and practical experience, serious subscriber reaction could result.

Major faults, when they occur, require immediate attention and it is necessary to be completely familiar with the layout of the exchange concerned to enable the faulty marker or unit to be isolated by blocking or exchanging relay set so that the loss of service can be minimised.

Because of the complexity of this equipment it has been proved from experience that best results in fault finding are achieved when two technical men work together, as it is relatively easy to assume the wrong condition of the fault and waste valuable time retracing the symptoms. Fortunately the equipment is so reliable that there are relatively few serious faults after the initial settling down period.

REFERENCE

1. D. Omond, "An Introduction to the Analysis of Subscribers' Complaints"; The Telecommunication Journal of Aust. Vol. 13, No. 6, Page 446.

MARIBYRNONG EXCHANGE - E.M.D. MOTORSWITCH SYSTEM M.

*T. Kuriata, H.N.D.(Elec.Eng.), Grad. I.E.E.**

INTRODUCTION

Prior to adoption of the L.M.E. Crossbar switching system as the new standard switching system, the Postmaster-General's Department had placed a contract with Siemens Halske Siemens Schuckert for 2,000 lines of exchange equipment using the E.M.D. Motor Switch System M. The E.M.D. stands for "Edelmetall Motor Drehwaehler" which means Noble Metal Uniselector Motorswitch. "System M" signifies the use of **marking** principle almost throughout the exchange. The equipment was installed by the Departments staff under Company engineers' supervision. The exchange was cut into service on the 4th of April 1961. Although the Motorswitch was not entirely new to the Department, the system used in this exchange was the latest developed by Siemens and Halske, and some of the common apparatus was installed for the first time in a working exchange. The purpose of this article is to briefly describe this system and to give some details of switching and discrimination and storage techniques employed, and as far as possible, to comment on its performance to date.

The following abbreviations have been used in this paper:

E.M.D.	(Edelmetall Motor Drehwaehler) — Noble Metal, Uniselector Motor switch.
S.L.C.	Subscriber's Line Circuit.
C.S.	Control Set.
L.F.	Line Finder.
R.S.A.	Relay Set A.
D.P.R.	Dial Pulse Repeater.
S.C.	Storage Connector.
G.S.	Group Selector.
F.S.	Final Selector.
R.S.	Routing Selector.
R.S.B.	Relay Set B.
R.S.C.	Relay Set C.

MAIN FEATURES

The E.M.D. Switch and Bank

The Noble Metal Motor Switch, is a high speed Uniselector driven by a small individual motor. Two types of switches of basically similar design are used throughout the exchange. One has 110 outlets (See Fig. 1a), and the other has 220 outlets (See Fig. 1b).

The essential features of the switch and bank are as follows:—

i. Noble metal contacts are used in speaking circuits.
ii. Speaking circuits wipers do not make to the bank contacts until the connection has been established.
iii. The switch operates in a smooth rotary motion 150 steps per second.
iv. Bank contacts multiple is solderless through-out the rack.
v. Bank contacts are vertically positioned.

Use of noble metal contacts results in low and stable contact resistance between bank contacts and wipers. The non-trailing speaking wipers are not subject to wear. The smooth rotary motion used eliminates microphonic noise and the high mechanical stress and wear, characteristic to step-by-step motion. The solderless bank multiple shown on

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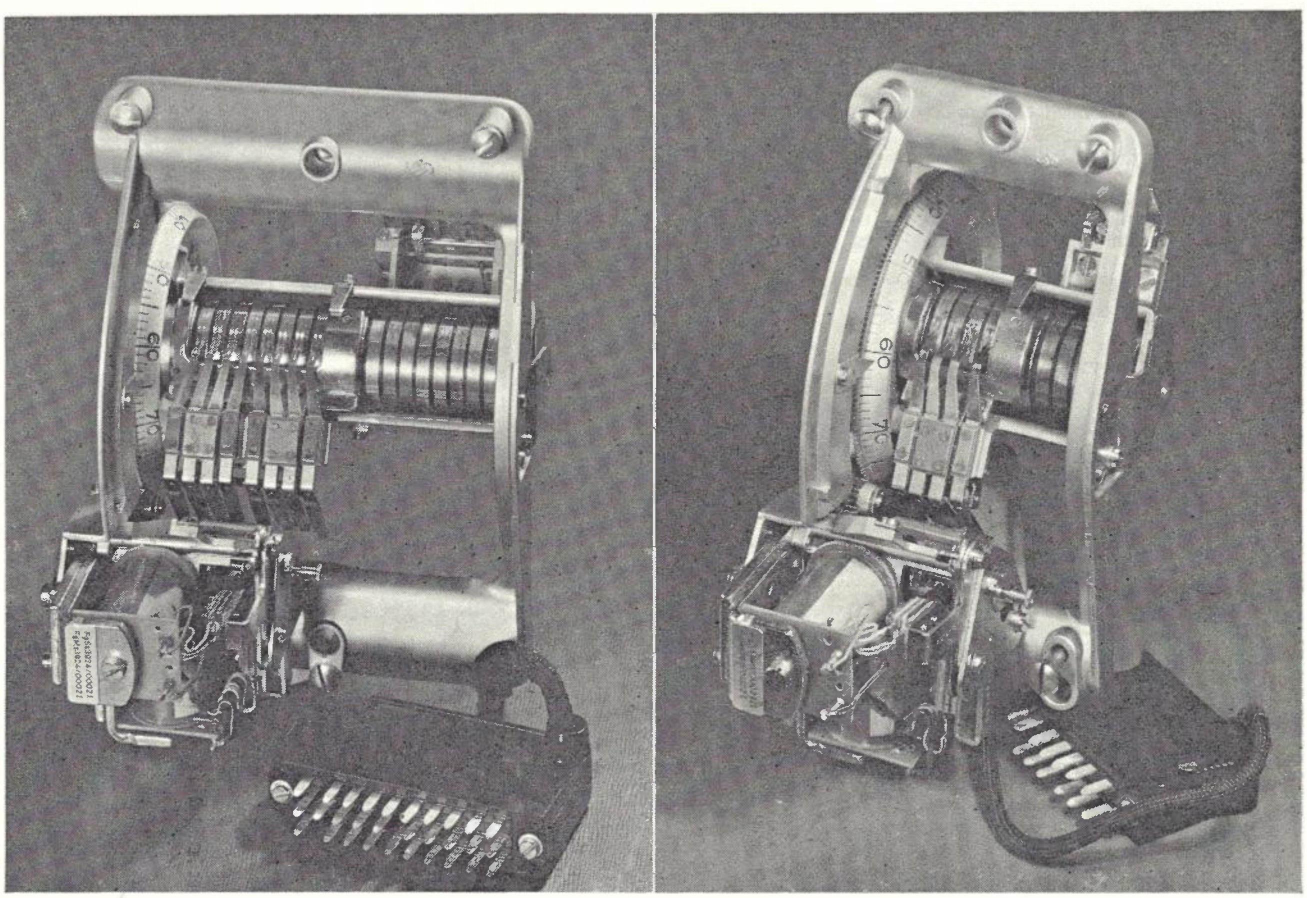

Fig. 1 — The E.M.D. Switch. Left: 110 outlets. Right: 220 outlets.

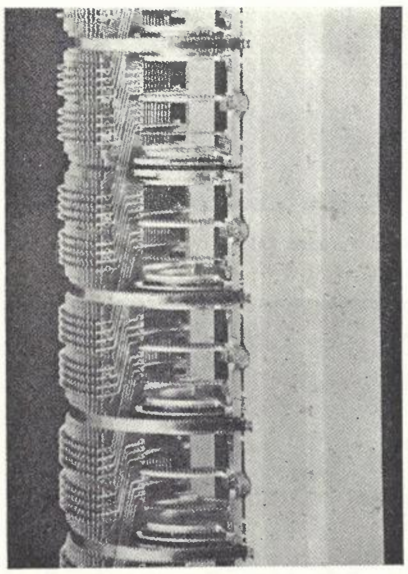

Fig. 2 — Partly Equipped Solderless Bank Multiple for E.M.D. Switches.

Fig. 2, effectively reduces noise and fault liability due to dry joints, and open circuits. Wiper wear is further reduced by the use of vertical bank contacts on which no dust, or other abrasive particles can readily settle. Reduced wear and a simple easy to adjust mechanism enhance the reliability of the switch. Use of the same switch in all switching stages, but one, the 200-pt. first routing switch, adds further advantages as far as flexibility, spare parts, and training of staff are concerned.

Automatic Rotation

The motion of the switch is controlled in a number of ways, but all methods utilise the automatic rotation feature of the switch. Fig 3a shows a basic circuit of an E.M.D. switch and Fig 3b a pictorial representation of the motor and drive mechanism in normal, or rest position. Closing of contact d of Fig. 3a energises the winding M1 of the motor, and the switch beings to rotate. The extended auxiliary pole of the "Z" shaped armature is attracted in to the magnetic field of M1. After a quarter of a revolution, when the main part of the armature is opposite the M1 magnet, the M1 contact is opened, and the M2 is closed. These contacts are operated by the interrupters which rotate together with the armature of the motor. The leading end of the armature is now attracted towards magnetic field of M2, now energised. This sequence is repeated for every quarter of a revolution resulting in a smooth rotary motion. The switch is stopped by closure of contact p. When contact p closes both windings of the motor are energised simultaneously and the switch is stopped instantly. Contact p is made to close when the switch has reached the marked contact i.e. the first step of the required decade (level), or a free outlet. After the switch has stopped contact d opens de-energising both fields of the motor.

Dial Pulse Repeater. (D.P.R.)

The dial pulse repeater is used as a buffer stage for impulses received either from a local subscriber's dial, or from another exchange. The D.P.R. shown on Fig. 4 is capable of receiving, storing, and sending out impulses at the same time.

The mechanism of the D.P.R. comprises three magnets, (storing, marking and retransmitting), and a laminated storing disc on which the pulses are stored. The storing magnet, on receipt of each pulse causes the laminated disc to advance by one step, i.e. by one lamination. The marking magnet controls the position of this lamination relative to the "guide ring" of the laminated disc. The retransmitting magnet controls the motion of the scanning arm. This arm moves in step-by-step motion in the direction opposite to that of the storing disc during retransmission of pulses, sampling for the position of

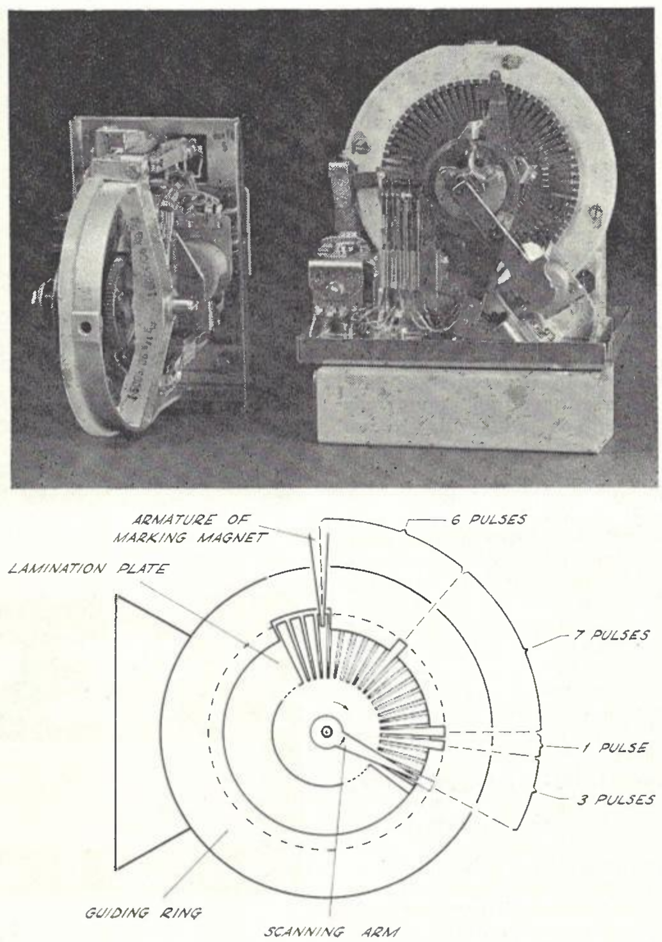

Fig. 4 — Top: Dial Pulse Repeaters. Bottom: Position of Laminations for 3176.

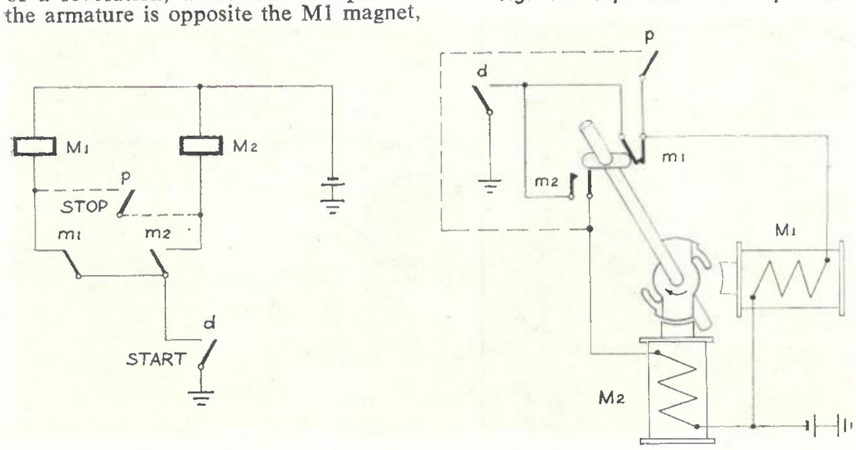

Fig 3 — Left: Basic Circuit of E.M.D. Switch. Right: Drive Mechanism Simplified

laminations stored (i.e. digits stored). To mark the beginning of each digit the marking magnet does not operate on the receipt of the first pulse. This results in the first lamination of each digit being left on top of the guiding disc. Fig. 4a shows the position of laminations when the local code 317 is being stored.

Relays

Flat Relay: The Flat type relay (See Fig. 5) is a general purpose relay used throughout the exchange. It has a soft iron core, an armature which can operate three piles of springsets, and can have one, or several inductive windings. Contact springs, slit at their contact ends and equipped with removable twin contacts, are of nickel-silver spring metal of average thickness, 0.5 mm. Springs of 0.2 and 0.8 mm. thickness are available for special purposes. Pure silver (AG50) is mostly used as contact material and may be loaded to 1 amp. Contacts which are used for lower currents are provided with contact rivets of noble metal alloys, i.e. platinum, gold and palladium. Spring assemblies can have from 2-15 springs; working contact pressures are between 18-22 gms. and 20-25 gms; operating times may be varied between 8-60 ms; release times may be varied between 10-250 ms.

Twin Relay: The Twin Relay (See Fig. 6) used at Maribyrnong for subscriber line relays, consists of two small relays operating independently of each other. Two coils with one armature each and corresponding contacts are mounted on a common yoke. There are 3 piles of contacts on each relay with a maximum of 3x5 springs per relay. Operating times may be varied from 6 to 15 ms; and release times from 4 to 19 ms; Working Contact pressures are 18-22 gms.

High Speed Relay. This type of relay is used in marking circuits throughout the exchange. It consists of a small relay of small mass, and a larger slave relay, enclosed in a metal case with two small windows in the front (Fig. 7). The overall size of the relay is approximately the size of the general purpose flat relay. The plug-in socket guarantees quick exchange of the relay and easy testing in case of trouble. The socket pins and contact springs associated with the relay are silver plated to ensure low contact resistance. The small relay, which has an operating time of 0.5 to 1.0 ms. has a spring load of six springs (3 make sets) and when used in the marking circuits arrests the switch; guards the circuit against further seizure; and cuts in the larger system, which in turn, by way of its 2x8 contact springs, controls all switching operations. The release time of the small relay is 0.8-1.5 ms. The contact material is platinum alloy (Pt/W 95/5).

ESK Relay. This is a high speed noble metal relay of novel design used in the common control equipment (translators, storages and storage connectors). It is also used as a "crosspoint" relay similar to crossbar switches, in the storage con-

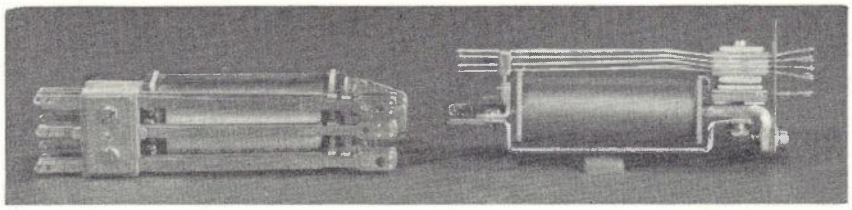

Fig. 5 — Flat Type General Purpose Relays.

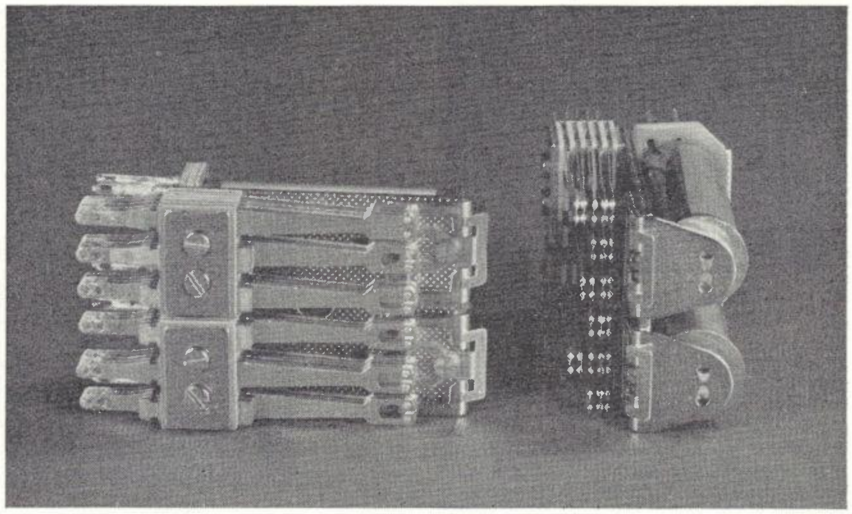

Fig. 6 — Twin Relays.

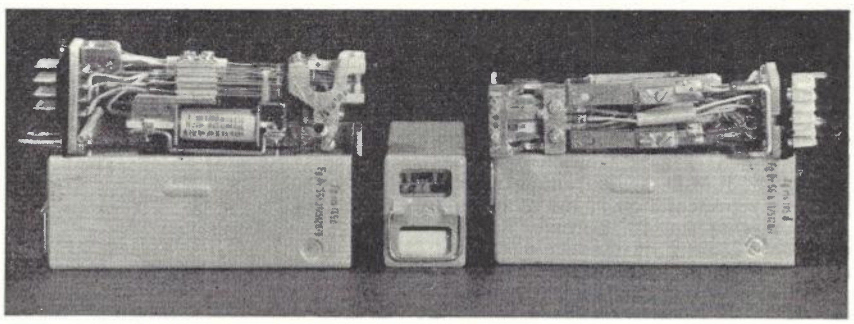

Fig. 7 — High Speed Relays.

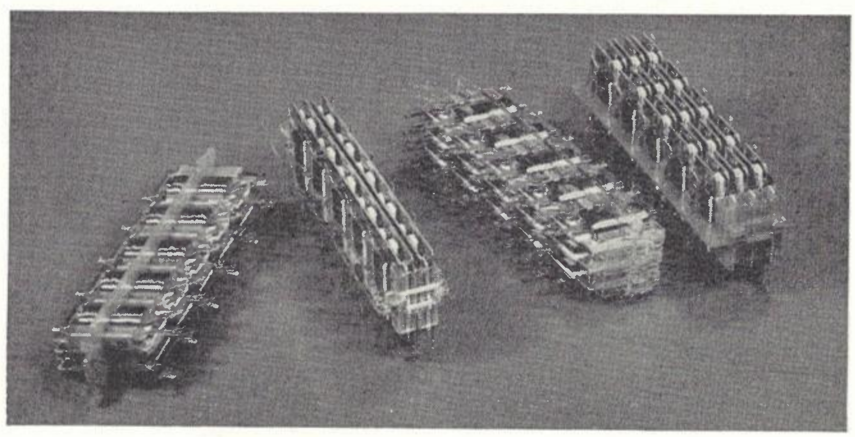

Fig. 8 — E.S.K. Relay Strips.

nector. The relay is extremely small, about one tenth the size and weight of a conventional type relay, and is very fast acting — less than 2 ms. operating time. Its armature and contact springs are combined into a single unit having an effective weight 250 times less than the armature of a flat type relay. The contact pressure is 20 to 25 gms. and contact combinations in use are:—

Four make contacts.
Two make and two make before break contacts.
Six make contacts.
Four make and two make before break contacts.

These relays are arranged in strips of five. Each contact is removable and the whole assembly is "press fitted" with no screws or rivets being used in its construction. Fig. 8 shows 2 types of strips of 5 ESK relays.

LAYOUT OF EQUIPMENT

Originally only 2000 lines of subscribers apparatus were provided, but some of the common equipment then provided could adequately serve the ultimate 5000 lines. The equipment capacity has been increased to 3000 lines since the original installation. The layout prepared by Company engineers is somewhat similar to that employed in step-by-step exchanges using composite primary racks (See Fig. 9). Subscribers line circuits and associated final selectors are positioned side by side, although on separate racks. Basically, one thousand lines of subscribers equipment are

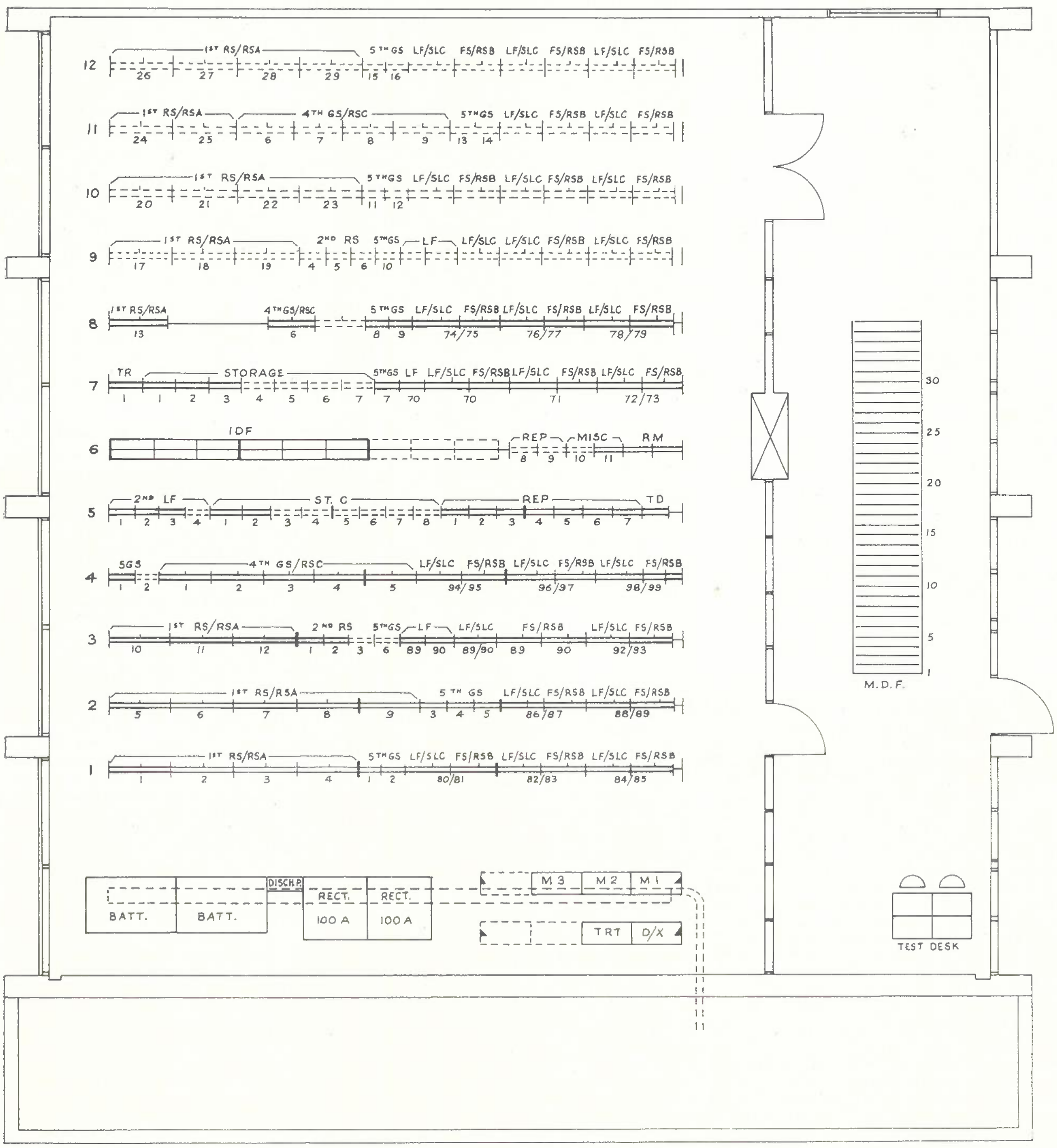

Fig. 9 — Equipment Floor Layout.

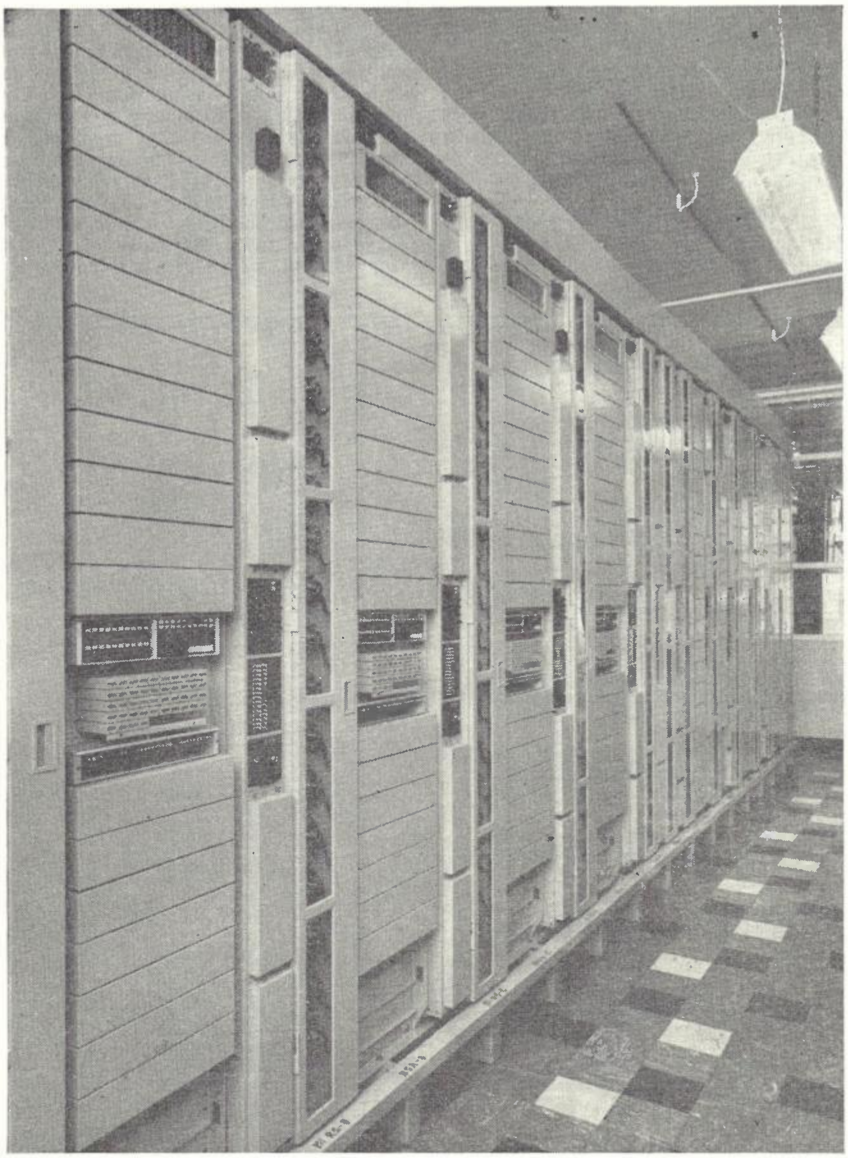

Fig. 10 — Suite of Equipment — Front View.

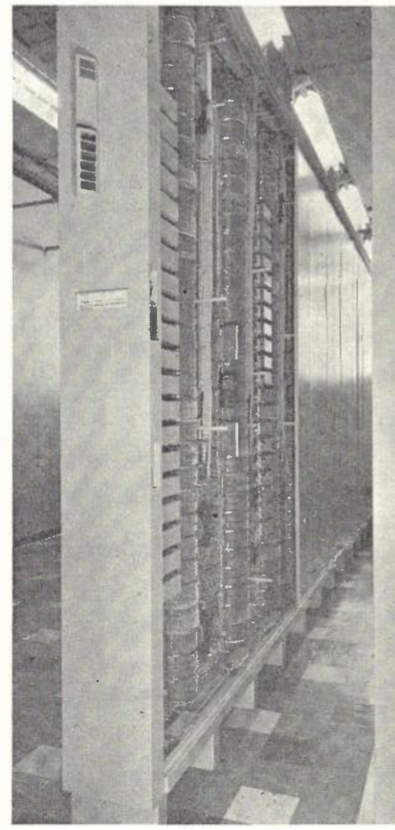

Fig. 11 — Suite of Equipment from the Rear with Three Rack Covers Removed.

located on one end of two suites. The associated fifth selectors are in the middle of the two suites and the rest of the two suites is occupied by Relay set A's and first routing selectors. The subscribers stage equipment is located in suites 1 & 2, 3 & 4, and 7 & 8. The incoming fourth selectors, relay sets repeater, and other miscellaneous racks of equipment make up suite 5 and a portion of suites 4 & 6. The translators and storages are located in suite 7. In the centre of the room, as is usual for an L.F. system is the I.D.F. The ringing machines (conventional D.C. driven) are located in suite 6. The two test desks are located in the M.D.F. Room. The subscribers meters (conventional 200A type) are in the Equipment Room in the Power Suite.

Face Layout of Racks: The overall height of racks is 10 ft. 2½ ins. All equipment is covered — removable panels are used to cover the back of the racks, while glazed rack doors and individual relay set covers are used to cover the equipment on the front. Glazed doors are used on racks housing motor switches. Fig. 10 shows a suite of equipment from the front, while Fig. 11 shows the same suite from the rear with first 3 racks' covers removed. The close up view of the back portion of the racks is shown on Fig. 12.

The Subscribers Stage: Fig. 13 shows a close up view of subscribers L.F. rack with the associated line and cut off relays together with a rack of final selectors and the associated relay set B rack. The glass doors on both the L.F. and final selector racks are shown open. Fig. 13 shows one cover removed of one SLC relay set (line and cut off relays) and of one R.S.B. The 2 L.F. control sets can be seen at the bottom of the extreme left hand side of the L.F. rack, below the panel containing the fuses, alarm lamps, and test access jacks. The L.F. rack can accommodate 30 switches which serve 2 groups of 100 lines of subscribers. Group one is served by switches 1-15 while group two by 16-30. The S.L.C. rack (Fig. 13) holds 200 sets of line and cut off relays for the 200 subscribers connected to the adjoining L.F. racks. Ten subscriber's line circuits are mounted in each S.L.C. relay base. The 30 final selectors on a rack serve two groups of 100 subscribers, except for 3 groups of 100 lines reserved for PBX subscribers with heavy traffic. Each of these 3 groups can be increased to 30 F.S. switches. The L.F. groups associated with these heavy traffic lines can be extended to 45 switches. Each final selector rack has 3 control sets and a fuse, alarm, and test access panel.

Relay Set A Rack: This can be seen on Fig. 10 together with its corresponding 1st routing selector. There are 20 relay set A's on each rack. In the middle of the rack can be seen a supervisory panel holding fuses, traffic meters, busying keys, occupancy lamps and test access jacks. A close up view of the panel can be seen on Fig. 14 left hand side, above a Relay Set A with cover removed.

First Routing Selector Rack: (See Fig. 10.). This rack has a capacity for 20 route selectors — 8 arm E.M.D.

switches, a supervisory panel with fuses, alarm lamps, and reset keys, and a test jack and an associated test access selector switch. Close-up view of this panel is shown on **Fig. 14, right hand** side. Above the supervisory panel are rack relays, and below it are access relays and a control set.

Second Routing Selector — and 4th and 5th Group Selector: These racks are in layout very similar to the L.F. racks and hold 30 E.M.D. switches each. Fig 15 shows a face layout of these racks together with other racks used in this system.

Storage Connector Rack: There are 13 groups of stage A and 3 groups of stage B connectors on one rack, laid out as shown on Fig. 15.

Storage Racks: This has a capacity of 8 storages and the associated supervisory panel and statistical meters. The supervisory panel shown on **Fig. 16** has also a test jack and a selector switch associated with the test access.

Translator Rack: This rack holds two translators, associated lockout relays, built-in tester, and a supervisory and test panel. Fig. 17 shows the supervisory and test panel. Using the selector switches any route can be set up for its calls to be registered on the statistical meters. The standby access equipment enables any of the translators to handle all the traffic while the other one is taken out of service.

SYSTEM CONFIGURATION

In this system calls are established using line finders, route selectors, group selectors and final selectors. Setting of switches is carried out under the control of control sets (C.S.), marking the wanted trunk group, or outlet on the switch multiple. The control sets are shared by a number of switches and are used for only the brief interval required to set the switch. Two or 3 control sets are used to handle a group of switches, thus allowing for one to be withdrawn from service for a short time, if required.

The switch circuit proper consists of holding relays only, as all switching elements used for setting up the switch are centralised in the C.S. The circuit elements required for the direction and supervision of the call, are grouped as separate relay sets i.e. relay set A on the originating end; and relay set B on terminating end, and relay set C for traffic incoming from other exchanges.

The impulses dialled by the subscriber on an outgoing call are stored on a dial pulse repeater which is a part of the relay set A. Selection of the route is accomplished by a route selector in conjunction with a relay set A, a storage, and a translator. The storage and the translators are complex common control items of equipment, also used for a very short time to determine the route, and charging zone for each call, and to set up the routing selector, and effect transmission of remaining digits from storage or R.S.A. to set up further

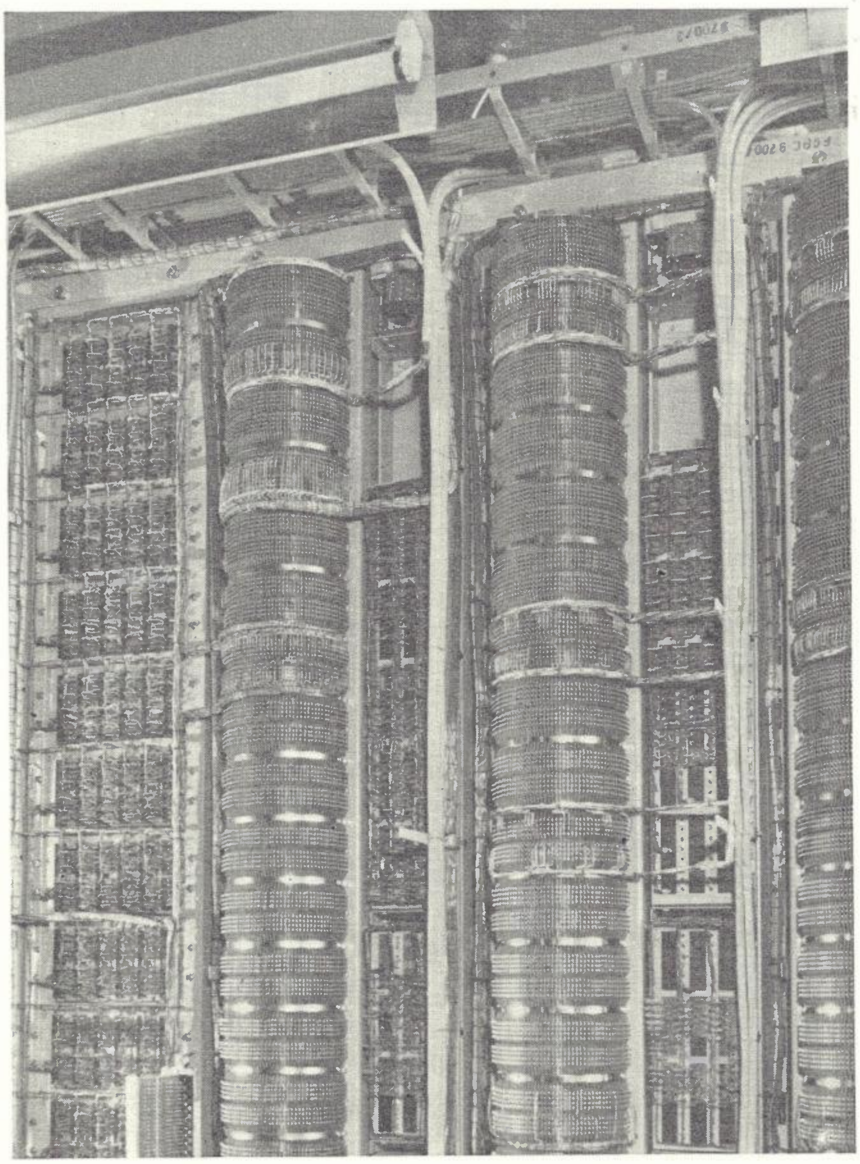

Fig. 12 — Close-up View of Rear of Final Selector and R.S.B. Sets with Covers Removed.

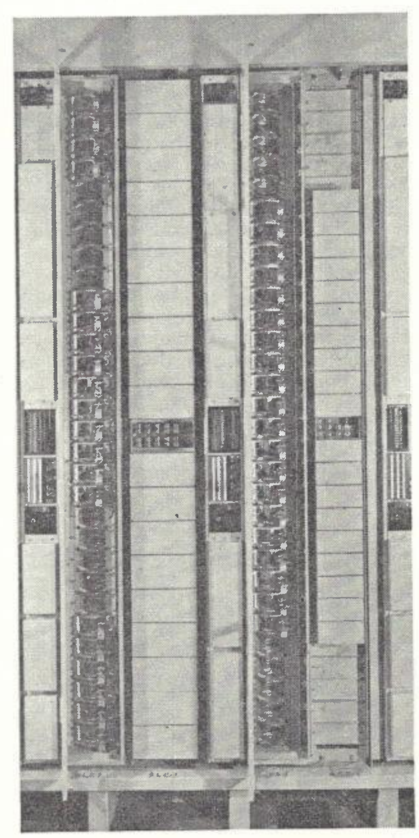

Fig. 13 — Subscribers' Stage Racks. P.L.F. — Primary Line Finder. S.L.C. — Subscribers' Line Circuits. F.S. — Final Selector. R.S.B. — Relay Set B.

switching stages. The routing selector with storage and translator equipment can evaluate up to 5 digits. This evaluation can be used to determine different charging zones on S.T.D. calls. On local calls the routing selector eliminates the 2nd, 3rd and 4th group selectors, and the routing selector outlets trunk into local 5th selectors. The incoming calls trunk via the relay set C into the 4th selector.

To increase the number of routes available a second routing selector stage is used at Maribyrnong, as can be seen in Fig. 18. The setting up of the 2nd routing selector is done under the control of the storage and translator in the same manner as in the first routing selector.

The system provides for alternative routing and up to 3 route choices can be made available. In case of local traffic trunked via the 2nd routing selector the traffic is made to overflow to the City West backbone route and come back on the incoming 4th in case of congestion, or failure of the 2nd routing selector stage.

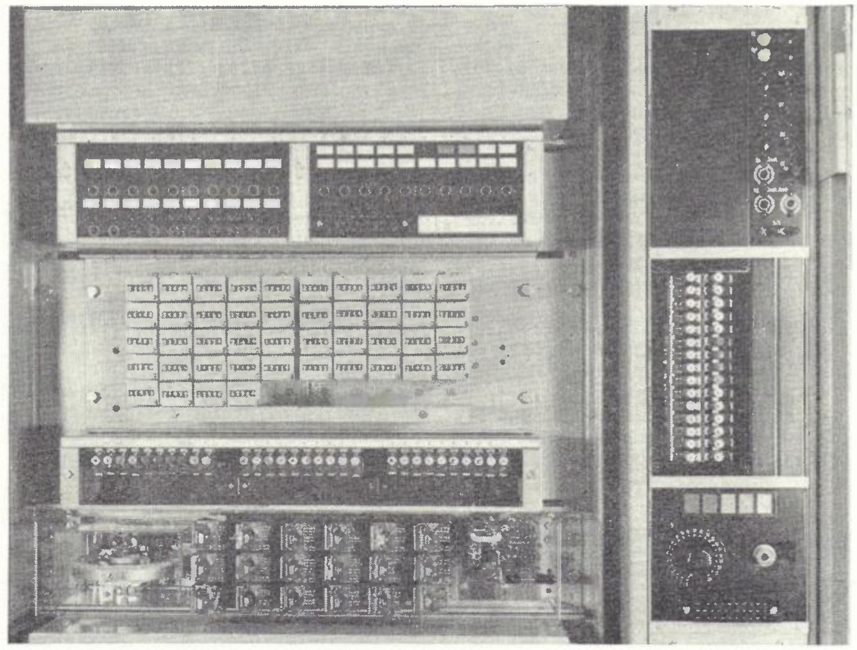

Fig. 14 — Supervisory Panel of R.S.A. Rack on the Left and First Routing Selector Rack on the Right.

FUNCTIONS AND STAGES

Subscriber's Line Circuit (S.L.C.)

The subscriber's line circuit comprises a set of twin relays shown on Fig. 6, designated as R&T. Relay R operates on subscriber lifting up his receiver to make an outgoing call. One of its contacts initiates the start condition in the L.F. control set. Another contact of R relay marks the subscriber's contact on the L.F. group to be found by the L.F. assigned to handle the call. R relays contacts also guard the subscriber against seizure by another L.F.

Relay T disconnects the start lead from the L.F. and disconnects these relays, earth, and battery from the speaking wires while the call is being set up. Both R & T relays are operated while the call is in progress. Relay R releases and relay T remains operated when for some reason the subscribers' line is under lock out condition.

Line Finder Stage

One hundred subscribers comprise one L.F. group, and have access to a number of direct and indirect finders. Direct finders are connected to R.S.A. and indirect are connected to secondary L.F.s. Each group has a capacity of 9 direct and 6 indirect L.F.s. The indirect L.F.s from all groups except 89/90 and 70 hundredths trunk into 2 common groups of secondary L.F.s. The capacity of the 2 secondary finder groups is 60 and 30 switches. The remaining 300 numbers are assigned for use by subscribers with many rotary lines and direct L.F.s only are used to handle this heavy traffic.

Two control sets are used for each group of 100 subscribers. The C.S. assigns a free L.F., tests for the marked contact of the subscriber calling out, and stops the L.F.'s on the contact marked by battery potential. It then disconnects itself and can be used for another call. A uniselector switch is used as an allotter in each control set. Fig. 19 shows a line finder control set. Both C.S.s can be used by all the L.F.s of the group.

When all direct L.F.s are in use an indirect L.F. is allotted to the next call. The same C.S. "sets" L.F. and 1st L.F., and the secondary L.F. finds the marked contact of the wanted subscriber and connects it to the R.S.A. A pre-select feature is used in the control set of the secondary L.F. resulting in a free secondary L.F. being always connected to the C.S.

Relay Set A

Relay set A contains a number of relays required for the duration of the call. It provides the dial tone and transmitter battery; it receives, stores, and retransmits the digits dialled and applies meter pulses at the appropriate rate; it feeds try again tone in case of all trunk busy conditions, and check number tone in case of a dead level being dialled.

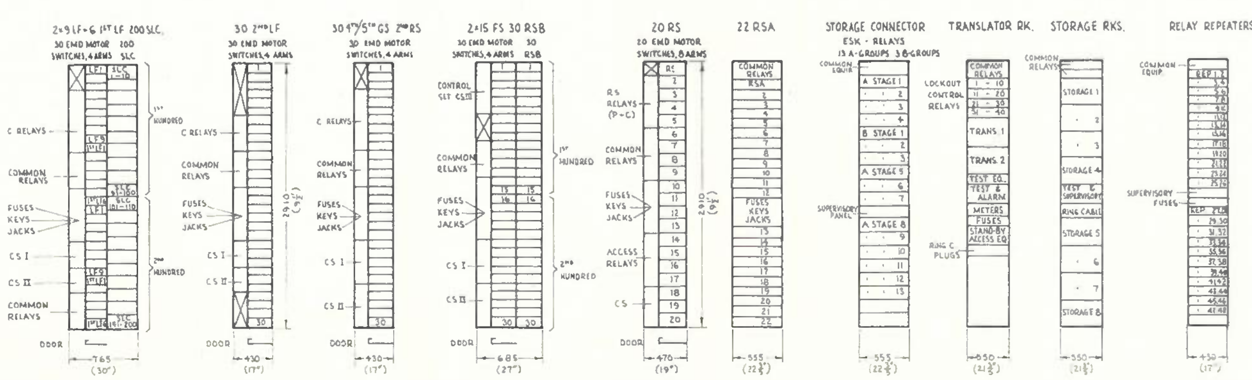

Fig. 15 — Face Layout of Racks.

Routing Selector

A 220 outlet, i.e. 8 arm, E.M.D. switch is used for route selection in connection with a R.S.A. storage and translator. The 220 outlets can be allotted to 15 routes of availability from 2 to 220. The number of routes and outlets in Maribyrnong exchange has been increased by the use of a 2nd R.S. stage which provides a further 15 routes. 110 outlet switches are used as 2nd R.S.s. R.S.s are set up by their C.S. working under the direction of the storage and translator equipment. The translator marks the route required and the R.S.'s control set causes the route and a free outlet to be found by the R.S.. The marking of the route is done by operating 2 out of 6 relays. One C.S. is provided for each rack of 2nd R.S s and the C.S. on the adjoining rack is used as a stand by for use in case of failure of the regular C.S.

Storages

These are centralised switching circuits which are connected to R.S.A. for a short time to receive digits required to determine the routing and charging rate of the call. On receipt, each digit is stored and presented to a translator for analysis. If this digit is not sufficient to determine the route the storage disconnects itself from the translator having called for a second digit to be sent from the R.S.A. These two digits are then presented to the translator for analysis, and so on. When the route has been determined the storage retransmits any digit required, or suppresses the superfluous digits and instructs the R.S.A. to continue sending remaining digits. It also marks the appropriate charging rate for the call in R.S.A. The storage is capable of storing up to 5 digits required for route determination. The storage comprises a great many high speed and conventional relays (approx. 170). Fig 20 shows a portion of 2 storage racks with the front gates of one storage open. Fig 21 shows some of the relays mounted on the rear of the rack.

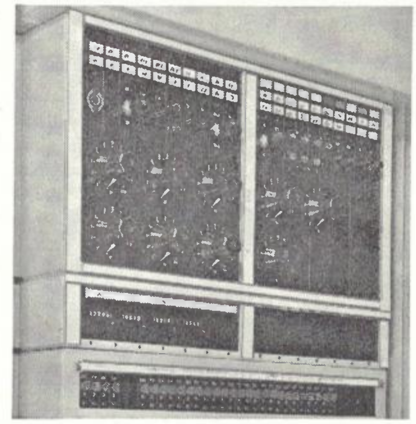

Fig. 17 — Translator Supervisory and Test Panel.

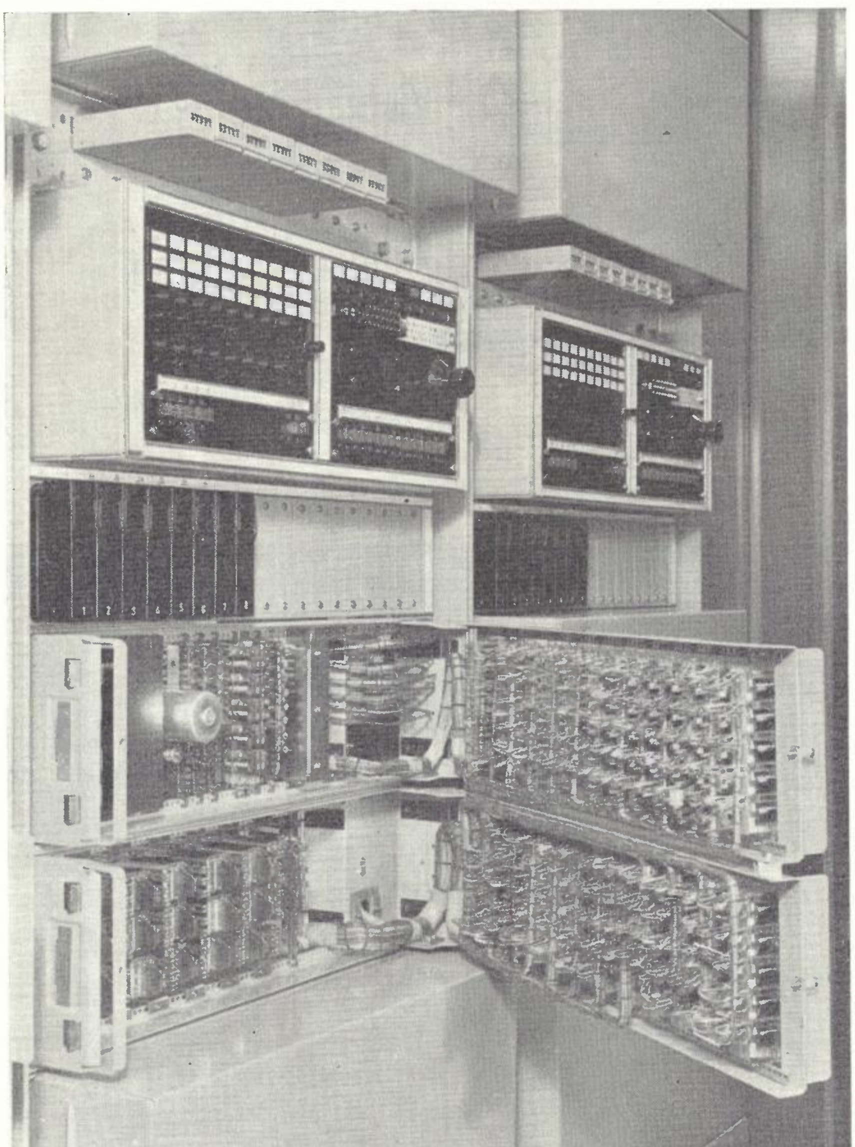

Fig. 16 — Storage Rack Supervisory Panel with One Storage with Front Gates Opened.

Translator

The translator is a complex highly efficient memory device constructed exclusively of ESK relays whose operating time is extremely short. Fig. 22 shows a front view of a translator with gates opened. The translator determines the routing and charging of the call on the basis of the exchange code received. It also advises the storage of the programme to be dialled for access to the last choice route available. It is seized through a self-locking electronic test multiple which ensures that only one storage is connected at a time. The test multiple is a self contained plug-in sub-assembly unit and is shown in Fig. 23. Digits are transmitted to translator from storage by means of 2-out-of-5 code and from translator to the routing selector control set by means of 2-out-of-6 code.

The translator is continuously informed of the free or busy condition of each individual 1st choice route and thus for each call indicates the most favourable route to be used. This automatic control of alternative routing in the translator is achieved by use of route relay for each route. The route relay is operated as long as there is a free outlet on the route. When this relay releases it energises the route relay of a second choice suitable route.

Storage Connector

Connection of an R.S.A. to storage is achieved by means of storage connectors. Since this connection must be established as quickly as possible it is done using ESK relay switching arrays. The storage connector consists of an A stage

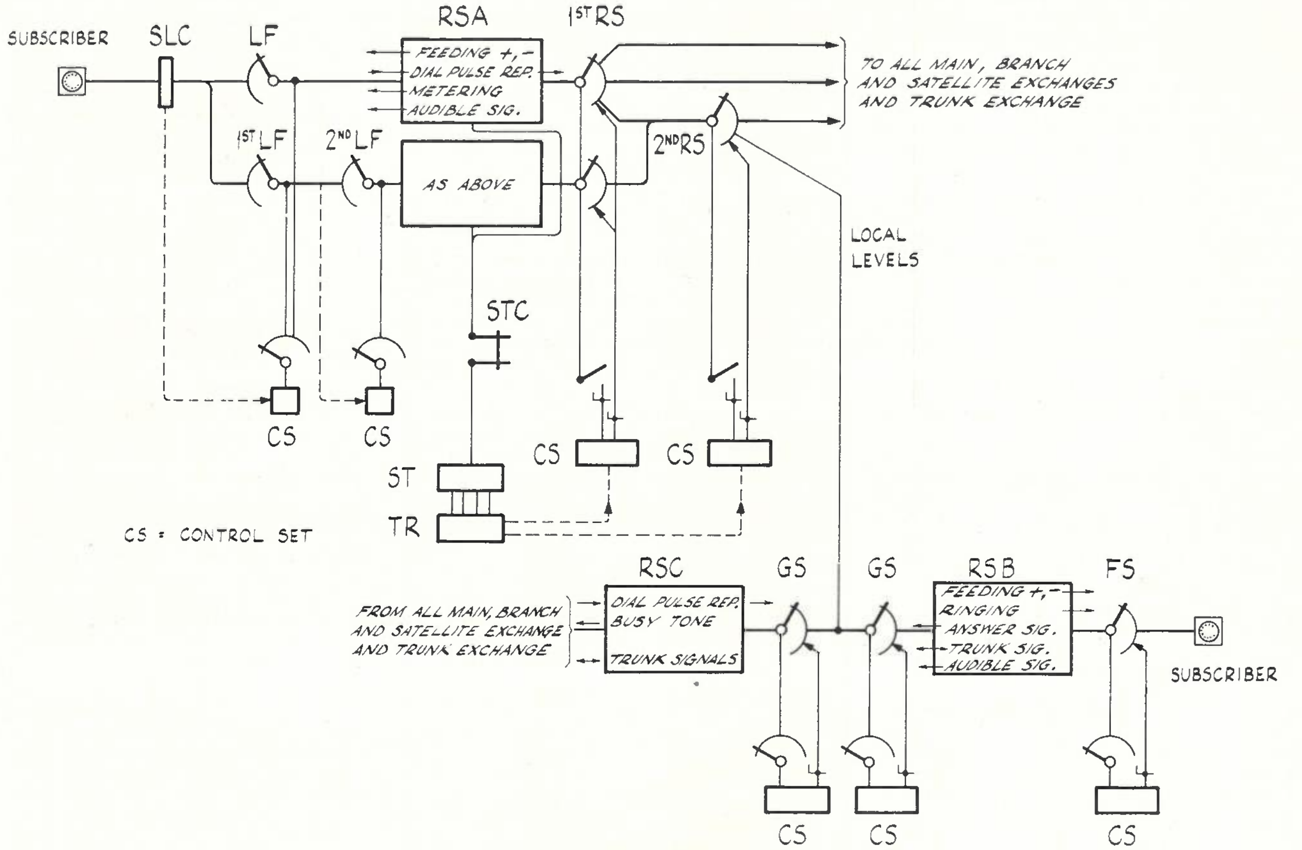

Fig. 18 — Block Schematic of E.M.D. Trunking Scheme.

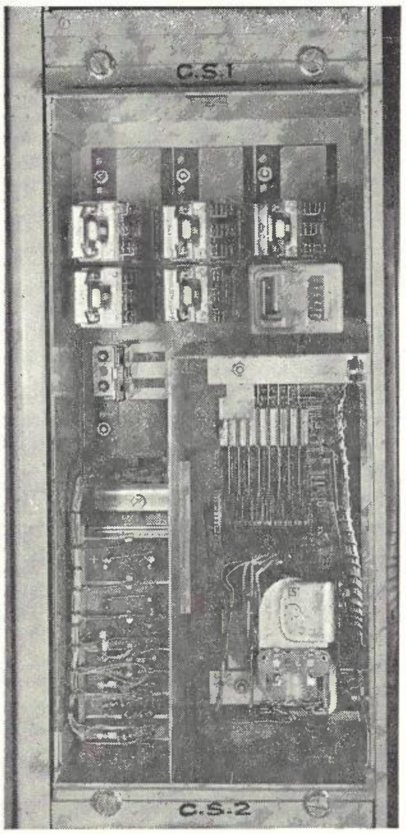

Fig. 19 — Line Finder Control Set.

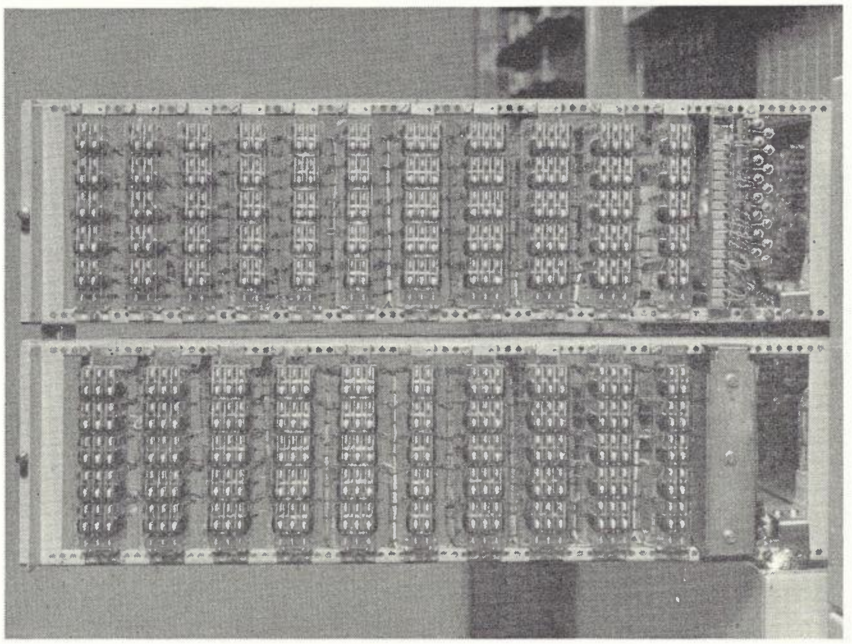

Fig. 20 — Storage — Front Gates Opened Out.

and a B stage connected together by links. The A stage consists of 13 groups with 10 inlets and 3 outlets each. The B stage has 3 B groups each with 13 inlets and 5 outlets. Thus 13 x 10 inlets, that is R.S.A.s can be connected to 3 x 5 outlets, that is, storages via 13 x 3 links.

The principle of conditional selection is used whereby seizure of a free link takes place only when a free outlet is available in the B stage to which the link is connected. There being 3 B groups, 3 connections can be switched simultaneously, and of course, 15 connections may exist simultaneously. Storage connectors are designed in accordance with the principle of delay system working. When no spare storage is available, R.S.A. stores the existing digits and a free storage is connected to the waiting relay set immediately it becomes free. Connection of R.S.A. to a storage is done via 8 wires.

Fig. 24 shows the arrangement of the A and B stages and their interconnecting by way of links. Fig. 25 shows an A stage and the storage connector rack supervisory panel.

Fourth, 5th, and Final Selectors

Each of these selectors consists basically of an 110 outlet E.M.D. switch and one or two relays required for the duration of the call. In the case of group selectors the switch outlets can be assigned to individual trunk groups (levels) as desired.

Testing of levels and setting of group selectors is performed by their C.S.s via an 8 armed switch working as an allotter, or an access selector. The pulses sent from the R.S.A. are received in the C.S. on a pulse counting chain of relays. The last of these relays operating, marks the appropriate selector level marking lead by applying one side of a charged capacitance to the start of the level and battery to the end, i.e. overflow contact, of the level. The other side of the charged condenser is then connected to the access switch and the group selector. The selector is then made to rotate to find this marked contact. The use of the charged condenser as an independent marking source of current prevents the contact being seized by another selector being stepped under the control of another marker. Having found the marking lead of the level dialled the selector proceeds to search for a free outlet; battery on a contact supplied by the subsequent switching circuit, i.e. group selector or an R.S.B. Having found a free outlet the connection is extended to the next stage and the switching process is repeated as above.

When a selector finds an all trunks busy condition in a marked level its control set registers an overflow on overflow meter, and causes try again tone to be sent from R.S.A., the latter also disconnecting itself from the selector.

Final selector is permanently associated with an R.S.B. This relay set contains all the circuit elements required to perform switching functions before, during and at the end of the call, after the C.S. is disconnected. The R.S.B. tests

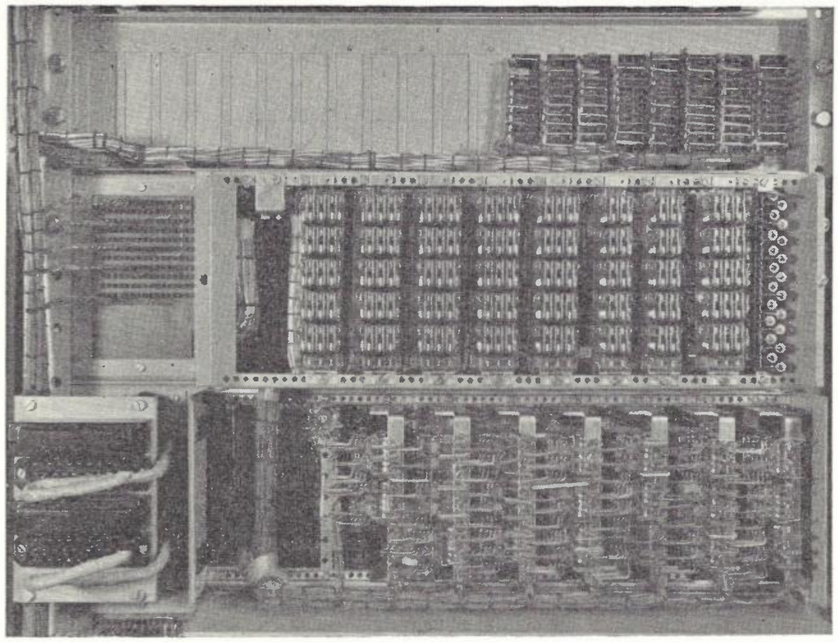

Fig. 21 — Storage from the Rear with Covers Removed.

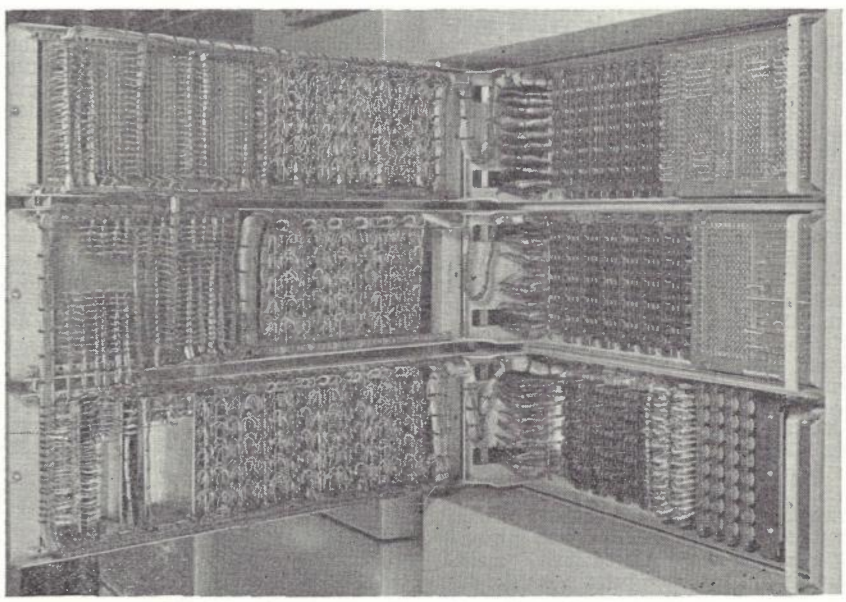

Fig. 22 — Translator — Front View, Gates Opened Out.

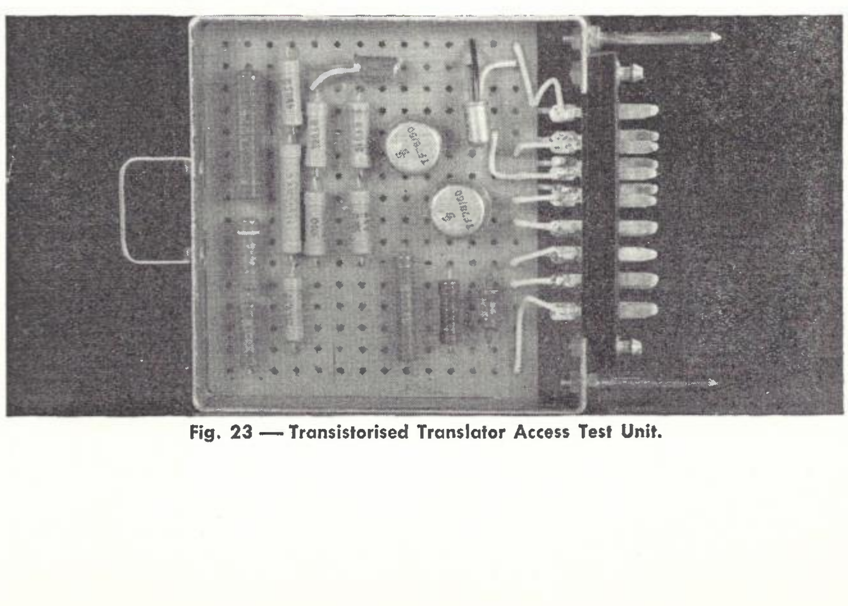

Fig. 23 — Transistorised Translator Access Test Unit.

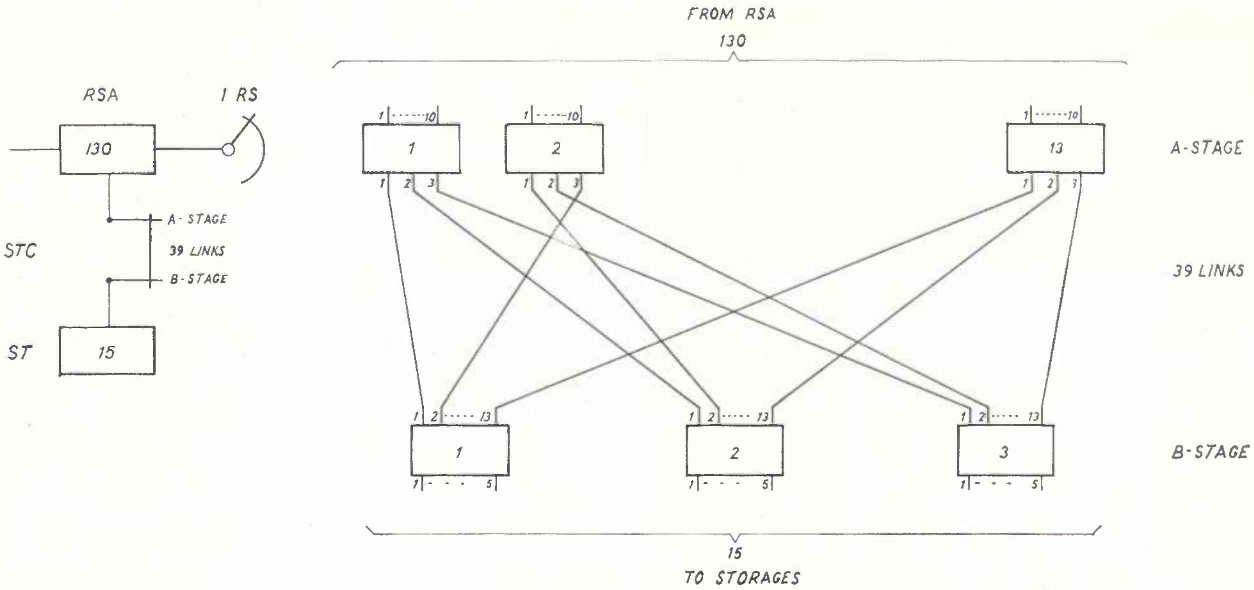

Fig. 24 — Storage Connector.

the called subscriber, transmits ringing current and tone signals and feeds the transmitter battery to the called subscriber. It also sends back the answering signal, and supervisory signals such as try again tone and check number tone in case of subscribers busy and number unallotted, respectively.

Besides the R.S.B. each ten F.S.s have a C.S. with basically similar functions to that of group selector control set. The F.S. control set has an additional function in causing the F.S. to step under the control of the last digit besides the conventional selection of the level marked by the last-but-one digit. The C.S. of the F.S. stage is called for twice on each call. When called for the second time it is informed of the fact that the F.S. must now step under the control of the arriving pulses.

If the called subscriber is a rotary subscriber the F.S. is made to hunt for the first free line in the rotary group of lines. The first line of a rotary group is marked with an earth via a 2500 ohm resistance, and the last line with a direct earth on C1 wire. A free line is marked with an 800 ohm battery on the C1 wire. Busy line has a direct earth on the C1 wire, applied by the associated subscribers line relays (S.L.C.).

Relay Set C

A special relay set called R.S.C. is used as an incoming "repeater". It receives the loop pulses sent by the step-by-step, or crossbar systems and stores them on its impulse repeater. The switching and control functions of R.S.C. are very similar to those described in case of R.S.A. To allow for the slower rate of arrival of pulses being stored on the pulse repeater the start of re-transmission of digits is delayed for 200 ms, thus ensuring that release of digits from storage does not overtake the arrival and storage of digits.

Connection of R.S.C. and the associated group selector is done by the group selector C.S. via its allotter. R.S.C. also reverses the potential on the incoming "a" and "b" wires when the called subscriber answers thus extending the metering condition to the originating exchange. It also sends back try again tone in case of congestion in the selector levels.

Relay Set Repeaters

These repeaters are used on outgoing junctions and when encountered in the switching sequence the pulses stored in the R.S.A. are retransmitted without further proceed-to-send signals, and with fixed interdigital pauses in the form of ground pulses. The repeater converts the circuit to two wire working. It back busies in case of open and reversed junctions.

Metering

In this system metering is done by operation of subscriber's meter on called party answering. The meter is operated by a battery pulse supplied by a charged capacitor. This method of operation of subscribers meter applies to local calls, and in case of S.T.D. calls would apply to the first metering pulse. Subsequent pulses on S.T.D. calls would be supplied by a common pulse generator at the rate determined by the translator and transmitted to R.S.A. via storage. The translator having determined the zone of the call sets the zoning switch in R.S.A. to

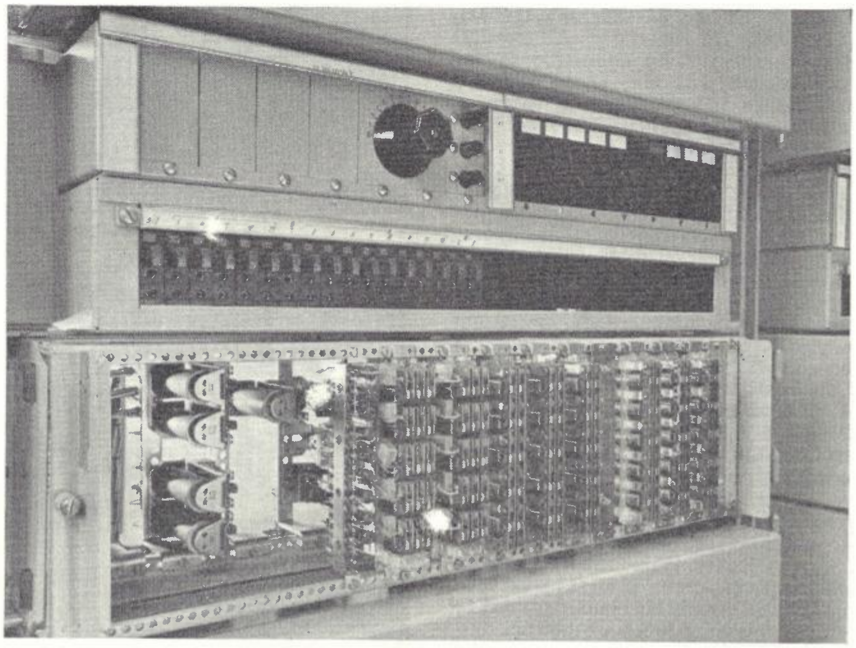

Fig. 25 — Storage Connector Rack Supervisory Panel with Storage Connector A-Stage.

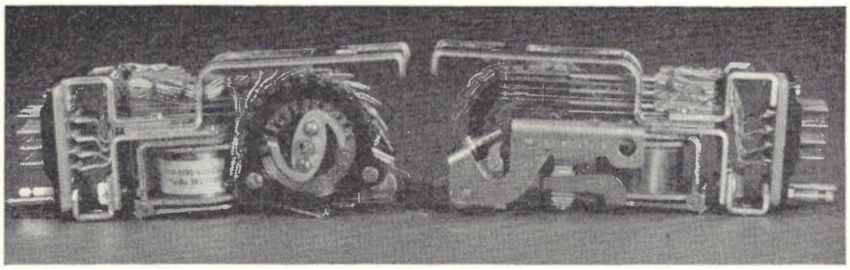

Fig. 26 — Zone Relay Selectors.

the contact feeding the appropriate metering rate from the multi-pulse generator. As the first metering pulse is supplied by the capacitor when the wanted subscriber answers, the first pulse from the zoning switch is suppressed to avoid it being applied too early. This is similar to the present arrangement on S.T.D. calls. At present Maribyrnong subscribers do not have access to S.T.D. routes.

The zoning switch is a small "relay selector" shown on Fig. 26. The appropriate metering rates would be connected to its small rotary selector, contacts 2-11. It would step to the appropriate rate contact under the control of the storage and could thus connect this charging rate to the metering wire. The relay type springs seen on Fig. 26 are self interrupters used to drive the selector home on completion of each call.

On non-metering numbers e.g. official services, 3171067, etc. the metering relay "Z" in the final selector is prevented from operating by grounding the "C" wire thus suppressing the metering pulse.

Operating Characteristics

Working voltage	48/50 (with 45V min. and 52V max.)
Operating limit on subscribers line	1500 ohms. incl. Telephone.
Operating limit on junction	1600 ohms.
Minimum tolerable insulation resistance between "a" and "b" or ground above.	on subs lines 13000 ohms. on junctions 16000 ohms.
Exchange losses	less than 1 db at 800 c/s.
Cross talk attenuation better than 77 db.	
Pulsing limits	7-13 i.p.s. approx.

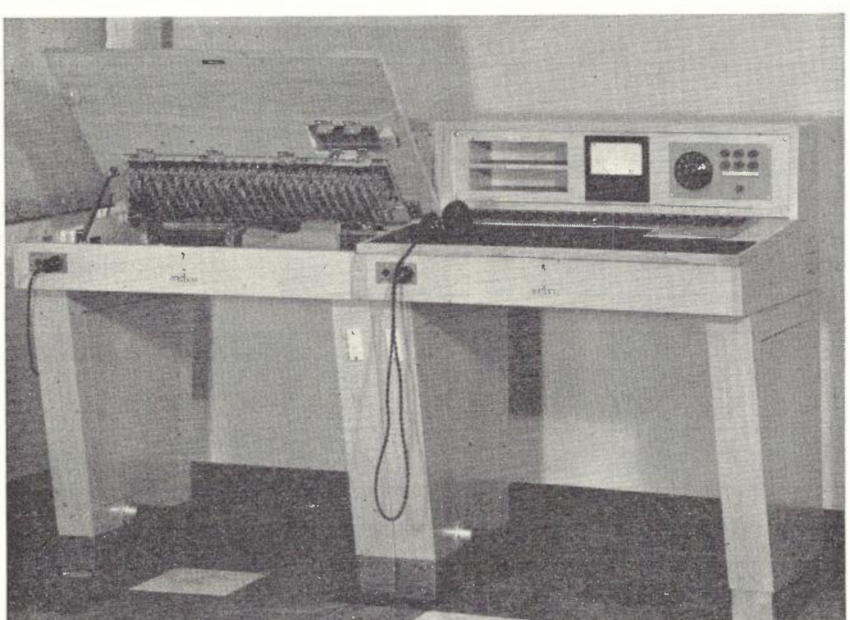

Fig. 27 — Test Desks.

P.B.X. Facilities

All numbers can be used for rotary working, and subscribers with up to 10 lines are connected on the final selectors serving the straight line subscribers. Groups in excess of 10 rotary lines are connected to the linefinder group equipped with direct finders only. Extremely large subscribers with many lines can be trunked directly from the routing selector or from a group selector levels. In the last case it is possible to provide indialling into the P.A.B.X.

Public Telephones

Any number can be used for connection of public telephone. The reversal necessary to collect coins is supplied by relay set A when the called subscriber answers. Conventional Pip-tone bases are used on multi-coin public Telephones.

Testing Equipment

The following testing equipment has been supplied for routine testing and fault-location:

Internal trunk tester — for testing of internal paths between switching stages for continuity and correct polarity of each wire and for insulation resistance.
Operation Tester Functional tester for use on line finders; group, and final selectors, and their control sets.
Relay set A tester.
Route selector tester.
Storage tester.
E.M.D. switch stepping speed tester.
Translator tester (built-in).

All testers functionally test the devices for their correct operation and indicate result of test by means of lamps or meters. All testers are manually operated and except translator tester, are connected to switches by means of cords, jacks and plugs.

Testing of Subscribers Lines

This can be done by plugging them on the M.D.F. or gaining access to subscribers line from test desks by way of test distributor, and test final selector, by dialling last four digits. An access selector is also provided to allow for after hours testing from a remote exchange. Two Company designed test desks have been provided and are shown on Fig. 27. An external dial testing device can be connected to the terminals shown at the top right hand corner. Besides the usual facilities that is In and and Out lines, shoes, etc., the test desk provides for the following measurements to be made:—

Resistance measurements "a" to "b" and "a" and "b" to earth.
Foreign battery leakage "a" to "b" and "a" and "b" to earth.
Capacity test between "a" and "b" and "a" and "b" to earth as direct meter reading, using 3.5 c/s tone.
Earth resistance e.g. on PBX earths.
Dial speed and ratio using standard A.P.O. testing circuit.

Press button keys are used on the test desks with internal lamps where appropriate.

PROGRESS OF A CALL

Calling Out (Local Call to 317 9876)

On lifting his handset a subscriber completes the loop and relay R in his line circuit (SLC) operates. This relay calls the L.F. CS and also marks the subscribers contacts on the L.F. bank multiple by connecting battery to its "c" wire. The allotter in the L.F. CS searches for a free L.F. whose contacts on the allotter bank would be marked by a battery applied by the associated R.S.A. Having found a free L.F. the CS causes it to search for the subscribers marked contact on the L.F. bank multiple. Having found this contact the L.F. is stopped. The subscriber is now extended via a L.F. to the associated R.S.A. The L.F. CS is disconnected from this call.

The R.S.A. is seized, by the L.F. applying an earth to the "c" wire. The R.S.A. also ensures that the associated R.S. is ready for seizure; sends dial tone to the calling subscriber and prepares metering circuit.

The subscriber begins to dial and the incoming digits are stored on the dial pulse repeater in the R.S.A. At the end of the first digit R.S.A. puts a "start" condition on the storage connector. As soon as the storage connector links the R.S.A. with a storage the R.S.A. retransmits the first digit to storage where it is received in the form of earth pulses and operates a counting chain, say S3 (digit 3 dialled) operating energises the appropriate relay in the 1st digit storing chain that is Z3.

Having stored the first digit the storage calls in a translator via the electronic test multiple. It then presents the stored digit in the form of a 2 out of 5 (relays) code for determination of route and zone. This information is not sufficient and the translator transmits to storage a call for next digit and disconnects itself. Storage calls for next digit which again is transmitted from R.S.A.; received on the storage counting chain; and stored on the second digit storage chain (that is S1 counting relay marks H1 storing relay). The two digits (31) are now presented to the translator which still is unable to determine the route and calls for the third digit and again disconnects itself. Storage calls for the 3rd digit. This is received by S1-S7 and stored on K7 — (third digit store chain relays). The translator is called for again and the three digits (317) are presented for analysis. The translator recognises these as requiring further analysis and converts this information to an intermediate result and stores this information in the storage on an appropriate Q relay. The three storing chains of relays in storage release, and can be used again. The translator having asked for next digit again disconnects itself from the storage. The next digit received from the R.S.A. is stored on the 1st digit store chain relays that is Z9. The translator is called for again and the appropriate intermediate code information and the fourth digit are together presented for analysis. The four digits now enable the translator to determine the route and zone of the call. It informs the storage of this fact, which in turn prevents the R.S.A. from sending any more digits. The translator also advises the R.S. of the route to be chosen and the storage of the metering zone, and of the programme for retransmission of digits for the setting of subsequent stages. The translator disconnects itself again. The 1st R.S. having found the desired route, the storage finds that the route goes to the 2nd R.S. and calls for the translator once again. The translator sends the route information in coded form to the C.S. of the 2nd R.S. and disconnects itself.

The second R.S. steps to the route just advised under the control of the C.S. and the storage. After the 2nd R.S. has found an outlet to a local 5th selector; the storage disconnects itself from the R.S.A.

The calling subscriber is now connected by means of an L.F. to an R.S.A. and by means of a 1st and 2nd R.S. to the 5th group selector. Digits 3179 have so far been removed from R.S.A. and 876 are either still stored on it or are being received by it. Relay set has been advised to send on the remaining digits directly to the next stage, and also its zone switch has been set to the appropriate zone charging rate, in this case zone 1 — local call charge.

The group selector C.S. connects itself to the group selector marked by the 2nd R.S. and signals the R.S.A. to send the next digit. Digit 8 is now received in the form of interrupted battery pulses, which are being received and counted on the marking relay chain which is set to corresponding digit dialled (8). The relay in the counting chain operated by the last impulse of the digit marks the start and the end of the level on the bank contacts of the group selector. The start of the level is marked by one side of a charged condenser being connected to it via wire "c", and the end of the

TABLE 1: CONTROL SIGNALS OVER WIRES "a" and "b"

Process	Device	Potential	Wire	Potential	Device
call for a GS-control set	RSA	(−) →	a	(+h)	GS-control set
GS-control set is connected, request for digit	RSA	(—)	a	← (+)	GS-control set
pulse train from RSA	RSA { "2"	(−) → — . —	a		GS-control set
path busy	RSA		b	← (−)	GS-control set
outgoing relay-repeater is seized	RSA		a	← (−)	o/g repeater
RSA transmits all digits with interdigital pauses	RSA { "2"	(+) → . .	a		o/g repeater
call for a FS-control set	RSA	(−) →	a	(+h)	FS-control set
FS-control set is connected, request for digit	RSA	(—)	a	← (+)	FS-control set
pulse trains from RSA	RSA { "2"	(−) → — . —	a		FS-control set
end-of-section signal	RSA		a	(—) PULSE ←	RSB
answering and off-hook condition	RSA		a + b	← (−)	RSB or o/g rep.
on-hook signal	RSA		b	← (−)	RSB or o/g rep.

(+) positive (ground) potential via low resistance

(+h) positive (ground) potential via high resistance

(—) negative potential

level, that is overflow contact, is marked by a battery connected to it by way of a marking relay. The group selector is then made to hunt under the control of the G.S.C.S. until the "c" wire wiper connected to the other side of the charged condenser reaches the marked contact.

The condenser discharges and operates a relay in the G.S.C.S. which prepares the closing circuit of the driving motor of the GS. The selector does not stop on this marked contact, but continues stepping until it finds a free outlet, that is a battery from the R.S.B.

R.S.B. and its associated final selector is found by F.S.C.S. and the next digit is sent from R.S.A. (digit 7). As in previous stage the start of the decade is marked, but in this case the final selector is made to stop on the marked contact. When the last digit is received by R.S.A. the C.S. of the F.S. is called for the second time and is aware of the fact that the digit about to be sent by the R.S.A. must step the F.S. By this means the F.S. previously set to level 7 is now stepped to contact 6 directly under the control of the 6 pulses of the last digit. The connection to 317 9876 has now been established and the condition of the line is tested by R.S.B. If the called subscriber is free the talking wires are extended and the ring current and tone are applied to the line. A free subscriber's line has earth potential on the C1 wire and 800 ohms battery on C2 wire while an engaged line has C1 wire open circuited except in case of first line of group of rotary lines when it is connected to an earth via a 2500 ohms resistance.

When the called subscriber answers, the ring is tripped; the line polarity reversed and the calling subscriber's meter is operated.

During the setting up of the successive stages the C.S. disconnects itself from the switching device at the end of switching function. The speaking wires are extended and the switch is held without the C.S., which is available for setting up the next call.

In case of the called subscriber being busy or any of the routes being congested the calling subscriber gets a try again tone and the connection is released. The try again tone is fed from R.S.A.

Call from Another Exchange (Non E.M.D.)

On a call going out to another exchange the process is similar except that the route having been determined by the translator, the call is extended to an outgoing repeater, and R.S.A. is advised to send the digits stored on it without a further "proceed-to-send next digit" signal, and in the form and with an interdigital pause suitable to the remote exchange i.e. 800 m/s in our case. If early choice routes are overflowing and the call is routed via say, the second-choice route, storage would first retransmit the last digit removed from R.S.A. and then advise it to proceed with retransmission of the remaining digits stored.

Call from Another exchange (Non E.M.D.)

Incoming routes trunk into 4th selectors which are permanently associated with individual incoming R.S.C.s. R.S.C. has a dial pulse repeater on which are stored the incoming digits in the form of received loop break pulses in the same manner as in R.S.A. These pulses are then retransmitted as in case of R.S.A. to effect setting up of the 5th and final selector, as in case of a local call.

SIGNALLING

Signalling between R.S.A. and subsequent stages while a call is being set up is shown in Table 1. These potentials operate or release relays which, in turn,

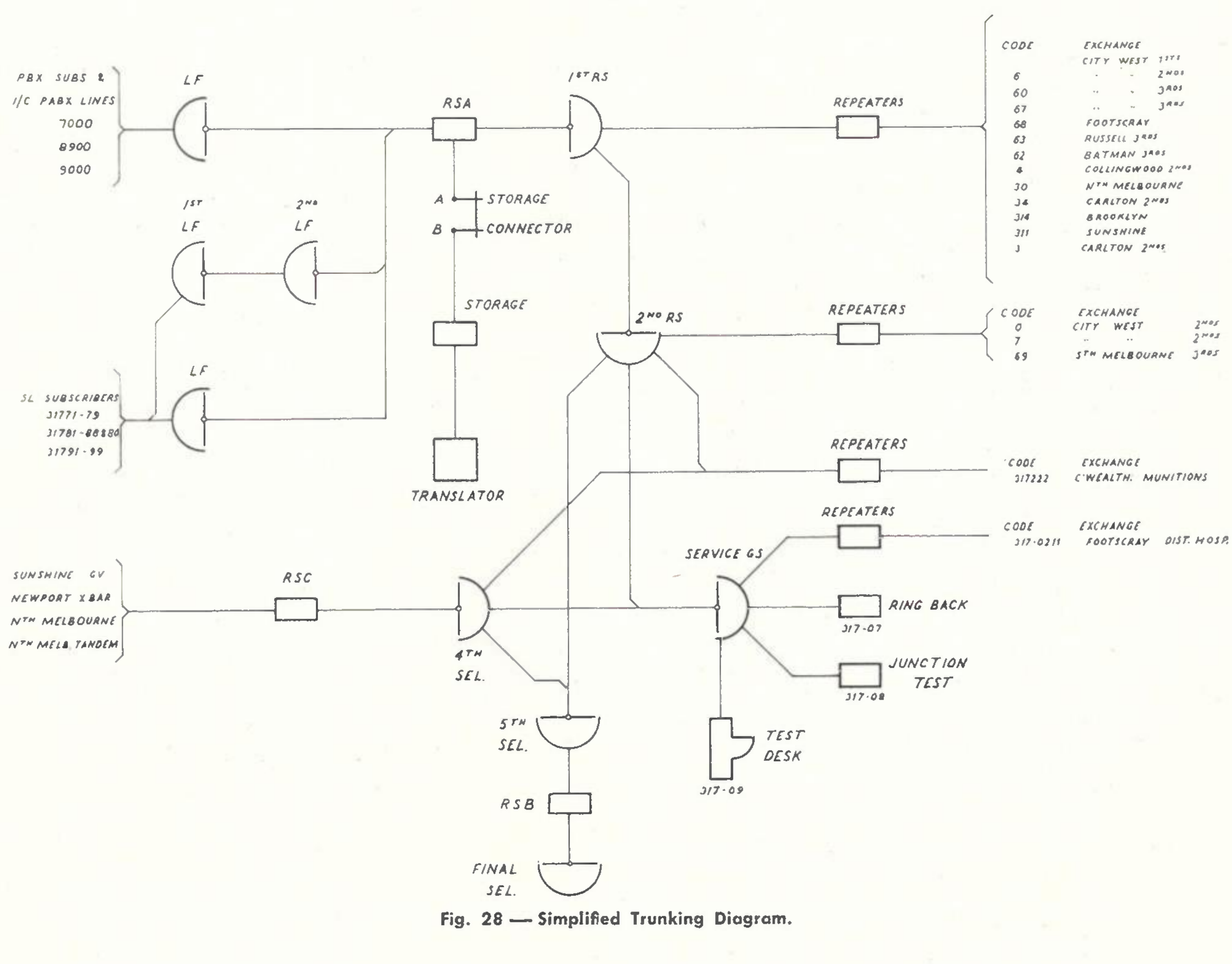

Fig. 28 — Simplified Trunking Diagram.

initiate the next function. Signalling between the storage and translator is very complex and requires 54 wires. The digit information is transmitted in the form of 2 out of 5 codes, i.e. 2 out of 5 relays operate for each digit. Table 2 shows the set of 2 relays, operating for each digit.

The routing information between translator and 1st R.S. is transmitted in the form of 2-out-of-6 code. The 15 routes are coded as shown on Table 2.

TABLE 2: TWO-OUT-OF-FIVE AND TWO-OUT-OF-SIX CODES

Digit	Relays Operating	
	2-out-of-5 Code	2-out-of-6 Code
1	0&1	0&1
2	0&2	0&2
3	1&2	1&2
4	0&4	0&4
5	1&4	1&4
6	2&4	2&4
7	0&7	0&7
8	1&2	1&2
9	2&7	2&7
10	4&7	X&0
11	—	X&1
12	—	X&2
13	—	4&7
14	—	X&4
15	—	X&7

TRUNKING DIAGRAM

A simplified trunking diagram is shown on Fig. 28. The alternative routing is well illustrated in case of a call to City West 67 or 60 subscribers. The first choice route is to the 60 and 67 thirds with overflow traffic going to 6 seconds and with a backbone route to City West 1st selectors. The number of outgoing routes can be further increased as required by opening routes from the second routing selector (15 routes are available from 1st routing selector and 15 from the second). Should more routes be needed another route selector stage could be added providing further 15 routes.

Trunking of large group subscribers can be either from levels of 4th selectors as in case of 317222 Commonwealth Munitions P.A.B.X., or from levels of service group selectors as in case of 317 0211, Footscray District Hospital P.A.B.X. The incoming routes trunk into R.S.C. and associated 4th selectors and local traffic on leaving the 2nd R.S. trunks into the 5th group selector. The incoming P.A.B.X. lines and P.B.X. subscribers with many lines are grouped on separate L.F. groups which have direct L.F.s. only.

The 1st R.S.s have 220 outlets and all other switches have 110 outlets. The availability of various routes (levels) varies from one to another and can easily be altered by shifting the (MS) marking leads. Fig. 29 shows bank contacts of 110 pt. group selector with 8 outgoing routes, or levels. Bank contacts of 1st and 2nd R.S.s are assigned to routes in a similar manner except that there can be up to 15 routes. In case of F.S.s each marking contact (M.S.) is followed by ten contacts. The marking contacts being the decades and the ten contacts the units. Skipped type grading is used on all routes and one is shown in Fig. 30.

M.D.F. AND I.D.F.

A conventional type M.D.F. has been used at Maribyrnong except that L.M.E. fuse-cum-heat coils and L.M.E. 3001 arresters have been fitted on equipment side and link mountings on the line side. The I.D.F. has been designed by the company. Terminal strips on one side are mounted vertically and are used to terminate wires from the following stages: L.F.s, R.S.A., 1st and 2nd R.S., 4th selectors, special (or service) G.S. test desk, and storage connectors, stage B. Terminals on the other side are mounted horizontally and the leads from these go to: 2nd L.F. R.S.A., Storage connectors A stage 2nd R.S., 5th G.S., Repeaters and M.D.F. Fig. 31 shows a portion of the I.D.F.

PERFORMANCE

The performance of the exchange has been quite satisfactory. There were very few teething troubles and the equipment settled down quickly and has worked well. The amount of attention required by the equipment is appreciably less than would be required to maintain a step-by-step exchange of similar size. To date the maintenance effort has been based on qualitative maintenance philosophy with a number of insurance tasks being done at regular intervals. Some of these insurances routines, other than the routine test of alarms, are as follows:—

Check of impulsing circuits in R.S.A., R.S.C. and storages — once a year.

Speed test of E.M.D. switches — every four months.

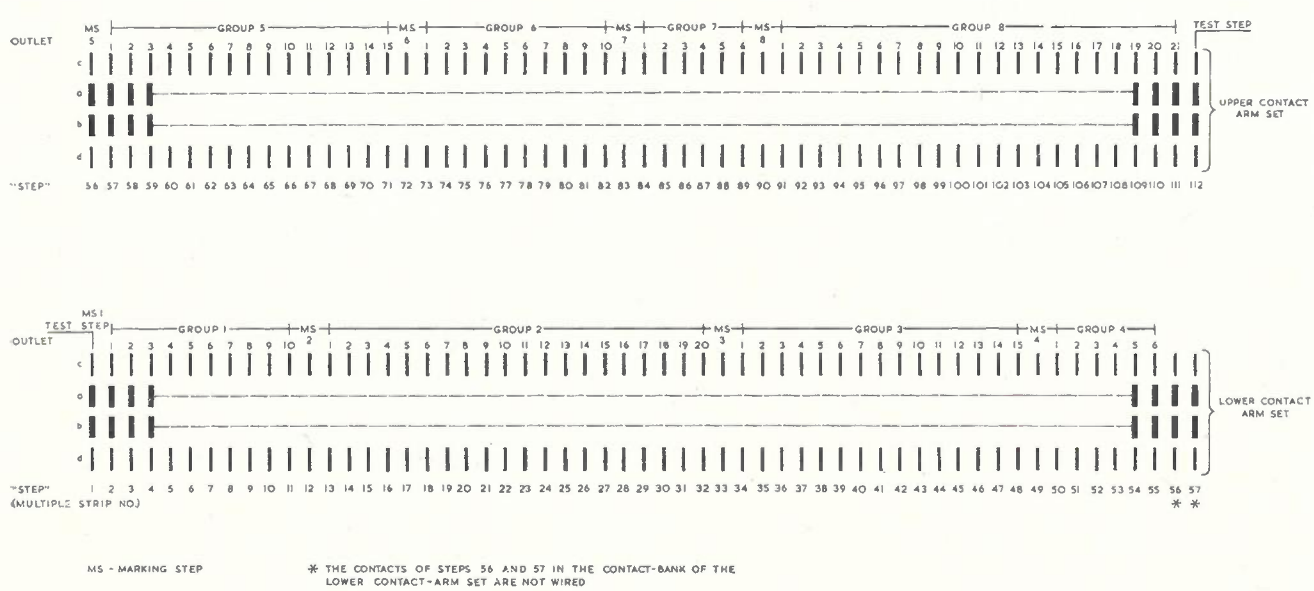

Fig. 29 — Bank Contacts of E.M.D. Group Selector 110 Outlets Divided into 8 Routes. (As seen from contact arms.)

TABLE 3: FAULT STATISTICS FOR PERIOD 1.7.64 TO 30.6.65

Type of Circuit	SLC	RSA	DPR	Storage Connectors	Storage	Translator	RSB	RSC	Zone Switch	End Switch	Control Sets	Bank
Number in Use	3,000	260	411	32	18	2	360	158	260	1,419	144	1,419
Number of faults	5	10	65	1	1	1	5	6	6	9	23	3

Impulse ratio test on repeaters — every two years.

Inspection and cleaning of drive contacts in all control sets, initiating and stopping the motion of the E.M.D. switches — every six months.

Lubrication of the allotters and D.P.R.'s — every six months.

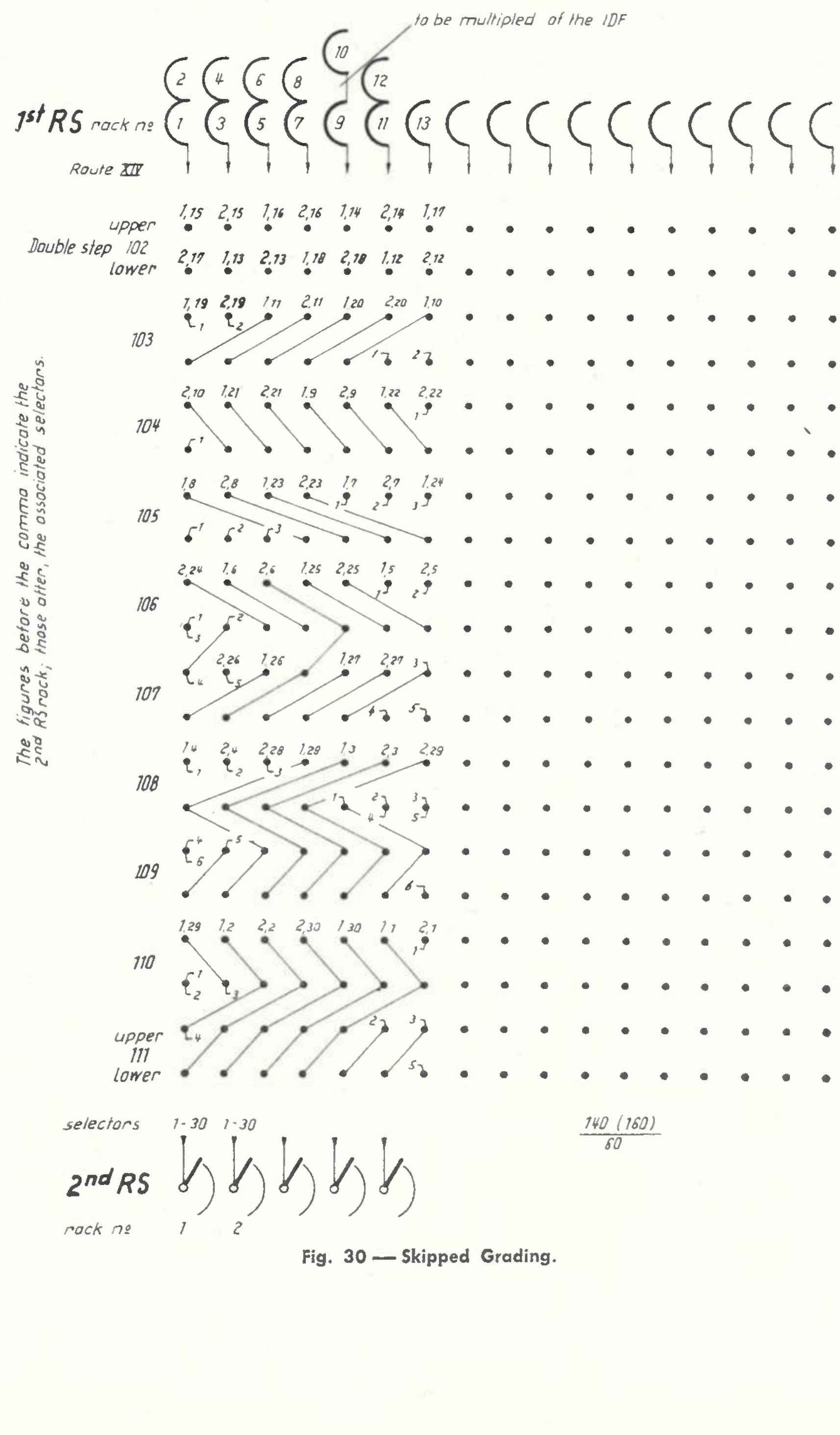

Fig. 30 — Skipped Grading.

Lubrication of zone switches — every 12 months.

Lubrication of E.M.D. switches is scheduled on the basis of every four and a half years. The bank contacts of the E.M.D. switches have not been cleaned as yet nor was there any attention given to wipers due to wear. All faults due to wipers were man-made and removed by minor re-adjustment or re-alignment of wipers.

The 12 months' fault figures for period 1.7.64 to 30.6.65 are shown in Table 3. The D.P.R.s have been the most troublesome. Not only did they have most of the faults but many of those faults were intermittent and difficult to find. The mechanism however, has been modified recently and it is confidently expected that its performance in the future will be much more reliable and troublefree. Of the nine E.M.D. switch faults, six were due to man-made wiper faults. It is noteworthy that the most complex devices, the storages had such a low fault incidence.

The grade of service given as observed by T.R.T. runs recorded recently is of the orders of one call lost in 1,000 on local calls, and two calls lost in 100 on calls to 15 other exchanges.

CONCLUSION

This interesting system thought of very highly when it was first purchased is now non-standard in Australia amongst the conventional step-by-step old system and the new crossbar equipment now installed by the Department. Being one off, it has its more than usual share of problems and difficulties. Training of maintenance staff has been a problem from the beginning. The Company's installing engineers gave lectures to the installing and maintenance staff and since then local on-the-job training only was given to all subsequent staff. All the present members of maintenance staff have been trained on-the-job since the cut-over. In addition the stock holding of spare parts and tools for a single exchange of a non-standard system, is not economical.

The above difficulties, however, do not in any way detract from the inherent advantages of this system, such as:—

(i) Solderless bank multiple.

(ii) Non-trailing speaking wipers used by E.M.D. switch.

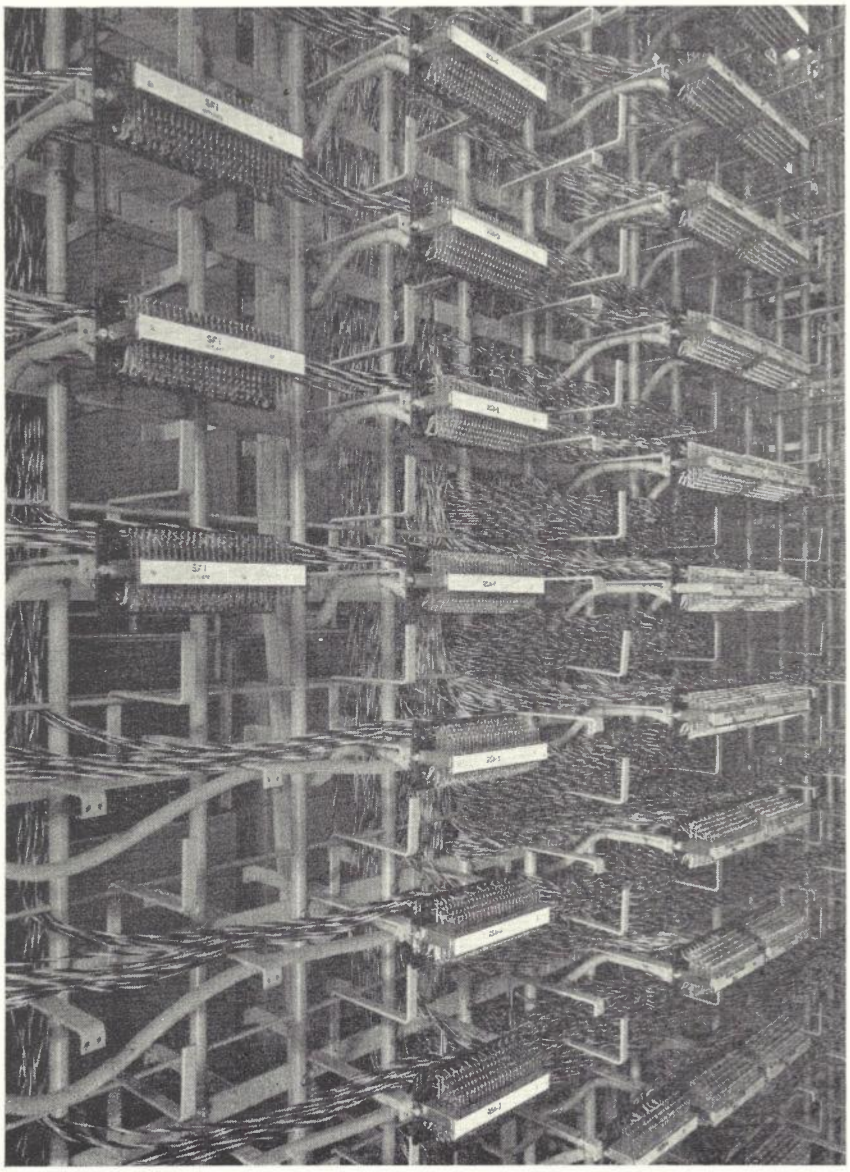

Fig. 31 — Portion of I.D.F.

(iii) Reliability and fault incidence of E.M.D. switch, its use in all switching stages; its high setting speed.

(iv) Reliability of ESK relay.

(v) High transmission quality resulting from use of noble metal contacts in speaking wires.

(vi) Regeneration of impulses by D.P.R. on all calls.

(vii) Conditional selection of storage connectors.

(viii) Alternative routing, and great number of routes available.

The equipment has been manufactured to a very high standard of workmanship. The glazed doors on the front and covers on the back of racks protect the equipment from dust, and also contribute to its excellent appearance.

ACKNOWLEDGMENTS

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EXPERIMENTAL DETERMINATION OF THE RADIATION PATTERN OF TELEVISION TRANSMITTING AERIALS

D. Gosden, B.E.*

INTRODUCTION

The function of a television transmitting aerial is to concentrate the radiated power of the transmitter into the area which it is desired to serve and away from those regions where no service is desired. It is obviously not required to transmit vertically upwards or downwards nor at elevated angles above the horizon as this not only wastes power but may cause interference by sporadic E layer reflections or refractions in the ionosphere or in the atmosphere. The concentration of power in a horizontal or near horizontal plane is achieved by using an aerial with numerous radiating elements and reflecting screens suitably arranged. In the required directions of radiation all the elemental radiations are closely in phase, whereas in undesired directions the vectorial resultant of the radiation is small.

The concentration of energy is measured as a gain (in (decibels). A so-called omnidirectional aerial is one which has almost constant gain in all horizontal directions. A directional aerial has a non-uniform horizontal pattern. The gain in any direction of an aerial is the improvement in field strength received at a point in that direction, over that which would be received if a half wave dipole were substituted for the aerial and faced the point.

The problem of accurately measuring the radiation patterns of television transmitting aerials after they have been installed is one which has been attempted by a number of different methods with varying degrees of success. One method, is to take field strength readings at a large number of points around the transmitting aerial and note the orientation of each point with respect to the aerial. The results of the measurements are then compared with values obtained theoretically for a given radiation intensity from the aerial in all directions. The results of this comparison show the variation in intensity in different directions, which may be resolved into two patterns. One of these patterns is traced out by a vector moving around the aerial in a horizontal plane — the variation in radiation intensity with its direction is known as the horizontal radiation pattern. The other vector traces a pattern around the aerial in a vertical plane and the variation in radiation intensity with its direction is known as the vertical radiation pattern. The accuracy of this method of developing the two patterns is limited since effects which reduce the accuracy of the experiment, such as reflections from hills which often occur, cannot be taken into account. Accuracy may be improved by increasing the number of test points, but this is laborious.

Another attempted method to measure the vertical pattern is known as the

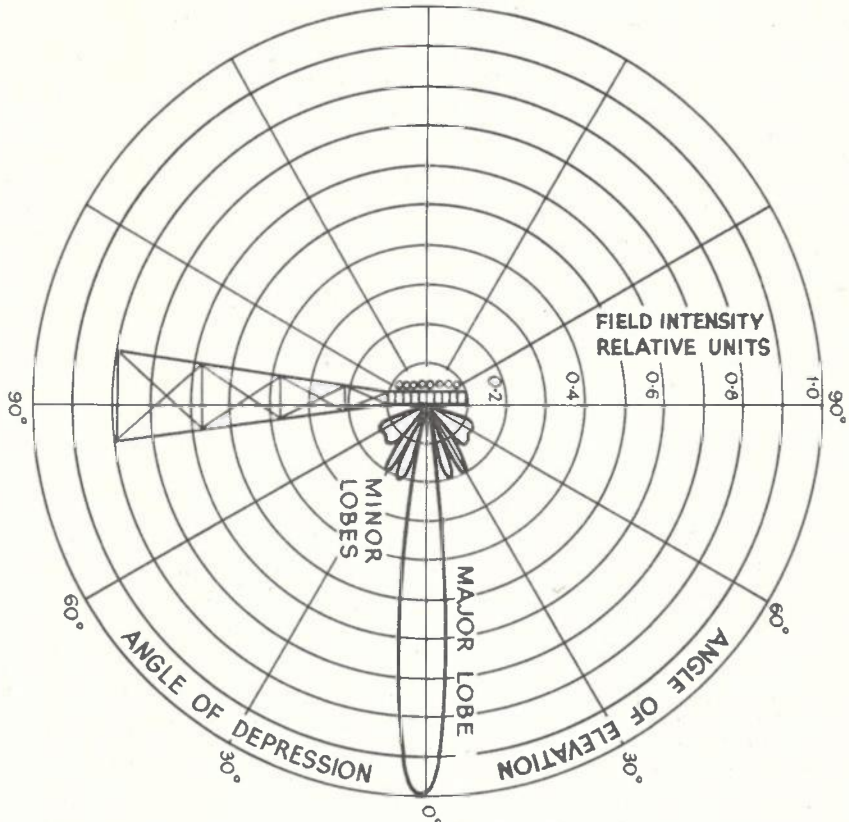

Fig. 1 — Typical Vertical Radiation Pattern. (polar co-ordinates)

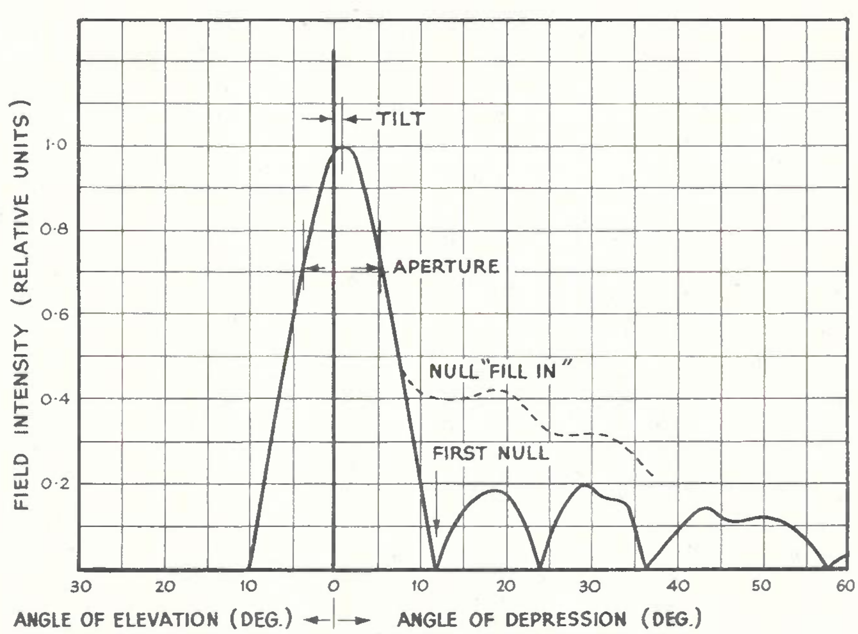

Fig. 2 — Typical Vertical Radiation Pattern Shown in Cartesian Co-ordinates.

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"rising sun" method, and is of academic interest. A sensitive receiver is connected to the transmitting aerial and is tuned to the frequency of the vision transmitter. As the sun rises, the receiver picks up the noise signal radiated by the sun on the frequency to which it is tuned. The variation in the signal which the receiver picks up as the angle of inclination of the sun increases gives the vertical pattern of the aerial. The accuracy of this method is usually limited by interfering signals and local noise in the receiver and variation in atmospheric conditions as well as unknown reflections.

The method described in this paper is easy to carry out and requires no complex equipment other than a field strength measuring device and a second small transmitting aerial — the test aerial.

The nature of various aerials and their patterns and methods of obtaining them will first be discussed briefly. Then the theoretical vertical pattern of a simple aerial will be calculated and compared with the experimental results. Details of the measuring techniques and some results will also be given.

VERTICAL RADIATION PATTERN OF AN AERIAL

The shape of the vertical radiation pattern of a television transmitting aerial which consists of a number of driven elements and reflector screens stacked vertically is shown in Figs. 1 and 2. Nearly all television transmitting aerials used at present fall into this category. Usually four requirements are considered in specifying the characteristics of the vertical pattern, These are:—

(a) The angle of depression of the axis of the major lobe of the pattern, and

(b) the angle of depression of the first null.

(c) The amount of radiation required in the direction of the major axis of the pattern.

(d) The suppression of high angle radiation to avoid interference to other stations service areas.

Fig. 3 shows diagrammatically a section through one face of a typical aerial and the feed system to the panels. The aerial is divided into two sections which are called the top and bottom stacks. The reason for this is that if part of the aerial is damaged by a severe lightning strike or any other cause, it is possible to maintain full transmitter power transmission on the undamaged half involving a loss of signal in the major lobe of 3db. This loss is due to the loss of half the concentrating capability of the aerial.

It will be noticed that the bottom stack feeder is slightly longer than the top stack feeder. The effect of this is to cause the phase of the radiation from the top stack to be slightly ahead of that from the bottom stack. The wavefront leaving the whole aerial is slightly ahead

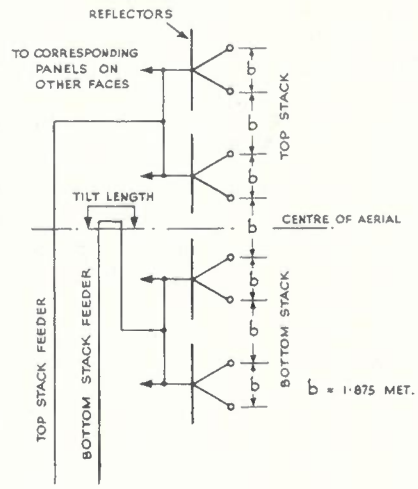

Fig. 3 — Sketch Showing Section Through Dipoles on one Face of Aerial.

at the top half of the aerial resulting in a tilt of the axis of the major lobe slightly downward. This downward tilt of one or two degrees of the major lobe is desirable to reduce the amount of wasted radiation above the horizon.

The angle at which the first null occurs depends on the number of, and spacing between, the radiating elements; the more elements there are, the smaller is the angle of depression of the first null. The first null is not a complete zero, due to spurious radiations and reflections from the aerial supporting structure; however, the direct radiation at the first null from an aerial of the type shown in Fig. 3 is very small. In cases where the centres of population are situated close to the transmitter in such a position that they would be in the region of the first null it may be desirable to employ "null fill-in". This means that the radiation from the aerial at the first null is increased as shown by the dotted curve in Fig. 2. This is achieved by unequal power distribution throughout the aerial and/or feeding some groups of the aerial with a different phase angle from others.

Calculation of Vertical Radiation Pattern

The aerial upon which the following calculation is based is reasonably simple because "null fill-in" is not employed. This means that all the dipoles on each face of each stack are fed in phase. Referring to Fig. 4, the untuned reflecting screens have been omitted from the calculation since the spacing between them and the dipoles is usually small compared to the height of the aerial, so their presence has very little effect on the shape of the vertical pattern up to the first null.

Let us consider the electric field intensity at a distant point, at an angle of depression relative to the aerial (see Fig. 4). The instantaneous electric field at the observation point due to dipole No. 1 at any time may be expressed by:—

$$E_1 = e \cos \omega t \quad \ldots\ldots\ldots\ldots\ldots \text{(i)}$$

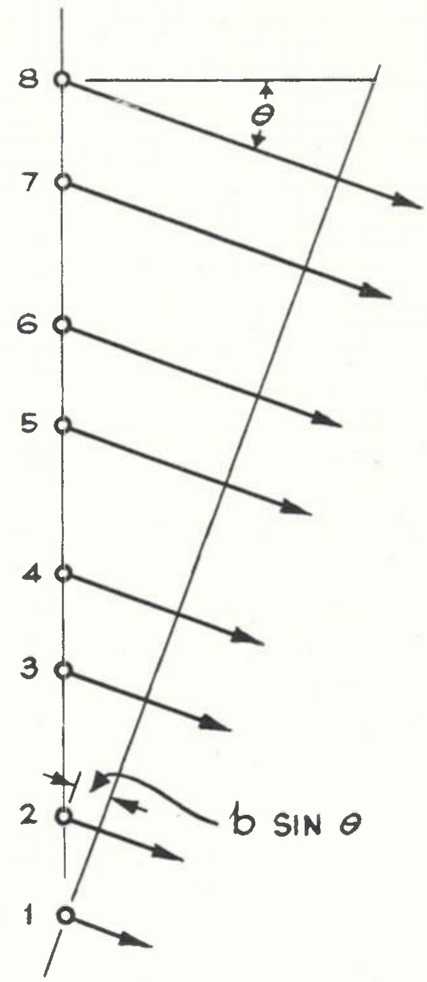

Fig. 4 — Phase of Radiation Received From Dipoles at Different Angles.

where e is the maximum field and ω is the angular frequency ($2\pi f$). The instantaneous field produced by dipole No. 2, radiating in phase with No. 1, will be delayed relative to the field produced by the dipole below it by an amount corresponding to the additional distance the signal has to travel. It has been assumed that the height of the aerial column is negligible compared with the distance to the measuring point.

This additional distance ($b \sin \theta$) must be expressed as a phase angle. This is done by relating it to the wavelength of the transmitted signal. The phase angle (ϕ), expressed in degrees, is given by:—

$$\phi = \frac{b \sin \theta}{\lambda} \times 2\pi \quad \ldots\ldots\ldots \text{(ii)}$$

where $b \sin \theta$ and λ are both in the same units of length and $2\pi = 360^\circ$.

Thus the instantaneous field produced at the measuring point by dipole No. 2 is given by:—

$$E_2 = e \cos (\omega t + \phi) \quad \ldots\ldots \text{(iii)}$$

Similarly the field produced by dipoles 3 and 4 is given by:—

$$E_3 = e \cos (\omega t + 2\phi) \quad \ldots\ldots \text{(iv)}$$

and $E_4 = e \cos(\omega t + 3\phi)$ ...... (v)

$$\text{where } 2\phi = \frac{2b \sin\theta}{\lambda} \times 2\pi \quad \text{...... (vi)}$$

$$\text{and } 3\phi = \frac{3b \sin\theta}{\lambda} \times 2\pi \quad \text{..... (vii)}$$

Referring to Fig. 3, an additional "tilt length" has been included in the bottom stack feeder. The effect of this is to cause the phase of the top stack to lead that of the bottom stack as explained above. This phase advance is designated δ and is constant for all dipoles in the top stack.

The fields produced by dipoles 5-8 are:—

$$E_5 = e \cos(\omega t + 4\phi - \delta) \quad \text{(viii)}$$
$$E_6 = e \cos(\omega t + 5\phi - \delta) \quad \text{. (ix)}$$
$$E_7 = e \cos(\omega t + 6\phi - \delta) \quad \text{.. (x)}$$
$$E_8 = e \cos(\omega t + 7\phi - \delta) \quad \text{. (xi)}$$

The total electric field at the measuring point is obtained by adding together all the fields produced by the individual dipoles.

The total field E_T is given by:—

$$\begin{aligned} E_T = {} & e \cos \omega t \\ & + e \cos(\omega t + \phi) \\ & + e \cos(\omega t + 2\phi) \\ & + e \cos(\omega t + 3\phi) \\ & + e \cos(\omega t + 4\phi - \delta) \\ & + e \cos(\omega t + 5\phi - \delta) \\ & + e \cos(\omega t + 6\phi - \delta) \\ & + e \cos(\omega t + 7\phi - \delta) \quad \text{(xii)} \end{aligned}$$

To apply this expression practically, it must be simplified to the product of a number of terms rather than the sum. This may be done by using the relationship:—

$$\cos A + \cos B = 2 \cos \frac{(A+B)}{2} \cos \frac{(A-B)}{2}$$

The first step is to combine terms 1 and 2, 3 and 4, etc., of equation (xii) and extract the common term. Therefore:—

$$E_T = 2e \cos \frac{\phi}{2} \times \left(\cos\left(\omega t + \frac{\phi}{2}\right) + \cos\left(\omega t + \frac{5\phi}{2}\right) + \cos\left(\omega t + \frac{9\phi}{2} - \delta\right) + \cos\left(\omega t + \frac{13\phi}{2} - \delta\right) \right) \quad \text{........................ (xiii)}$$

Repeating this process:—

$$E_T = 4e \cos \frac{\phi}{2} \cos\phi \times \left(\cos\left(\omega t + \frac{3\phi}{2}\right) + \cos\left(\omega t + \frac{11\phi}{2} - \delta\right) \right) \quad \text{........................ (xiv)}$$

The final expression is:—

$$E_T = 8e \cos \frac{\phi}{2} \cos\phi \cos\left(2\phi - \frac{\delta}{2}\right) \cos\left(\omega t + \frac{7\phi}{2} - \frac{\delta}{2}\right) \quad \text{.......................... (xv)}$$

Only one time dependent term appears in this equation; the other terms which depend on the angle of depression and the dimensions of the aerial determine the vertical radiation pattern. Numerical values for the aerial under consideration are:—

$$b = 1.875 \text{ meters}$$
$$\text{Tilt Length} = 13 \text{ cm}$$
$$\lambda = 2.93 \text{ meters}$$

$$\text{Therefore: } \phi = \frac{1.875}{2.93} \times 360^\circ \times \sin\theta = 230^\circ \times \sin\theta$$

$$\delta = \frac{13}{2930} \times 360^\circ = 16^\circ$$

These values are substituted in equation (xv) and the graphs of the individual terms are shown in Figs. 5 and 6. The complete theoretical vertical pattern

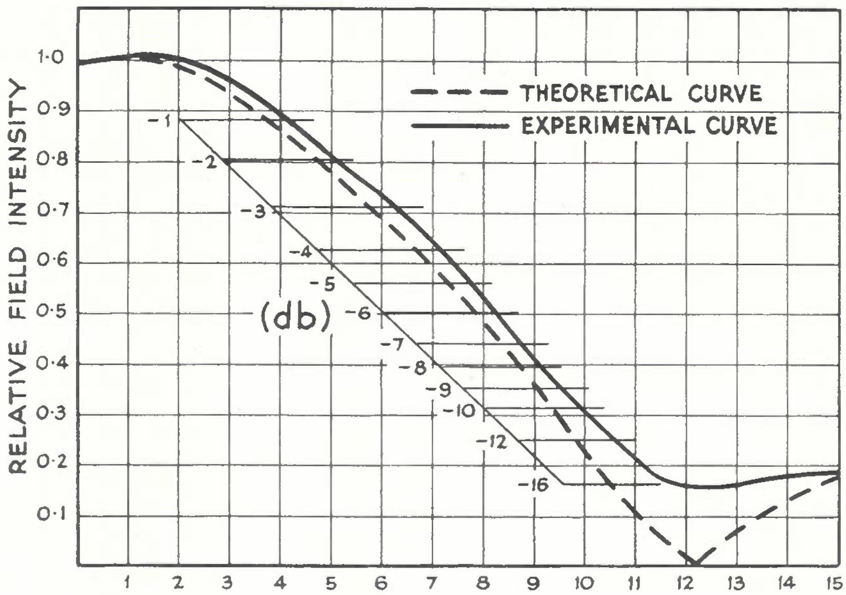

Fig. 5 — Variation of Phase Angles of Terms in Vertical Pattern Expression with Vertical Angle.

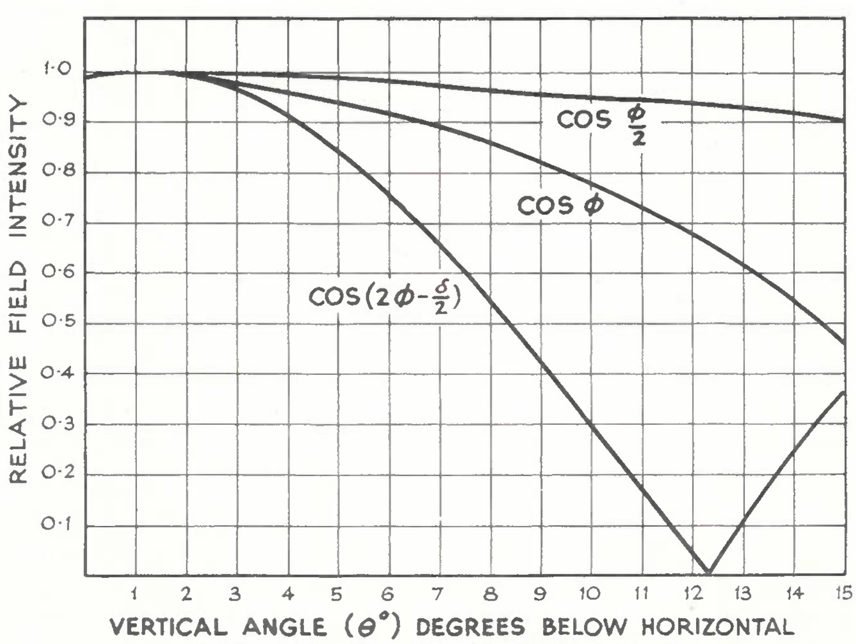

Fig. 6 — Relative Contribution of Terms in Vertical Pattern Expression.

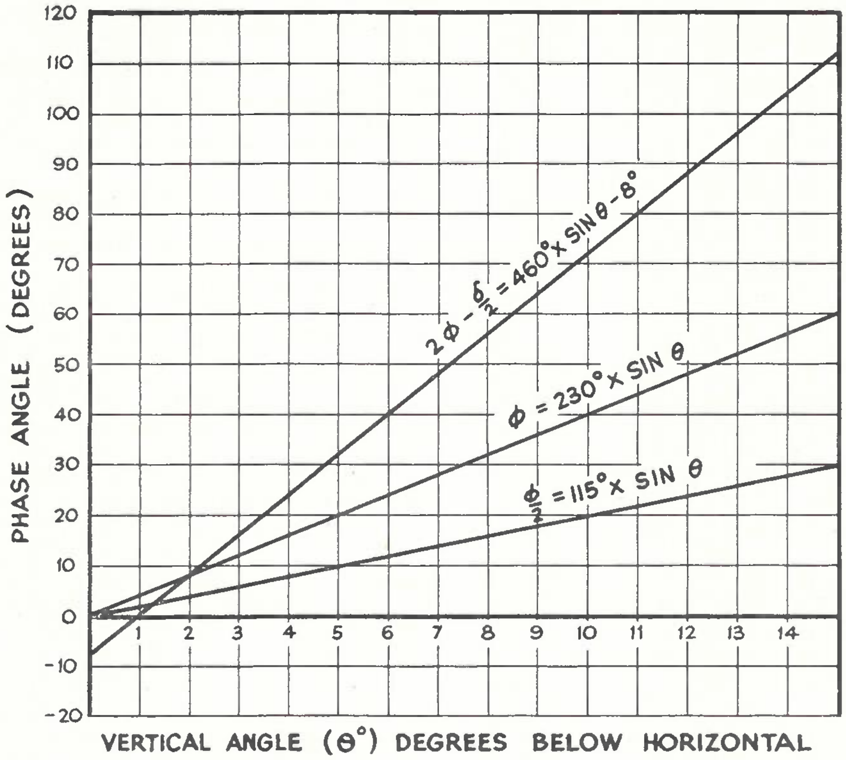

Fig. 7 — Vertical Radiation Pattern of Typical Transmitting Aerial.

shown in Fig. 7 is obtained by multiplying together the terms shown in Fig. 6. The pattern is only shown extending to 15° below the horizontal since usually only this range is of interest.

HORIZONTAL RADIATION PATTERN

Most television transmitting aerials are designed to radiate nearly equally in all directions in the horizontal plane. However, in some cases it may be desirable to intensify the radiation in a particular direction at the expense of other directions. An example of this is the transmitting aerial of N.T.S. station ABWN situated near Wollongong on the south coast of New South Wales. This aerial has been designed to radiate four times as much power along the coast, roughly north and south, as it does east and west. This condition is obtained by orientating the aerial panels as shown in Fig. 8. The designed radiation pattern is shown in Fig. 9. Unfortunately, no measurements have been carried out on this aerial at the time of writing.

It will be noticed that as well as being placed at an angle to the support structure, the centres of the panels are displaced from the centres of the sides of the support structure. This displaced positioning of the panels is also employed in omnidirectional aerials when "quadrature feed" is employed. Quadrature feeding of an aerial means that the feed to each panel around the aerial is advanced (or retarded) by ninety electrical degrees to the panel adjacent to it. In this way the similar reactive component of the impedance of each panel of the aerial cancels that of its neighbour, the two forming a conjugate pair. To restore the horizontal pattern to its design shape when using quadrature feed, the panels are displaced across the support structure by the small amount shown.

A theoretical calculation of the horizontal pattern of a horizontally polarised aerial is not given here because it

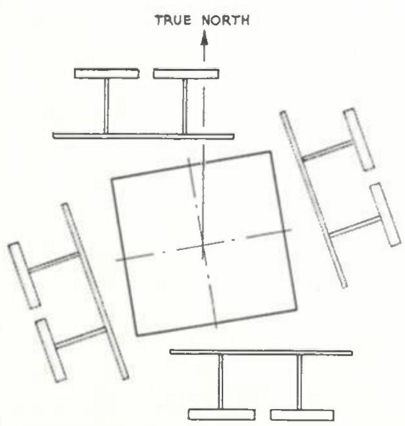

Fig. 8 — Orientation of Aerial Panels to Obtain a Non-circular Horizontal Radiation Pattern.

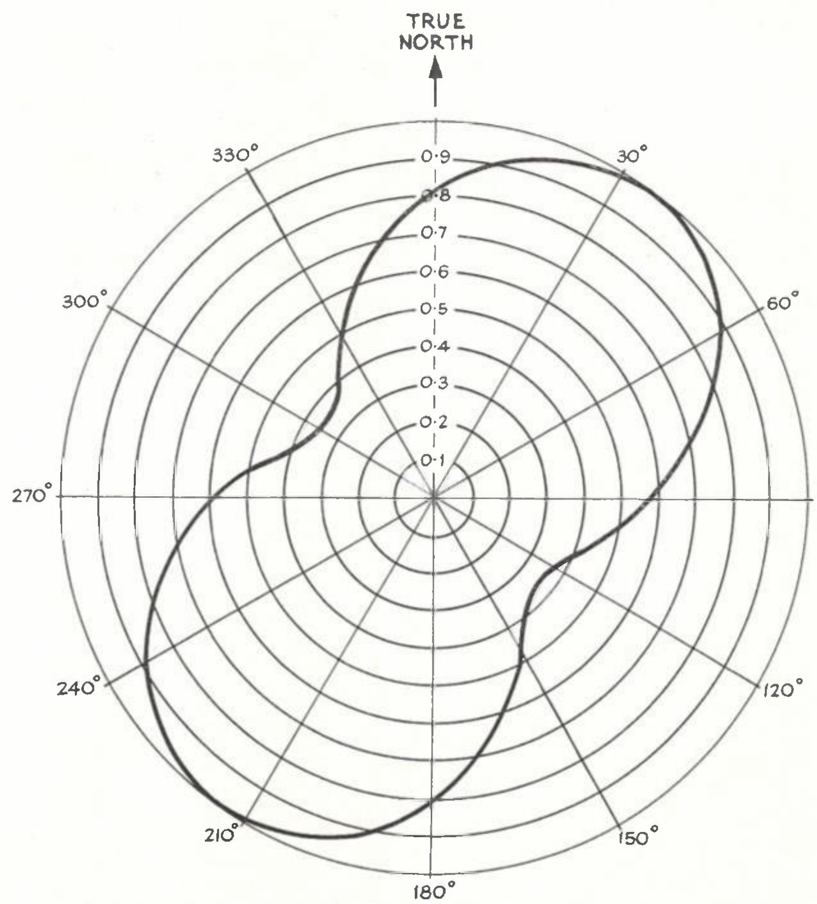

Fig. 9 — Design Shape of Horizontal Radiation Pattern of Station ABWN.

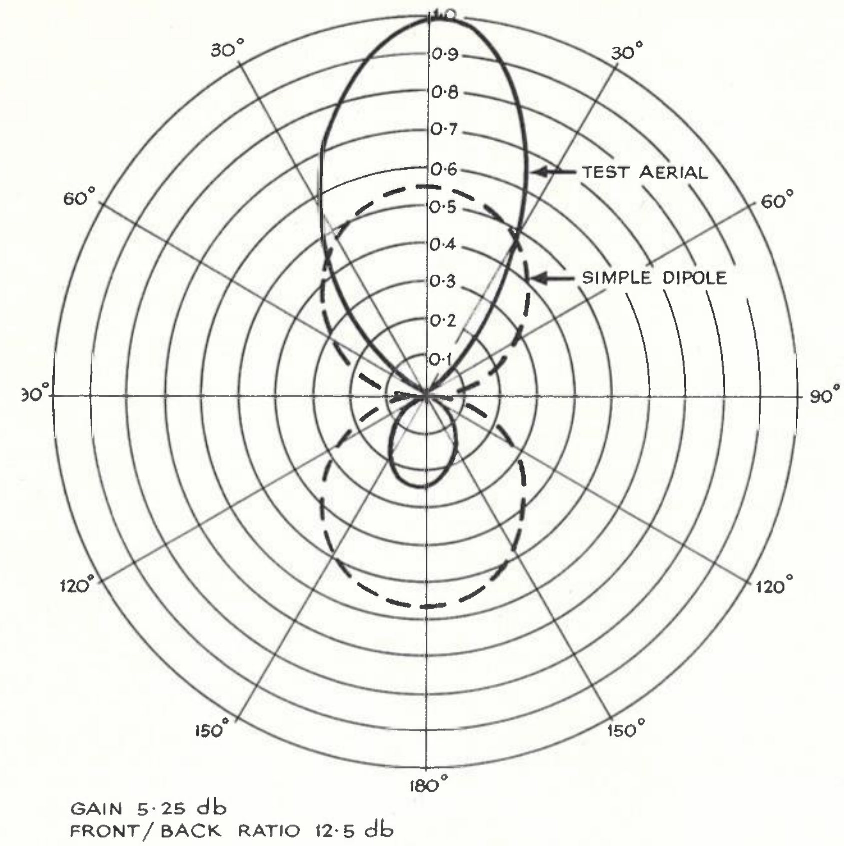

Fig. 10 — Horizontal Radiation Pattern of Test Aerial.

is impossible to take into account in a simple calculation, the effects of fringing at the extremities of the dipoles. The theoretical pattern is usually obtained by building a scale model of a small section of the aerial and measuring its pattern. An increased frequency must then be used corresponding to the scale of the model.

METHOD OF MEASUREMENT OF PATTERNS

The principle of the method to be described involves a comparison of the received field strength from the main transmitting aerial with the received field strength from a test aerial which is used as a reference. These tests were carried out at N.T.S. Station ABHN, near Newcastle, N.S.W.

The test aerials chosen in the cases already investigated were heavy duty Yagis of medium gain, "gamma" matched to a 50 ohm unbalanced feeder. The horizontal polar pattern of the test aerial used for tests described in this paper is shown in Fig. 10. The test aerial was mounted at the top of the transmitting tower as high as possible above the tower structure to minimise any effects of the tower on the characteristics of the test aerial. Power for both the main aerial and the test aerial was taken from a medium power stage in the transmitter where a modulated carrier with a peak power of approximately 300 watts was available. This signal could be positively identified on the field strength meter.

The Four Major Measurements

These are:—

(i) Verification of tilt angle.

(ii) Measurement of gain of the main aerial.

(iii) Measurement of vertical pattern.

(iv) Measurement of horizontal pattern.

Verification of Tilt Angle: (not employing test aerial). In selecting a point for this test, two conditions were satisfied:—

(i) The test point was at an angle of depression below the transmitting aerial equal to the angle of tilt. This angle was 1°.

(ii) The path between the transmitter and test point was "line of sight" with no large obstructions nearby.

This test is performed with full power applied to the aerial and can only be carried out in the following manner with a system incorporating parallel-operated transmitters.

Referring to Fig. 11, it is seen that the output of the exciter unit is split and passes through two phase adjusting networks which feed the two transmitters whose outputs are combined in a diplexer. The phase adjusters are capable of producing a considerable phase shift to ensure that the outputs of the transmitters arrive at the diplexer in the correct phase relationship under all conditions. The signal is then split again in a tee transformer which feeds each stack of the aerial separately. As explained previously, the relative electrical feeder lengths from the tee transformer to each stack of the aerial produce the required tilt.

The outputs of the transmitters were connected directly to each stack of the aerial, thus by-passing the diplexer and tee transformer as shown by the dotted lines. It was possible, by operation of the phase adjuster, to vary the phase of the signal applied to each stack which, in turn, varied the angle of tilt. The phase adjusters were operated until the field strength at the test point reached a maximum, the value of which was recorded. The system was then restored to normal and the phase adjusters were operated for normal conditions. The field strengths received under both conditions were found to be equal making allowances for small losses in the di-

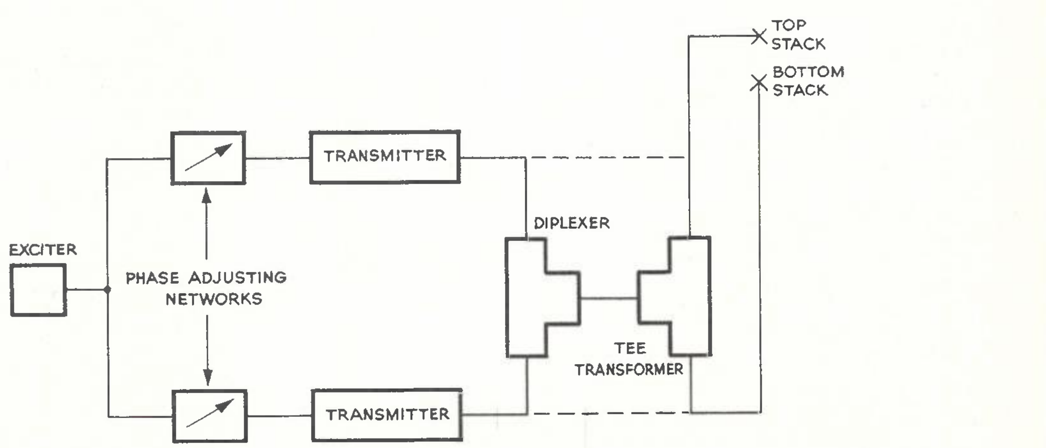

Fig. 11 — Block Diagram of Transmitting Equipment.

plexer and transformer in the second case and the tilt angle was therefore verified as correct.

Measurement of Gain of the Aerial in a Particular Direction: The requirements of a test point for this test are the same as those for verification of the tilt angle.

Both the main aerial and the test aerial were fed in turn by a low power signal and the received field strength recorded in each case. The ratio of the field strength from the main aerial to that from the test aerial (R), expressed in db, is given by:—

$R = GM - LM - GT + LT$

where

GM is the gain of the main aerial in db.
LM is the loss in the main feeders in db.
GT is the gain of the test aerial in db.
LT is the loss in the test aerial feeder in db.

Thus $GM = R + LM + GT - LT$
(See Table 1.)

TABLE 1: GAIN OF TRANSMITTING AERIAL.

R	LM	GT	LT	GM
15.5 db	0.7 db	5.25 db	12.9 db	8.6 db

Figures for the loss in the main feeder and the gain of the test aerial were supplied by the manufacturers. The figure for the loss in the test aerial feeder was obtained by measurement.

Vertical Radiation Pattern: In measuring the radiation patterns, two variables exist and one must be eliminated or a correction applied for it. It is naturally desirable to measure the vertical pattern by selecting test points along only one horizontal radial from the aerial. In many cases this will not be possible and it may be necessary to select points on a number of horizontal radials in order to obtain sufficient points to check the vertical pattern. If this is the case then points must be selected along the different radials at a common angle of depression so that a correction factor may be obtained for the change in radiation with horizontal angle. This approach can only be adopted if the vertical pattern is uniform around the aerial.

Military maps were used to locate test points of angles of depression up to approximately 4° taking into account the curvature of the earth. For larger angles a clinometer was used to determine the angles more accurately. Line of sight from the aerial for these measurements is essential so that the angle of depression may be accurately determined. If line of sight is not obtained, then the signal must arrive at the test point either by diffraction or reflection or both, thus reducing the accuracy of the test.

Measurements on the aerial investigated were taken approximately every degree along two radials, the correction for the horizontal pattern being obtained by overlapping readings on the two radials. The results of measurements of the vertical pattern are shown in Table 2 and in Fig. 7.

TABLE 2: TEST RESULTS OF VERTICAL PATTERN MEASUREMENT OF AERIAL

Vertical Angle (Deg.)	Horizontal Angle (Note 1) (Deg.)	Field Strength (mV/M)		Ratio (db)	Correction for Horiz. Angle (db)	Relative Gain of Main Aerial (db)	Numerical Ratio
		Main Aerial	Test Aerial				
0.8	0	1.2	0.2	15.5	0	0	1.0
2.0	0	1.8	0.28	15.7	0	+0.2	1.03
3.6	0	8.4	1.5	14.8	0	-0.7	0.92
4.6	0	24	5.0	13.6	0	-1.9	0.81
8.5	0	36	13.5	8.5	0	-7.0	0.445
5.25	345	32	8	12	1.7	-1.8	0.81
7.0	345	22	6.7	10.4	1.7	-3.4	0.675
8.5	345	28	13	6.6	1.7	-7.2	0.435
10.0	345	15	10	3.5	1.7	-10.3	0.305
12.0	345	15	21	-2.9	1.7	-16.7	0.146
12.5	345	10	14	-2.9	1.7	-16.7	0.146
15.2	345	23	25	-0.72	1.7	-14.5	0.19

Note 1: The horizontal angle is referred to one particular face of the aerial.

Horizontal Radiation Pattern: The procedure adopted for determining test points is very similar to that used in measuring the vertical pattern. Test points for the measurements were selected starting at 0° and then at intervals of 22½° around the aerial with two additional points at 11¼° and 33¾°. It was proposed to direct the test aerial at the measuring point in each case to eliminate errors being introduced due to the variation in radiation intensity from the test aerial in the horizontal plane. This was to be achieved by observing the field strength from the test aerial and having it rotated until the field strength reached a maximum. However, due to communication difficulties this was not readily possible. It was then decided to rotate the test aerial in steps of 45° resulting in the test points selected at odd multiples of 22½° being off the centre line of the test aerial. The correction factor for the radiation intensity in these cases was obtained from the manufacturer's radiation pattern. The positioning of the test aerial at intervals of 45° was facilitated by the geometry of the tower.

The results of this test are shown in Table 3 and Fig. 12.

CONCLUSION

The aim of this paper has been to outline the principles involved in this particular method of aerial pattern measurement, and to describe some measurements. Minor details in the actual measuring process and the operation of the field intensity meter have not been entered into since these processes will alter under varying circumstances. The method is simple and allows a reliable check of the performance of an aerial to be made in a few days.

A number of assumptions have been

TABLE 3: TEST RESULTS OF HORIZONTAL PATTERN MEASUREMENT.

Horiz. Angle (Deg.)	Vert. Angle (Deg.)	Field Strength (mV/M)		Ratio (db)	Correction for Vert. Angle (db)	Correction for Dir. of Test Aerial (db)	Relative Gain of Main Aerial (db)	Absolute Gain of Main Aerial
		Main Aerial	Test Aerial					
0	7.5	38	9.0	12.5	5.0	0	17.5	8.6
11.25	9.0	47	19.0	7.8	8.0	–1.5	14.3	5.4
22.5	8.5	36	15.5	7.2	7.0	–3	11.2	2.3
33.75	8.5	35	13.0	8.6	7.0	–1.5	14.1	5.2
45	8.2	13	4.0	10.2	6.0	0	16.2	7.3
67.5	7.7	13.5	4.8	9.0	5.0	–3	11.0	2.1
90	6.0	12	2.4	14.0	3.0	0	17.0	8.1
112.5	6.0	7.5	2.0	11.5	3.0	–3	11.5	2.6
135	7.0	18	5.4	10.4	4.0	0	14.4	5.5
157.5	5.2	34	7.5	13.1	2.0	–3	12.1	3.2
180	4.0	1.7	0.27	16.0	1.5	0	17.5	8.6
202.5	4.0	0.54	0.11	13.8	1.5	–3	12.3	3.4
225	4.0	0.15	0.032	13.4	1.5	0	14.9	6.0
247.5	3.0	2.7	0.5	14.5	0.5	–3	11.5	2.6
270	3.8	2.2	0.4	14.8	1.9	0	16.7	7.8
292.5	4.25	20	4.7	12.4	1,2	–3	10.6	1.7
315	5.6	15	3.2	13.3	2.5	0	15.8	6.9
337.5	6.0	34	8.1	12.4	3.0	–3	12.4	3.5

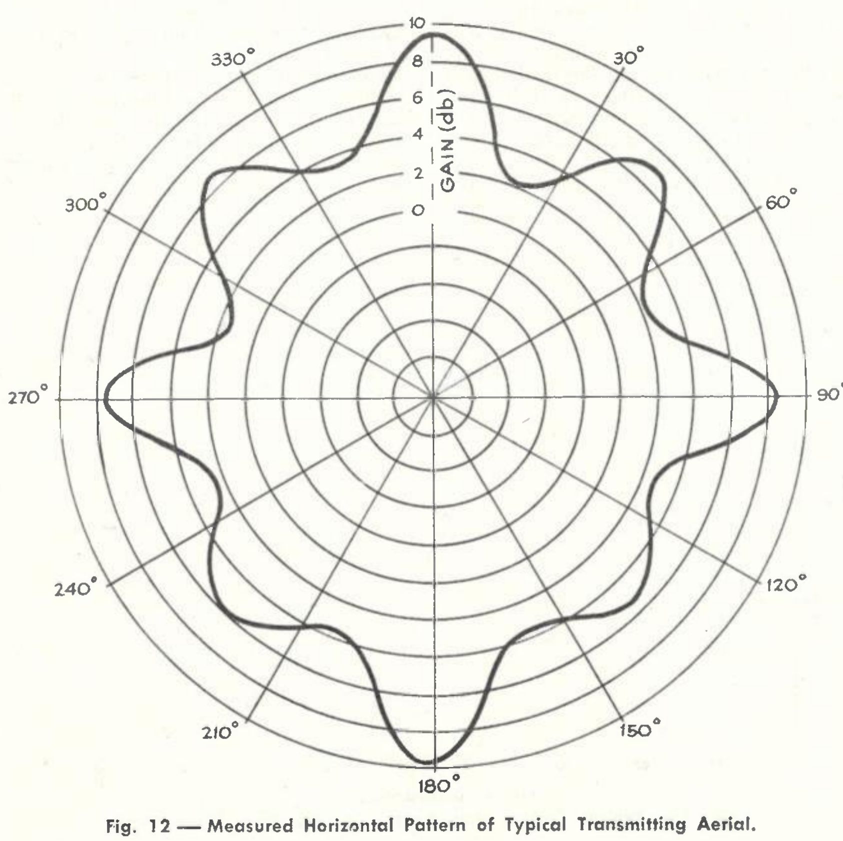

Fig. 12 — Measured Horizontal Pattern of Typical Transmitting Aerial.

made. One in particular is the assumption that the radiation intensity from the test aerial remains constant in the vertical plane over the range of interest—namely, from its axis to approximately 15° below it.

Another factor which can be of importance is that the horizontal radiation patterns of the main aerial and the test aerial are different. Therefore, signals received at the measuring point by reflection and originating from the back or sides of the transmitting aerial modify the direct signal and reduce the accuracy of the test. It was endeavoured to reduce the effect of any reflection which may have occurred by selection of suitable test points and such possible reflections have been ignored. The substitution of a single rotatable dipole for the multi-element test aerial would eliminate the need for the first assumption and reduce any effects of the second, since the radiation from the back of a dipole is equal to that from the front and so its characteristics in this regard are similar to those of most transmitting aerials. In the case of a vertically polarised system a coaxial dipole may be used for the test aerial thus eliminating the need for rotating it when measuring the horizontal pattern.

ACKNOWLEDGMENTS

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LIGHTNING PROTECTION FOR BURIED TRUNK CABLES

F. J Harding, A.M.I.E.E. and T. N. Pimm, Grad. I.E. Aust.***

INTRODUCTION

General

Lightning protection for buried cables has only recently assumed a major significance in Australia and this has been mainly due to the installation of coaxial cables. However, although this article is primarily concerned with the protection of coaxial cables in various situations, the principles apply equally to other cables in similar locations. Until recently few cables had been installed in Australia in places where lightning was a problem although cables that were in such locations have suffered damage and efforts have been made to improve their security (Reference 1).

The main situations causing concern in regard to lightning damage are:—

(a) Cables to high towers.
(b) Cross country cables.
(c) Trunk cables in mountainous areas where soil resistivity is high.

Cables laid in towns and cities except for (a) above are almost immune to lightning damage owing to the large mass of metal conductors in the ground in the form of water and gas service pipes, cables, tramways and railways. Such conductors tend to lower substantially the general resistivity of the ground and allow rapid dissipation of lightning currents.

There is a major problem associated with the increase in the television network and the growth of broadband telephone facilities using micro wave radio propagation. The towers associated with these facilities are often linked to remote equipment centres by high capacity (up to 12 tube) coaxial cables. Since a significant number of these installations are located on high ground often in areas of higher than average thunder day level (number of days per year on which thunder is heard), and usually in locations having high soil resistivity, the hazard due to lightning may be extremely high.

Cross country cables may also be exposed to lightning hazards, particularly where they pass through areas of varying soil resistivity and thunder day level, and because the probability of lightning strike to such cables is increased due to their long length. Examples of such cables are Sydney-Melbourne 604 miles, Brisbane-Lismore 140 miles, Perth-Bunbury 117 miles, and Wagga-Griffith 119 miles.

Small size cables in mountainous areas are often prone to lightning damage for the reasons already discussed and special precautions may be required to ensure their protection.

Historical

The first coaxial cable in the trunk network was laid in 1959 and over the succeeding six years the total sheath mileage of coaxial cable has increased to about 1,500 in service or under construction. The same period has also seen the development of broadband bearer systems, part radio and part cable, and sections of both National and Commercial Television Broadcast networks incorporating coaxial cable links. A good percentage of such links connect television and radio telephone stations to remote long line equipment terminal buildings, and are characterized in having one end terminated adjacent to a tower on a hilltop and the other end terminated in low lying ground in a position where low resistance earthing is usually available.

The first trouble in Australia on coaxial cables due to lightning discharge occurred in April 1961 during the construction of the Brisbane-Lismore route when lightning discharge to a tree beside the newly laid cable gave us our first experience of the "cold lightning" phenomenon (Ref. 2). "Gold" lightning has a short current duration and tends to cause crushing of the cable rather than breakdown of internal insulation or fusing of sheath and/or conductors. The next damage due to lightning was on the Black Mountain television cable in Canberra in September, 1962, again before the cable was fully jointed and terminated. Since then damage has occurred twice to the Sydney-Melbourne cable at Collector near Canberra and twice to the Brisbane-Lismore cable.

In all cases except the Black Mountain cable, crushing was evident. This crushing was caused by an explosion of the volatile material between the lead sheath and the steel tape armouring, following the occurrence of arcing between steel tapes and sheath. Coaxial cable is susceptible to crushing damage as it has very low radial strength due to the large internal air spaces. Therefore the use of steel tape armouring for coaxial cable is to be avoided.

NATURE OF A LIGHTNING DISCHARGE

A lightning discharge consists of several leaders or strokes by which negative charge (in most cases) is lowered from cloud to ground (Ref. 3). The first photographically visible portion of the stroke is a "stepped leader". This consists of a series of discharges advancing in steps of about 50 meters at intervals of about 100 microseconds. Schonland (Ref. 3) considers that this must be preceded by a pilot streamer with a velocity of about 150 Km/sec., the advance of which is due to the continual formation of electron avalanches in front of its tip. Another theory (Ref. 4) views the process as a series of corona "bursts" in which the sharpest or longest protuberance from the corona sheath forms the new channel for the next "step".

By the time the leader reaches the ground a large proportion of the cloud's charge has been lowered into the leader channel and corona sheath.

When the corona sheath approaches to within a few hundred feet of the ground the electrical gradient will be sufficient for channels to form from the earth, especially from any protuberances (trees, masts, buildings etc.). This is when the heavy current "return" stroke begins. This current then removes the charge from the already formed channel, its branches and the cloud, and lowers it to earth.

The return stroke causes the channel to become brilliantly luminous as the head of the stroke travels upwards at a velocity of from 0.1C to 0.3C, (C = velocity of light). The main current surge in the return stroke may last for

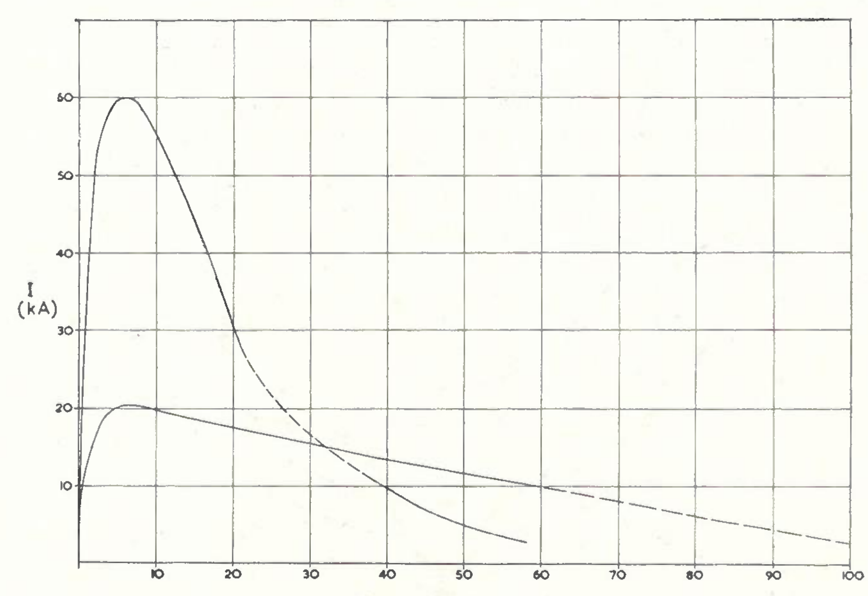

Fig. 1 — Typical Current/Time Curves for Lightning Discharges.

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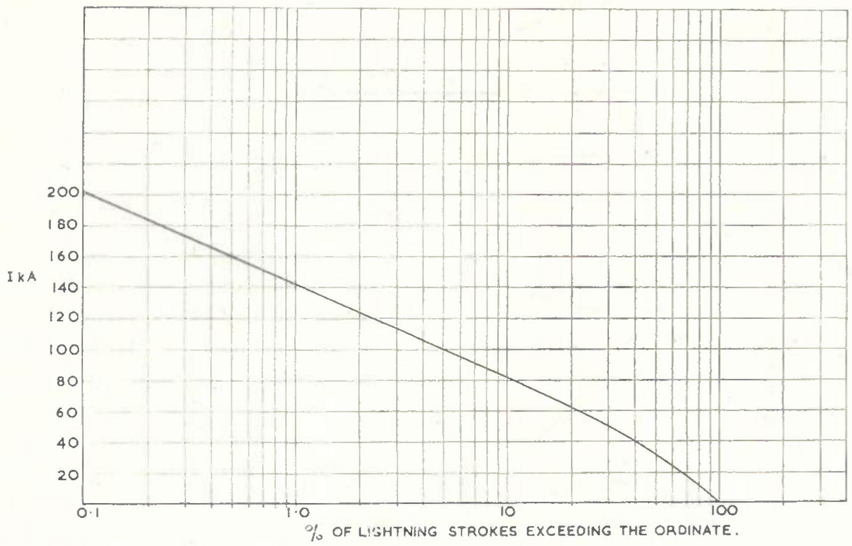

Fig. 2 — Currents in Strokes to Buried Structures.

an average of 100 microseconds. Following this there may be a second leader and return stroke as a different cloud centre discharges to ground. In fact as many as 40 strokes have been observed in the one channel although discharges having more than 6 strokes would be rare. The diameter of the arc in the main or return stroke is estimated at about 15 cms and the ionised air is compressed to 20 Kg/cm^2 (288 lb./in.^{2}) by magnetic forces and is heated to a temperature of about 15,000°C. It is estimated that the impedance of the lightning channel during the initial stage of the return stroke is of the order 5,000 ohms.

The characteristic shapes, assumed for calculation purposes, of typical current surges are shown in Fig. 1. The wave shape is usually specified by the time (in microseconds) to the peak value and the decay time to half peak value. e g. 10/65 may be considered as a typical wave shape. The two important parameters of the lightning stroke, as far as cable protection is concerned, are the peak current and the total electric charge. The incidence of peak currents of various magnitudes are shown in Fig. 2 (Ref. 6) and calculations are usually based on this distribution of peak currents.

However the voltage developed between core and sheath of a cable is also dependent on the charge in the stroke and as surges with longer durations have (for a given peak current) higher charges, a relationship may be obtained between cable damage and duration to half value (Appendix 2). The range for times to half value varies from low values of about 20 microseconds to many hundreds of microseconds with an average probably in the ranges 100-150 microseconds. Similarly charge distribution varies from a few coulombs to values of the order 100 coulombs although such charges are thought to be extremely rare. Lightning surges in mountainous areas usually have higher charges than those in flat terrain and Popp and Schultz (Ref. 5) indicate peak values in each case to be about 20 and 200 coulombs.

HAZARDS TO A CABLE

When an arc has been established between the leader and the ground there will be a very rapid increase of current in the ground as the return stroke collects charge from the channel. This current radiates from the point of discharge in all directions through the ground and results in a hyperbolic distribution of potential between this point and remote earth (Fig. 3).

If there is a conductor in the vicinity (waterpipe, cable etc.) much of the current will flow to it. The flow of current in the ground between the lightning channel and the conductor may give rise to such a large potential drop that the breakdown voltage of the soil at the surface is exceeded, particularly when the earth resistivity is high. Ionisation of the soil will occur and the lightning stroke will then arc directly to the conductor and the lightning current will flow along it and be attenuated as it flows to remote points. Calculations on the probability of this occurring are given in Appendix I.

For an unprotected plastic jacketed, standard coaxial cable there are two principal hazards in the conditions described:—

(i) Sheath to ground breakdown through the plastic jacket
(ii) Conductor to sheath and/or conductor to conductor breakdown within the cable.

It can be shown that strokes, which are within arcing distance of a cable having its sheath in contact with the ground, will also arc to, and breakdown the jacket of a plastic jacketed cable (See Appendix 1). Thus the isolating effect of the plastic jacket may be neglected.

The lightning current travelling along the cable sheath will develop a difference of potential between the insulated sheath and ground sufficient to cause arcing through the plastic jacket at numerous equidistant points provided the insulation and the earth are assumed to be uniform (Ref. 6). It has also been shown (Ref. 6) that where the stroke is close enough to cause arcing to the cable then

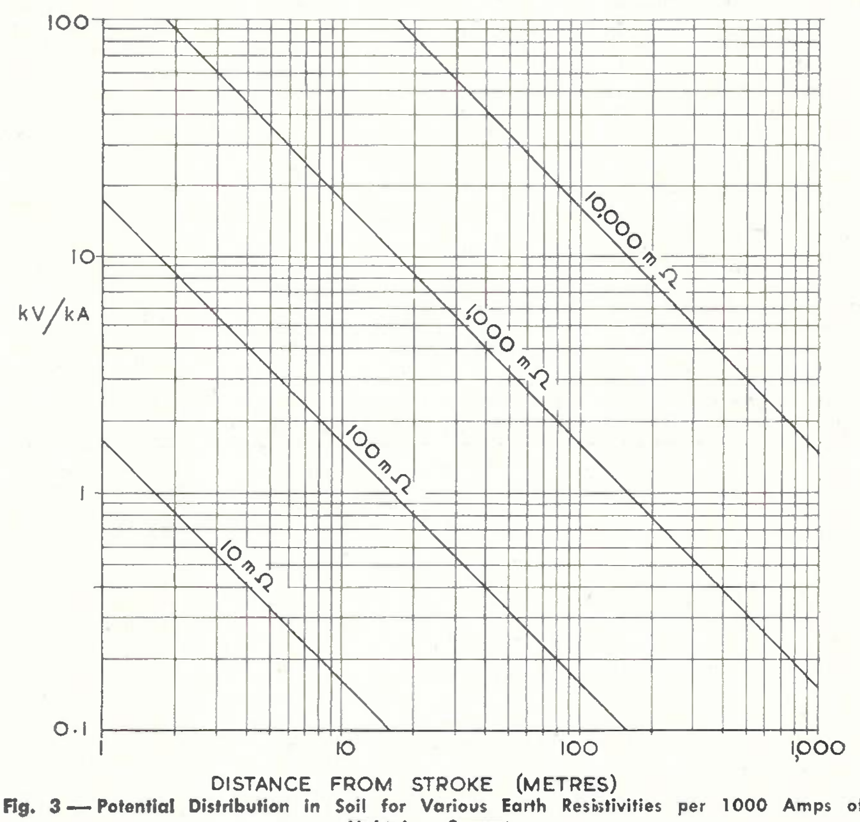

Fig. 3 — Potential Distribution in Soil for Various Earth Resistivities per 1000 Amps of Lightning Current.

the cable will act as though the sheath is in direct contact with the soil. The same comment will apply to cables connected to radio towers where the cable sheath may carry a large proportion of the total current.

Some preliminary tests conducted by the A.P.O. Research Laboratories have indicated impulse breakdown voltage for the thermoplastic jacket (polythene) of the order 100 kV.

Current flowing in the cable sheath may give rise to a large potential difference between sheath and core. The potential will depend upon the magnitude of the current and the conductivity of the cable sheath (See also Appendix II). The construction of regular cables having paper lappings over the core is such that the average breakdown potential is of the order 6kV.

Soil Resistivities

As soil resistivity is one of the main parameters in determining the extent of lightning damage to cables, knowledge of soil resistivities, either along a cable route or at tower installations is a prerequisite to the design of an adequately protected cable system. Information on seasonal changes in resistivity is also relevant.

Although precise data should be sought for installation purposes some background knowledge on the range of resistivities which may be encountered is helpful in assessing the problem.

There is an approximate correlation between the age of geological formations and their resistivities.

This is shown in Table 1 although the level of the water table and the presence of salts in solution will considerably affect the soil resistivity.

Resistivity varies with changes in soil or rock type and any reading is necessarily an average of the soil type met by the current between the test electrodes. Thus it is usual in measuring resistivity to take readings at a number of electrode spacings (e.g. 5 ft., 10 ft., 20 ft., 40 ft., 60 ft., 100 ft.) when knowledge of the underlying subsoil or rocks is required. It should be noted that increasing the electrode spacing results in an increase in the mean depth at which resistivity is measured. Some examples of resistivities are shown in the accompanying graph, (Fig. 4).

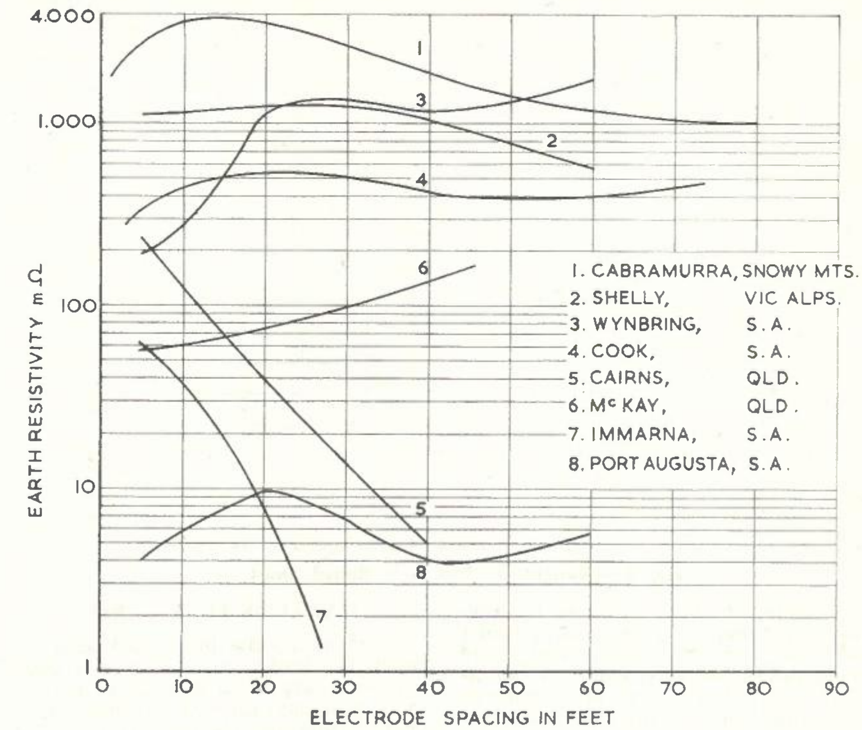

Fig. 4 — Samples of Earth Resistivity v Electrode Spacing.

Lightning Strokes to Ground and Resulting Soil Potentials

The ground surface potential at the point of discharge will depend on the current magnitude and the soil resistivity. The standard methods of measuring soil resistivity are well known and the equivalent resistance of the ground is $R = \frac{\rho}{2\pi a}$ where "a" is the radius from the point of entry to the point of measurement. Thus for a current I amperes the potential, in relation to remote earth, at any point distant "a" from the discharge is $V = \frac{I\rho}{2\pi a}$.

If it is assumed that the ground is level and of uniform resistivity then points of equal potential lie on concentric circles around the point of discharge. Successive equidistant circles have potentials decaying hyperbolically outwards. In fact such circles are the peripheries of equipotential hemispheres whose axes pass through the point of discharge. This concept is illustrated in Fig. 5.

While this theoretical concept is unlikely to exist in practice, due to non-homogeneity of soil resistivity, as well as the ionisation characteristics of the soil, it is a useful guide to the potential gradient environment for a buried conducting structure located radially to a point of discharge e.g. a communication cable terminating at a radio station. Fig. 3 indicates the ground potential patterns per thousand amps of discharge current for various values of soil resistivity.

If the average value of lightning current is taken as 30 kA and the soil resistivity (for Australia) as 300 metre ohms then the potential gradient 10 metres from the point of discharge will be about 15 kV per metre.

TABLE 1: APPROXIMATE SOIL RESISTIVITIES FOR VARIOUS GEOLOGICAL FORMATIONS

Resistivity	Geological Formation	Rough Classification
Low under 100 metre ohms	(Loam (chalk (clay	Mostly Soils
Medium 100 to 1000 metre ohms	(Diabase (Shale (Limestone (Sandstone	Mostly sedimentary formations
High 1000-10000 metre ohms	(Dolomite (Coarse Sands and Gravels (Quartzite (Slates (Granites (Gneiss	Mostly Igneous or metamorphosed rock

CABLE DESIGN PARAMETERS FOR LIGHTNING PROTECTION

There are several logical steps in designing the lightning protection requirements for a cable in a given situation. The first of these is to assess the amount of lost service time which can be tolerated, e.g. for a cross country coaxial cable carrying traffic of the order 1000 telephone channels plus television, a loss of 8 hours per year may be tolerable. Correspondingly, increased lost time may be allowable for less important routes.

Secondly, it is necessary to determine the probable time required to restore the cable to service. Restoration in this context means temporary return to service via. patching or interruption cable. Full repair may then take place with less urgency. If the temporary restoration time is assessed at 8 hours then it follows that one fault may be tolerated per year and this then becomes the basis for design. Another way of expressing this concept is to consider it as a percentage reliability i.e. 8 hours loss per year would approximate 99.9% reliability or a loss of 1 hour per 1000.

To provide a basis for comparison the number of faults per year are usually determined on a 100 mile basis. i.e. N = No. of faults per 100 miles per year. Thus for a cable of say 600 miles with a tolerance of one fault per year,

N = 0.167

It follows that a relationship must be obtained between the tolerable fault rate and the various parameters on which lightning damage is dependent. This relationship is calculated in Appendix 1 and is shown to be dependent upon:—

(a) The crest lightning current I
(b) The soil resistivity ρ
(c) The thunder day level or number of days per year on which thunder is heard T

In a given location the soil resistivity may be determined by measurement and the thunder day level obtained from the average annual Thunder Day Map (See Fig. 6). Both these parameters may vary considerably over the length of a cable and it is therefore necessary to

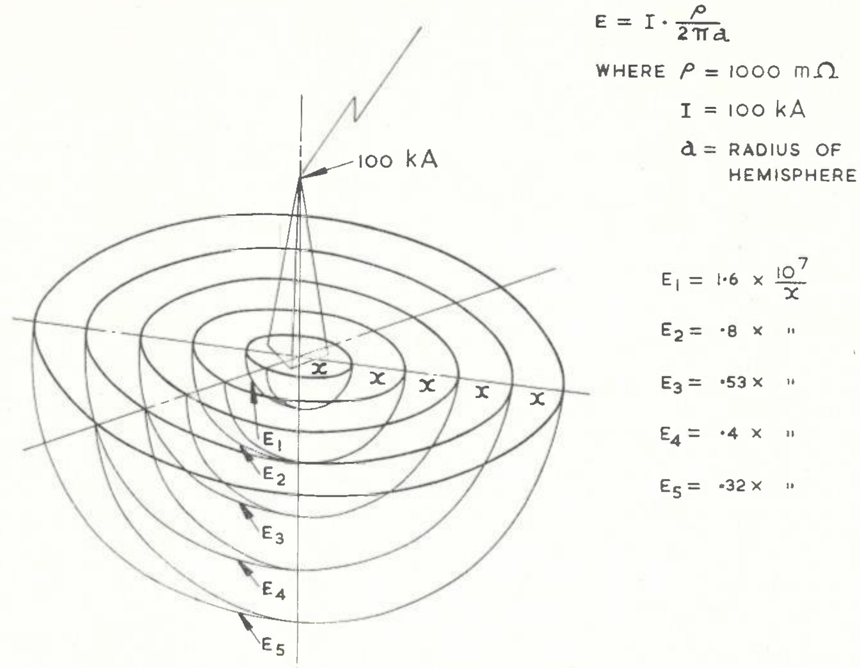

Fig. 5 — Equipotential Surfaces during Lightning Discharge. (Uniform Soil conditions assumed).

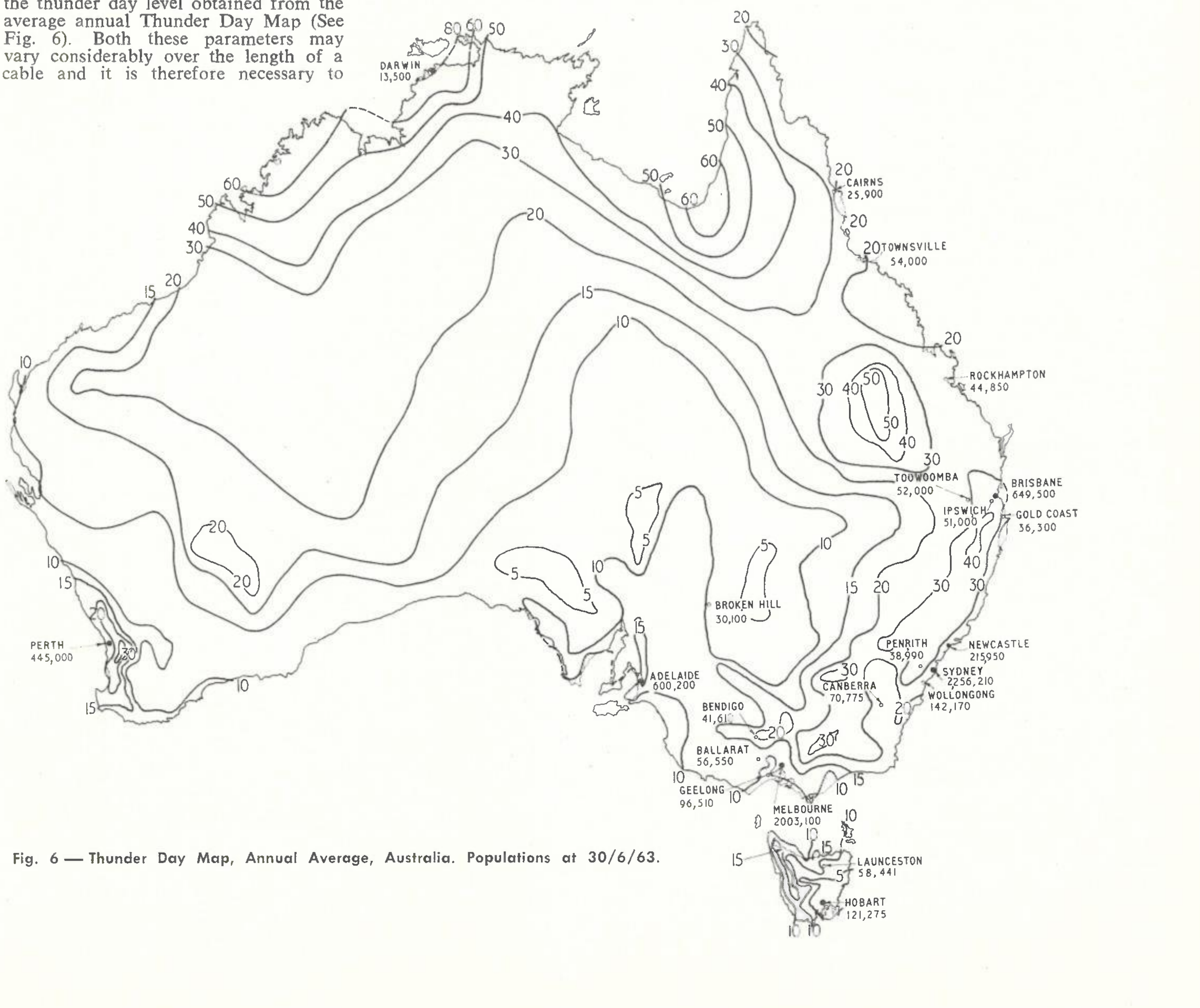

Fig. 6 — Thunder Day Map, Annual Average, Australia. Populations at 30/6/63.

make measurements in a number of places in order to assess the magnitude of the hazard.

Assuming an average earth resistivity $\rho = 300$ metre ohms and a thunder day level $T = 20$ then the product:—

$$\rho^{\frac{1}{2}}T = 17.3 \times 20 = 346.$$

Referring to Fig. 7 and inserting $N = 0.167$ and $\rho^{\frac{1}{2}}T = 346$ the design value of lightning current against which protection should be afforded is 120 kA.

If the cable however, passed through the Snowy Mountains area where the earth resistivity may be 2000 metre ohms and $T = 30$ then

$$\rho^{\frac{1}{2}}T = 1340$$

and for $N = 0.167$ the design current would be

$$I = 160 \text{ kA}.$$

Knowing this current against which protection must be provided, it is then possible to design a cable which will withstand it.

It is shown in Appendix II that the voltage developed between sheath and core of metal sheathed cable (or between an outer concentric shield and the sheath) due to a lightning current flowing in the sheath, (or the shield) is:—

$$V = 7.6 \times 10^{-3} \frac{I}{2} R_s \rho^{\frac{1}{2}}$$

where V is the sheath to core (or shield to sheath) voltage in kV,

I is the lightning current in kA,

R_s is the sheath (or shield) resistance in ohms per kilometre,

ρ is the earth resistivity in metre ohms.

If V is set at the breakdown voltage of the insulation then the current which will cause breakdown may be determined.

V and R_s can be controlled (within limits) by cable design and can be equated to the measured or predictable lightning hazard in terms of I and ρ:—

$$\frac{V}{R_s} = 7.6 \times 10^{-3} \times \frac{I}{2} \rho^{\frac{1}{2}}$$

$$= 3.8 \times 10^{-3} I\rho^{\frac{1}{2}}.$$

The ratio $\frac{V}{R_s}$ is termed the cable breakdown coefficient and a graph showing this relationship for various values of I is given in Fig. 8. For example, if ρ is equal to 300 metre ohms and the design objective is 120 kA (as determined above),

then from Fig. 8 $\frac{V}{R_s}$ should not be less than 8. Appendix I indicates the method whereby the design current may be determined.

The normal construction of a 4 tube non-layer lead sheathed coaxial cable has a paper insulation between sheath and core with a breakdown voltage of approximately 6 kV and a sheath re-

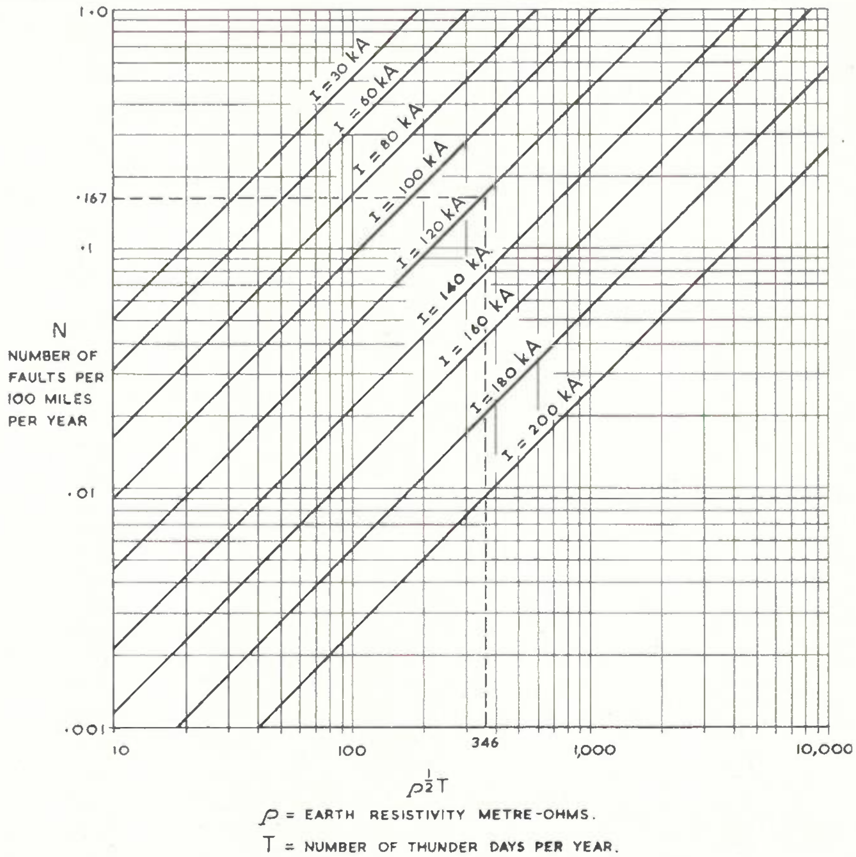

Fig. 7 — Probability of Damage per 100 miles per Year.

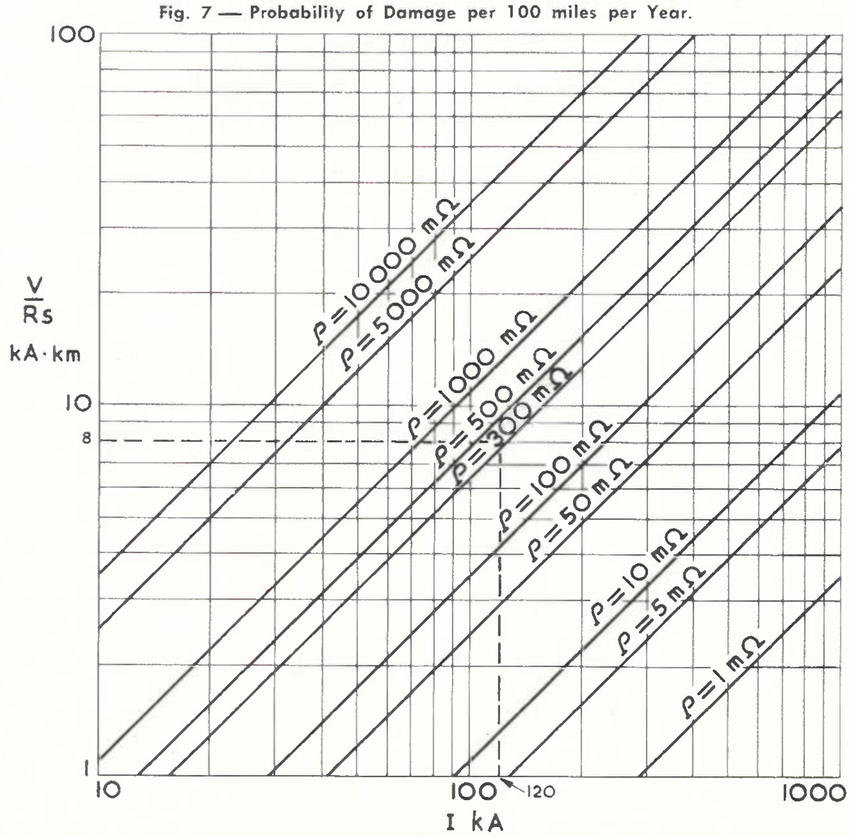

Fig. 8 — Cable Breakdown Coefficient $\frac{V}{R_s}$ Versus Lightning Current (kA) for Various Values of Soil Resistivity.

TABLE 2: SHEATH RESISTANCES AND BREAKDOWN COEFFICIENTS FOR U.A.P.J. COAXIAL CABLES

Cable	R_s ohms per kilometre	V/Rs (approx.)
4 Tube Non Layer	1.0	6
6 T " "	0.75	8
8 T " "	0.58	10
12 T " "	0.39	15

sistance of 1Ω per Km. (See Table 2 for various sizes of coaxial cable.) Thus $\frac{V}{R_s} = 6$, and this cable would therefore need extra protection to withstand the hazard postulated above.

DESIGN PARAMETERS FOR CABLES TO HILLTOP RADIO STATIONS

So far the article has been concerned primarily with long distance trunk cables in which protection must be applied for the full length of the cable. However where cables are installed to microwave radio towers on hilltop or mountain sites conditions are much more severe and a different approach is necessary when assessing the magnitude of the hazard. One point to note is that for mountainous localities the soil resistivity is generally high and measurements in the Snowy Mountains area indicate figures of 2,000 to 10,000 metre ohms.

Furthermore, owing to the prominence of many hills and the additional height of towers built upon them, more strokes are expected for a given thunder day level and (apart from frontal storms) thunder-clouds tend to develop more often in hilly situations.

Another point which should be stressed is that strikes to towers on mountains release greater charges than strokes of equal current magnitude in open country. Popp and Schultz (Ref. 5) indicate maximum charges of 20 coulombs in strokes in open terrain compared to 200 coulombs in high terrain. As the extent of damage sustained by a cable is related to the charge in a stroke, greater protection may be required to avoid damage.

As for the design parameters for cross country cable, an assessment is required of the out of service time which can be tolerated and, as coaxial cables to microwave stations are generally of large size and carry heavy traffic, it is essential that they be given high security. Thus a service reliability of 99.99% may be a more realistic design objective i.e. a loss of only one hour in 10,000. Most of these cables will be close to a major town and temporary restoration will probably be carried out in less than four hours. If 3½ hours is taken as an average figure then such a cable should have no more than one lightning fault in four years i.e. 0.25/year. The microwave system will have cables at each end and, to maintain the designed reliability, faults due to lightning should not exceed 0.25 per year for the whole system i.e. 0.125 per year or one in eight years at either end.

As determined in Appendix III the number of strokes per year to a tower of height 300 metres (including an average allowance for height of hilltop) is given by:—

$N = 0.87T$

and for $T = 40$, $N = 35$ strokes per year.

Thus in eight years such a tower would probably sustain 280 strokes. It would be necessary to protect against all but one of these i.e., 1/280 or 0.36%.

Referring to Fig. 2 this corresponds to a value for I of 170 kA.

However some microwave systems may be classed as so important that no damage is tolerable throughout the life of the cable. An example is the Seacom 'E' system, Sydney to Cairns. In this case the cable must be designed to sustain the highest anticipated lightning currents which are of the order 200 kA.

If it is assumed that only half the total current travels on the cable sheath and half is dissipated in the station earth system, then the cable design coefficient, $\frac{V}{R_s}$, to withstand values of I up to 200 kA, and $\rho = 1000$ metre ohms is:—

$$\frac{V}{R_s} = 7.6 \times 10^{-3} \times \frac{200}{2} \times 31.6 = 24.$$

The assumption of half the current flowing down the cable is probably safe for resistivities of 1000 metre ohms or less or where station earth resistances are below 2 ohms. However when it is considered that in high resistivity areas the cable will reach soil of significantly lower resistivity it could easily carry the majority of the current. Thus in higher resistivity areas (2,000-10,000 metre ohms) or where station earths exceed 5 ohms then a greater proportion will flow in the cable sheath and the breakdown coefficient should be designed to:—

$$\frac{V}{R_s} = 7.6 \times 10^{-3} I\rho^{\frac{1}{2}}.$$

The assumption that the whole of the current will flow in the cable sheath allows an increased factor of safety in protection for cables in mountainous areas where the total charge is likely to be higher. The effect of higher charges has not hitherto been applied in the above expression (See Appendix II).

Most studies on lightning protection for cables have based their protection requirement on peak lightning current values and have considered that the resultant voltage and damage is independent of the charge. However they point out that greater damage will be sustained after breakdown where charges are large.

Calculations outlined in Appendix II indicate that the voltage is dependent on the charge. Doubling the time to half value results in peak voltage being increased by a factor of 1.5 approximately. Riedel (Ref. 7) indicates that the impulse voltage is proportional to the square root of the charge or, if the charge is constant, to the square root of the amplitude of the impulse current. Therefore, for a given peak current, breakdown may be expected more often when the total charge is larger and, in addition, greater damage may be expected. Studies are at present incomplete and further field work is required to obtain more data on lightning currents and the associated charges for various locations throughout Australia.

METHODS OF CABLE PROTECTION

Cable Sheath Design

As shown earlier the breakdown coefficient, $\frac{V}{R_s}$, is directly proportional to the breakdown voltage of the insulation between sheath and core and inversely proportional to the cable sheath resistance. The paper insulation used in normal construction has a breakdown voltage of the order 6kV. This may be increased by additional layers of paper or by wrapping a thermo plastic dielectric over the core. The first of these methods is practicable to double or treble the breakdown voltage but would be uneconomic for any further increase. The use of thermo plastic insulation over the core of a cable however is not recommended owing to difficulties associated with the removal of moisture from cable core, both during and after manufacture. This would tend to reduce the insulation resistance between paper insulated conductors thus reducing the quality of the cable. Other objections include the difficulty of maintaining continuity of the plastic dielectric at cable joints.

The sheath resistance of the cable may be varied by the use of different metals. For example for a 4-tube cable of preferred sheath design the value of Rs for various materials would be as follows:—

Steel	4.9	ohms per kilometre (thickness 0.4 mm)
Lead	1.0	ohms per kilometre (thickness 2.0 mm)
Aluminium	0.25	ohms per kilometre (thickness 1.3 mm)
Copper	0.4	ohms per kilometre (thickness 0.5 mm)

It should be noted that hard metal sheaths will be formed from longitudinal strip, butt welded and then spirally corrugated. This form of construction being necessary to obtain required radial strength and bending characteristics.

Using the present figure of 6kV as the breakdown voltage, the breakdown coefficient, $\frac{V}{R_s}$, may be stated for the four materials, assuming preferred design for 4-tube cables:—

$$\frac{V}{R_s} \text{ Steel} = 1.2$$

$$\frac{V}{R_s} \text{ Lead} = 6$$

$$\frac{V}{R_s} \text{ Aluminium} = 24$$

$$\frac{V}{R_s} \text{ Copper} = 15.$$

These materials have characteristic advantages and disadvantages which limit their use in particular situations. However action is proceeding to evaluate the economics of hard metal sheathed cables which will overcome the three principal disadvantages of lead as a sheathing material; namely poor radial strength, high specific weight and susceptibility to intercrystalline fatigue fracture.

Shield Wires

These are conductors laid above the cable which serve to divert some of the lightning current away from the cable sheath. It may be shown (Ref. 6) that where a cable is protected by shield wires the voltage between sheath and core conductors may be reduced by a factor K where:—

$$K \simeq \frac{L_{22} - L_{12}}{L_{11} + L_{22} - 2L_{12}}$$

where L_{11} = unit length self inductance of sheath.

L_{22} = unit length self inductance of shield wire.

L_{12} = unit length mutual inductance sheath to wire.

The values for K may be obtained from

$$L_{11} - L_{12} = \frac{\mu}{2\pi} \ln \frac{r_{12}}{r_{11}}$$

$$L_{22} - L_{12} = \frac{\mu}{2\pi} \ln \frac{r_{12}}{r_{22}}$$

where r_{11} = radius of sheath.

r_{22} = radius of shield wire.

r_{12} = distance between sheath and shield.

μ = permeability of free space ($4\pi \times 10^{-7}$ henries per metre).

ln = $\log_e$.

Where there is more than one shield wire r_{22} is the geometric mean radius of the wires and r_{12} is their geometric mean separation from the sheath. The voltage reduction provided by shield wires depends only to a small extent on a reduction in resistance from the use of larger wires, and the above expression is a reasonable approximation.
For two wires placed 10 inches above the cable with a separation of 12 inches the reduction factor is approximately 0.5.

Steel Tape Armouring

If the cable is steel tape armoured, the reduction in voltage is dependent on the reduction in resistance due to the steel tapes. For a 4-tube cable the diameter is approximately 1.5 inches and the resistance of two steel tapes is R = 10 ohms per kilometer approximately. In calculations for steel at high frequencies, skin effect due to the high permeability of the steel must be considered and it is estimated that this causes doubling or trebling of the D.C. resistance of tapes depending on the thickness of the steel. For tapes of thickness 0.04 inches a factor of 2 is approximately correct, i.e. R is equal to 20 ohms per kilometer approximately.

In normal construction a bituminous compound is laid between the steel tapes and the lead sheath. The insulation resistance of this compound is low and current will readily arc between armouring and sheath. Once an arc is established the bituminous compound will rapidly volatilize, causing crushing of the lead sheath. Although actual measurements have not been carried out to determine the voltage which will cause arcing between tapes and sheath, examination of cable faults indicates that it may be of the order 5 kV. As the resistance of the steel tapes is about 20 ohms per Km, the breakdown coefficient between tapes and steel $\frac{V}{R_s} = \frac{5}{20} = 0.25$. It should be noted that breakdown in this case is external to the cable core, but, due to the low radial strength of the sheath, damage occurs by explosive deformation of the sheath leading to crushing of the coaxial tubes.

Therefore, as the breakdown coefficient is low and the resultant fault liability is high, it is undesirable to use steel tape armouring for coaxial cables. Location of faults of this kind could also involve additional effort, as even when the cable is exposed in the vicinity of the fault no apparent damage is usually discernible and removal of the tapes for some distance on either side of the nominal point of fault location may be necessary.

However the use of steel tapes over a plastic jacket would not have the disadvantages mentioned. The breakdown voltage of the plastic jacket is approximately 100 kV and the breakdown coefficient for a 4-tube cable would be $\frac{V}{R_s} = 5$ approximately.

A figure of 5 may be suitable in many cases, but it is probable that a higher figure can be obtained more economically with longitudinal rather than helical tapes and with the use of copper in place of steel. This is discussed later.

Wire Armouring

The normal construction of wire armoured cable uses bituminous compound similar to steel tape armoured and is to be avoided for the reasons given above. However the use of wire armouring over a plastic jacket does not have the same disadvantages.

A 4 tube cable with wire armouring over the plastic jacket (W.A.P.J.) will have 48 x 12 gauge (0.104 in.) wires and the resultant longitudinal resistance is approximately 0.7 ohms per kilometre. This may be trebled to allow for skin effect at high frequencies i.e. Rs = 2.1 Ω/Km. The breakdown voltage of the plastic jacket V = 100 kV. Therefore the breakdown coefficient is $\frac{V}{R_s} = \frac{100}{2.1} = 48$. Large size cables will have correspondingly higher coefficients as shown in Table 3.

TABLE 3: LONGITUDINAL RESISTANCES OF WIRE ARMOURING IN W.A.P.J. CABLES

Cable	R_s (armouring wires)	$\frac{V}{R_s}$
4 T	2.1 Ω/Km	48
6 T	1.8 Ω/Km	55
8 T	1.5 Ω/Km	67
12 T	1.2 Ω/Km	83

Galvanised Mild Steel Conduit (G.I. Pipe)

The longitudinal resistance of steel pipe is significantly lower than all other means considered for protection. A 4 in. G.I. pipe has a resistance of approximately 0.1 ohms per kilometer or 0.3 Ω/Km allowing for skin effect. Thus the breakdown coefficient (pipe to cable sheath) is:—

$$\frac{V}{R_s} = \frac{100}{0.3} = 330.$$

Assuming the worst soil conditions and the highest probable lightning current, and that the total current flows along the conduit, the required breakdown coefficient is:—

$$\frac{V}{R_s} = 7.6 \times 10^{-3} \times I \times \rho^{\frac{1}{2}}$$

$$= 7.6 \times 10^{-3} \times 200 \times (10^4)^{\frac{1}{2}}$$

$$= 152.$$

Therefore steel pipe protection may be considered as 100% effective. In addition steel pipe affords the best possible mechanical protection and this is often a further justification for its use. The cost of steel pipe is high but, whereas other methods of protection are applied directly to the cable and will be applied usually for the full length, steel pipe may be terminated after a relatively short run where calculations show that the breakdown voltage (soil to sheath) has been reduced to a small value.

G.I. pipe proves of value particularly for protection of cables to Radio Telephone or Television Stations where, for the reasons already indicated greater protection than normal is required.

In order to determine the lengths of pipe required it is necessary to calculate the distance from the tower at which the earth potential will have fallen to below 100 kV.

Assuming that $I = 200$ kA and $\rho = 10^4$ metre ohms then

$$a = \frac{I\rho}{2\pi V} = \frac{200 \times 10^4}{2\pi \times 10^2} \simeq 3200 \text{ metres.}$$

At the end of the steel pipe a deep driven earth is desirable to lower the earth resistance at this point and thus minimise reflections of voltage. In this regard it may be advantageous to seek a pocket or localised area of low soil resistivity.

Conducting Shield Over Plastic Jacketed Cable

The main parameters of cable sheath design for future long distance coaxial cables are:—

(i) Suitable for laying in very long lengths.

(ii) Suitable for rail transport.

(iii) Suitable for ploughing.

(iv) A service reliability of at least 99.9%.

(v) As economical as possible.

Of the four metals already mentioned as possible sheathing materials lead fails in items (i) to (iii) above, copper is too expensive and aluminium is both expensive and prone to a high rate of corrosion. Currently attention is focussed on the possible use of corrugated steel sheathed cable with thermoplastic jacket. However steel has the disadvantage of relatively high resistance (4.9 Ω/Km compared with lead = 1.0 Ω/Km for a 4-tube cable) and the plastic jacket must be protected from pests in order to guarantee corrosion protection for the steel.

Both objectives, lightning and pest protection, can be achieved by the provision of a longitudinally applied lightly corrugated copper shield over the plastic jacket. The $\frac{V}{R_s}$ ratio for such a cable (shield to sheath) would be $\frac{100}{0.9} =$ 110 approximately, where R_s for the copper shield is about 0.9 ohms per kilometre. If a maximum value for ρ of 10,000 metre ohms is assumed then $\frac{V}{R_s} = 110$ giving protection against lightning currents exceeding the usually accepted maximum value of 200 kA, i.e. 100% protection, assuming that the current divides equally in both directions from the lightning strike. Investigations are proceeding to evaluate the economics of such a cable design and to confirm its mechanical and electrical performance by means of a trial installation.

PROTECTION OF CABLES FITTED WITH SOLID STATE LINE AMPLIFIERS

For coaxial cables equipped with solid state line amplifiers, surge voltage developed between the inner and outer conductors of the coaxial line must be controlled within close limits since the magnitude of the surge that a transistor can withstand is very small. Typical maximum allowable values quoted by manufacturers for high frequency transistors are 0.5 volts base to emitter and 20 volts collector to emitter (Ref. 9).

Field measurements made in Germany (Ref. 10, 11) show that isolation of tube outer conductor from earth results in reduction of potential between inner and outer conductors by a factor of more than 30 compared with the same line under the same surge conditions but with the outer conductor earthed. This reduction factor depends, of course, on complete isolation of the outer conductor from sheath and ground (i.e. there must not be sheath to core breakdown). It is in order to take advantage of this reduction factor that virtually all solid state coaxial line systems are designed for operation with the outer conductors isolated from ground.

Under lightning discharge conditions it is unlikely that the reduction factor described above will of itself be sufficient protection for the line amplifiers, even if the tube outer conductors remain isolated from the cable sheath — which cannot be guaranteed under the most adverse lightning discharge conditions without an intolerable cost of cable protection e.g. steel pipe.

For these reasons line amplifiers are designed to incorporate elaborate overvoltage protection (Refs. 9, 10). This takes two forms:—

(a) Primary protection in the form of gap type arresters across the line terminals in which flash over occurs at a voltage higher than the normal power feed potential of the cable system. Input and output transformers and capacitors are protected by this means.

(b) Secondary protection in the form of Zener diodes is applied to the semiconductor circuitry of the line amplifier.

In cases where Zener diodes are used at repeaters in power feed regulating circuits, an equally satisfactory arrangement can be provided with gas tube arrestors and step-up transformers so that the gas tube strikes at sufficiently low primary surge voltages and yet does not strike due to the normal D.C. power feed voltage.

The above type of two stage protection has been subjected to many thousands of impulses from high voltage generators delivering up to 100 kV peak and with rise times as small as 1 μ sec. Such tests have been carried out without failure of protection components and without variation in the performance of the line amplifiers.

It follows from the above that the cable outdoor plant design engineer need not take any special action in respect of lightning protection for solid state equipment used in cable systems.

CONCLUSION

This article has set out to give an up to date summary of lightning protection theory and practice and highlights the importance of cable design in this context. An attempt has been made to set out the basic theory in such a form as to assist telecommunication engineers in the design of trunk cable installations to achieve uniform service reliability of a high order in a measureable environment of potential lightning damage.

It has been shown that steel tape armoured cable is particularly vulnerable to lightning damage where a jute and bitumen bedding is incorporated between the steel tapes and the lead sheath. Experience with 800 miles of such cable of average age four years has produced four crushing faults due to lightning so far, and such cable is no longer installed on new coaxial routes.

Plastic jacketed lead sheathed cables do not incorporate volatile substances between conducting components and therefore are immune from this type of damage. Experience with 400 miles of such cable of average age two years has produced zero faults due to crushing by lightning. However it may be too soon to be certain that such cable will not be crushed by the vaporisation of water in the ground when close lightning discharges occur. It has been shown that the plastic jacket provides little protection against lightning current arcing from ground to sheath, and it may be expected that numerous pinholes will be formed in the jacket from this cause during the life of the cable. However such pin holes will not be of any significance provided the cable is not in a corrosive environment. If corrosion occurs due to pinholes then some years after the initial installation, it may become necessary to apply cathodic protection. The fact that lead sheathed plastic jacketed cables are significantly cheaper in first cost than steel tape armoured counterparts means that capital deferment occurs, part of which may be employed later in the life of the cable if corrosion should occur in isolated locations.

The shielding provided by guard wires has been shown to be small, nevertheless such protection may be important in special locations e.g. where the cable breakdown coefficient $\left(\frac{V}{R_s}\right)$ is too small by a factor not greater than two for isolated locations in an otherwise safe cable route.

The magnitude of the hazard to cables connecting radio stations with remote long line equipment terminals has been demonstrated. It has been shown that standard lead sheathed, plastic jacketed cables installed in steel pipes over part of the route distance (which may be calculated from the data given) can be regarded as virtually completely protected against lightning damage.

Hard metal sheathed cables have many advantages and it has been shown that they can be protected adequately against lightning and corrosion, even where steel is the chosen sheath material. It remains to be seen whether such cables can be produced economically in Australia and whether the promise of reduced installation costs for such cables can be realised in practice.

ACKNOWLEDGMENTS

The authors wish to acknowledge the valuable advice and assistance received from colleagues in the Lines Section, Engineering Works Division, P.M.G.'s Department Headquarters in the preparation of this article and associated studies. Also to colleagues in the Physical Sciences Section of the Research and Planning Division in respect of high voltage measurement work carried out on a wide range of coaxial cable samples. Also to the Automatic Data Processing Section of the Management Services Division for assistance rendered in the preparation of a computer programme for the solution of equations described in Appendix II.

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APPENDIX I

ASSESSMENT OF DAMAGE PROBABILITY

Cable Sheath in Contact with Ground

The distance within which arcing will occur is dependent on the crest lightning current (I) and the soil resistivity (ρ).

It is given by $y \simeq 0.2\ (I\rho)^{\frac{1}{2}}$ feet where I is in kilo amperes, ρ is in metre ohms.

Thus the area susceptible to direct strokes of current magnitude I kA is:—

A = 2y.L where L is the length of cable in miles

$$= \frac{2 \times 0.2(I\rho)^{\frac{1}{2}} \times 100}{5280} \text{ Sq. mls per 100 mls of cable.}$$

$$= 7.6 \times 10^{-3}\ (I\rho)^{\frac{1}{2}}.$$

It has been determined (Ref. 6) that for a thunder day level of 10 there are about 2.4 lightning strokes to ground per square mile per year, (S = 0.24 T).

Observations at Queensland University over the three years 1960 to 1963 (Ref. 12) indicate an average value of 0.15T per square mile per year.

The incidence of lightning currents is shown in Fig. 2 where it may be seen that strokes exceeding a given value may be determined by the product of the total number of strokes per unit area per year, the area susceptible to strokes of a given value and the probability "p" of such a stroke occurring.

Thus $N = S \times A \times p$

and, using the larger of the two values for S,

$$N = 1.82 \times 10^{-3} \times I^{\frac{1}{2}} \times p \times \rho^{\frac{1}{2}} \times T.$$

From Fig. 2 it is seen that 0.1% of all strokes exceed 200 kA. Now, if the cable is designed to withstand all stroke currents up to but not exceeding 200 kA, then the number of damaging strokes will be

$$N = 1.82 \times 10^{-3} \times (200)^{\frac{1}{2}} \times \frac{1}{1000} \times (\rho^{\frac{1}{2}}T)$$

$$= 2.6 \times 10^{-5}\ (\rho^{\frac{1}{2}}T) \text{ per 100 miles of cable per annum.}$$

For economic reasons it may be undesirable to set the design limit for protection against strokes as high as 200 kA. In order to clarify the parameters, a family of curves is given in Fig. 7 which permits the probability of damage to be related to the factor $(\rho^{\frac{1}{2}}T)$ for a wide range of lightning stroke currents from 30 kA to 200 kA below which protection can be guaranteed.

As an example of the application of Fig. 7

let $T = 20$ and $\rho = 300$ metre ohms.

i.e. $(\rho^{\frac{1}{2}}T) = 346$.

then the predicted number of strokes which will cause damage to a 100 mile length of cable in one year is 0.009 for a design limit of 200 kA. Therefore, for 600 miles of cable one fault will occur in 18.5 years.

If the design limit is reduced to 100 kA, one stroke in 3 years will probably cause damage to a 100 mile length of cable. Therefore for 600 miles of cable one fault will probably occur in 0.55 years i.e. 1.8 faults per year.

Cables with Insulated Sheaths

The foregoing paragraphs have referred to the design of a metal sheathed cable having the sheath in continuous contact with the ground. However, for corrosion protection, coaxial cables presently manufactured are provided with a plastic isolating jacket. The surge breakdown voltage of this jacket is of the order 100 kV.

Considering again a lightning stroke to ground in the vicinity of the cable, current will not arc directly to the cable unless the earth potential exceeds the sheath potential by more than 100 kV. Assuming a homogeneous soil in the vicinity of the stroke, the potential distribution in the soil in relation to a remote earth for various distances from the stroke may be seen from Fig. 3. Now as the isolated cable sheath will be earthed at each buried repeater, it may be assumed that this full potential will appear across the isolating jacket at points remote from repeaters.

Consider an earth resistivity of 1000 metre ohms and a lightning stroke $\geqslant$ 30 kA (50% probability) then such a stroke within 50 metres of the cable will cause the jacket to breakdown.

An argument may be developed as before in which an acceptable level of damage is considered. Thus the area within which strokes will cause breakdown is A = 2y. L.

But $y = \dfrac{I\rho}{2\pi V}$ metres where I is stroke current in kA, ρ is earth resistivity in metre ohms, and V is breakdown voltage of plastic jacket in kV.

$= 1.6 \times 10^{-3}\, I\rho$ metres

$= 5.3 \times 10^{-3}\, I\rho$ ft. approx. for a jacket breakdown of 100 kV.

It has been shown (Ref. 13) that the crest current distribution for strokes to ground may be written:—

$$P(i) = c \int_i^{\infty} i^{\frac{1}{2}}.P'_0(i)\, di.$$

Where P'_0 is the derivative of P_0 and $P'_0(i)\,di$ represents the probability of a a current in the interval i and (i + di), and $ci^{\frac{1}{2}}$ the probability that it will be within the required distance to breakdown the plastic jacket.

The mean distance through which a cable will attract lightning strokes of all magnitudes may be determined from the above equation and it is found roughly equal to a current of 25 kA. If I is made equal to 25 kA in the expression

$y = 5.3 \times 10^{-3} I\rho$ feet.

then $y = 0.13\rho$.

Since the area in which strokes will cause breakdown is $A = 2y.L$

$$A = \frac{2 \times 0.13\rho \times 100}{5280} \text{ sq. mls per 100 mls. of cable}$$

$= 0.45 \times 10^{-2}\rho$ sq. mls per 100 mls of cable

and, from S = 0.24T, the number of strokes within this area is:—

$N = 0.24TA$

$= 1 \times 10^{-3} T\rho.$

For values of $T = 10$ and $\rho = 1000$ metre ohms, N = 10 strokes per 100 miles per year.

Obviously if such a large number of strokes caused a loss of service this damage would be intolerable. However, provided the metal sheath and the core insulation are designed on the basis described in the main text the only damage will be to the plastic jacket. This however can allow access to the metal sheath of moisture, soil chemicals and earth currents, each of which can cause corrosion. Therefore, although overall corrosion is reduced by the plastic jacket, small holes and localized corrosion may occur owing to the probability of damage to the jacket.

In the case of lead sheathed cables chemical corrosion is usually slight and it is easier to overcome the effects of earth currents where entry is localized due to small holes in insulation than for the bare sheath cable. The same argument may apply equally to copper sheathed cables as copper in general is less susceptible to corrosion than lead.

However design attention is required in this regard for sheaths of steel or aluminium as corrosion may be expected to be more rapid for each of these metals.

A possible solution, which will at the same time combat the pest hazard from ants and termites, is to use a corrugated and welded steel sheath cable plastic jacketed, with a longitudinal thin copper outer shield over the plastic jacket in order to bring the ratio $\dfrac{V}{R_s}$ up to a suitable value.

APPENDIX II

DETERMINATION OF MAXIMUM VOLTAGE BETWEEN SHEATH AND CORE OF CABLE DUE TO LIGHTNING

Sheath to Core Voltages

Lightning current in a cable sheath in contact with the ground causes a voltage to be developed between the sheath and the core. This voltage is proportional to:—

(a) The amplitude and duration of the lightning current.

(b) The longitudinal resistance of the sheath.

(c) The soil resistivity.

In order to determine the maximum potential difference between core and sheath at any point along the cable due to a lightning current, it is convenient to consider first a sinusoidal current flowing in the sheath. Thus when a sinusoidal current I enters the sheath at a point remote from the ends and divides equally in both directions, the current at a distance 'x' from this point is:—

$$I(x) = \frac{I}{2} e^{-\gamma x}$$

Where γ is the propagation constant of the transmission line equivalent sheath-earth circuit and the voltage at "x" between sheath and core can be shown to be (Ref. 6):—

$$V(x) = \frac{IZ}{2(\gamma^2 - \gamma_0^2)} . (\gamma e^{-\gamma x} - \gamma_0 e^{-\gamma_0 x})$$

where γ_0 is the propagation coefficient for the core-sheath circuit and Z is the mutual impedance of the sheath-earth and core-sheath circuits.

The maximum voltage will occur at $x = 0$.

$$V(0) = \frac{IZ}{2(\gamma + \gamma_0)}.$$

The expression can be simplified if Z is assumed to equal the D.C. resistance R_s (ohms per metre) of the sheath and if the velocity of propagation along core and sheath is assumed to be infinite. These assumptions introduce only a small error and Fig. 9 indicates the comparison between measured and calculated voltages on a small cable using both exact and approximate constants.

Furthermore as γ_0 is small in comparison to γ (approx. 3%) γ_0 may be neglected and

$$V_0 \simeq \frac{IR_s}{2\gamma}$$

and γ may be written

$$\gamma \simeq (i\omega\alpha)^{\frac{1}{2}}$$

where $\alpha = \dfrac{\mu}{2\rho}$

and $\mu = 4\pi \times 10^{-7}$ henry per metre (permeability of free space)

ρ = Soil resistivity in metre ohms.

$$\therefore V_0 \simeq \frac{IR_s}{2(i\omega\alpha)^{\frac{1}{2}}}.$$

V_0 is the voltage for an applied sinusoidal current I.

The wave shape of the current in a lightning stroke may be approximated by

$$I(t) \simeq I(e^{-at} - e^{-bt})$$

where a and b are constants depending on the shape of the particular stroke.

Fig. 9 indicates a typical lightning current in which

I = 1150 amps.

$a = 0.013 \times 10^6\ sec^{-1}$

$b = 0.5 \times 10^6\ sec^{-1}$.

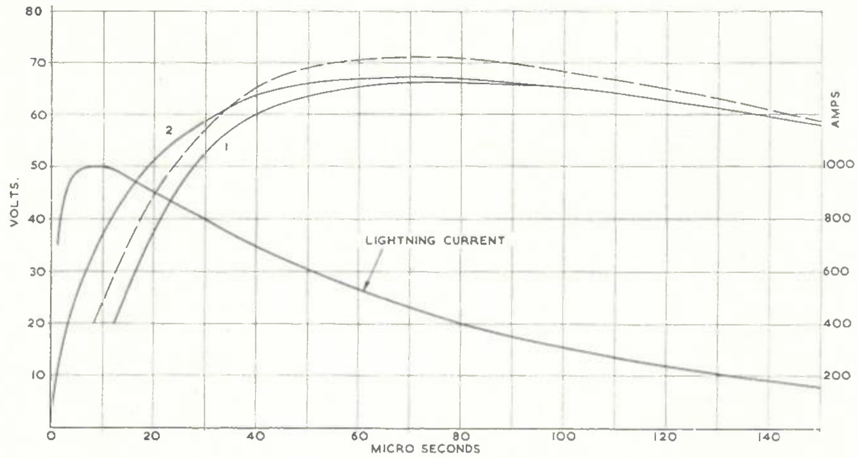

Fig. 9 — Comparison of Measured (dotted line) and Calculated Maximum Voltages between Sheath and Core Conductors shown by Curves 1 and 2 for Average Lightning Current.
1. Calculated from full information.
2. Calculated using only d.c. resistance of sheath and infinite velocity of propagation.

This current reaches its crest of 1000 amps in 10 microseconds and decays to half this value in 65 microseconds (known as a 10/65 wave).

Sunde then shows that for such a current the voltage at x = 0 and time "t" is

$$V_0(t) = \frac{IR_s}{2\alpha^{\frac{1}{2}}} \cdot [a^{-\frac{1}{2}}h(at)^{\frac{1}{2}} - b^{-\frac{1}{2}}h(bt)^{\frac{1}{2}}]$$

(Ref. 6)

where the function h(u), $u = (at)^{\frac{1}{2}}$ or $(bt)^{\frac{1}{2}}$ is defined by:—

$$h(u) = \frac{2}{\pi^{\frac{1}{2}}} \cdot e^{-u^2} \int_0^u e^{\tau^2} d\tau.$$

Tables are available for the function h (u) (Ref. 6) and by substitution of values for a, b and a range of values for t, the value at which the expression:—

$$\{a^{-\frac{1}{2}}h(at)^{\frac{1}{2}} - b^{-\frac{1}{2}}h(bt)^{\frac{1}{2}}\}$$

is a maximum may be obtained. This value is 60×10^{-4} and occurs at approximately 70 microseconds.

Therefore V max. may be expressed as

$$V\ max. = \frac{IR_s}{2\alpha^{\frac{1}{2}}} \times 60 \times 10^{-4}$$

$$V\ max. = \frac{IR_s}{2}\left(\frac{2\rho}{4\pi 10^{-7}}\right)^{\frac{1}{2}} \times 60 \times 10^{-4}$$

$$V\ max. = 7.6 \times \frac{IR_s}{2} \times \rho^{\frac{1}{2}}$$

V in Kilovolts

I in Kiloamps

R_s in ohms per metre, and

ρ in metre ohms.

This relationship is shown in Figs. 10 and 11 (Ref. 7) for various values of R_s and ρ and is a reasonable approximation for the maximum voltage appearing between core and sheath of an unprotected cable.

Sunde (Ref. 8) uses a lower value $V = 2.25IR\rho^{\frac{1}{2}}$.

The same formula may be applied to the maximum voltage appearing between an insulated cable sheath and an external surrounding metal shield.

The foregoing indicates the maximum voltage developed between sheath and core or shield and sheath for a wave shape 10/65. For a cable in which the conductors are insulated at the point of strike (x = 0) and do not breakdown, this maximum will appear at x = 0 and will reduce with distance along the cable. However if conductors and sheath are connected (or breakdown) at x = 0 then the voltage will increase with distance and the maximum will appear at varying distances depending on the earth resistivity and the duration of the surge (time to half value).

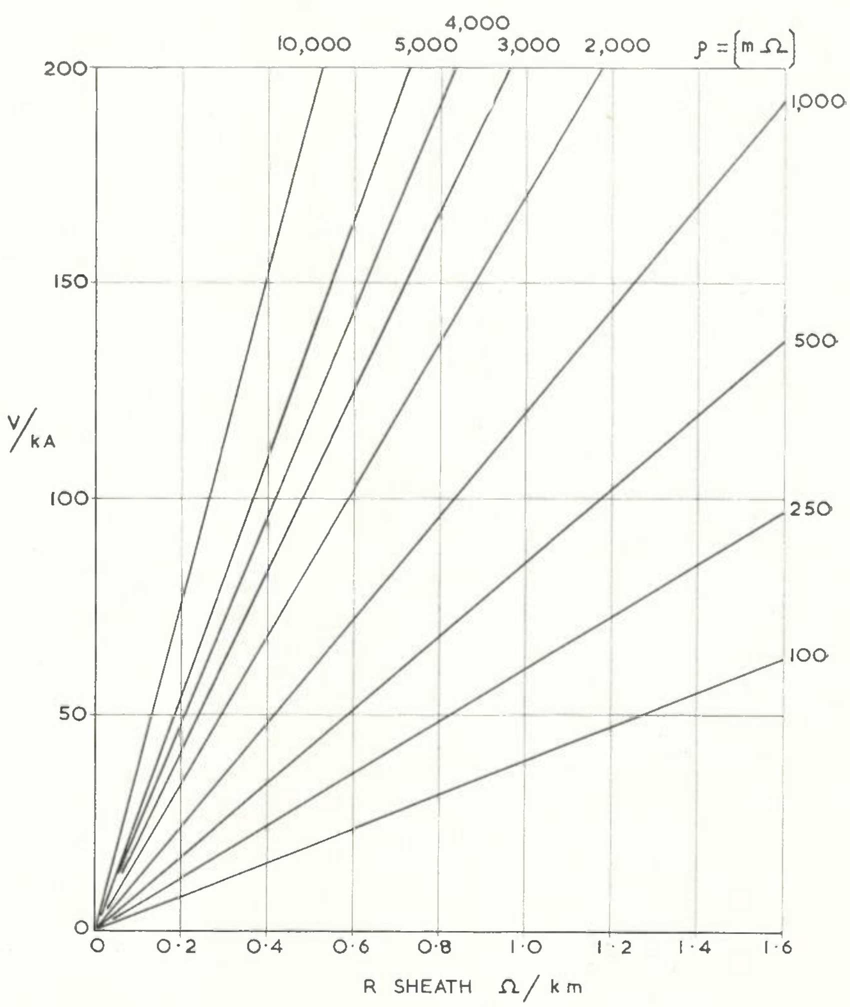

Fig. 10 — Maximum Voltage between Sheath and Conductors at the Point of Entry of Lightning Current (5/65), Plotted for various values of Sheath Resistance and Earth Resistivity. The point of entry is assumed to be at a point remote from the ends.

In order to determine the variation with distance and time, calculations were carried out using a GE. 225 computer. The basis of the computations being obtained from a C.C.I.T.T. contribution (Ref. 14) using parameters applicable to a 4 tube coaxial cable. A wide range of calculations were carried out to determine potential differences between various components of the cable for both shielded and unshielded conditions and two examples are included here.

Fig. 12 indicates how the sheath to core voltage for an unshielded 4 tube coaxial cable varies with time and distance for the case where core conductors are insulated at x = 0. When conductors and sheath are connected together at x = 0, the maximum voltage under the same conditions appears at 3000 metres (Fig. 13) and 70 μ seconds.

It has been indicated earlier that the voltage is also proportional to the total electric charge in the lightning stroke. In order to verify this, allowance was made in the computer calculations to alter the parameters governing wave shape. Sunde (Ref. 6) postulates an average wave having a rise time of 10μ seconds and a decay time to half value of 65 μ seconds and this has been used for the foregoing calculations.

Such a wave may be expressed in the form:—

$$I(t) = I(e^{-at} - e^{-bt})$$

where $a = 0.013 \times 10^6$

$b = 0.5 \times 10^6$, and

$I = 1150$.

This wave has a peak value of 1000 amps.

By alteration of a and b as shown in Table 4 a variety of wave shapes were obtained and results were calculated for a peak of 1000 amps in all cases.

TABLE 4: CONSTANTS 'a' and 'b' FOR VARIOUS WAVE SHAPES

$I(t) = I(e^{-at} - e^{-bt})$.

a	b	Decay time to half value
0.001	0.5	700 μ secs
0.002	0.5	350
0.005	0.5	150
0.01	0.5	80
0.013	0.5	65
0.02	0.5	42
0.05	0.5	20
0.1	0.5	12

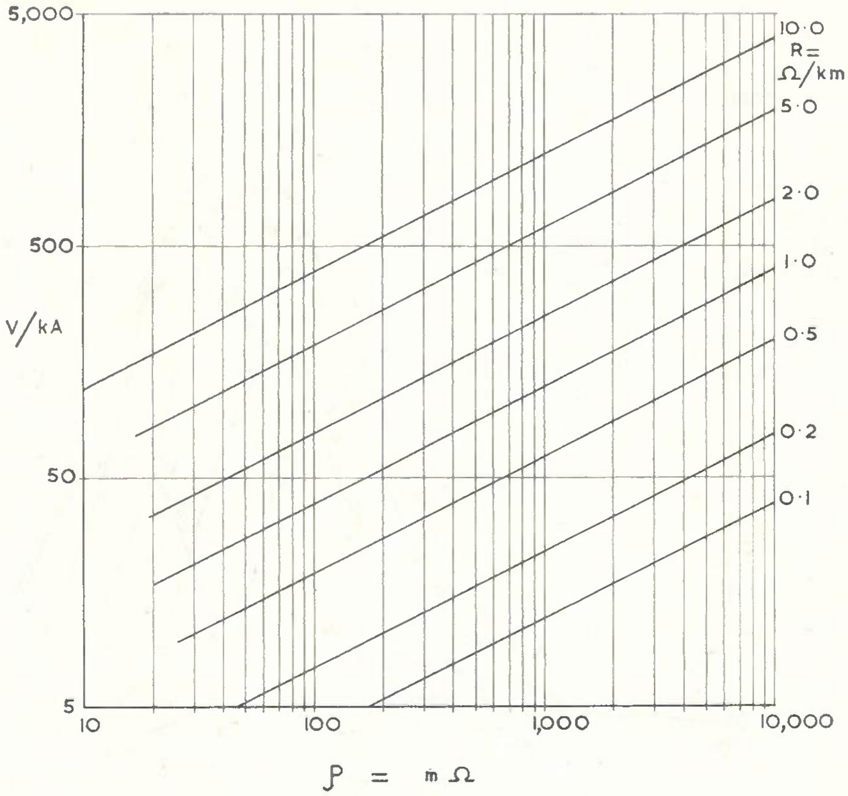

Fig. 11 — Sheath to Core Voltages for Various Values of Sheath Resistance and Earth Resistivity. Same conditions as for Fig. 10 but with earth resistivity as the abscissa.

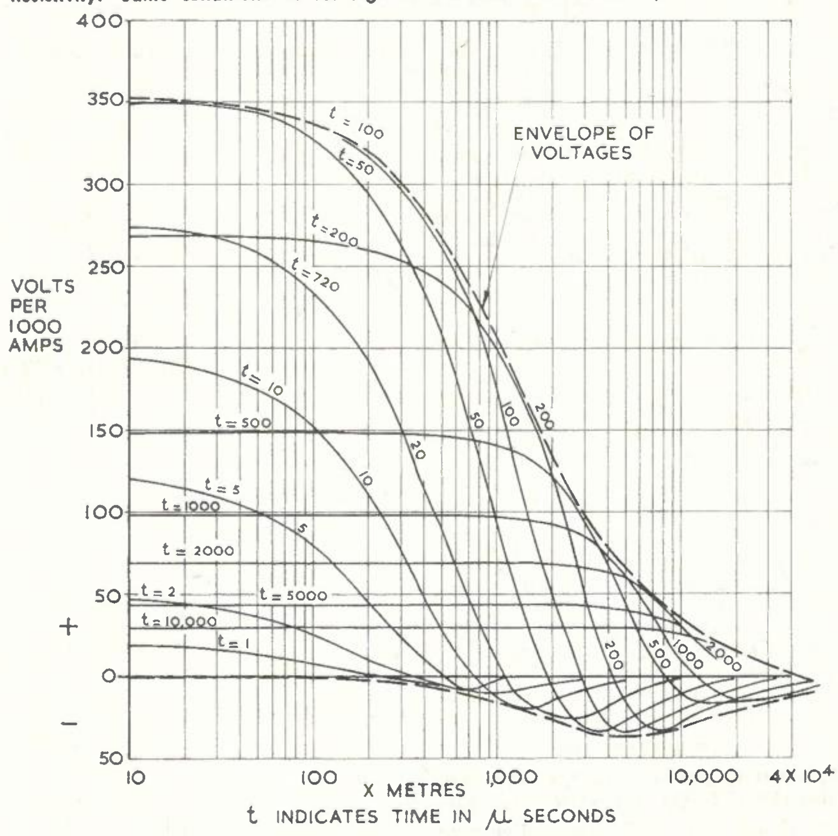

Fig. 12 — Voltage Core-Sheath Versus Distance from Current Entry. (Conductors and sheath insulated at x = 0).

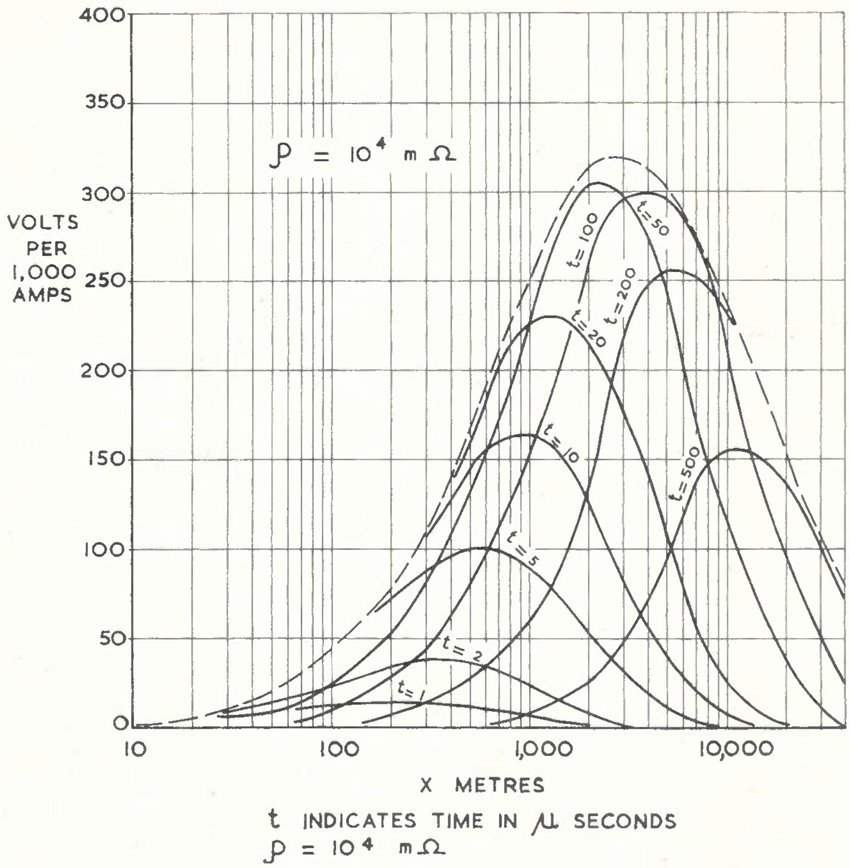

Fig. 13 — Voltage Core-Sheath Versus Distance from Current Entry (Conductors and Sheath connected together at $x = 0$).

Fig. 14 shows the maximum voltage developed between sheath and core of a 4 tube cable for each of the wave forms considered. The relationship between voltage and charge may be indicated by variation of decay time to half value (t_d) where

$$V \propto t_d^{\frac{1}{2}} \text{ (Fig. 15)}$$

and approximates the parabolic form $y^2 = 4ax$.

Measurements on cross country cable (Ref. 8) indicated average decay times to half value of 150 μ sec. for which voltages would be approximately $\left[\frac{150}{65}\right]^{\frac{1}{2}}$ or 1.5 times the voltage for a decay time of 65 μ secs. The charge in these strokes was of the order of 10 coulombs. A further observation indicated that the rate of attenuation is inversely proportional to $t^{\frac{1}{2}}$. Thus for a cable with core conductors connected to the sheath at the point of strike the maximum voltage will appear at a greater distance for a higher value of t_d.

APPENDIX III

THE PROBABILITY OF LIGHTNING DISCHARGE TO A RADIO TOWER

A radio tower will attract lightning strokes within a certain distance depending upon the height of the tower. However investigations have shown considerable variation in the estimates of this distance. Sunde (Ref. 6) indicates a distance of 3 to 5.5 times the height. Popp and Shultz (Ref. 5) estimate 3 H and Prentice (Ref. 15) suggests 1 H. All the above are based on investigations to open wire lines.

Arrangements are being made to carry out measurements of lightning currents and their frequency at a number of television and radio telephone tower locations throughout Australia in order to obtain first hand information in this regard.

Pending actual results, the authors consider it prudent to use the upper value 5.5H as the distance within which lightning will be attracted to a tower. The area within which strokes to the tower will occur will be $A = \pi(5.5H)^2$.

As shown in Appendix I it is estimated that the number of strokes to ground per year is:—

$S = 0.24$ T per sq. mile

$\simeq 0.1$T per sq. kilometre

where T is the thunder day level.

Therefore the number of strokes to a tower may be calculated from

$N = 0.1T.\pi(5.5H)^2$ where H is in kilometres.

In calculating the height "H" account should be taken of the height of the hill as well as the tower if the hill slope exceeds 1 in 5.5 and the hill is an isolated peak in otherwise level country or the rising edge of a range facing the direction of the major weather fronts. Table 5 indicates the order of the number of expected strokes to towers in given situations.

TABLE 5: NUMBER OF STROKES PER ANNUM TO TOWERS OF VARIOUS HEIGHTS

H. (in feet)	Thunder Day Level (T)					
	10	20	30	40	50	60
150	< 0.5	< 0.5	< 1	1	1	1
300	1	2	3	4	5	6
450	2	4	6	8	10	13
600	4	8	11	15	19	23
900	9	17	26	35	44	50
1200	15	30	45	60	76	90
1500	24	50	70	100	120	140

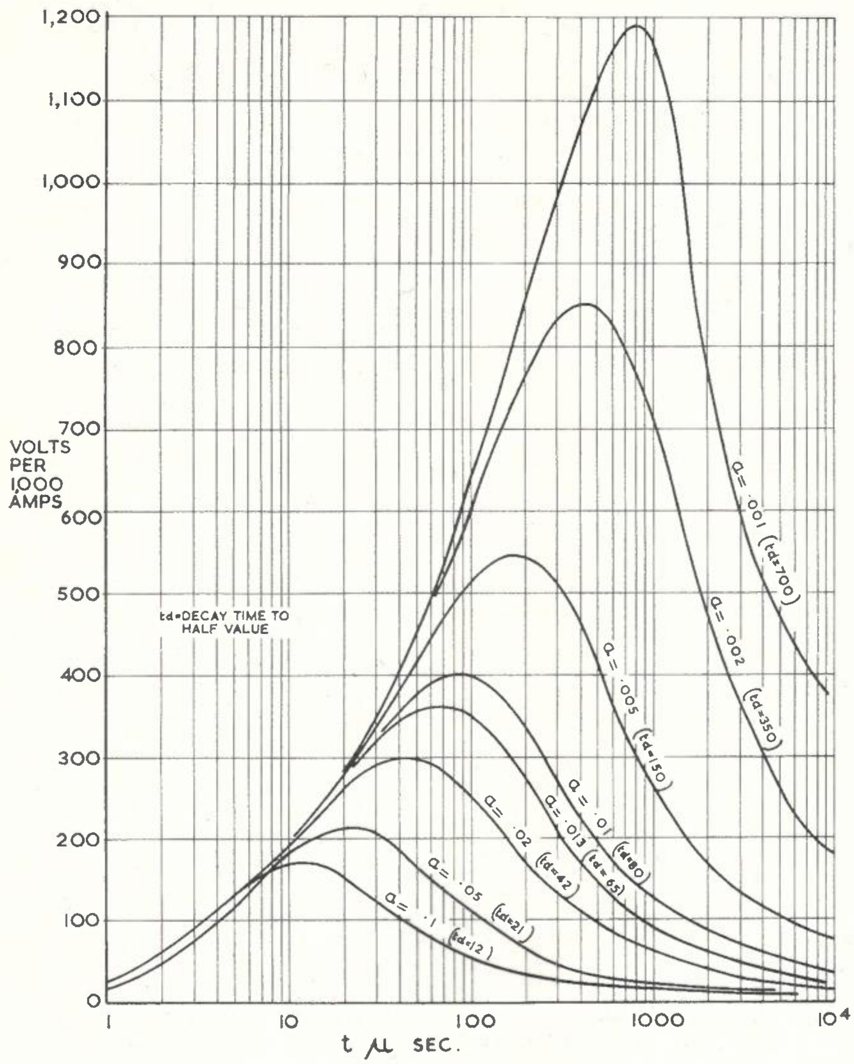

Fig. 14 — Variation of Developed Voltage Core-Sheath with Change in Wave Form for Constant Peak Current.

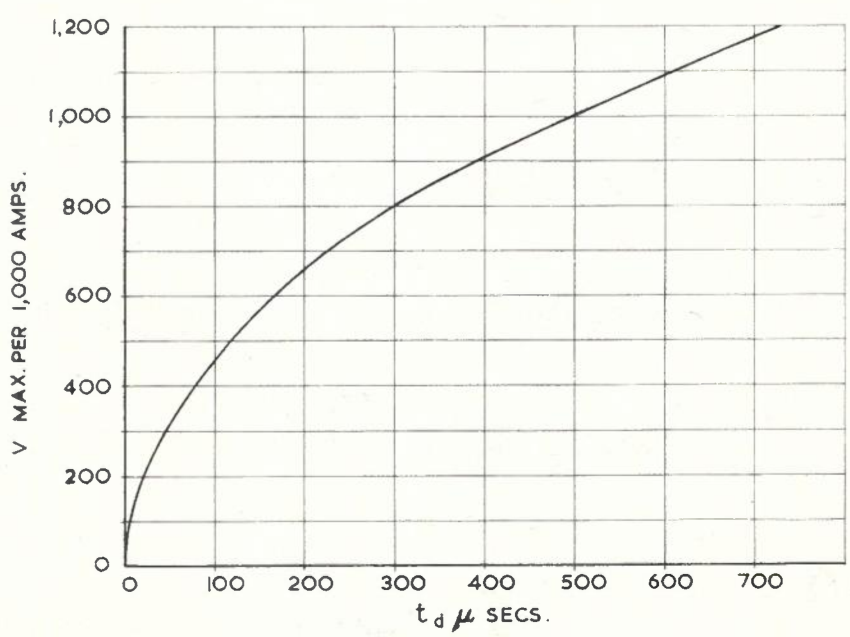

Fig. 15 — Maximum Voltage between Core and Sheath of Cable in Relation to the Time (micro secs.) to half Value of the Lightning Surge Current.

TECHNICAL TRAINING IN THE AUSTRALIAN POST OFFICE PART 1

V. J. White, B.A., S.Sc., A.M.I.E. Aust., A.M.B.Ps.S.*

INTRODUCTION

The bulk of the technical manipulative staff in the Postmaster-General's Department have to work on types of equipment and plant which are not encountered outside the Department to any large extent, and conventional apprenticeship schemes therefore do not provide for training in appropriate skills. Accordingly, the Department has had to design special courses of training to meet its needs and over the years has developed extensive technical training facilities involving large scale provision of its own technical training schools. (See Table 1, and Ref. 1).

The Department conducts two broad types of technical training course. Primary courses train new recruits for a base grade qualification, and secondary or conversion type courses train existing staff for work on new types of equipment or give them refresher training in new developments. Primary training courses were conducted by the Department as early as 1914 when a 3 year junior mechanics-in-training syllabus was used. The early training courses involved attendance at State Education Department Technical Colleges or Postal Institute classes for general theory training but this policy was finally discontinued in 1954.

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TABLE 1: DATA ILLUSTRATING SCOPE OF DEPARTMENTAL TECHNICAL TRAINING

STATE	No. of Schools		Typical Annual Enrolments		No. of Instructors	
	Tech.	Lines	Tech.	Lines	Tech.	Lines
N.S.W.	3	4	3000	600	96	42
VIC.	3	3	2250	600	101	42
Q'LD.	2	1	1250	200	49	14
S.A.	1	1	700	300	40	16
W.A.	1	1	500	250	27	16
TAS.	1	1	370	120	21	5
TOTALS	11	11	8070	2070	334	135
	22		10,140		469	

The purpose of this paper is to trace the history of technical training in the Department, to isolate syllabus developments and trends, and to record in some detail, new syllabuses of training which have been recently introduced. Some comments will be made on syllabus design aspects and some indication of possible future developments will be attempted.

TRAINING OF TECHNICIANS

General

The general structure of primary training courses for technicians (See Fig. 1) is to recruit school leavers in the 15-18 age range to undergo a 5 year training course, comprising a graded school syllabus interspersed with periods of on the job training. The school syllabus involves a common course through which all technicians pass followed by a specialization phase in which trainees are given different kinds of specialized training according to the Section to which they have been allocated. In both the common course and specializa-

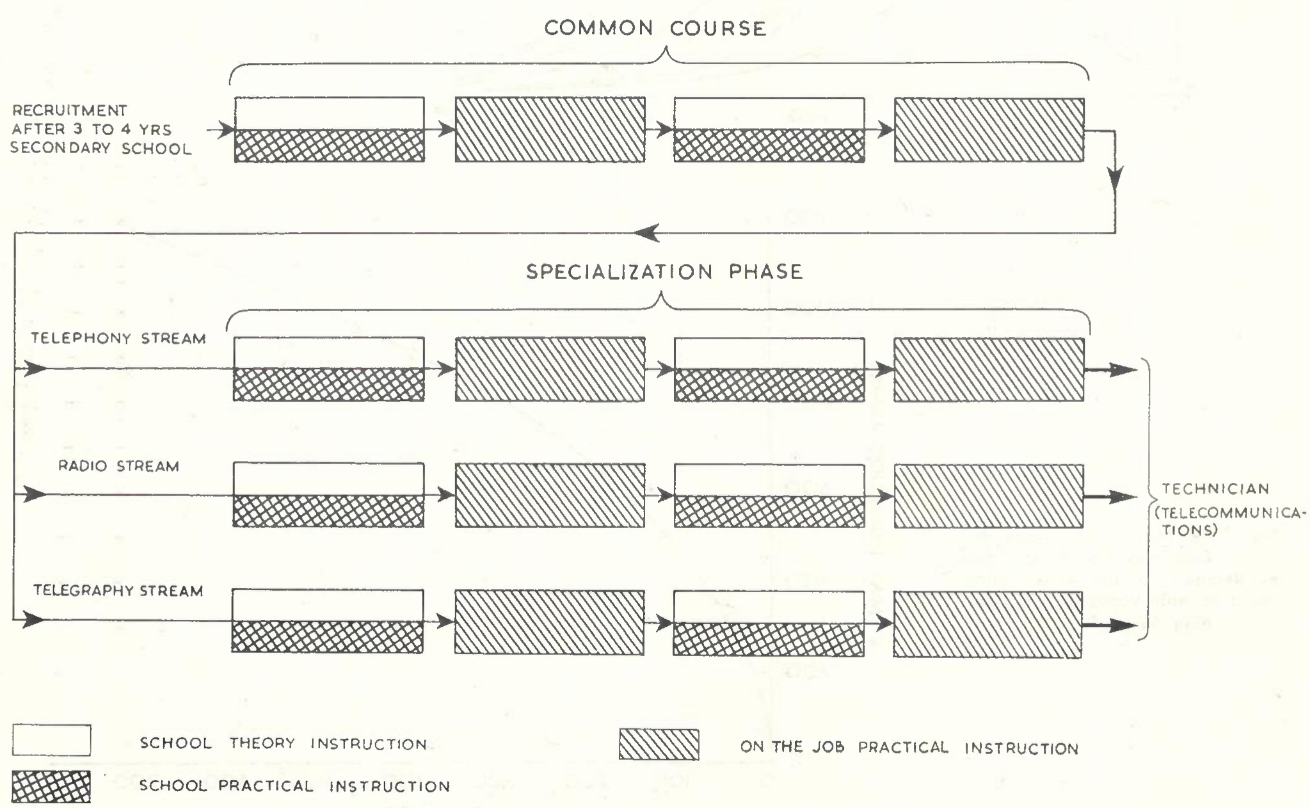


Fig. 1 — General Course Structure for Technician Training.

tion phases the school instruction may be divided into two broad types, — theoretical and practical. Theory instruction includes lectures and laboratory sessions on principles and underlying theory, whilst practical instruction is made up of demonstrations and practical bench exercises in manipulative skills associated with the various tools and equipment used on the job.

Past School Syllabuses

Technician training syllabuses have changed progressively over the years, both in content to cater for technical changes and in overall arrangement to meet changed conditions. Some idea of the changes occurring during 1926-1958 in syllabus content can be gained from Appendixes 1 and 2 which give brief details of the 1926 and 1958 syllabuses. Changes in overall training arrangements in this period are illustrated in Fig. 2, and may be summarized as follows:—

(i) Establishment of Departmental schools for theory and practical training.
(ii) Discontinuance of the use of "outside" technical colleges for theory training.
(iii) Discontinuance of the requirement that trainees attend some theory lessons in their own time.
(iv) Introduction of a specialization phase of training.
(v) Transfer of control of on-the-job practical training from training schools to field sections.
(vi) Progressive change in the ratio of school theory to school practical instruction.
(vii) Allocation of trainees to their specialization early in the training course (at end of first year).

The 1965 Revision

In 1965 a new revised syllabus was introduced. Technical changes occurring since the design of the 1958 syllabus had revealed shortcomings in the content of the syllabus, whilst the increased diversity of equipment types and the spread of new equipments to country centres had revealed the inadequacy of the existing specialization phase. After considerable study a new syllabus was designed to provide the following features:—

(i) A completely revised common course of training spread over the first 2-1/3 years of the course to cover fundamental principles and basic practical skills common to technician's work in all fields.
(ii) A new approach to the provision of specialized training, whereby the various specialized skills have been broken down to a large number of short courses each of 1 week school instruction. These courses, known as Unit Courses, can be combined in various ways to make up training courses to meet any combination of skills likely to be required in the field.
(iii) Closer integration of theory, laboratory and bench instruction.
(iv) Closer correlation of school instruction with on-the-job practical training.
(v) Concentration of wastage in first year by providing earlier teaching of the more difficult concepts.
(vi) Co-ordination of primary training with secondary training through the Unit Course programme.

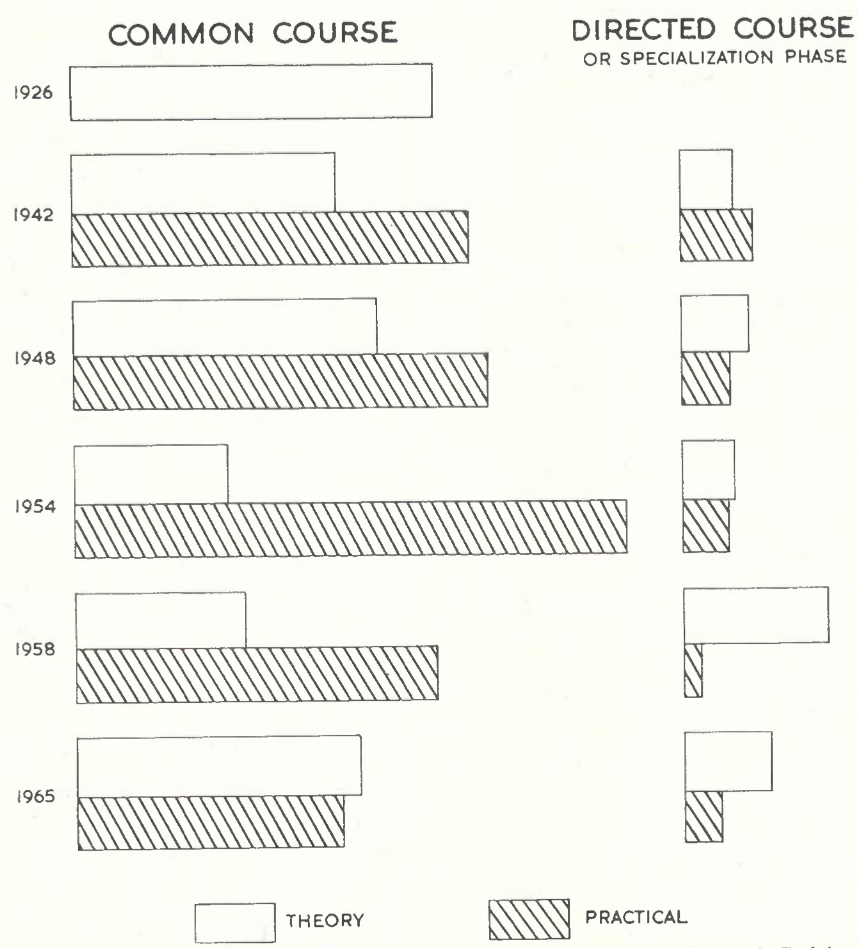


Fig. 2 — Relative Amounts of Theory and Practical School Training in Technician-in-Training Syllabuses in the Period 1926-1965.

THE NEW COMMON COURSE OF SCHOOL INSTRUCTION: The main aim in designing the new common course of school instruction was to lay a firm foundation of fundamental principles, training and basic practical skills on which to build subsequent specialized training courses covering the application of these principles and skills to particular equipments.

Detailed teaching programmes have been arranged to allow for close integration of theory lessons with laboratory and bench projects to ensure that fundamental principle training is reinforced as soon as possible by opportunities to undertake related practical work. In addition the detailed programmes provide for a progressive development of each topic with frequent review and revision sessions to check that basic concepts taught earlier have been retained.

The broad subjects taught in the common course and the number of hours allocated to each are shown in Table 2. Each subject is described briefly in the following sections; details are given in Appendix 3.

Telecommunication Principles: This subject covers basic principles of electricity, magnetism, and electronics.

Telecommunication Techniques: This is the name given to a variety of topics dealing generally with how the fundamental principles and concepts taught in Telecommunication Principles are applied in the manufacture, construction and operation of basic telecommunication materials, components and equipment. Lecture and laboratory periods as well as practical bench work are involved in the teaching of this subject.

Telecommunication Mathematics: This subject is concerned with the application of fundamental mathematical processes to problems arising from the telecommunication principles and techniques sections of the syllabus. The maths processes dealt with include fractions, decimals, ratio and proportion, transformation of formulae, graphs, trigonometrical ratios, radian measure, indices, logarithms, squares and square roots, vector representation and degrees of accuracy.

TABLE 2: ALLOCATION OF SYLLABUS HOURS TO BROAD SUBJECTS IN COMMON COURSE OF SCHOOL INSTRUCTION IN THE 1965 TECHNICIAN-IN-TRAINING SYLLABUS

YEAR	Telecom. Principles	Telecom. Techniques	Telecom. Maths.	Telecom. Practices	Telecom. Drawing	Miscellaneous	Total
1st	250	656	97	455	24	24	1,506
2nd	180	100	72	59	—	60	471
First Term Third Year	29	29	—	—	—	—	28
TOTALS	459	785	169	514	24	84	2,035

Telecommunication Practices: In this subject trainees learn the care and use of tools and develop basic manipulative skills involved in the installation and maintenance of telecommunication equipment.

Telecommunication Drawing: This subject covers drawing types and methods and provides practice in reading drawings used in telecommunication work.

Miscellaneous: Included under this heading are school induction activities and lectures on such subjects as public relations, reading and study habits and first aid. Also included in this subject are 60 hours of corespondence lessons given in 2nd Year and covering assignments on work done in 1st year in the telecommunication principles, techniques and maths areas.

The Unit Course Programme: The 1958 syllabus provided for four specialization streams:

Telephone and Long Line Equipment — Installation
Telephone and Long Line Equipment — Service
Radio
Telegraphy

Increased diversity of equipments which may be installed at any one centre created a demand for technicians with a greater variety of special skills and led to the idea of breaking down all the specialized training into short Unit Courses which could then be combined in a wide variety of ways to provide specialized training to meet practically any combination of skills likely to be required by field sections. Each Unit Course provides one week of full time school instruction in a particular equipment or technique.

This arrangement gives the specialization phase of training a high degree of flexibility, in that, within the limits of practical school course programmes:

(i) Field sections may select courses for their trainees which will match as closely as possible the particular equipments installed in the Section. As new equipment types arrive on the scene field sections can select appropriate courses to meet the new needs.

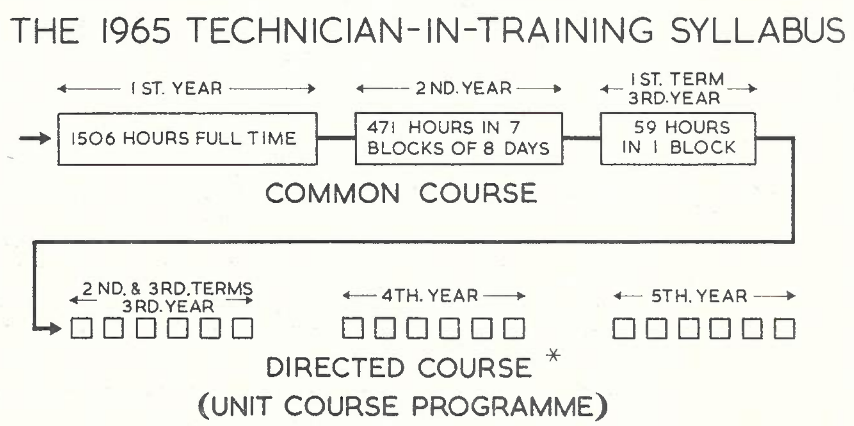
(ii) Technical changes can now be incorporated in the training syllabuses more readily through the design of additional Unit Courses which can be added to the overall Unit Course programme without the need for seeking a major syllabus revision.

(iii) Co-ordination of on-the-job training with school instruction is facilitated since sections can now select and schedule specialization training courses in equipment and techniques to fit in with those currently in use in the section, thus ensuring that the school instruction is reinforced by appropriate field training within a reasonable period.

(iv) The amount of training given to a trainee can, within certain limits, be more accurately matched to the actual current requirement for specialized skills in his section.

Details of the Unit Courses currently available, are given in Fig. 3. It will be seen that approximately 130 Unit Courses are planned already. As technical changes occur and new requirements develop it is anticipated that the number of Unit Courses offered will increase progressively.

To qualify as a technician a trainee must complete the common course of training and a minimum of 12 unit courses. Under certain conditions trainees may be required to undergo additional unit courses up to a maximum of 18.



***Note 1: Trainees must complete 6 unit courses in 3rd year and no less than 3 in 4th year. No less than 12 and no more than 18 unit courses are to be completed overall.**

Fig. 3 — General Structure of the 1965 Technician-in-Training Syllabus.

Trends in Technician-in-Training Syllabuses

Analysis of the various changes occurring in syllabuses over the years reveal some interesting changes in the theory component of the syllabus, in the degree of specialization offered and in the relative roles of on-the-job and school instruction in the development of practical skills.

Theory Instruction Trends: Theory instruction in this context is instruction which is imparted by lecture and laboratory sessions in the traditional class room or laboratory setting; practical instruction refers to instruction in practical skills given in the school in special work-bench type situations or in the form of on the job training. It is recognized that lessons given in a classroom and experiments conducted in a laboratory setting may have a heavy practical bias, and that some theory instruction may be imparted during practical skill instruction sessions on the work bench in the school or even during on the job training. But in general, use of criteria derived from the type of setting for the period, serves as a fairly accurate measure of the relative amounts of theory and practical instruction involved in the various syllabuses.

The use of technical colleges for theory instruction in the early syllabuses has already been mentioned. The trend away from the use of outside technical colleges started as early as 1935 when lectures in telephony were given in Departmental classrooms. This trend was continued in the 1948 revisions and concluded in the 1954 revision which provided that no instruction was to be given in outside technical colleges. The main reason for this move away from the use of technical colleges was the difficulty of controlling both the content and the timing of the theory instruction. Efficient instruction calls for a close integration of theory instruction with practical work and this was found to be difficult when outside bodies controlled the theory syllabus. Another weakness probably stemmed from the fact that often trainees had to learn a large amount or irrelevant theory in order to cover a few essential topics taught late in the technical college syllabuses. This attitude was expressed in the drastic reduction in theory instruction (1116 to 542 hours) which occurred when the use of technical colleges was discontinued in 1954.

Table 3 gives the amount and proportion of theory instruction in the syllabus at various times. It will be seen that apart from the 1954 syllabus, the amount of theory instruction has been of the order of 1,100 hours or more and the proportion of theory in the whole syllabus has varied between 40% and 58%. It appears that in breaking away from the use of technical colleges for theory instruction in 1954, there was too drastic a reduction in theory content which the 1958 and 1965 syllabuses have corrected.

Another interesting point is the amount of general theory material taught as opposed to applied or specialized theory material directly related to Departmental practice or equipment. Thus, for example, lectures on electro-magnetism may be regarded as general theory whilst lectures on the operation and construction of telephone relays may be regarded as applied or specialized theory. Table 4 sets out the changes in amounts of general and applied theory instruction in five of the revisions occurring in the 1926-65 period. It will be seen, that whilst the technical colleges were being used the amount of general theory instruction was high. However, in the 1954 revision, when technical college instruction was eliminated, the amount and proportion of general theory was reduced sharply. Although the 1958 revision increased the total theory content, the proportion of general theory was not increased to pre-1954 levels until the 1965 revision.

TABLE 4: TRENDS IN AMOUNTS OF GENERAL THEORY AND APPLIED THEORY IN TECHNICIAN-IN-TRAINING SYLLABUSES

YEAR	Amount of General Theory (1)	Amount of Applied Theory (2)	Ratio (1) : (2)
1926	798	546	1.5
1948	588	777	0.8
1954	162	376	0.4
1958	292	816	0.4
1965	542	763*	0.7*

*These figures vary according to Unit Courses undertaken

TABLE 3: CHANGES IN AMOUNT AND PROPORTION OF THEORY INSTRUCTION IN TECHNICIAN-IN-TRAINING SYLLABUSES

YEAR	No. of Hours of Theory Instruction	% of Total Syllabus Hours
1942	1,170	40%
1948	1,368	44%
1954	731	25%
1958	1,100	45%
1965	1,425*	58%*

*This figure varies according to Unit Courses undertaken.

Practical Instruction Trends: The development of practical skills in trainees is shared by the school, where basic skills are developed, and by on-the-job instruction where trainees develop specialized skills by taking part in actual work operations. On the job, the trainee is counted as part of the work force, and is required to perform actual productive work. In these circumstances it is difficult to be precise about the amount of instruction and guidance a trainee receives in the on-the-job training situation.

It is interesting to note that recent syllabus changes have reduced the amount of practical instruction given in the schools (See Table 5). The practical instruction elements which have been eliminated are mainly traditional exercises in woodwork and metalwork which involved the development of a degree of facility with hand tools which is not now required by the work situation. There has however also been some reduction in the amount of school instruction on equipment skills such as adjustments, etc., and to this extent it must be concluded that greater reliance is now being placed on on-the-job training for the development of practical skills.

Specialization Trends: The general trend in the directed or specialization phase of the syllabus has been toward a greater degree of specialization. This has been achieved by commencing specialized on-the-job training earlier in the course, and in the 1965 revision through the Unit Course approach to school instruction.

The various changes in specialized training arrangements are described briefly below:—

1926 — No specialization.

1942 — Specialization introduced. Available only to selected graduates (Mechanics Grade 1) from the primary course.
Qualifiers promoted as Mechanic Grade 2. Specialized training commenced at beginning of 4th year. Four categories:— Telephone Equipment, Tele-

TABLE 5: CHANGES IN AMOUNT AND PROPORTION OF PRACTICAL INSTRUCTION GIVEN IN SCHOOLS

YEAR	Amount of Practical Instruction in School Syllabus (hours)	Hours on School Practical instruction expressed as % of Total Hours spent on practical work in school and on-the-job.
1942	1,710	23%
1948	2,324	27%
1954	2,191	27%
1958	1,328	17%
1965	1,050*	14%*

*Thes figures vary according to Unit Courses undertaken.

	UNITS		1	2	3	4	5	6	7	8	9	10	11	12
CROSSBAR SWITCHING	INTRODUCTORY AND CONVERSION	AA	BASIC INTRODUCTION	PRINCIPLES	SWITCH & RELAY ADJUSTMENTS									
	ARF EXCHANGES	AB	FACILITIES, TRUNKING & SIGNALLING	BLOCK DIAGRAMS & GROUPING	ORIGIN. TRAFFIC CIRCUITS	REGISTER – L CIRCUITS	NON METRO IGV (GIV) CIRCUITS	METRO IGV STAGE CIRCUITS	SL STAGE (TERM) CIRCUITS	INTERWORKING CIRCUITS	INSTALLATION	MAINTENANCE		
	ARK521 EXCHANGES	AC	FAC. TRUNKING AND GROUPING	ORIGIN. TRAFFIC CIRCUITS	INTERNAL CALL CIRCUITS	OUTGOING CALL CIRCUITS	INCOMING CALL CIRCUITS							
	ARK511 EXCHANGES	AD	FAC. TRUNKING AND GROUPING	INTERNAL CALL CIRCUITS	OUTGOING CALL CIRCUITS	INCOMING CALL CIRCUITS								
	P.A.B.Xs	AE	TRUNKING	MAINTENANCE										
	ARM EXCHANGES	AF	ARM20 – TRUNKING GROUPING, CIRCUITS	ARM20 – REGISTER CIRCUITS * Note 1	ARM20 – MISC. R.S., ALARMS & POWER * Note 1	CONTROL EQUIPMENT CIRCUITS								
	ARB EXCHANGES	AG	FAC. TRUNKING GROUP. O/G CALL	ARB111 – OUTGOING CALL – CIRCUITS	ARB111 – I/C CALL AND P.B.X. EQUIP – CIRCUITS	ARB101 SYSTEM CIRCUITS	SERVICE CENTRE CIRCUITS	TEST EQUIPMENT						
TELEPHONE EQUIPMENT	SUBS EQUIPMENT	BA	TELEPHONE INSTRUMENTS	PUBLIC TELS. AND CORDLESS P.M.B.Xs	CORD LAMP SIGNAL P.M.B.X.	INTERCOMMUNICATION TELEPHONES								
	STEP – BY – STEP EXCHANGES	BB	SUBS. LINE CIRCUIT & TEST DESK	GROUP SELECTORS * Note 2	FINAL SELECTORS * Note 2	MULTI-EXCH WORKING & DISTORTION * Note 2	SPECIAL SERVICES ALARM & TESTING	2000 TYPE LINE FINDER SYSTEM						
	STEP – BY – STEP P.A.B.Xs	BC	UNI-SEL. LINE FINDER & UNIT TYPES	UNIT TYPE AND FAULTS										
	COUNTRY EXCHANGES	BD	50/200 LINE R.A.X.	40 LINE R.A.X.	SLEEVE CONTROL C.B. EXCHANGE									
	TRUNK EXCHANGES	BE	MOTOR UNI-SELECTOR & 2V.F. SIGNALLING	TRUNK SWITCHING	TRUNK EXCHANGE									
TELEGRAPH EQUIPMENT	THEORY	CA	TELEGRAPH CIRCUITS	MISC. SUBS EQUIPMENT	TRANSMISSION & DISTORTION	TESTING & TEST EQUIPMENT	FACSIMILE & REGEN REPEATERS	TAPE RELAY EQUIPMENT						
	MACHINES	CB	SIEMENS MODEL 100 (1)	SIEMENS MODEL 100 (2)	SIEMENS TAPE MACHINES	TELETYPE	TELETYPE TAPE MACHINES	TELEPRINTER						
	T.R.E.S.S.	CC	PRINCIPLES	CROSS-OFFICE TRANSMISSION	AUTO NUMBERING & LOAD DISTRIBUTOR	M.A.R. SEC. SWITCH AND FAULTS								
	CONVERSION	CD	INTRODUCTION TO TELEGRAPHY	PRINCIPLES OF TELEGRAPHY										
RADIO EQUIPMENT	INTRODUCTORY	DA	SERVICES TEST EQUIP & POWER SUPPLIES	R.F. AMPLIFIERS & OSCILLATORS	AMP. MODULATION & RECEIVERS	TRANSMISSION LINES & ANTENNAE								
	A.M. SOUND TRANSMISSION	DB	AUDIO EQUIPMENT	A.M. SOUND TRANSMITTERS	A.M. TRANSMITTER MAINTENANCE	STUDIO EQUIPMENT								
	R.T. SYSTEMS (H.F. & V.H.F.)	DC	H.F. RADIO COMMUNICATIONS	V.H.F. TECHNIQUES	V.H.F. RADIO COMMUNICATIONS	INSTRUMENTATION								
	TELEVISION	DD	PULSE TECHNIQUES WAVEFORM SHAPING	PULSE TECHNIQUES WAVEFORM GENERATION	VIDEO TRANSMISSION T.V. FUNDAMENTALS	VIDEO TRANSMISSION T.V. EQUIPMENT	BROADCASTING TRANSMITTERS	BROADCASTING AUXILIARY EQUIPMENT						
	BROADBAND R.T. SYSTEMS	DE	PULSE TECHNIQUES GENERAL	VIDEO TRANSMISSION GENERAL	U.H.F. & S.H.F. TECHNIQUES	U.H.F. & S.H.F. TECHNIQUES	BROADBAND SYST. GENERAL	BROADBAND SYST. DETAIL * Note 3	BROADBAND SYST. SUPERVISORY * Note 3	BROADBAND SYST. TESTING TECHNIQUES				
	CONVERSION	DF	RADIO FUNDAMENTALS											
LONG LINE EQUIPMENT	CARRIER EQUIPMENT	EA	TRUNK TESTING & QUALITY CONTROL	CARRIER & PROG. EQUIPMENT	RURAL & THREE CHANNEL SYSTEMS	V.F. TELEGRAPH SYSTEMS	12 CHANNEL SYSTEM CHANNEL EQUIP	12 CHANNEL SYSTEM GROUP EQUIP	BROADBAND SYSTEMS (1)	BROADBAND SYSTEMS (2)				
	T.V. TRANSMISSION	EB	T.V. SWITCHING & LINE TESTING	CO-AXIAL VIDEO TRANSMISSION * Note 4										
BASIC THEORY & GENERAL EQUIP	POWER	FA	POWER EQUIPMENT											
	ELECTRONICS	FB	TRANSISTORS & OTHER SEMI-COND											

*Notes — 1(a) Telephone
(b) Telegraph
2(a) 2000 Type
(b) Pre 2000 Type
(c) SC 50 Type
3(a) S.T.C.
(b) Marelli FV8 (Short Haul)
(c) Marelli FV14 (Long Haul)
(d) G.E.C.2
(e) Siemens
(f) N.E.C.
4(a) C.V. Transmission
(b) V.S.B. Transmission

Fig. 4 — The Unit Course Programme in the Present Technician-in-Training School Syllabus.

graphs, Broadcasting and Light and Power.

1948 — Specialization extended to include all trainees. Three categories: — Telephone Equipment, Radio and Telegraphs. Specialization commenced at start of 4th year for Telephone Equipment and Radio trainees, and at start of 3rd year for Telegraph trainees.

1954 — Only change in specialization training was to commence it earlier — in second half of 3rd year for all categories.

1958 — Specialization increased by splitting the Telephone Equipment trainees into two groups, installation and service, for on-the-job training. Trainees allocated to their specialization at end of 1st year.

1965 — Specialization increased to meet practically any existing or future requirement through the Unit Course technique.

Overall Trends: The overall trends in syllabuses which emerge from the above analyses are: —

(i) An initial trend away from general theory instruction which was expressed by a progressive withdrawal from participation in "outside" courses.

(ii) A swing back in recent years toward an increase in general theory instruction.

(iii) A progressive reduction in amount of practical instruction given in the school.

(iv) A progressive increase in degree of specialization training.

An observation which might be made at this stage is that the trend towards an increased general theory component in recent years might eventually justify reconsideration of technical college courses as the proper means for providing this type of instruction.

Comparison of Technician-in-Training Course with Outside Technical College Courses

A question often asked is, "How does the Department's Technician-in-Training course compare with courses in outside technical colleges?" A partial answer to this question can be obtained from an examination of the syllabuses but a complete answer would have to take account of such factors as differences in instructor-training requirements, relative standards of examinations, extent to which syllabus is actually taught, and course entrance standards.

The technician-in-training syllabus may be compared with trade training syllabuses on the one hand and with engineering technician certificate syllabuses on the other. Broad subjects taught in a typical electrical trades course in Victorian Technical Colleges are shown in Table 6. The subjects taught in the Sydney Technical College Communica-

TABLE 6: TYPICAL ELECTRICAL TRADES SYLLABUS (VICTORIA)

Subject	No. of Hours
Electrical Fitting Theory and Practice	108
Electricity and Magnetism	72
Trade Drawing	72
Trade Maths	72
Electric Wiring Theory and Practice	828
Elective Subject	144
TOTAL	1,296

tion Certificate Course are shown in Table 7.

These outside courses have been compared with the Departmental course on the following criteria:—

Entrance standard

Total number of hours of school instruction in syllabus

Amount of practical instruction in school syllabus

Total amount of theory instruction in school syllabus

Amount of general theory instruction

Amount of specialized or applied theory instruction

Ratio of general theory hours to specialized theory hours (this may be taken as a measure of the breadth of the theory syllabus).

Ratio of theory hours to practical hours.

The classification of theory instruction as either general or specialized, was mentioned when discussing trends in Departmental syllabuses.

TABLE 7: A COMMUNICATION TECHNICIAN CERTIFICATE COURSE — SYDNEY TECHNICAL COLLEGE

Subject	No. of Hours
English	72
Maths	388
Physics	108
Circuit Theory	388
Electron Devices	216
Communications	108
Measurements	108
Workshop Technology	108
Elective Subject (Radio, Television or Industrial Electronics) Theory	108
Practical	108
TOTAL	1,712

Theory instruction has been regarded as general when it involves the teaching of general principles which can be applied to a variety of situations or equipments. Thus principles of electricity and magnetism have been classed as general theory as have such topics as the principles of amplifiers and oscillators. On the other hand, lectures on particular items of equipment such as telephone relays, switching equipment, carrier and radio equipment have been classed as specialised theory. Mathematics, Physics and Circuit Theory are clearly general theory subjects. The subject Electron Devices in the Certicificate Course has been classed as general theory also, because topics in this subject mainly deal with general principles which are similar to topics in the telecommunication principles subject in the Departmental syllabus.

Table 8 sets out the results of the comparison of the three types of course on these criteria. The Departmental course is strongest in terms of the length of the overall school syllabus, in the amount of practical instruction given in the school, and in the amount of specialized theory. The trade course is inferior to the Departmental course in all the criteria examined in this analysis, but the certifi-

TABLE 8: COMPARISON OF TECHNICIAN-IN-TRAINING COURSE WITH ELECTRICAL TRADES COURSE AND COMMUNICATION CERTIFICATE COURSE

Criterion	Electrical Trade Course	Technician-in-Training Course	Engineering Technician (Communication Cert.) Course
Entrance Standard	Junior Technical Cert. or Intermediate	Pass in special maths and science papers and suitable standard in two aptitude tests. (The maths and science papers include topics taught in all State Intermediate Certificate level courses up to 2nd term of the Intermediate Cert. year).	Pass in Intermediate Cert. Maths I and II, English, Physics (or Combined Physics and Chemistry).
Total School Instruction	1,296 hours	2,475 hours (min.) 2,695 hours (max.)	1,712 hours
Amount of practical instruction in School Syllabus	648 hours	1,050* hours	108 hours
Total Amount of theory instruction	648 hours	1,425* hours	1,604 hours
Amount of General Theory	216 hours	688 hours	1,388 hours
Amount of Specialized Theory	432 hours	737* hours	216 hours
Ratio of General Theory to Specialized theory	0.5	0.9	6.5
Ratio of Theory to Practical	0.5	0.6	15.0

*Figure varies slightly according to unit courses taken.

cate course is strongest in terms of general theory content and entrance standard.

The level of maths in a course is often taken as an indication of the general level of the course. This is a reasonable enough assumption since maths is usually regarded as a "hard" subject by educators and the level of maths reached often determines the level to which science instruction can be taken. The level of maths in the certificate course appears higher than in the technician-in-training course. Topics taught in the certificate course include, simultaneous quadratic equations, expansion of series, calculus, simple differential equations, determinants, hyperbolic functions. When these topics are compared to those taught in the Departmental subject of telecom maths, the higher level of the certificate course in this aspect is confirmed.

It appears from this attempt to compare the technician-in-training course with outside trades and certificate courses, that the Departmental course falls somewhere between the trades and certificate courses. Table 9 places the courses in rank order or merit according to relevant criteria used in the above discussion.

TABLE 9: RANK ORDER OF COURSES ACCORDING TO VARIOUS CRITERIA

	Elec. Trade	Tech-in-Trng.	Eng. Tech.
Entrance Standard	3	2	1
Total length of School Instruction	3	1	2
Total theory	3	2	1
Breadth of theory instruction	3	2	1
Level of Maths	3	2	1
Overall Rating	3	2	1

Secondary Training Courses

Many new types of equipment adopted by the Department involve new skills and knowledge on the part of the technicians required to install, maintain and operate the equipment. Some of the skills can be developed by on-the-job training arrangements, but in many cases the numbers involved and the nature of the training call for the provision of formal training courses in the technician training schools. An important sector of the Department's training effort is concerned, therefore, with the provision of secondary training courses. (Ref. 2).

These courses are of variable length but usually do not exceed three weeks in duration. As the Unit Course programme for technicians-in-training develops, it is intended to provide unit courses for all secondary training needs, thus facilitating co-ordination of technician-in-training and secondary training programmes.

Editorial Note: Part II of this article will describe the training of linemen, school staffing, course design, programmed instruction, and future trends.

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APPENDIX I
THE 1926 JUNIOR MECHANIC-IN-TRAINING SYLLABUS

Year	Departmental Training (On-the-job)		School Training in "Outside" Technical Colleges	
	Subject	Period	Subject	Period
1st	Manual Switchboard Operating Workshop Training Use of tools, batteries, simple repairs, assembly work	1 month 11 months	Elementary Science Practical Maths or Trade Calculations Workshop Course Elementary Mechanics Trade Drawing	8 hrs/week*
2nd	Workshop Training (Cont'd) General repairs, switchboard repairs, wiring and testing Subscribers Installation	 7 months 5 months	Heat Magnetism and Electricity Practical Maths II Trade Drawing II Applied Electricity I Telephony I	8 hrs/week*
3rd	Subscribers Installation (Cont'd) Subscribers Maintenance	3 months 9 months	Applied Electricity II Practical Maths III Telephony II	8 hrs/week*
4th	Subscribers Maintenance (Cont'd) Manual Exchange Installation and Maintenance	3 months 9 months	Applied Electricity III Telephony III Internal Combustion Engines I	4 hrs/week xx
5th	Automatic Exchange Installation and Maintenance	12 months	Telephony IV Internal Construction Engines II Telegraphy	4 hrs/week xx

*4 hours in Departments time, 4 hours in trainees time. xx all in trainees time.

APPENDIX II
THE 1958 TECHNICIAN-IN-TRAINING SYLLABUS

Year	Trainees	Departmental School Training				On-The-Job Training	Period
		Lessons		Practical Work			
		Subject	Period	Subject	Period	Subject	Period
1st	All	Induction Telecom. Principles I Drawing First Aid Basic Electricity Telephony, Radio, Telegraphy Telecom. Practice	3 days 15 hrs 6 hrs 126 hrs 126 hrs 132 hrs	Telecom. Principles I Practical work associated with tools materials and equipment covered in Telecom. Principles lessons	44 weeks less time spent on lessons		
2nd	All	Telecom. Principles 2 A.C. Electronics Line Transmission	 80 hrs 65 hrs 38 hrs	Telecom. Practice Practical work associated with theory lessons	58 hrs		
	Telephony and Long Line Equip. — Installation	Telephony	95 hrs	Telecom. Practice Practical work associated with theory lessons	58 hrs	Telephone Equipment Installation	46 weeks less time spent in school
	Telephony and Long Line Equip. — Service	Telephony	95 hrs	Telecom. Practice Practical work associated with theory lessons	58 hrs	Telephone Equipment Service	46 weeks less time spent in school
	Radio	Radio	95 hrs	Telecom. Practice Practical work associated with theory lessons	58 hrs	Radio Equipment Installation and Service	46 weeks less time spent in school
	Telegraph	Telegraphy	95 hrs	Telecom. Practice Practical work associated with theory lessons	58 hrs	Telegraph Equipment Installation and Service	46 weeks less time spent in school
3rd	Telephony and Long Line Equip. — Installation	Telecom. Principles 3 L.L. Equipment Telephony	 131 hrs 147 hrs	Telecom. Practice Practical work associated with theory lessons	58 hrs	Telephone and L.L. Equip. Installation	46 weeks less time spent in school
	Telephony and Long Line Equip. — Service	L.L. Equipment Telephony	131 hrs 147 hrs	Telecom. Practice Practical work associated with theory lessons	58 hrs	Telephone and L.L. Equip. Maintenance	46 weeks less time spent in school
	Radio	L.L. Equipment Radio	78 hrs 200 hrs	Telecom. Practice Practical work associated with theory lessons	58 hrs	Studio operation and Maintenance	46 weeks less time spent in school
	Telegraph	L.L. Equipment Telegraphy	78 hrs 200 hrs	Telecom. Practice Practical work associated with theory lessons	58 hrs	Telegraph Maintenance	46 weeks less time spent in school
4th	Telephony and Lone Line Equip. — Installation	Telecom. Principles 4 Telephony L.L. Equipment	 74 hrs 73 hrs			Metro and/or Country Installation	44 weeks less time spent in school
	Telephony and Long Line Equip. — Service	Telephony L.L. Equipment	74 hrs 73 hrs			Telephone and L.L. Equip. Maintenance	44 weeks less time spent in school
	Radio	Radio	147 hrs			Transmitter Operation and Maintenance	44 weeks less time spent in school
	Telegraph	Telegraphy	147 hrs			C.T.O. Maintenance	44 weeks less time spent in school
5th	All	Nil.				Full time on the job training in duties of Section to which allocated.	46 weeks

APPENDIX III

ALLOCATION OF PERIODS TO THE VARIOUS TOPICS TAUGHT IN EACH OF THE SUBJECTS IN THE 1965 TECHNICIAN-IN-TRAINING SYLLABUS

TELECOM. PRINCIPLES

Topic	No. of Periods (55 minutes)
Simple electron theory	5
Current Electricity, basic electrical circuits, electric energy — power	29
Cells, batteries, electrolysis	17
Magnetism and magnetic materials	16
Electromagnetism	36
Motors, generators and rectifiers	33
A.C. theory and circuits	97
Measurements and measuring instruments	33
Electron tubes	42
Solid state electronics	46
Amplifiers	57
Oscillators	22
Modulators	11
Multivibrators	4
Revision, tests, exams	52
TOTAL	500

TELECOM. TECHNIQUES

Topic	No. of Periods	
	Theory	Practical
Introduction	8	3
Materials used in Telecom.	6	1
Manual switching components — equipment	23	42
Signalling circuits and components	7	20
Protective components	2	8
Electro-acoustic components	11	8
Subscribers telephone service and facilities	33	49
Telephone relays	16	46
Resistors	2	
Automatic telephone equipment	107	100
Telegraph service	15	
Telephone and telegraph lines	16	
Telephone networks	9	
Radio and TV Service	15	
Transmission	62	
International communications	2	
Maintenance and measuring and fault finding techniques	10	82
D.C. motors		3
Telegraph relays		16
Power plant	19	12
Amplifiers		32
Oscillators		12
Transistors		12
Electron tubes		8
Revision, tests and examination	42	
TOTALS	405	451

TELECOM. MATHS

Application of Maths Processes to Promblems in	No. of Periods (55 minutes)
Current electricity	4
Electric circuits	8
Electrical energy — power	3
Magnetic circuits	2
Electromagnetic induction	6
Capacitors and inductors	5
Measuring instruments and measurements	6
A.C. theory and circuits	48
Electron tubes	7
Solid state electronics	15
Equipment maintenance (graphs)	2
Generators, motors and rectifiers	5
Amplifiers	13
Transmission	9
Oscillators	9
Revision, tests and exams	42
TOTAL	184

TELECOM. PRACTICES (INCLUDES UP TO 50 LESSON AND DEMONSTRATION SESSIONS)

Topic	No. of Periods (55 minutes)
Safety precautions	6
Equipment construction and use and care of tools	100
Stripping, forming, lacing and terminating cables	96
Fixing equipment to walls and floors	30
Wiring of standard equipment	76
Maintenance and replacement of parts, and servicing equipment	66
Testing lines and equipment	26
Visits to telecom. centres and repair and maintenance of training equipment	80
Orientation to equipment and practices in Section to which allocated	80
TOTAL	560

TELECOM. DRAWING

Topic	No. of Periods (55 minutes)
Drawing types	4
Drawing methods	2
Drawings for equipment and plant	12
Lines and lettering	2
Circuit reading	6
TOTAL	26

THE ALBURY CUTOVER

*D. L. Shaw, B.E., A.M.I.E.Aust.**

INTRODUCTION

The climax of an installation project is the "cutover" when the new equipment is placed into service. When the cutover involves changing a large country telephone network from manual to automatic working, it is essential that the whole operation be carefully planned and controlled so that every participant in the cutover knows exactly what to do and when to do it. Over the years a number of successful techniques and procedures have been developed by Installation Engineers to plan and control cutovers. The aim of this article is to describe some of these techniques and procedures which were used at Albury. It is hoped that they will be of interest to those who have not had the opportunity to be associated with the cutover of a large automatic network.

THE ALBURY PROJECT

General Description

The cutover of the Albury subscribers from manual to automatic working was part of the final stage of a three stage cutover for the whole of the Albury Secondary Telephone Network.

The Albury project covered three activities:

(a) The establishment of the Albury Secondary Trunk and Junction Switching Scheme,

(b) The rearrangement of the Sleeve Control 2VF Transit Trunk Switching Scheme,

(c) The cutover of 3062 Albury C.B. Subscriber's lines to automatic working.

The Secondary Switching Scheme used the crossbar GV stage as the switching medium to connect incoming circuits to a total of 37 outgoing routes to trunks, junctions and service levels. Details of the types of routes and number of circuits in each are shown in Fig. 1. Fig. 1 also gives a diagrammatical presentation of the cutover arrangements.

Because of the complexity and size of the switching scheme it was decided that the whole cutover be done progressively in stages over a 5 week period, rather than attempt to cutover the whole scheme instantaneously.

The complexity is illustrated, for example, by the practical problems in the introduction of S.C.D.C. (single commutation double current) dialling over a circuit which was previously 17 cps ring. Associated with this is the problem of modification and testing of magneto switchboards for dialling and push button metering facilities. The size can be appreciated from the fact that it would just not have been possible to have staffed, even with a total of 57 installation and maintenance technicians, the large number of widely separated exchanges to meet the requirements of an instantaneous cutover.

Sequence of Cutover

The sequence of the cutover was as follows:

First and Second week
Establishment of trunk and manual office junction routes,

Third and Fourth week
Cutover of the C.A.X's so that they trunked through the crossbar exchange to the Albury Trunk Telephonists,

Fifth Week
No cutovers — final preparations for subscriber's cutover

Final 9 hours
From 10 p.m. to 6.30 a.m. (8½ hours). Change of the transit dial codes and thorough testing of the transit for "tail eating" operation.

From 6.55 a.m. to 7.00 a.m. (5 minutes).
(a) Cut away of subscribers from the CB manual exchanges,
(b) Conversion of Albury North exchange to "trombone" working into the Albury crossbar exchange.

From 7.00 a.m. to 7.02 a.m. (2 minutes). Cutover of subscribers onto the crossbar exchange.

The details of activities between 6.50 a.m. and 7.10 a.m. of the subscribers cutover day (26th June, 1965) are given in Table 1 and are described under the section heading "Subscribers Cutover".

Staffing

As this project was large and complex it was placed under the control of an Engineer (Class 2) with three Supervising Technicians resident at Albury. A Supervising Technician Grade 3 was responsible for the crossbar exchanges and its ELSA area, a Supervising Technician Grade 2 for the re-arrangements and preparations in the C.B. and sleeve control trunk exchange and a Supervising Technician Grade 1 for the Subscriber's telephone conversions.

*Mr. Shaw is Engineer Class 3, Systems Development, Research Laboratories and at time of writing was Engineer Class 2, Country Installation, N.S.W.

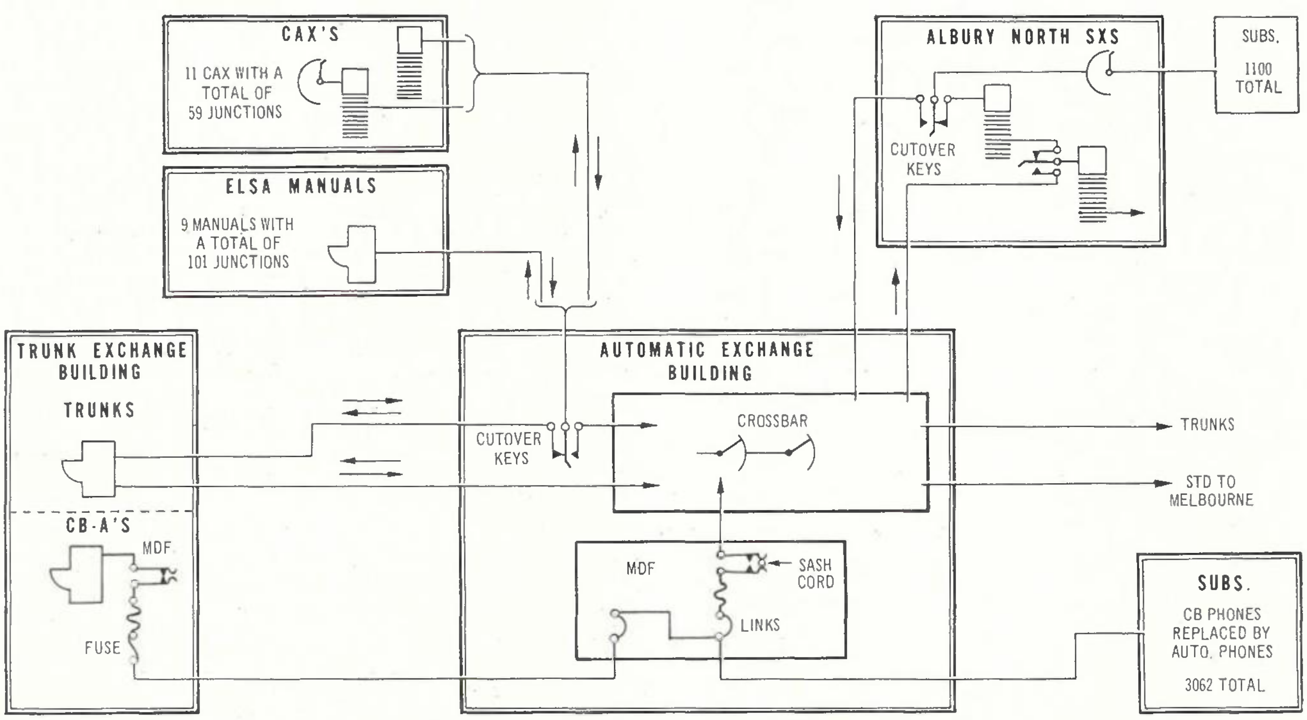


Fig. 1. — Albury Cutover Arrangements.

THE TECHNIQUES AND PROCEDURES

The following techniques and procedures as used at Albury are described in this article:

(a) Regular co-ordinating conferences,
(b) Production of a Cutover Handbook,
(c) Production of a Cutover Programme,
(d) Use of a Cutover Intercommunication Network.

Co-ordinating Conferences

Regular weekly conferences were held to co-ordinate the activities of the three Installation Supervising Technicians, the Maintenance Supervising Technician, the Victorian Installation Group and the Telecommunication Division Staff. Minutes of each conference were prepared and distributed to those who attended. The exchange of ideas and the airing of problems established good will and a strong feeling of team spirit which was of incalculable value to the ultimate success of the project.

The Cutover Handbook

As there were many local and distant groups working in support of the Installation Group at Albury it was important that they be advised of the programme of events, the proposed cutover techniques and whom to contact for questions.

To meet these requirements and to provide useful information for all participants in the cutover, a cutover handbook was produced in early May, two weeks before the commencement of the trunk and junction cutover. The foolscap sized handbook was made up of 14 typed pages, 5 pages of explanatory diagrams and a distinctive cover. The handbook was prepared and published by the N.S.W. Engineering Drawing Office Staff from material supplied by the Albury Installation Staff.

The handbook contained the following sections:

(a) An outline of the project,
(b) A time table of events,
(c) Details of the Trunk Exchange rearrangements,
(d) Details of the ELSA junction cutovers,
(e) Details of the subscribers cutover.

Appendices in the handbook covered the following:—

(i) Albury Installation Organisation Chart.
(ii) Temporary Crossbar Telephone Directory,
(iii) Crossbar dialling codes alphabetically and numerically,
(iv) Transit access codes, alphabetically and numerically,
(v) List of useful telephone numbers of associated Groups in New South Wales and Victoria.
(vi) A list of all the trunk and junction relay sets used in Albury Crossbar Exchanges.

The handbook was used extensively by many "distant" Groups such as the Installation and Telecommunication staff at the Melbourne and Sydney Trunk Exchanges.

The Cutover Programme

As the cutover handbook was produced 8 weeks before the subscribers cutover and covered the whole 5 weeks of the cutover period (23rd May to 26th June) a special cutover programme was produced for the establishment of the subscriber's exchange. This cutover programme like its predecessor was also a foolscap sized book.

As the aim of the cutover programme was to specify in detail exactly what had to be done at a definite time by a particular person, it was of necessity produced in the final days before the subscriber's cutover.

In this case all the detail of the programme was finalised at the regular conference 5 days before cutover. A local commercial duplicating service then very speedily reproduced the programme

TABLE 1: PORTION OF THE DETAILED CUTOVER PROGRAMME

Item	Time	Locality in Albury	Activity	Responsibility
11	6.50 a.m.	CB Manual and Trunk Exchange	(a) Clear all PGs — advise new MDF staff of PGs. (b) Clear all CB and CB subs. trunk calls, (c) Connect only short duration urgent calls.	**CI 6** (Installation Staff) Supv. Tech. Sawtell Sen. Tech. Meridith **Telecom.** Div. Staff Earle Leonard
12	6.50 a.m.	Albury North	(a) Clear all PGs, (b) Clear all 1st Selectors. (c) Cutover balance of I/C junctions from crossbar.	**CI 6** Sen. Tech. Garling
13	6.50 a.m.	Crossbar	Block all local registers except Reg K.	**CI 6** Supv. Tech. Hardie
	6.55 a m.		CUTOVER STEPS	
14	6.55 a.m.	CB Manual	(a) Remove fuses from MDF. **See** Cutover Handbook drawings NSK.11266 shts. 1 and 2.	**CI 6** Sen. Tech. Meridith
15	6.55 a.m.	Albury North	(a) Throw cutover keys for O/G junctions to crossbar. (b) Cutover PTs to Crossbar,	**CI 6** Sen. Tech. Garling
16	7.00 a.m.	MDF (new)	(a) Remove Sash Cords — Miss Talbot 1st 200 lines then 800 lines at a time.	**Guest of Honour** Miss M. Talbot **CI 6** Sen. Tech. Chapman
17	7.02 a.m.	Crossbar	(a) Clear all PGs, (b) Release local registers.	**CI 6** Sen. Tech. Hardie
18	7.05 a.m.	Public Telephones	Check operation into the crossbar	**CI 6** Supv. Tech. Mumby
19	7.05 a.m	Crossbar	(a) Check power equipment, (b) "Observe" traffic, (c) Spot check on O/G trunk and junction routes.	**CI 6** Supv. Tech. Hardie
20	7.10 a.m.	P.A.B.X's	Check operation into the crossbar.	**CI 6** Supv. Tech. Mumby

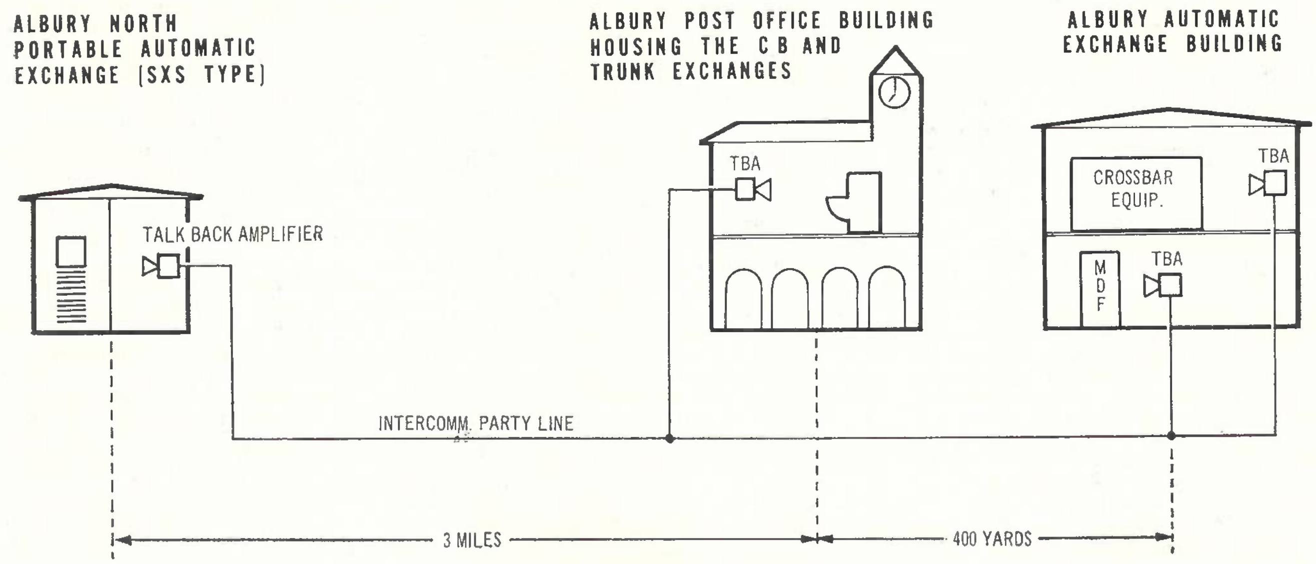


Fig. 2. — Albury Cutover Intercommunication Network.

using the conventional Roneo process. In this way the programme was available for all staff to study in the final days before cutover.

The cutover programme contained three Sections:—

(a) An outline time programme,
(b) A detailed cutover programme,
(c) A list of staff and their responsibilities.

A section of the detailed cutover programme is reproduced as Table 1.

It will be seen that each stage of the cutover was:—

(a) Given an item number for reference,
(b) Described by time, location and activity,
(c) Allocated as a task to a member of the staff.

Two days before the subscriber's cutover all the 57 installations and maintenance technicians who were to participate in the cutover attended a special briefing, where each man was given a copy of the cutover programme.

By use of blackboard diagrams and reference to the cutover programme the details of the cutover were explained to the staff. In this way every man was advised of what was going to happen and what was his responsibility.

Besides "timing" the activities, the printed programme enabled participants to refer to an activity by an item number, thus avoiding confusion in verbal orders and reports. The application of this cross reference to an item is described in the next section.

The Cutover Intercommunication Network

The subscribers cutover involved co-ordinated timed activities at four widely separated localities (see Fig. 2). The method of co-ordinating the activities was to establish an intercommunication network using talk back amplifiers working on a "party line" system.

TABLE 2: PORTION OF THE CUTOVER SCRIPT AS USED AT ALBURY

Step	Time	Sender	Message	Reply
10	6.50	MDF	All stations 6.50 time call — call given using Melb. "Time".	Albury North Heard CB Heard Crossbar Heard
11	6.50	MDF	CB Carry out Item 11	CB will do
12	6.51	MDF	Albury North Carry out Item 12	Albury North will do
13	6.52	MDF	Crossbar Carry out Item 13	Crossbar will do
14	6.53 approx.	CB	CB Item 11 completed	MDF Thank you
15	6.54 approx.	Albury North	Albury North Item 13 completed	MDF Thank you
16	6.55 approx.	Crossbar	Crossbar Item 13 completed	MDF Thank you
17	6.55	MDF	Carry out Item 14	GB will do
18	6.55	MDF	Albury North Carry out Item 15	Albury North will do
19	6.59 approx.	CB	CB Item 14 completed	MDF Thank you
20	6.59 approx.	Albury North	Albury North Item 15 completed	MDF Thank you
21	6.59	MDF	All stations Listen in — Crossbar about to cutover — Miss Talbot will you please prepare to cutover the first 200 lines.	No replies
22	7.00	MDF	Miss Talbot cutover now please Sen. Tech. Chapman cutover 800 lines please Tech. Heffernan cutover next group please.	

Network stations were established at:
(a) Albury North
(b) The CB and Trunk Exchange
(c) The MDF in the crossbar building
(d) The crossbar equipment room.
The MDF station acted as "control" for the network.

The party line arrangement allowed all stations to hear what was going on at any one station. Also it provided the means whereby one station could instantaneously call up another station if there was trouble.

As the cutover had to go to a set programme that required that each stage to be successfully completed before the commencement of the next stage, a cutover script was prepared. A sample of the actual cutover script is shown as Table 2.

The cutover script was composed using Military radio communication voice procedure. From Table 2 it will be seen that following an instruction, an acknowledgment of receipt of that instruction was given by the receiver. The same acknowledgment technique applied to the advice of the completion of each stage. In this way the controller was able to see by his "marked off" script the exact stage of the cutover. The script was designed to serve as a basic "skeleton" of the messages to be passed.

It might be noted that the script referred to items on the cutover programme. By using this cross reference to a standard instruction there was no confusion as to what had to be done. This allowed instructions to be very brief, leaving the network "clear" for any urgent traffic. Also it allowed all participants and visitors by using their programmes to follow the progress of the subscriber's cutover in detail.

After a little uncertainty during the rehearsals the operators became confident and proficient on the intercom and it was proved that the use of the intercom was a great success. Elaborate care was taken to ensure that the party line itself was clear of all cutover arrangements. As a safety precaution a back up magneto order wire was established between the CB and auto exchanges.

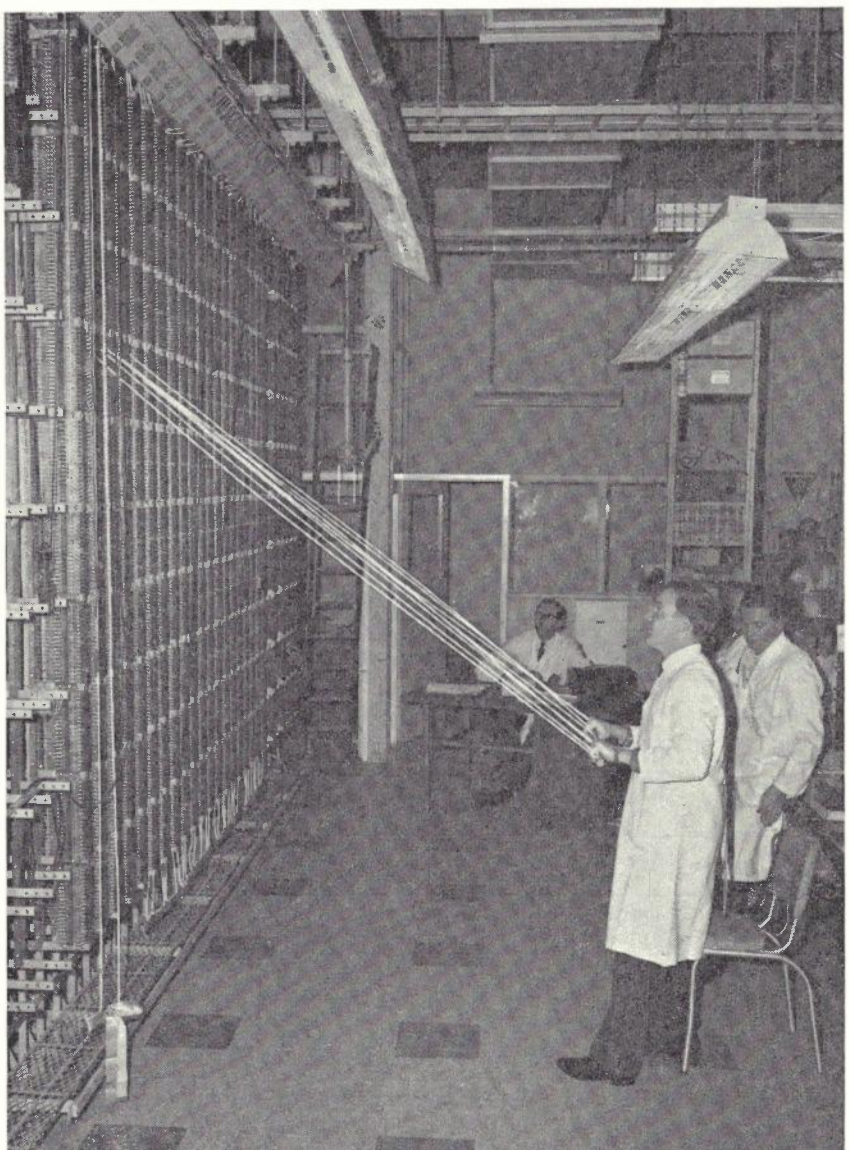


Fig. 3 — Cutting Over the First Large Group of Subscribers. (Photograph by courtesy of Border Morning Mail).

THE SUBSCRIBERS CUTOVER

An early Saturday morning cutover was chosen because:

(a) The Saturday morning business traffic would subject the exchange to a heavy load of limited duration, followed by a day and a half of light traffic before Monday morning business. In this way the Installation staff had plenty of time to isolate and correct any faults that the initial traffic load might reveal.
(b) An early morning cutover uses the staff when they are at their best mental and physical condition, and if required staff can be used for the full day.

The "Cutover" commenced at 6.30 a.m. and concluded at 7.20 a.m. It was made up of the following stages

6.30 a.m. (a) Opening of the intercom. network
(b) Pre-cutover tests
6.45 a.m. Preliminary cutover steps
6.55 a.m. (a) Cut away of subscribers from CB exchange by removal of the old MDF's fuses and links.
(b) Cutover of Albury North to trombone working into Albury Crossbar.
7.00 a.m. Cutover of subscribers on to the crossbar exchange by removal of sash cords.
7.02 a.m. Immediate post cutover activities.
7.05-7.20 a.m. Post cutover tests and checks.

The timings and co-ordination can be seen by reference to Table 1.

The actual cutover of the crossbar exchange was carried out by six technicians in turn, each cutting over approximately 800 lines at a time. The first 200 lines were cutover by the Supervisor of the Trunk Exchange, Miss M. Talbot, as a token of the recognition of the services of the Albury telephonists over the 67 years of the subscriber's manual exchange operation.

From Fig. 3 it will be noticed that sash cord technique was used. This method can only be used where the MDF has 40B type arrestors on the equipment aids. As the proposed practice is to use link blocks on future MDF's, a new cutover technique will have to be developed.

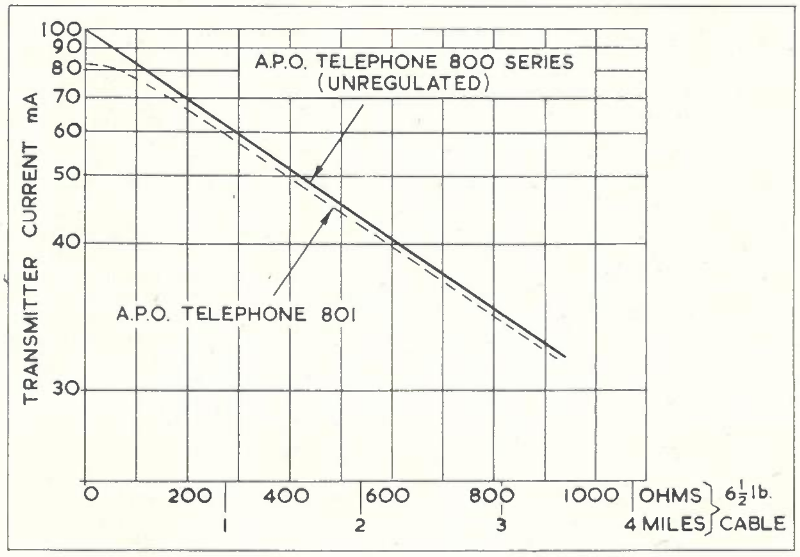
As a result of an appeal through the Press there was no local subscriber traffic in the last 15 minutes before cutover. The appeal also requested subscribers not to lift the receivers of their telephones when they heard the bells tingle during the cutover. As a result of the appeal there was no inconvenience to subscribers due to broken conversations or lack of dial tone due to unnecessary register blockages.

SUMMARY

The aim in any cutover is to introduce a new system of telephone operation with the least amount of inconvenience to the subscribers. In country centres the change from manual to automatic working plus the introduction of a large area switching scheme with S.T.D. has many problems that are not met in Metropolitan areas. The author considers that the employment of the described techniques and procedures at Albury were invaluable in the successful completion of such a large project. It is hoped that these ideas may be of use to Installation Engineers in charge of future large country exchange type cutovers.

ERRATUM

The transmitter current scale for the 801 telephone shown on Fig. 11 on page 439 of Vol. 13, No. 6 is incorrect. The correct scale is shown below:



TECHNICAL NEWS ITEM

CARRIER GENERATOR FREQUENCY SYNTHESISER

Within the telecommunications network operated by the P.M.G.'s Department, the requirement for continuous reliable operation of carrier systems has become increasingly important. Loss of a single carrier oscillator frequency can result in serious loss of service.

To increase the already high reliability of their carrier network, Victorian Country Branch asked that the Research Laboratories develop an emergency carrier oscillator, possibly in the form of a crystal oscillator allowing the use of plug-in crystals covering two frequency ranges — approximately 50-110 kc/s and 300-600 kc/s. After considering the difficulty and expense involved in producing crystals, in the frequency ranges required, which could be plugged in and oscillate within 2 parts in 10^6 of nominal frequency, it was decided instead that the development of a frequency synthesiser as an emergency carrier-frequency generator could be justified for use in both present and future systems.

Several methods of frequency synthesis were considered. The system evolved in the Frequency Standards Division of the Laboratories will more than fulfil the present requirement of Country Branch and offers possibilities of development for other applications, such as VLF synthesis.

Synthesiser

A block diagram of the system is shown in Fig. 1. The voltage controlled oscillator (VCO) is an LC oscillator, varactor-tunable from approximately 4.5 to 6.5 Mc/s. For synthesiser use its required output range is 5.001 Mc/s to 6.000 Mc/s. The sine wave output of the oscillator is squared in a zero crossing pulse generator and drives a digital frequency divider with a variable division ratio N. N can be varied in unit steps from 5001 to 6000 inclusive. The frequency divider output is applied to one input of a sawtooth phase comparator and its phase is compared to that of a 1 kc/s signal from the reference crystal oscillator. The phase comparator output voltage, after filtering in the low pass RC filter, is applied to the varactor in the oscillator tuned circuit and used to control the frequency of the oscillator. The loop so described is a phase controlled loop and will control the oscillator frequency such that when the loop is 'in lock' at any given divider ratio N the output of the frequency divider will be 1 kc/s, with a constant phase relative to the 1 kc/s reference. The constant phase difference is sufficient to produce a constant voltage output from the phase comparator to tune the oscillator to a frequency of N x 1 kc/s. Therefore when 'locked', the oscillator frequency can be set to 5001 kc/s to 6000 kc/s in 1 kc/s steps.

The resulting oscillator frequency is mixed, in a switched or keyed mixer, with 5 Mc/s from the same reference crystal oscillator which supplies the 1 kc/s reference. The two references are coherent and have a constant frequency ratio. The mixer, which operates by alternately passing and blocking the VCO output at the 5 Mc/s rate, has a sin x/x spectrum-output with discrete components given by the sum and difference frequencies between its two inputs. The low pass LC filter, having a cutoff frequency at 1.1 Mc/s, passes only the lower sideband components of the mixer output. For example, for N = 5308, VCO output frequency is 5.308 Mc/s and is mixed with 5.000 Mc/s to produce 0.308 kc/s, 4.702 kc/s, 5.308 Mc/s etc. The only output from the LC filter will be 308 kc/s. The filtered output is amplified and is then available for further amplification if necessary.

The stability of such a synthesiser can be very nearly as good as the frequency stability of the crystal reference oscillator itself. Further work will be devoted to an investigation of the incorporation of an integrator in the phase-controlled loop to produce a true phase-locked oscillator.—I.P.M.

THE P.M.G. CENTRAL ENGINEERING LIBRARY

*M. CUZENS, B.A., A.L.A.A.**

INTRODUCTION — THE INFORMATION EXPLOSION

Gone is the day when the scientific and technical man could personally cope with an adequate coverage of the literature which communicated to him most of what was going on in his speciality — the latest discoveries and inventions, different and revised methods and new ideas. The increasing difficulty for the scientist and technologist to keep abreast of his subject fields has brought to him the awareness of the increasing flood of literature covering his own and related fields of science and technology and of the very real possibility that solutions to many current research problems may be submerged somewhere in the flood. Resulting from this state of affairs there has been a rapid growth of the technical library and an expansion of its functions, until now, the scientist and technologist see the need to learn the proper use of library facilities as an indispensable tool in keeping abreast of the latest information in their speciality.

To the librarian, who must handle the literature for more than one speciality, the problem is even more apparent. The Postmaster - General's Department Engineering Library receives approximately 700 periodical titles with up to 52 issues per year and acquires some 2,500 books, pamphlets and reports per year. Even so this is only a small fraction of the total output of scientific literature. Figures published in 1958 showed that scientific periodicals totalled 55,000 titles at that time and this number was expected to increase to 100,000 by 1979 and 400,000 by 2,006. Chemical Abstracts increased its volume by 143% between 1949 and 1959 and the National Research Council of Canada has estimated that 60,000,000 pages of scientific information are being published annually. (Ref. 1).

If it is to be of any use, this material, must be handled efficiently and speedily to ensure that the information reaches the user before it is out of date and to ensure that it can be readily retrieved when required. Computers are already being used by some libraries to assist with the storage and retrieval of information and the need for some form of automation in libraries is becoming more apparent.

SPECIAL LIBRARIES

Of course, no one library, certainly at less than a National level, attempts to handle all the world's scientific literature. Special libraries (the librarian's term for libraries which handle a particular subject or group of subjects) are set up by organisations such as government departments, learned societies and industrial and commercial undertakings to deal with material on the subject or subjects of specific interest to the organisation concerned. A special library will, of course, also hold a certain amount of material on subjects of fringe interest. It has two essential qualities; its information is up to date and it offers service. An important distinction between it and other types of libraries is that it deals with and files information rather than publications. For the most part the people who use it are scientists, medical practitioners, engineers, research workers and other professionally and technically trained people. No special library can ever be entirely self-sufficient and its staff must know how to locate information outside the library as well as in it. Thus a well-trained staff will accurately and economically be able to supplement its own resources and contribute to the organisation's daily activities.

ORGANISATION AND POLICY OF THE P.M.G. ENGINEERING LIBRARY

The P.M.G. Engineering Library is a Special Library with telecommunications as its central subject. The associated subject fields covered include electrical and electronics engineering, physics, chemistry, metallurgy, mathematics, statistics, automatic data processing, computer technology, mechanical and technical aspects of transport, building and management.

Although located in the P.M.G. Research Laboratories, the Library provides a service to all officers of the Engineering Divisions and assists all other officers of the Department where possible in scientific and technical problems. Under the Senior Librarian it is staffed by trained Library Officers assisted by clerical officers. A position for a Technical Librarian has not yet been filled. Some of the Library Officers are "outposted" to staff branch libraries providing a more local service to Plant Sections and the Planning Branch.

The Department's State Engineering Libraries are independent from the Central Engineering Library as far as organisation is concerned but depend on it for information not available in their own collections.

LIBRARY SERVICES

The Library staff are engaged in the following services, all aimed at making information quickly available to its customers.

Selection — Building the Collection: Book-trade catalogues, government lists, publishers' advance notices, periodical literature book reviews, staff suggestions, bibliographies, etc. are perused and, if possible, relevant publications are obtained on approval from book shops. These are referred, usually to the engineer specialising in the particular field, for evaluation and recommendation for purchase. If it can be definitely established from review information available that a publication is pertinent to requirements, it will be purchased outright without first obtaining it on approval. All officers in the Engineering Divisions are free to bring to the Librarian's attention information about any publication likely to be of interest.

Technical Services: This involves acquisition, ordering, processing and cataloguing of all publications; in fact, generally making the material available. It is on the efficiency with which this work is carried out that the library depends; if a publication is not classified and catalogued correctly, it is likely to be irretrievable.

Loans: All library material going out to the library's users, other than current journals on circulation, passes through the Loans desk. This includes also material borrowed from other libraries on inter-library loan.

Reference Services: Reference work in any library consists of the exploitation of the stock for the benefit of the readers. The reference staff must know the holdings of its own library and have a good idea of what exists in other libraries, particularly in those dealing with similar subjects. Reference work can involve anything from checking a date of publication to the compilation of an extensive bibliography. The reference librarian has the task of aiding readers with all the library's resources. Much reference work consists of locating specific information; for example, what firm makes a certain type of transistor; what is the derivation of a certain word; what are a certain person's academic and other qualifications. Most of these answers are found in directories, trade catalogues, encyclopaedias, etc.

The Library has only recently commenced to build up its collection of reference material. This includes such publications as a full run of the Official Year Book of Australia, scientific and technical language dictionaries, year books such as Whitaker's Almanac, atlas and street directories, road maps and Encyclopaedia Britannica. These publications form a special section in the Library and are not available for loan, their purpose being that of reference.

Literature Searches: These involve an extensive search for information on a specific topic, usually confined to one or two facts and ranging through all the library's resources. To be effective, all possible clues as to what the information is to be used for, what the project is and how information may be related to known facts of larger topics have to be obtained from the person requesting the search. The librarian must know the earliest and latest dates of information likely to be useful, also the degree of thoroughness of the search or minuteness of the information desired. The

*Miss Cuzens is Senior Librarian, Research Laboratories.

advice of the Laboratories' Information Officer and the specialised knowledge of other members of the Laboratories' staff can be called on when required.

Subject Interest Index: An index of subject interests of all officers is being compiled. It is a very simple system of entering subjects on cards and listing the names of the officers having such interests on that particular card. By this method the library staff is able to divert new publications to the right person speedily. As the Library subscribes to the card service of "Engineering Index" this subject interest index is used to divert a copy of each card to the person who is most likely to be interested. This is a valuable method of acquainting engineers of work being carried out in very specialised fields.

Accessions List: This is issued monthly. It lists all the publications (excluding periodicals) processed during the previous month. Further, it indicates the availability for loan and if the publication is likely to be of interest for acquisition by the Department's Engineering libraries in the States.

Quite a number of libraries throughout Australia receive this list, usually on an exchange basis for their own, and arrangements can be made for any person or organisation outside the Department to receive a copy.

Translation Services: These services are provided by the Department's Translation Section. Arrangements for translation of all foreign language library material are made through the library. The person requesting the translation receives a copy, one copy is placed in the library, one is sent to the C.S.I.R.O. National Standards Laboratory, and one copy is sent to London. This procedure is part of inter-library co-operation in making known that a translation has been made and this often avoids the expense and effort of other institutions translating the same work.

Index to Journal Articles: Each officer is encouraged to indicate for indexing any article appearing in a circulated periodical; it may be one he thinks he may need later, or it may be pertinent to the work of the Department either in the present or the future. In the library these articles are listed on cards under specific subject headings which are filed alphabetically. Anyone has access to this index. It can be used as a first step in a literature search.

Circulation of Periodicals: Current issues of some seven hundred titles are circulated around twenty-three locations in Melbourne. This is a mammoth task and some journals can be over a year old by the time they complete their circulation. To begin with, overseas journals are often months old by the time they reach Australia by ship, then each of the twenty-three locations requires each issue of the periodicals in which officers have an interest for a period of one to three weeks. The period depends on the number of people to see it. Naturally, the library endeavours to circulate periodicals first to the people with a primary rather than a fringe interest in the subject field.

A routing slip is attached to the front of each issue and this provides space to indicate articles for indexing, pages required to be copied by the Xerox process and any other notes.

Xerox Copying: To facilitate speedy circulation of information in periodicals, Xerox copies of articles of particular interest will be made on the return of journals from each location if requested on the circulation list.

INTER-LIBRARY CO-OPERATION

As mentioned earlier, no special library can ever hope to be self-sufficient even in its own speciality, despite the fact that it largely concentrates on only one or a few subject fields, nor is it desirable on economic grounds that it should be self sufficient, hence, a very extensive web of inter-library co-operation and lending has been woven. As far as the Department's Engineering Library is concerned, it largely exists between other Commonwealth Departments and also with some company librarians dealing in similar subject fields. Librarians know each other through Library Association activities and also there is an added fraternity between librarians of the Commonwealth Service. It must always be borne in mind that an inter-library loan is a privilege and not a right.

The Engineering Library participates in the National Library's co-operative projects such as LURB (List of Unlocated Research Books). This is a system which issues periodically, lists of books which librarians have been unable to locate for their users. The need of such an item is registered with the National Library and it appears on the next list circulating to Australian libraries. All members agree to search their collections to see if any of the needed publications are held and to make them available for short term loan. The Library is also a member of the National Library Clearing Centre's system. Lists of duplicates — periodicals, books, reports and other unwanted material — are circulated to all members and a library is often able to fill in gaps in its collection by this means.

HOW TO MAKE BEST USE OF THE LIBRARY

Library staff often find that references to periodical literature are inaccurate. A new recruit to the library profession quickly learns how human memory fails to register time — a vague "Saw a reference on such and such about six months ago" may turn out to mean anything from two months to six years ago. Therefore, librarians appreciate as much information as they can get when a search is required. A few extra words may save hours of work. If an engineer finds the librarian probes further, he should realise that he has not given her sufficient data for her to carry out her assignment. It is helpful to give details of the form of the information should take, e.g. only from periodicals; any possible authors who write on the particular subject; the approximate date of any specific publication; the original reference to the information; the time limit of the search, say, 1960 to date, or the last ten years, etc. It is often helpful to give the name of a person in the organisation who may be able to supply further information. When asking for a specific reference, the page number is of considerable importance; this helps to identify information promptly and saves time. For example, if a wrong year of the periodical is quoted, often the page number will identify the information in another year. An engineer should not expect miracles if he is only able to supply a few "leads". The librarian is not an expert in any subject field but does aim to be an expert in locating information — her stock in trade is putting information to work.

A particular problem to librarians the world over is the circulation of periodicals and they are very much aware of the library users' vital need to keep up with the reading of periodical literature. The best solution that can be offered to help both parties is that the user should attempt the following procedure in dealing with his periodicals.

As soon as possible after receiving a periodical on circulation he should scan the contents list. An excellent chance to do this is whilst hanging on to a telephone call awaiting for the other person to answer. If there is nothing of interest he should immediately sign it off and send it on its way. If there are items of particular concern which he has no time to read within a day or so, he should indicate that he would like the article indexed in the library so that he can locate it again later, or ask for a Xerox copy or for the issue of the periodical to be returned to him at a later date. Holding the publication hoping that he will find time to read it is fatal; he seldom will, and in the meanwhile he is selfishly precluding others who have as much need as he, to see it whilst it is current.

It is seldom that a periodical is to be read from cover to cover; no man can now hold all the knowledge relevant to his subject in his head and information pertinent to a particular matter can usually be relocated by the library.

ACCOMMODATION

The Engineering library is housed in the Research Laboratories' building at 59 Little Collins Street, Melbourne. This building has recently been completely renovated to become the administrative block of the Research Laboratories and the Library has been allocated considerably more space. It has been refurnished and a pleasant, quiet room with sturdy carrels has been provided.

It is hoped that this improved accommodation will quickly show a dividend by enabling the library staff to give an improved service and make it much easier for the Department's officers to avail themselves of the resources of valuable information in the world's engineering and scientific literature.

REFERENCE

1. Andrew D. Osborne, "Sixty Million Pages a Year"; The Aust. Library Journal VII, No. 1, Jan. 1962, p. 23.

APPENDIX

SOME USEFUL SOURCES OF INFORMATION HELD IN THE LIBRARY

AUSTRALIA

of official publications of the Commonwealth of Australia, Territories and States.

Australian Government Publications — Annual list by the National Library

Australian National Bibliography — Annual list of publications lodged under copyright deposit or otherwise acquired by the National Library.

Australian Public Affairs Information Service — Annual subject index to current Australian literature and a list of current Australian serials

Australian Science Index — Index of articles published in Australian scientific and technical periodicals.

C.S.I.R.O. Abstracts — Abstracts of papers published by C.S.I.R.O. authors and translations notified to C.S.I.R.O.

GREAT BRITAIN

Government Publications, H.M.S.O. — Monthly list of all H.M.S.O. publications, U.K. Atomic Energy Authority reports and other publications "sold but not published" by Her Majesty's Stationery Office.

British National Bibliography — Weekly list (with quarterly and annual cumulations) of publications lodged with the British Museum Library under copyright laws.

British Technology Index — Monthly subject guide to articles in British technical journals.

D.S.I.R. Monthly Summary — Lists reports of the British Research Association, D.S.I.R., National Laboratories (Engineering, Physical, Road Research) and other official laboratories.

UNITED STATES OF AMERICA

U.S. Government Research Reports — Twice-monthly list of new reports of research and development released by the Army, Navy, Air Force, Atomic Energy Commission and other Agencies of the Federal Government.

Monthly Catalog of U.S. Government Reports — Lists all reports issued by official Government Departments and Agencies.

GENERAL ABSTRACTING SERVICES

Science Abstracts:
Section A — Physics Abstracts
Section B — Electrical Engineering Abstracts.

Engineering Index:
(Annual).

Engineering Index:
Plastics Index Section (monthly).
Electrical and Electronics Section (monthly)

Applied Science and Technology Index

Computer Abstracts:

TRADE DIRECTORIES AND GUIDE BOOKS

Australian Manufacturers' Directory

The Business Who's Who of Australia

Australian Purchasing Yearbook

Tait's Directory (Australia)

Electronics Buyers' Guide (U.S.A.)

Federation of British Industries Register (U.K.)

C.S.I.R.O. Scientific and Technical Research Centres in Australia

Federal Directory

TECHNICAL NEWS ITEM

RURAL AUTOMATIC TONE DIALLING PARTY LINE SERVICE

Low quality part-privately erected (P.P.E.) lines in rural areas pose problems when the extension of automatic telephony is considered since they frequently exceed the operating limits for standard automatic circuits; in addition a large proportion are earth return party lines.

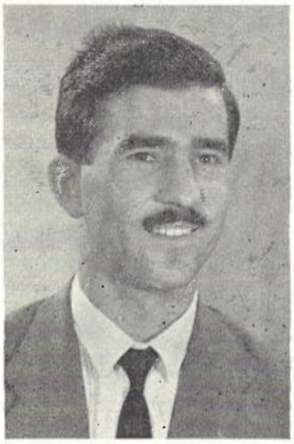
As a solution to this problem the Department's Research Laboratories have developed a party line service using tone signalling for dialling and party identification. This system is suitable for up to ten parties. A unit has been on field trial in the Mildura (Victoria) area since July this year.

The service provided by the system is similar to other automatic party line services; no secrecy, automatic dialling, code ringing, and a hand generator for interparty calls. The system is designed for lines of either earth return or metallic construction. Dialling and party identification are performed by transmission of tones from subscriber to exchange. Each subscriber is assigned two tones on a two out of five basis, allowing up to ten parties per line. In dialling, one tone is transmitted continuously during the dial off-normal period, and the second tone is superimposed during dial breaks. By this means very good speech immunity is obtained, giving high reliability of dialling. Adequate checks in the exchange end circuits prevent registration on a wrong subscriber's meter. Although a local battery is used for transmitter and oscillator power, loop supervision is carried out with DC from the exchange battery. This means that the joints in most lines must be repaired to reduce the loop DC resistance. Pressed sleeve joints are satisfactory, at least, as a short term solution, even when the lines are rusted G.I. However, the Research Laboratories are investigating other, more permanent methods of joint repair. The designed line limits are: loop resistance 3,000 ohms, leakage resistance 10,000 ohms, line loss 27 db.

The telephone is an 800 type, with a modified circuit to allow local battery working, DC loop supervision, and tone dialling. An associated plinth contains the two oscillators, hand generator, protection equipment and a relay to give additional off-normal functions. The local battery is 6 volts, which gives an appreciable improvement in transmitter performance. A small optional high pass filter has been designed also to improve the receiver performance in those common cases where power hum interference is present. To avoid multiple exchange looping during interparty calls, the subscriber must lift off before using the generator; the exchange-end equipment will recognise this loop condition, but will drop out if dialling signals are not received within six seconds.

The exchange end equipment consists of about thirty relays, three transformers, a uniselector, an L.M.E. type KST code receiver and two cards of filter and electronic circuits. The field trial equipment was built up on L.M.E. relay bases. In installing this equipment, modifications must be made to the associated subscribers' line and metering circuits similar to those required for existing automatic party line equipment. With slight modifications the equipment will work in either step-by-step or L.M.E. crossbar exchanges.—F.W.W.

OUR CONTRIBUTORS



T. KURIATA

W. D. McKENZIE

J. J. ANDREWS

D. GOSDEN

T. KURIATA, author of the article "Maribyrnong Exchange — E.M.D. System M" was recruited in London in 1955 as Engineer Grade 1 P.M.G. Department, Victoria. Upon completion of a six months' induction course he was attached to Metro. Exchange Installation No. 1 Division. Since March, 1957, he has been in various Metro. Equipment Service Divisions as Class 2 Engineer. Mr. Kuriata was educated in London and is a holder of Ordinary National Diploma (Mechanical) and Higher National Diploma (Telecommunication). He is a Graduate Member of Institution of Electrical Engineers, London.

★

W. D. McKENZIE, author of the article, "SEACOM: Broadband Line and Terminal Equipment for the Brisbane-Cairns Route", joined the Department in Sydney in 1927 as a Junior Mechanic in Training. He qualified for appointment as Engineer in 1942 and was employed as Production Engineer in the Research Laboratories Melbourne prior to his transfer to Queensland as Engineer, Transmission Equipment Maintenance in 1946. He was promoted as Divisional Engineer, Transmission Equipment Installation in 1949. From 1955 to 1958 Mr. McKenzie was seconded to the Technical Assistance Administration of United Nations as adviser to the Government of Pakistan on "Long Distance Telephony". Since 1958 he has been Divisional Engineer, Long Line Equipment Installation in Queensland. He is an Associate Member of the Institution of Engineers, Australia.

★

J. J. ANDREWS, author of the article "The L. M. Ericsson AKL-10 Detached Exchange", joined the Postmaster-General's Department as Cadet Engineer in 1956. After graduation from University of Queensland with degree of Bachelor of Engineering (Electrical), he has served for three years as Engineer Class 1 in Service No. 1 Division and 12 months in Metropolitan Exchange Installations Division. He is a Graduate member of the Institution of Engineers, Australia.

★

B. W. HYDE, author of the article, "Fault Finding in ARF 102 Crossbar Equipment", joined the Postmaster-General's Department in 1948 as a Technician-in-Training. He qualified as Technician in 1953 and as Senior Technician in 1954. Mr. Hyde has had several years experience in the equipment maintenance and postal workshops areas. He participated in the Petersham Crossbar installation project and was subsequently given the task of developing maintenance and fault-finding techniques. Since October 1964, he has been employed as a Technical Officer Grade I to carry out special investigations on crossbar equipment service problems.

★

B. W. HYDE

D. GOSDEN, author of the article "Experimental Determination of the Radiation Pattern of Television Transmitting Aerials," joined the Postmaster-General's Department as a Cadet Engineer in 1959 and after completion of the Bachelor of Engineering Degree at the Sydney University in 1962 he was advanced as Engineer Class 1, Broadcasting No. 3 (Television) Sub-Section, Radio Section, Sydney. He has been closely associated with the expansion of the National Television Service in N.S.W. and 1964 he carried out the final stages of installation of the Richmond-Tweed National Television Station ABRN.

Since June, 1965, Mr. Gosden has been engaged on planning work associated with the conversion to remote control of the Commericial Television Station WIN4 which station is operated and maintained by staff of the Postmaster-General's Department.

★

T. PIMM, co-author of the article "Lightning Protection for Buried Trunk Cables", is an Engineer Class 2 in the Lines Section, Headquarters. He joined the Postmaster-General's Department as a Technician's Assistant in 1947, after discharge from the A.I.F. He became a Trainee Engineer in 1958 and obtained his Electrical Engineering Diploma in 1960. One year was then spent on major cable installations in Sydney, during which, experimental work was carried out on the hauling of very long lengths of cable in ducts. Since transferring to the Lines Section at Headquarters he has been in the Trunk Cable Network Design Division, mainly associated with coaxial cable developments, including about two years study of ground conduction effects and their influence on performance of buried trunk cables. Mr. Pimm is a Graduate Member of the Institution of Engineers, Australia.

T. PIMM

D. L. SHAW

V. J. WHITE

MISS CUZENS, authoress of the article, "The P.M.G. Central Engineering Library", gained a Bachelor of Arts degree at Melbourne University and has the Registration Certificate of the Library Association of Australia. She has worked as librarian in the Departments of Defence, Air and Repatriation and was promoted to the position of Senior Librarian, Engineering Division, Postmaster-General's Department Central Office, and took up duty in January, 1964. She takes an active interest in the affairs of the Library Association of Australia. She was Federal President of the Special Libraries Section from 1961-1963, and at present, is a committee member of the Victorian Division of the Special Libraries Section of the Library Association of Australia. The year 1958 was spent on exchange duty in the Carnegie Library of Pittsburgh, U.S.A. In 1963, Miss Cuzens spent some weeks overseas attending the Second International Congress of Medical Librarians, the Annual Conference of the Special Libraries Association, U.S.A., and then investigated matters of specific interest to the Repatriation Department in allied government departments in United States of America and Great Britain.

★

MISS CUZENS

D. L. SHAW, author of the article "The Albury Cutover", joined the Postmaster-General's Department as a Cadet Engineer in 1950 while he was undertaking a course in Electrical Engineering at the University of New South Wales. He obtained his B.E. Degree with 2nd Class Honours in 1953 and completed his cadetship in 1954. From then until 1963 he was employed in the New South Wales Country Installation Long Line Divisions on the installation of carrier systems and equipment, trunk signalling equipment and transit switching schemes. In 1963 he was transferred to one of the Country Installation Exchange Divisions and was responsible for the installation of C.A.X.'s, P.A.B.X., manual and automatic exchanges in South Western New South Wales. This year he has been promoted to the position of Engineer Class 3 in charge of the Multichannel Division of the Systems Development Subsection at the Research Laboratories. Mr. Shaw has been a member of the Citizen Military Forces for 12 years with the University of New South Wales Regiment and is an Associate Member of the Institution of Engineers, Australia.

★

V. J. WHITE, author of the article "Technical Training in the Australian Post Office", joined the Postmaster-General's Department in Western Australia as Cadet Engineer in 1941. Following two years service in the RAAF and successful completion of the cadetship, he gained early experience in external plant sections in W.A. and was promoted Divisional Engineer, Lines Section, Central Office in 1955. Promotion to Sectional Engineer, Lines Section occurred in 1958 and after a period in the Public Service Board on examination and recruitment policies he was appointed Sectional Engineer, Training, at Headquarters in October, 1962. Mr. White holds the degrees of Bachelor of Science and Bachelor of Arts, University of Western Australia and for a brief period in 1953-54 held a commission as a Psychologist in the Australian Regular Army. He is an Associate Member of the Institution of Engineers, Australia and of the British Psychological Society. Mr. White joined the Board of Editors of the Journal in 1958 and has been Editor-in-Chief since November, 1963.

★

J. B. GOODFELLOW, author of the article "A Suction Duct Robber," which appeared in Vol. 15, No. 3, was recruited during 1951 to the Departmental Workshops in Sydney from the British Post Office, Research Station, London, where he had been engaged on the design and development of various telecommunications prototypes. During the war years while based in London with the Ministry of War Transport he was associated with engineering problems of transporting personnel and equipment by land and sea and also with two of the better known projects. "Pluto" and "Mulberry Harbour". Part of this service was on the European Continent as acting Major without Warrant. During recent years Mr. Goodfellow has been responsible for the administration of the field operations sub-section of the Automotive Plant Section in Sydney.

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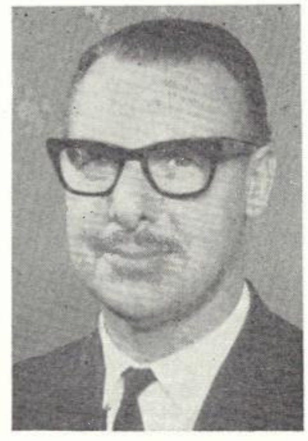


J. B. GOODFELLOW

ANSWERS TO EXAMINATION QUESTIONS

Examination No. 5372 — 24th July, 1965, and subsequent dates for promotion, appointment or transfer as Technician, Telecommunications (Telephone), Postmaster-General's Department.

SECTION A. BASIC ELECTRICAL THEORY

QUESTION 1.

Calculate the power dissipated in each of the resistors in the network shown in Fig. 1, and prove that the answers are correct by comparing with the total power dissipated in the network.

20 ohm/M

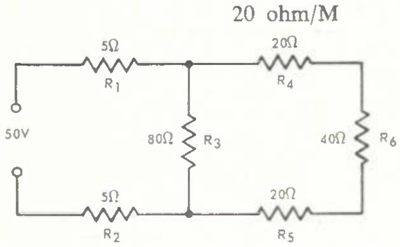
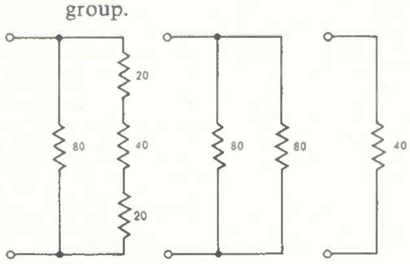


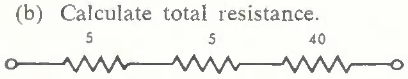
Fig. 1

ANSWER 1.

(a) Calculate resistance of parallel group.



(b) Calculate total resistance.



$R = r1 + r2 + r3$
$= 5 + 5 + 40$
$= 50$ ohms

$I = \frac{E}{R} = \frac{50}{50} = 1$ Amp

Total Power $= I^2R = 1^2 \times 50$
$= 50$ Watts

$PR1 = I^2R = 1^2 \times 5 = 5$ Watts
$PR2 = I^2R = 1^2 \times 5 = 5$ Watts
$PR3 = I^2R = .5^2 \times 80 = 20$ Watts
$PR4 = I^2R = .5^2 \times 20 = 5$ Watts
$PR5 = I^2R = .5^2 \times 20 = 5$ Watts
$PR6 = I^2R = .5^2 \times 40 = 10$ Watts
Total Power $= 50$ Watts

QUESTION 2.

(a) Define the magnetic term "Permeability".
(b) State the UNIT of measurement of magnetic flux and of flux density and state the relationship between the two units.
(c) Draw a schematic diagram which illustrates the principle of magnetic screening showing the lines of magnetic force, the magnetic screen and the shielded apparatus.

ANSWER 2.

(a) A complete answer is given in the Course of Technical Instruction, Applied Electricity I, paper 7, para. 8.3.
(b) Unit of magnetic flux = MAXWELL.
Unit of flux density = GAUSS.
One gauss = One maxwell per square centimetre,
or

$$B = \frac{\phi}{a}$$

where B = flux density
ϕ = magnetic flux
a = cross-sectional area.
(c) See Course of Technical Instruction, Applied Electricity 1, paper 7, para. 8.5.

QUESTION 3.

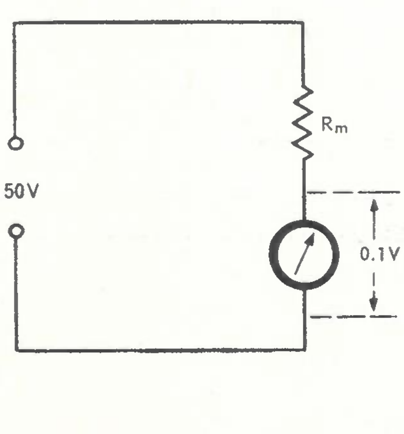
The moving coil system of a meter has a resistance of 10 ohms and the pointer reaches full scale deflection (F.S.D.) when a current of 10 m.A. passes through the coil. Calculate the following—
(i) the maximum voltage across which the meter may be connected.
(ii) the "multiplier" needed for the meter to measure 50 volts (F.S.D.).
(iii) the "shunt" required to adapt the meter to read 5 amperes (F.S.D.).

ANSWER 3.

(i) $E = I \times R = 0.01 \times 10$
$= 0.1$ Volt.

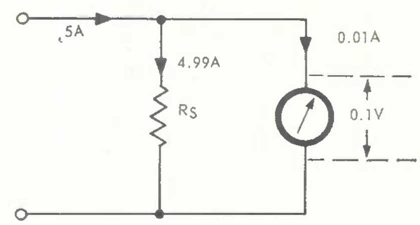
(ii) PD $Rm = 50 - 0.1 = 49.9$V.

$$Rm = \frac{E}{I} = \frac{49.9}{0.01} = 4990 \text{ ohms}$$



(iii) I shunt $= 5 - 0.01 = 4.99$ Amps

$$Rs = \frac{Es}{Is} = \frac{0.1}{4.99} = 0.02 \text{ ohm}$$



QUESTION 4.

Fig. 2 shows a circuit containing resistance in series with capacitance. The applied voltage (E) is found from the vector sum of the potential differences across the resistance (E_R) and the capacitance (E_C).

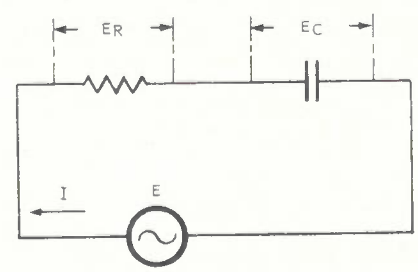
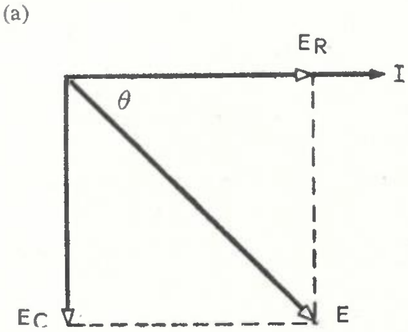


Fig. 2

(a) Draw a vector diagram of the circuit.
(b) Describe briefly the meanings of the component parts of the vector diagram, and in particular how the vector diagram provides the information necessary to obtain the formulae for calculating Applied Voltage (E) and Phase Angle (θ).

ANSWER 4.

(a)



(b) I = Current which is the same in all parts of the series circuit and is used as the reference vector.
E_R = P.D. across the resistance and is in phase with the current.
E_C = P.D. across the capacitor and lags the current by 90°.

E = Applied voltage.
θ = Phase angle between the applied voltage (E) and the circuit current (I).

The applied voltage (E) may be calculated by applying Pythagoras' Theorem.

The sum of the squares of the base plus the sum of the squares of the height equals the sum of the squares of the hypotenuse.

Therefore $E^2 = E_R^2 + E_C^2$

or

$$E = \sqrt{E_R^2 + E_C^2}$$

The phase angle θ may be calculated from

$$\tan \theta = \frac{E_C}{E_R}$$

SECTION B. TELEPHONE EQUIPMENT

QUESTION 5.

(a) State the four main factors which affect the release lag of a telephone relay.

(b) State what is meant by a fast acting relay; explain how the effects of eddy currents are overcome using nickel iron cores and nickel iron sleeves in producing fast acting relays.

ANSWER 5.

See Course of Technical Instruction, Telephony 2—

(a) Paper 1, Section 3.

(b) Paper 1, Section 4.

QUESTION 6.

(a) Draw a schematic circuit of the "Undivided" type of transmitter feed which is used for a C.B. cordless type P.M.B.X. showing the central battery, two telephones and associated retards, and the retards for two additional circuits.

(b) Explain the reason why this type of battery feed is not suitable for a C.B. or Automatic exchange subscribers' network.

ANSWER 6.

(a) See Course of Technical Instruction, Telephony 2, Paper 2, Fig. 5.

(b) This type of battery feed is most suitable when the lines from the PMBX to the telephones are approximately the same length. If the lines were of unequal length, as well might be on CB or Automatic exchange networks, the line having the lower resistance will have more current enabling it to operate more efficiently than the line with the higher resistance.

See Course of Technical Instruction, Telephony 2, Paper 2, Section 2.

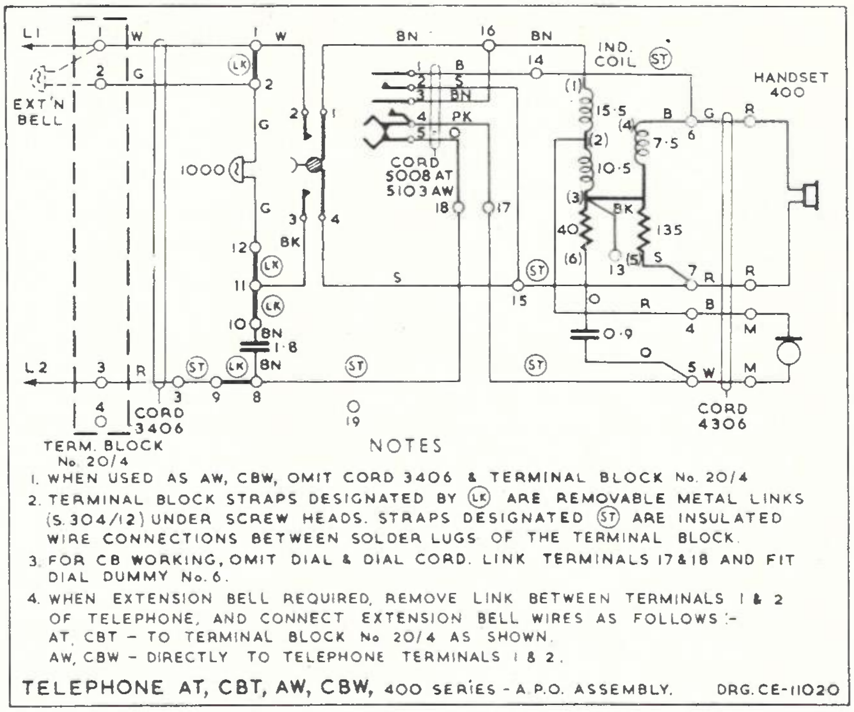


Fig. 3

QUESTION 7.

The circuit of a 400 AT is shown in Fig. 3.

(a) Describe how the permanent magnet in the receiver is not affected by the transmitter battery while a call is in progress.

(b) Describe why a call cannot be answered on the telephone if the dial face has been damaged and is jammed with the digit hole 1 in a position at the first finger stop of the dial.

ANSWER 7.

(a) The capacitor 1.8 μF prevents direct current from passing through the receiver.

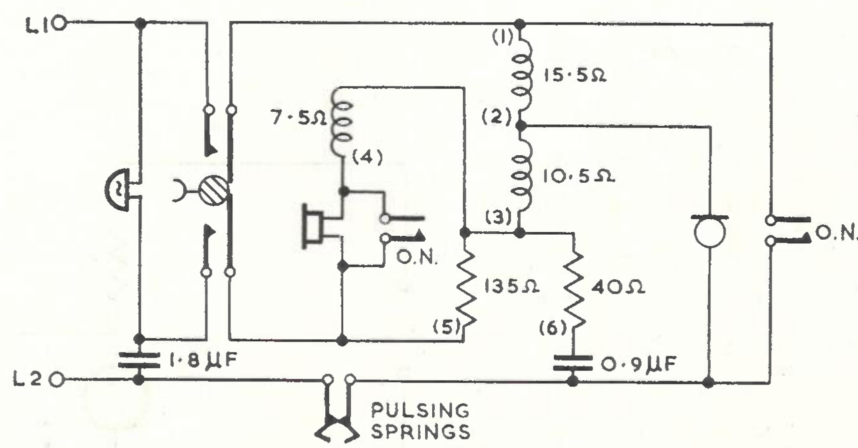
With the digit hole 1 at the finger stop the dial is "off normal" causing the off normal springs to operate.

When an incoming ring is received, i.e., bell rings, the receiver is lifted and the ring tripped (D.C. loop via O/N springs). The call cannot be answered:—

(i) D.C. is shunted away from transmitter.

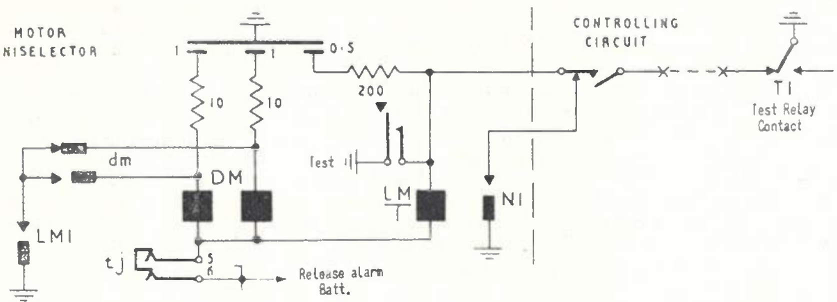
(ii) Receiver short circuited.

(c) Draw the relevant part of the 400 AT circuit which shows the anti-sidetone circuit of the telephone.



(c) See Course of Technical Instruction, Telephony 1, CB and Auto Telephones, Fig. 18(b).

QUESTION 8.



(a) With reference to the typical schematic circuit of a Motor Uniselector shown in Fig. 4 briefly describe the following:—
  (i) The physical construction of the spark quench provided.
  (ii) What circuits are provided with the spark quench.

(b) Sketch **any four** of the following conventional symbols used in circuits to represent the various arrangements of Motor Uniselector wiper assemblies and banks.
  (i) Double - ended wiper non - bridging.
  (ii) Single - ended wiper non - bridging.
  (iii) Single-ended wiper bridging.
  (iv) 50 outlet selector with double-ended wipers, 2 normal cams at 180°.
  (v) 100 outlet selector with single-ended wipers, 1 normal cam at 360°.
  (vi) 200 outlet selector using wiper switching, 1 normal cam at 360°.

ANSWER 8.

See Course of Technical Instruction, Telephony 5 —
(a) Paper 4, Para. 3.3.
(b) Paper 4, Para. 3.4 and Fig. 8.

QUESTION 9.

List and briefly describe **five circuit facilities** which are available to be provided to R.A.X. subscribers which are similar to those provided in a metropolitan automatic exchange area.

ANSWER 9.

See Course of Technical Instruction, Telephony 5, Paper 8, Section 3.

Contributions, Letters to the Editors, and Subscription Orders

may be addressed to:

the State Secretaries or the General Secretaries at the following addresses:—

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TECHNICAL NEWS ITEMS

AN AUTOMATIC SYSTEM FOR THE ANALYSIS OF EXTERNAL PLANT FAULTS IN THE AUSTRALIAN POST OFFICE

Following successful pilot operation in Adelaide, Dandenong and Darwin late in 1963, a system of Automatic Line Fault Analysis — known as A.L.F.A. has been progressively introduced throughout the Commonwealth. A Technical News Item in the January/February 1962 issue of the Journal describes earlier experimental computer matrix analyses of line fault codes taken from manually compiled fault location records.

During 1966, the A.L.F.A. scheme will completely replace a manual system of fault recording which had been developed to the limit of its capabilities. Approximately 570,000 faults occur each year on the external plant of the Post Office communication system. Manual analysis of the information available for such a sample, even when supplemented by punched card studies, is very time consuming and cannot be extended to produce the detail required for material design and for the evaluation of installation and maintenance techniques.

Maintenance of external telecommunication plant in the Commonwealth is undertaken on a regional basis by 70 Divisions. For each service interruption that occurs, a fault docket is issued giving location details, clearance times and a comprehensive code which identifies the fault cause and item of plant concerned. Under the manual system a Fault Foreman in each Division had the task of collecting, collating, recording and analysing the dockets and maintaining a geographical plot of faults. Quarterly and annual returns gave a variety of analyses including total faults, faults per plant unit installed and fault clearance times for both cable plant and aerial wires. Matrix type analyses of fault causes and the item of plant concerned were also produced. These Divisional returns were further processed to produce State and Commonwealth results. This analysis work occupied at least half of the Fault Foreman's time and severely restricted his other duties such as field investigations in areas yielding excessive faults and the implementation of remedial action.

Under the automatic system the Fault Foreman collects and checks the coding of a random sample of the fault dockets and forwards them for card punching and subsequent computer analysis. A.L.F.A. print-outs were initially produced on a hired computer but are now produced on the Post Office Honeywell 1800 machine in Sydney. Print-outs are returned to each Fault Foreman for distribution to field maintenance staff and State and Commonwealth results are forwarded to the appropriate administrative Sections. Analysis of the basic data can be far more comprehensive than in a manual system and in fact some 80 different service print-outs and matrices reports are regularly produced. In addition special print-outs can be easily programmed as required.

TELEVISION RELAYS FOR THE NATIONAL TELEVISION SERVICE

Under Phase 3 of the expansion of the National Television Service in Australia, transmitting stations were set up in 13 major regional districts during 1962-3-4. Under Phase 4 a further 20 transmitting stations are being set up in country areas. With the opening of the Maryborough (Queensland) transmitter on 8th October, 1965, eight of the Phase 4 stations are operating and apart from Mackay (Queensland), the remainder will be operating by the end of 1966.

In conjunction with Phases 3 and 4 of the expansion of the National Television Service, the Post Office is providing television relays from the various State capital city studios of the Australian Broadcasting Commission to the transmitters being established in the country areas.

The table below shows the number of miles of television relays which were operating at October 1965 and which will be operating on the completion of Phase 4. The route miles represent the distances along the actual routes taken by broadband bearer systems on which television relays are being established and take no account of multiple relays along any one route. The relay miles represent the distances along the actual routes taken by the television relays and include increased mileages for multiple relays along any one route. However, no allowance has been made for protection bearers (standby channels) in the case of microwave radio systems or for spare tubes in the case of coaxial cable systems.

TELEVISION RELAYS FOR NATIONAL TELEVISION SERVICE

State	Operating October 1965				On Completion of Phase 4			
	Microwave Radio		Coaxial Cable		Microwave Radio		Coaxial Cable	
	Route Miles	Relay Miles	Route Miles	Relay Miles	Route Miles	Relay Miles	Route Miles	Relay Miles
N.S.W.	940	969	17	71	1260	1422	142	205
Vic.	596	608	16	61	720	732	16	68
Qld.	432	432	10	20	1328	1328	16	40
S.A.	149	149	5	5	659	659	14	19
W.A.	17	17	118	118	299	299	125	126
Tas.	—	—	—	—	122	122	4	4
TOTAL	2134	2175	166	275	4388	4562	317	462

TECHNICAL NEWS ITEM

NEW POWER SOURCES

The Postmaster-General's Department Research Laboratories is currently investigating the application of new types of power supplies which are particularly suitable to equipment which must of necessity be located in remote areas. It has been standard practice in many remote installations to install either three-diesel generator sets or a secondary battery bank which is charged intermittently by either a diesel generator set or wind-powered generator. Because of the extensive maintenance required on a system utilising rotating parts, this practice is uneconomical when large distances separate the remote site and the nearest service centre as is the case in many parts of Central Australia. The advent of transistorised equipment with its inherently lower power consumption has enabled consideration of some of the newer power supply devices which as yet have only limited capabilities.

The major requirement of the new power sources is that maintenance need only be required at intervals of about 10,000 hours (i.e. approximately once every year). This figure does not apply to refueling but naturally the longer the device can operate between refueling operations, the more economical the device will be to run since transport and labour costs can represent a large portion of the cost of operation. The following paragraphs contain an outline of the types of supply being investigated by the Department.

In some systems where power consumption is low it is possible to use either normal dry cells or air-depolarised cells feeding a semiconductor-type voltage regulator. Tests which are in progress at the moment will reveal whether the use of dry cells will be an economical proposition and whether a large enough capacity can be installed for periods of six months or more without serious loss of output due to shelf life limitations.

The use of Solar Cells may be a worthwhile proposition. The cells are used to convert the sun's radiant energy to electricity to charge secondary batteries which provide power during darkness and cloudy periods. The capital cost of such an installation is extremely high since large numbers of solar cells are required to collect sufficient solar energy during daylight hours to give greater than twenty-four hours requirement with enough energy in reserve to provide for periods of cloudy weather. The secondary batteries used are of the Nickel-Cadmium type and are completely sealed so that they do not require maintenance. Since solar energy is free and maintenance is low, it may be expected that the capital cost of the equipment will be absorbed well before maintenance is required. A possible problem, however, may be that continual deposition of dust in arid areas may require that the cell faces be cleaned at regular intervals. Field trials to be conducted by the Laboratories will enable this query to be answered.

The use of semiconductor materials for thermocouples has made the Thermoelectric Generator a practical possibility. Consisting of many heated semiconductor junctions whose outer ends are connected in series, this type of power source is available for commercial use with power outputs up to the order of 100 watts. This power can be extended by series-parallel combinations of units. The source of heat can be either propane gas, natural gas or radioisotopes. The gas powered units will operate for 5 to 10 years without maintenance, the only requirement being that the fuel be replenished at intervals, dictated by the distance from the supply centre, the accessability of the remote site, available storage volume at the remote site and size of tanker available for transportation of liquid-petroleum gases. The radioisotope powered models, some commercial versions of which will be available in 1966, have a minimum life of 5 years and are powered by the heat generated by the decay of Strontium 90. It is expected that these units once charged, will eventually operate for periods approaching the half life of Strontium 90 (i.e. 20 years); the isotope will require replacing at a stage when the power output of the device drops below the required level for the particular application. The cost of replacement of the isotope is proportional to the amount used. The cost of an isotope powered thermoelectric generator is extremely high (e.g. approximately £(A)18,500 for 60 watts) but because its long maintenance free life, unattended operation in remote areas could be attractive.

A further area of research is in the field of Fuel Cells which produce electricity by chemical combination between oxygen and a hydrocarbon fuel (such as methanol) in the presence of a catalyst. The fuel cell has the highest theoretical efficiency of all the abovementioned processes and because of this may, in future years, be the best solution to the remote power supply problem. At present, the Research Laboratories and the C.S.I.R.O. are jointly working on experimental cells and their testing. The main problems at the moment are production of a cheap catalyst, extending the cell's development to a stage where it can be fuelled by cheap hydrocarbon fuels such as petroleum products, and preventing poisoning of the catalyst which at the moment limits the cell's life to the order of a few months.

Conditions in Australia's outback are such that a reliable power source with a maintenance period of at least 10,000 hours is required. Research at present in progress should reveal the type of supply which is most suitable for this application. All of the above systems have a high capital cost but the small maintenance costs and the large periods between refuelling are expected to make one or more of these systems an attractive proposition in the near future. — G.M.W.

AUSTRALIAN TELECOMMUNICATION MONOGRAPH No. 3

Subscribers to this Monograph (Power Coordination and Lightning Protection) are advised that copies are expected to be available shortly and should be posted to subscribers before the end of February, 1966.

Orders can still be taken for this and previous Monographs which are all available at $1.00 Australian currency, post free. Remittances may accompany orders, or an invoice will be sent, as preferred.

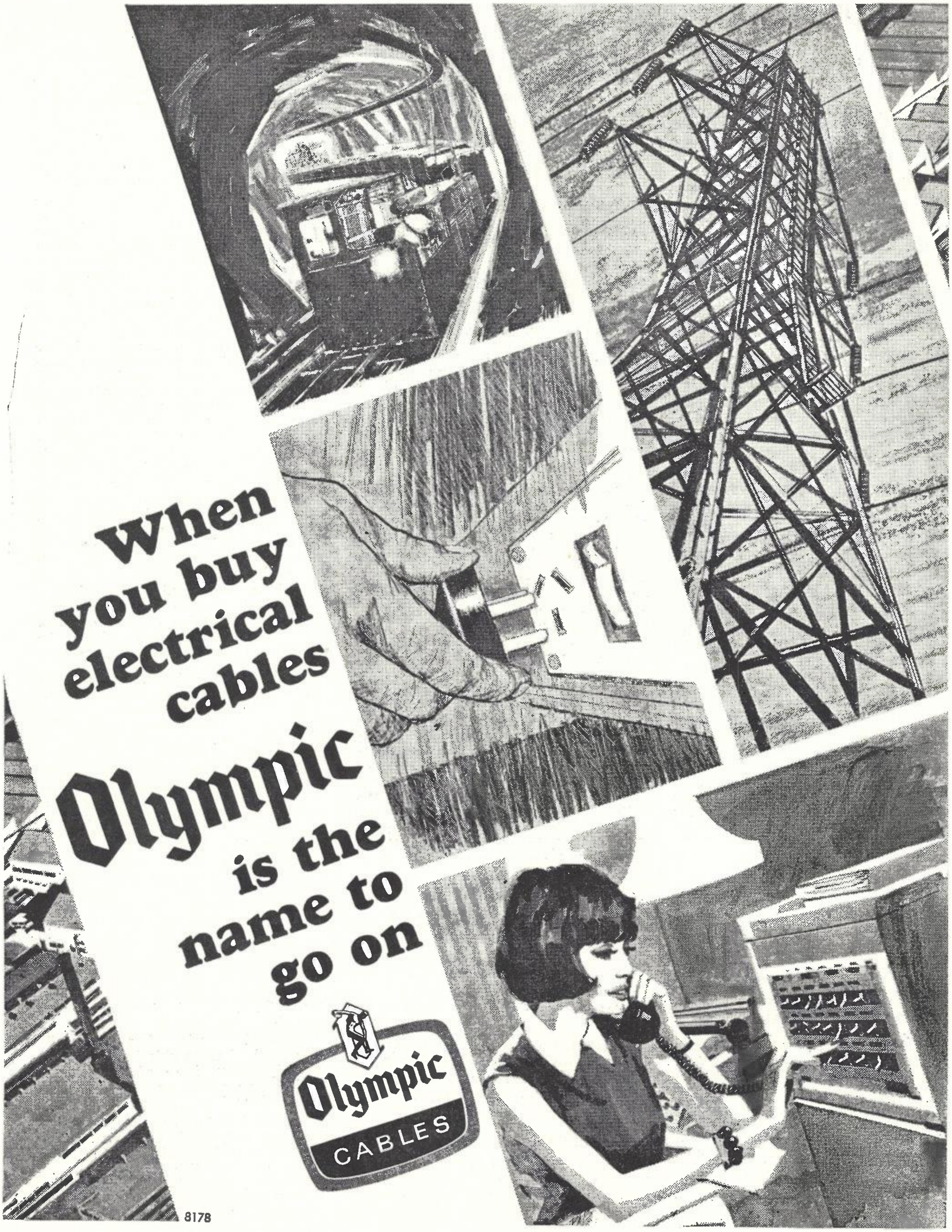
Orders for all addresses should be addressed to: General Secretary, Telecommunications Society of Australia, Box 4050, G.P.O. Melbourne, Victoria, Australia.

READER SURVEY

A good response has been received from Australia and overseas to the questionnaire included in the last issue of the Telecommunication Journal of Australia.

Completed questionnaires were still being received when this issue went to press. The next issue of the Journal will include a report on the analysis of the questionnaires.

The Board of Editors wishes to thank all readers and agents who participated in the survey, the results of which will guide editorial policy for future issues of the Telecommunication Journal of Australia.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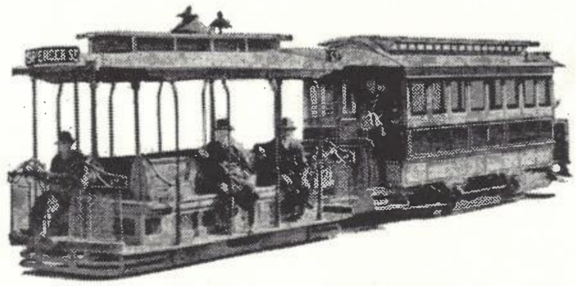
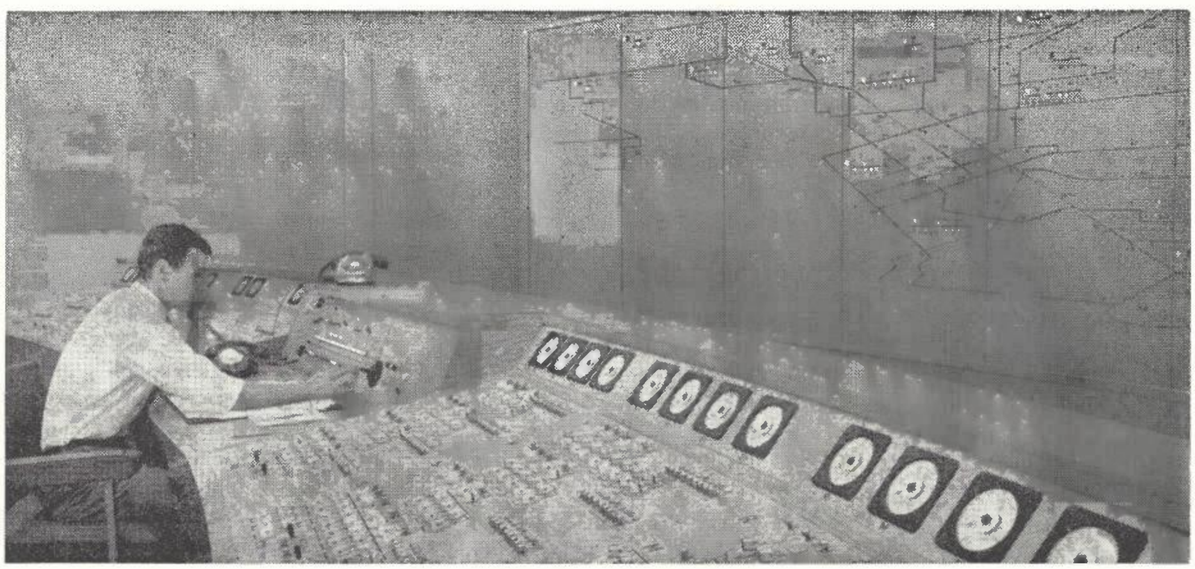
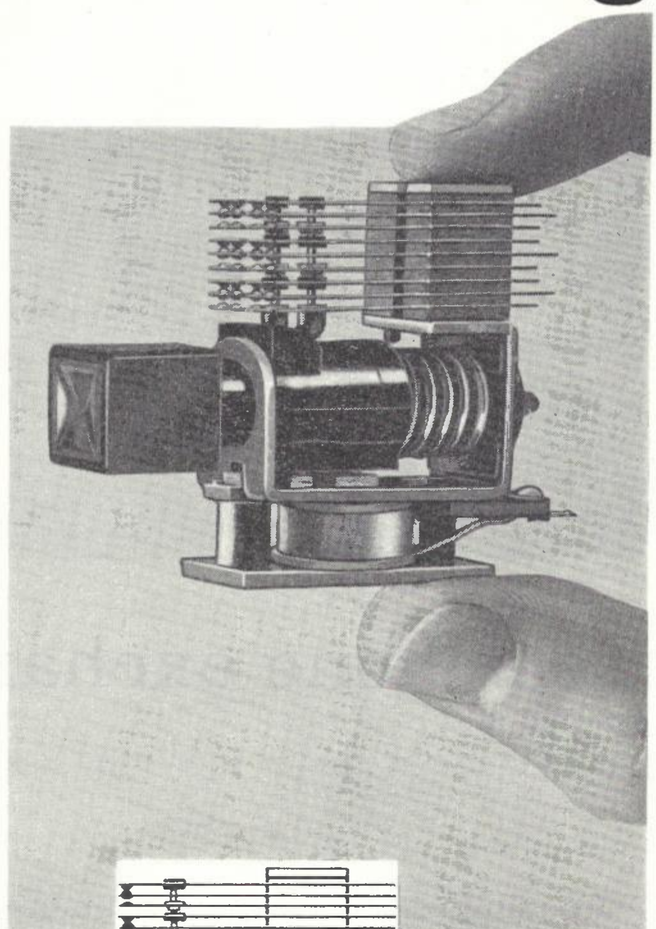
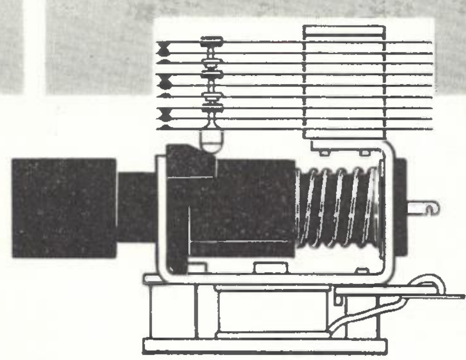
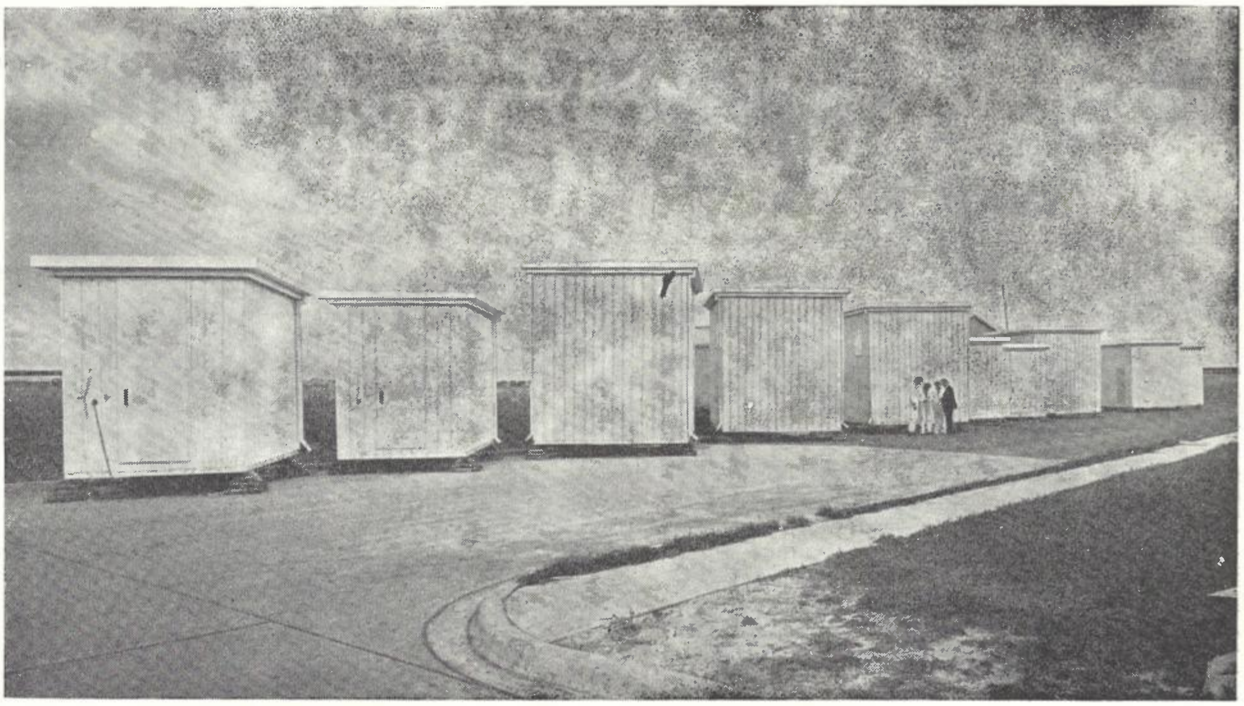






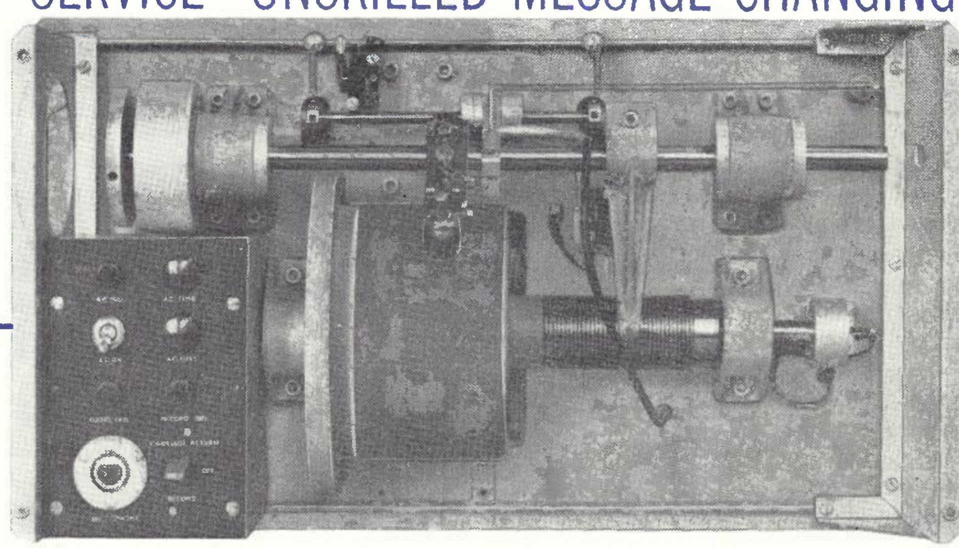




ROLA VMR Heavy Duty Continuously Operating Drum Announcement Unit

The Rola Variable Message Repeater offers these features:

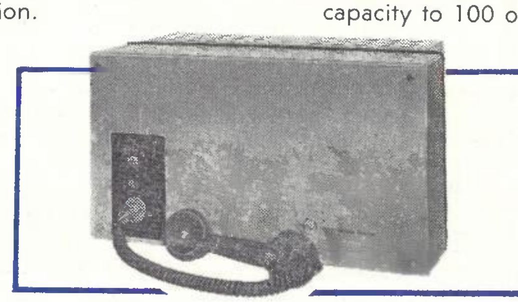
HIGH REVENUE CAPACITY — ONE SWITCH OPERATION — 20 YEARS OF CONTINUOUS SERVICE — UNSKILLED MESSAGE CHANGING



The Rola VMR MkII is a Variable Length Message Repeater capable of handling messages of 3 seconds to 3 minutes' duration.

A.G.C. on the Replay-to-Line Amplifier ensures a Constant Signal Level up to the unit's maximum capacity to 100 output lines.

Designed for Completely Reliable Operation its electronics are all Solid State and include the use of Silicon Transistors in its circuitry.



Operational ease is another feature. One-switch operation and A.G.C. on the Record function make message changing almost automatic.

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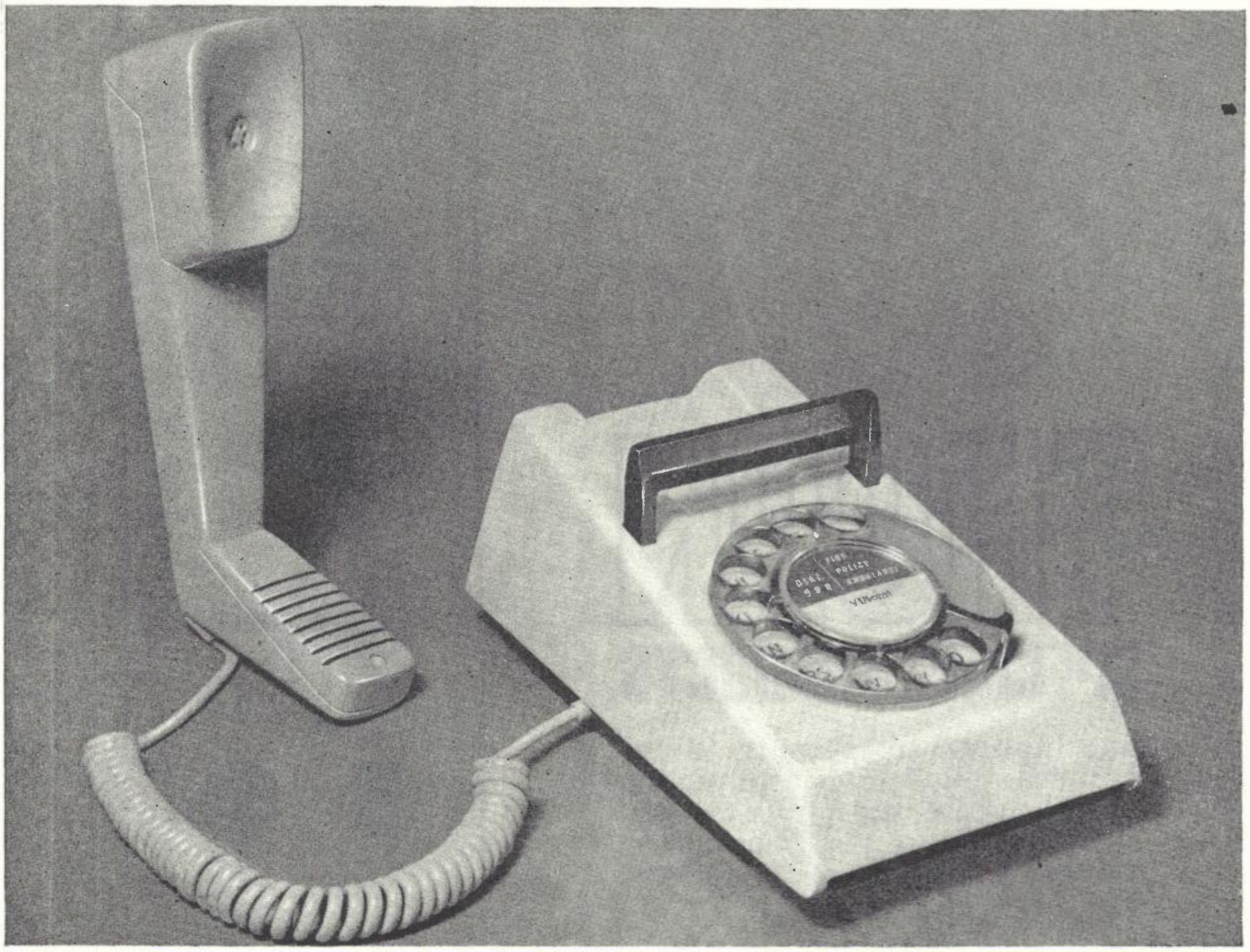

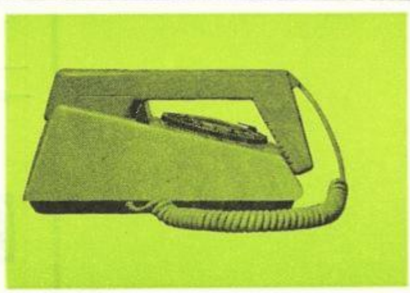

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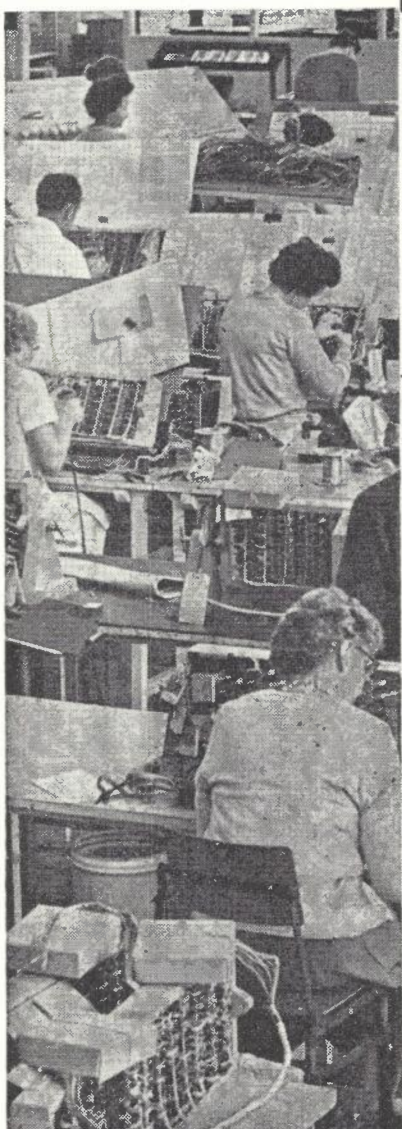

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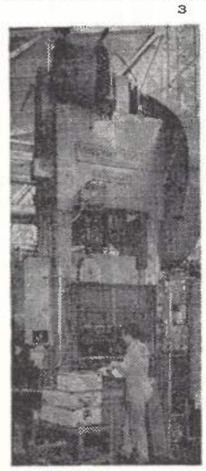

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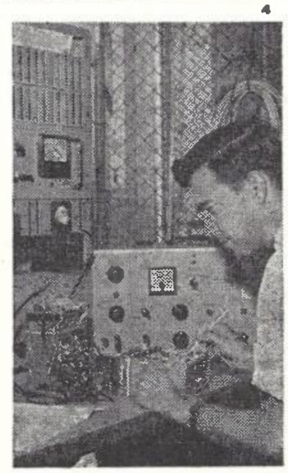
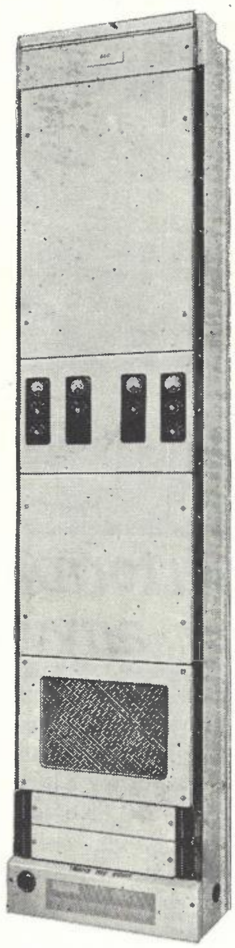


4

1. Aerial view of factory.
2. A section of the Relay Set wiring line.
3. In the press shop—Relay Set base manufacture.
4. A corner of the Line Transmission laboratory.

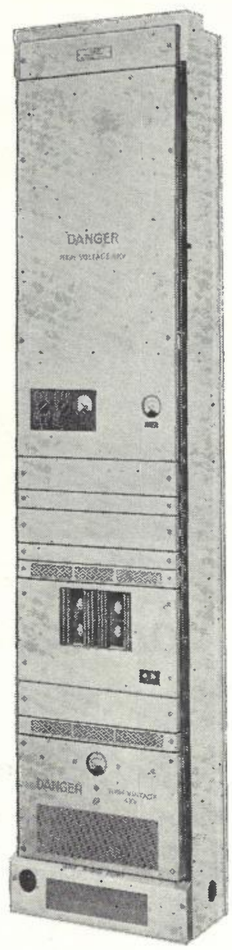
PLESSEY GROUP

NEW **G.E.C.** RANGE OF SEMICONDUCTORED MICROWAVE SYSTEMS



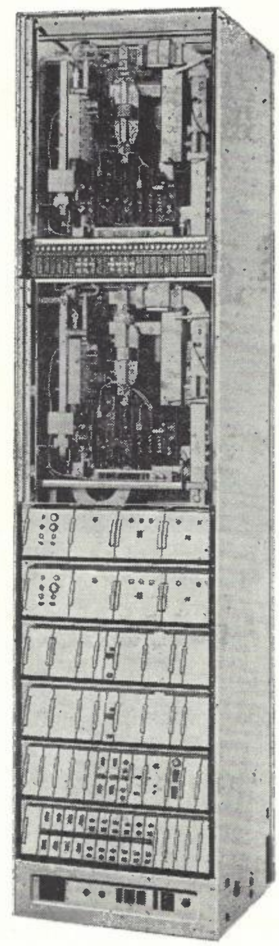
2000 Mc/s Transmitter/Receiver Rack

TYPE SPO 5504 for main line systems. Maximum capacity 960 speech circuits or TV. Operates in the 1700-1900 Mc/s and 1900-2300 Mc/s frequency bands. Completely semiconductored. The associated auxiliary radio channel and multi-RF protection switching equipment is fully transistored.



6000 Mc/s Transmitter/Receiver Rack.

TYPE SPO 5558 for main line systems. Capacity 1800 speech circuits or TV. Operates in the frequency band 5925-6425 Mc/s. Semiconductored apart from a travelling wave amplifier output stage which is retained and provides a 10 watt output. Fully transistored associated auxiliary radio channel and multi-RF protection switching equipment.



7500 Mc/s Repeater Rack

TYPE SPO 5575 for spur routes and lightly loaded main routes. Operates in the 7500 Mc/s frequency band; provides up to 300 speech circuits. The equipment is completely semiconductored. A twin-path both way repeater is packaged on one rack, complete with switching, engineers order wire and remote alarm equipment.

The new range of microwave systems in production at G.E.C. makes maximum use of semiconductor techniques; building into the equipment the increased reliability and reduced maintenance qualities inherent in these devices. The greatly reduced power consumption of semiconductored equipment offers further major advantages, particularly to unattended stations in remote areas. Three systems of varying capacities are in current production and these are described above. El Salvador, Norway, United Kingdom and Zambia have ordered these systems. Write for further details and learn for yourself why these administrations have chosen G.E.C. semiconductored equipment.

All equipments accord with C.C.I.R. recommendations.

G.E.C. everything for telecommunications

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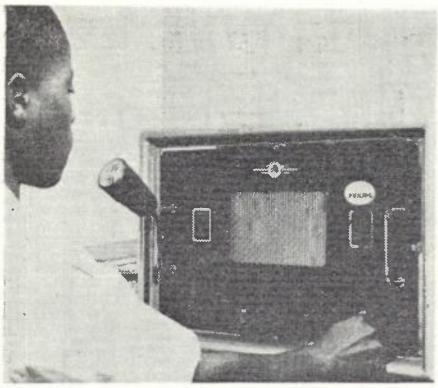
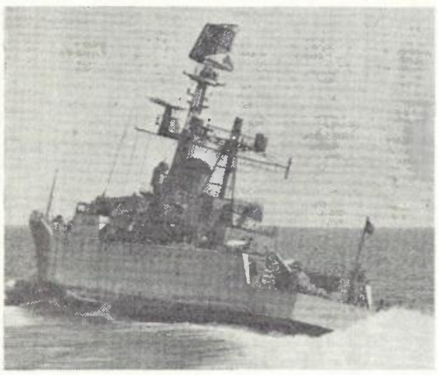
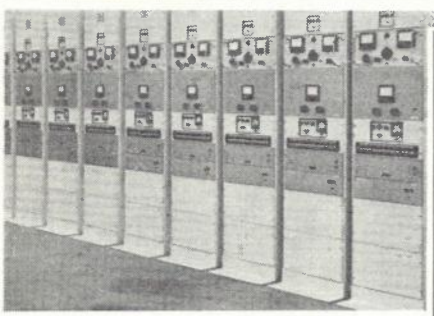
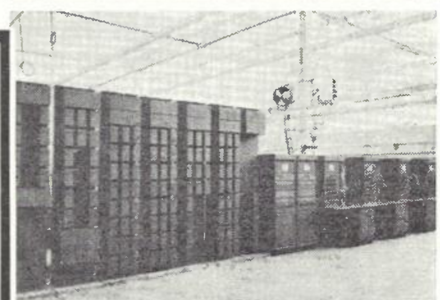
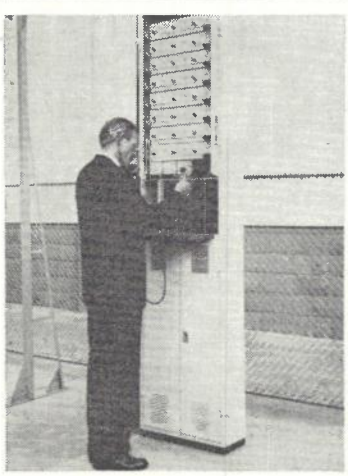
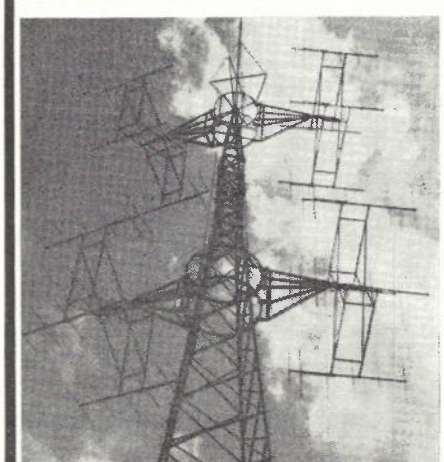




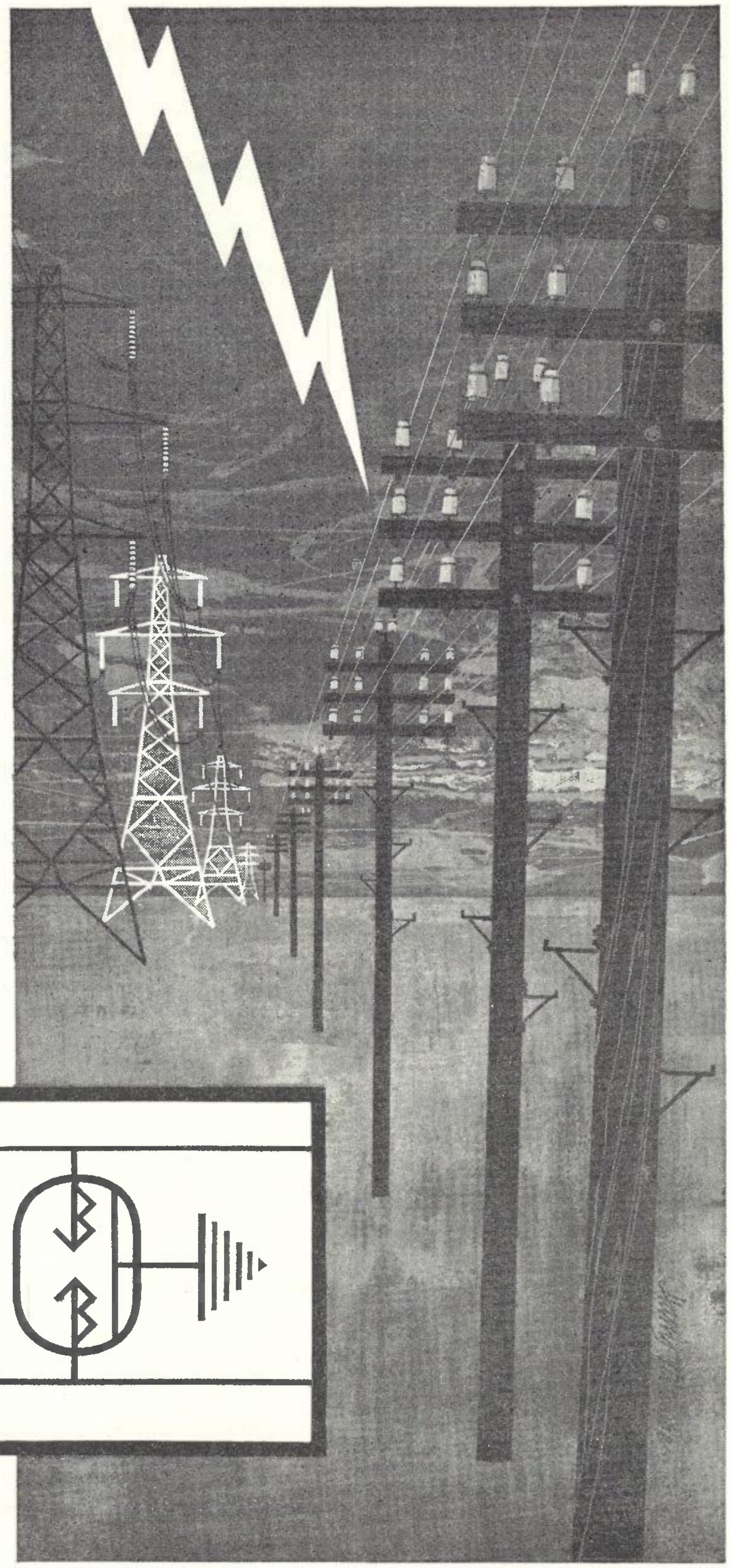








Increased protection cuts maintenance costs



The latest A E I Protector – No. 16

provides an exceptionally high degree of protection for communication and instrument circuits.

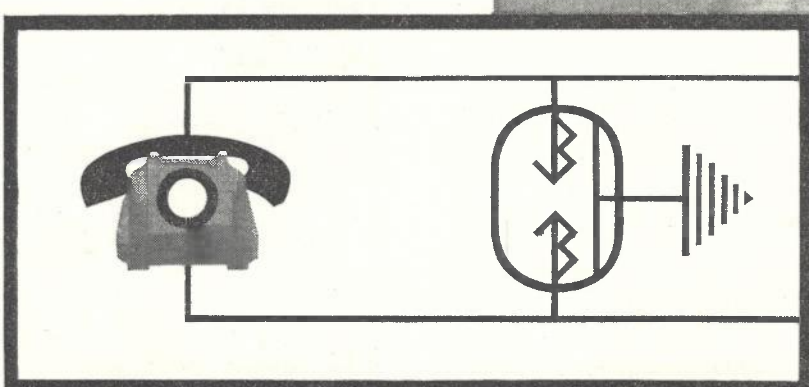
It operates many times without attention and thus considerably reduces maintenance costs. The three-electrode construction enables it to replace two conventional protectors and, due to the tendency of both gaps to break down simultaneously, it minimises the excess voltages to which the apparatus is subjected.

The protector will withstand momentary peak currents of about 20,000 amps and many hundreds of 100 Joule discharges.

Prompt delivery can be offered, because demand from many parts of the world has proved so high that production capacity has been greatly expanded.

The protector is available in three breakdown voltage ranges:

150 — 350 d.c.
300 — 500 d.c.
500 — 900 d.c.



AEI COMMUNICATIONS

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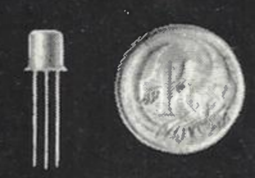
NEW SILICON TRANSISTORS FROM Mullard



A new range of silicon planar transistors is now available from Mullard with a wide application in the entertainment, industrial and professional fields.

- **Low Cost** ■ **Improved signal handling capability**
- **Good noise performance** ■ **Excellent AGC characteristic**
- **Low knee voltage** ■ **TO-18 encapsulation**

TO-18 encapsulation offers the following advantages—

- **a metal can and glass header which provide complete sealing against moisture penetration**
- **low inter-electrode capacitances resulting in higher available gain for a given set of parameters**
- **very low leakage current maintained over normal life, particularly at elevated temperatures**

Type Number	Description	V_{CBO} (V)	V_{EBO} (V)	I_C (mA)	P_{tot} (mW)	f_T (Mc/s)	h_{FE}
BF115	n-p-n RF silicon planar epitaxial transistor	50	5	30	140	230	45 to 165
BC107	n-p-n AF silicon planar epitaxial transistor	45	5	50	300	85	125 to 500
BC108	n-p-n AF silicon planar epitaxial transistor	20	5	50	300	85	125 to 500
BC109	n-p-n low-noise AF silicon planar epitaxial transistor	20	5	50	300	95	240 to 900

Mullard silicon planar transistors are designed so that each gives optimum performance for a particular application, such as RF or AF amplifiers. The BF115, for example, is designed as an AGC controlled RF amplifier, its low value of feedback capacitance providing high gain; and low knee voltage (less than 1V at 10mA) enabling a large voltage swing to be achieved in IF stages.

More detailed information on these transistors may be obtained from the Mullard Technical Service Departments at the addresses below.

Mullard

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M170

SILICON

CONTROLLED RECTIFIERS

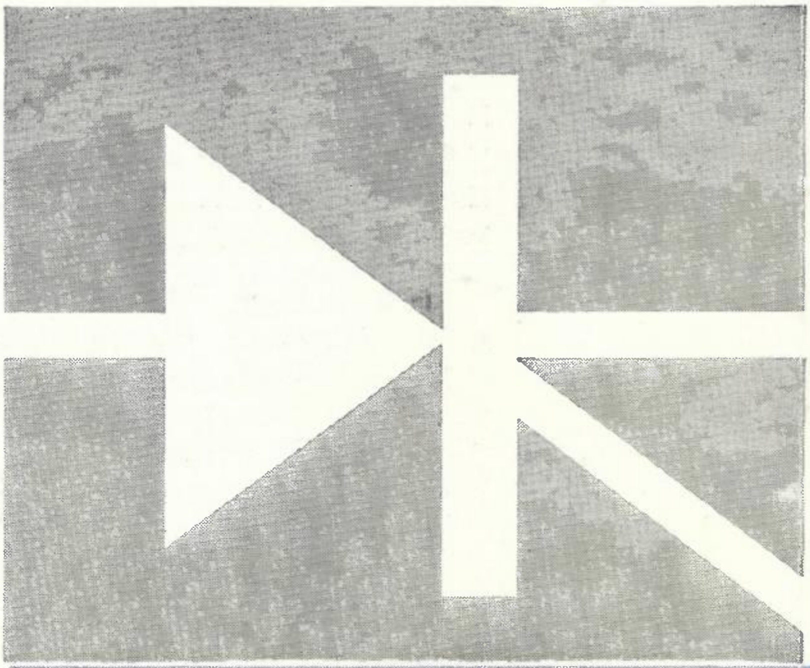
Now available in a wide range . . . and in

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.



The 2SF series silicon controlled rectifiers are available in extended voltage range and are identified by the following coding:

P.I.V.	300 mA	6.5A	11A	22A	55A	80A	200A
50	2SF101	2SF11	2SF21	2SF31A	2SF111	2SF121	2SF310
100	2SF102	2SF12	2SF22	2SF32A	2SF112	2SF122	2SF311
150	2SF103	2SF13	2SF23	2SF33A	2SF113	2SF123	2SF312
200	2SF104	2SF14	2SF24	2SF34A	2SF114	2SF124	—
250	2SF105	2SF15	2SF25	2SF35A	2SF115	2SF125	—
300	2SF106	2SF16	2SF26	2SF36A	2SF116	2SF126	2SF313
400	2SF108	2SF18	2SF28	2SF38A	2SF118	2SF128	2SF314
500	—	2SF200	2SF205	2SF210A	2SF120	2SF130	2SF315
600	—	2SF201	2SF206	2SF211A	—	—	—
700	—	2SF202	2SF207	2SF212A	—	—	—

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 . . .

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