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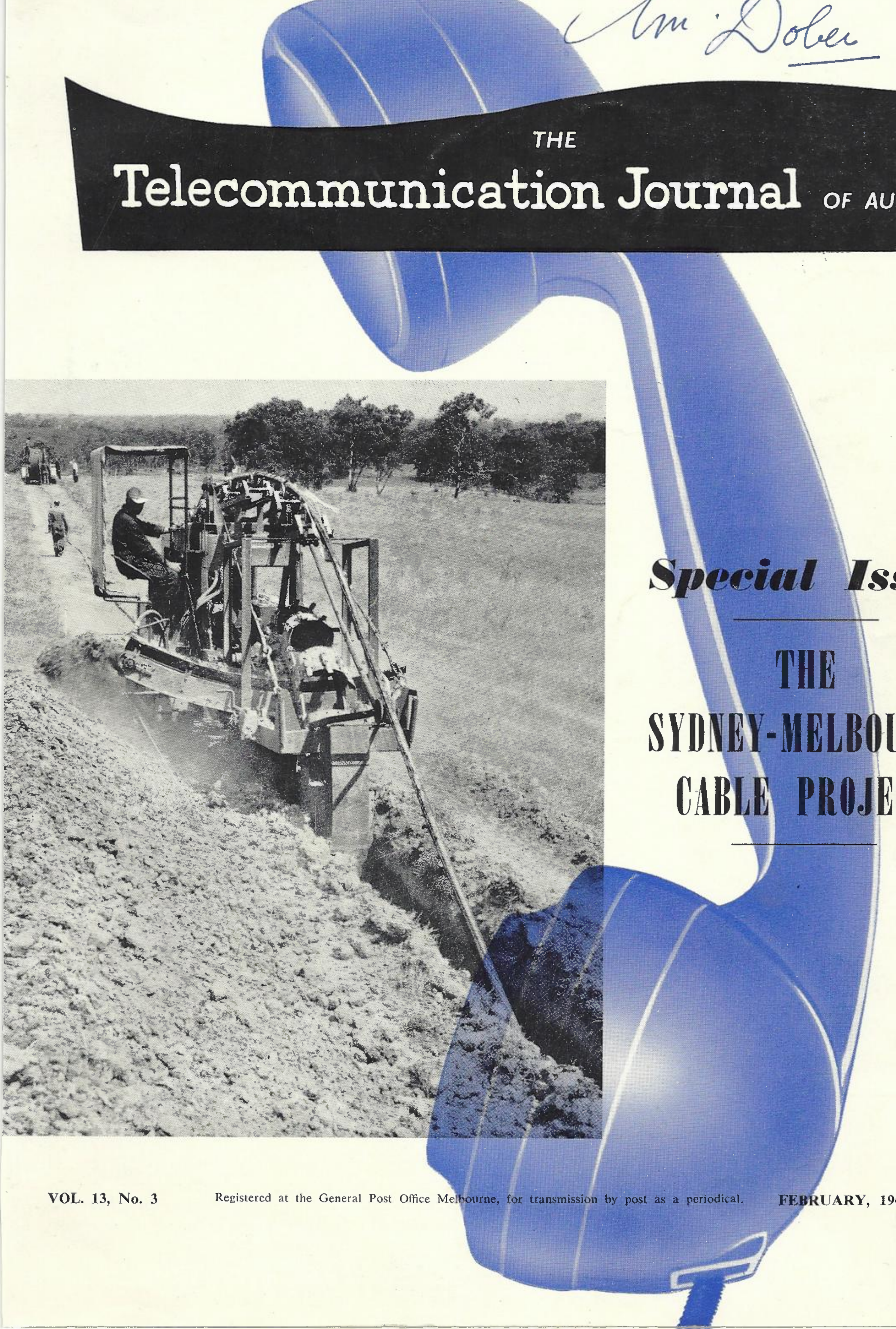
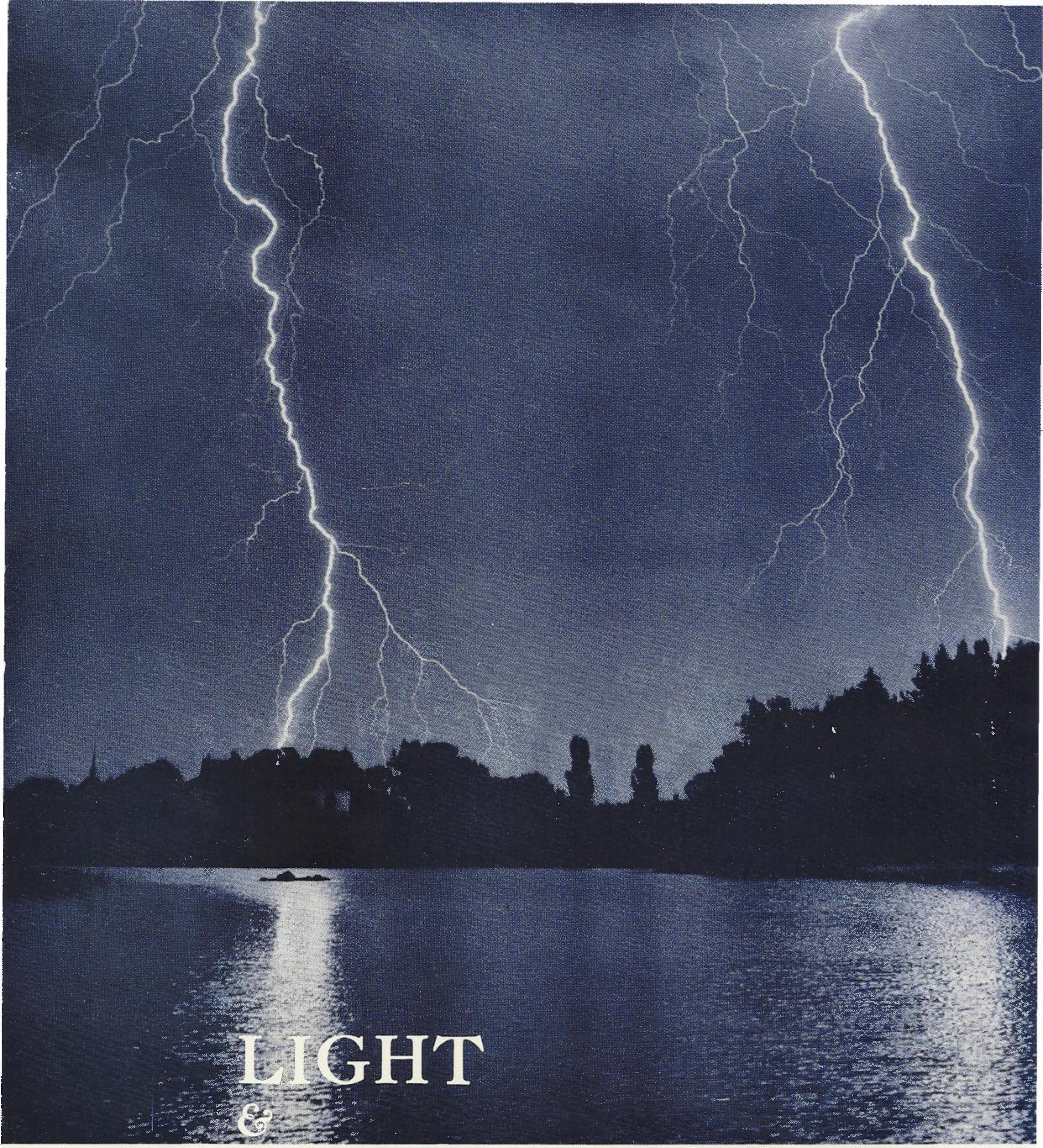
THE
Telecommunication Journal OF AUSTRALIA



Special Issue

THE
SYDNEY-MELBOURNE
CABLE PROJECT

VOL. 13, No. 3 Registered at the General Post Office Melbourne, for transmission by post as a periodical. FEBRUARY, 1962



The
TELECOMMUNICATION JOURNAL
of Australia

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

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

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*For addresses see page (i)

EDITORIAL

THIS special issue of the Journal consists entirely of articles giving a general description of the work carried out and the problems encountered on the Sydney-Melbourne coaxial cable project, and the general design of the system. Its issue coincides with the completion of the cable itself and the placing in service of the first Sydney-Melbourne telephone circuits. This is the first occasion in twenty-seven years of publication that the opportunity of presenting such an issue has arisen. It is a proud occasion as the project is the largest telecommunication engineering work undertaken in Australia and is a notable one by world standards. It is also a landmark in the development of Australia that such extensive telecommunication facilities should now be required between the two major cities and that the economy of the country should be developed sufficiently to provide them.

It is difficult to convey the vastness of the project to those who were not associated directly with the work. Telecommunications engineering works are not spectacular in nature, and now that the Sydney-Melbourne cable has been laid, there is little outward visible evidence that the work was undertaken. Even at the height of the cable construction, the effort extended over such a long length of the route that its magnitude was not obvious.

Nevertheless it involved the laying of 600 miles of cable across difficult terrain, buildings were provided and equipment was installed, and the first through telephone circuits are being brought into service within 33 months of the signing of the contracts for the work. Some one million tons of rock and soil were excavated for the trench in which the cable was laid, and this represents a major civil engineering effort equivalent to the excavation involved in the construction of a large dam. Even so, this part of the work absorbed only about 17% of the total labour effort required for the cable installation. As another comparison, the amount excavated is about 40% of that required for the Melbourne-Albury railway standardisation project, a work which is commonly regarded as being of a civil engineering nature.

The cost of the Sydney-Melbourne project can be divided into three approximately equal parts, the cost of manufacturing the cable itself, that of installing the cable, and the cost of the transmission equipment. In general, costs are reflected ultimately in the work of individuals, and each of the three main divisions of the project represents a very great effort by individuals in three separate fields. The work of installing the cable was undertaken mainly by the line staff of the Postmaster-General's Department who can justifiably be proud of their contribution to the project, while many more people, both in Australia and overseas, were engaged in producing the raw materials and in manufacturing the cable, the equipment, and the laying plant.

Again many individuals contributed to the general planning of the scheme, the design of the plant and the organisation and control of the installation operations. Twenty-two of the people closely associated with these aspects appear as authors of the articles in this issue, but many more undertook work of at least equal importance. Most of these belong to the manufacturing organisations overseas and will remain anonymous as far as Australia is concerned. Of the people in Australia it seems fitting to single out the work of Mr. J. W. Read, who is no longer with the Postmaster-General's Department, and who devoted a large amount of time to planning the project and to obtaining approval for it to proceed in the first place.

One aspect of the work which must be recorded is the harmony with which it was carried out and the atmosphere of co-operation and good faith which existed between all parties. This is all the more striking considering the number of separate groups involved and their geographic separation. In the Post Office the work was carried out by several different sections of the Engineering Division in association with the Buildings, Stores and Contracts, and Transport Services Branches as well as the Administrative groups and the Finance Branch; the Commonwealth Department of Works had a vital role with buildings and the Department of Interior with site acquisitions; the cable was manufactured partly by Felten and Guilleaume Carlswerk A.G. (West Germany) and partly by Olympic Cables Pty. Ltd.; the cable laying plant and many minor items of material were supplied by companies too numerous to record here; the transmission equipment was manufactured principally by Felten and Guilleaume Fernmeldeanlagen G.m.b.H. (West Germany) with some items by N. V. Phillips Telecommicatie Industrie (Holland); the power plant was manufactured principally in England by the Electric Construction Company Ltd., and installed by McColl Electric Works Pty. Ltd.; and Telecommunication Company of Australia Pty. Ltd. carried out the installation of transmission equipment, arranged and co-ordinated the supply of all equipment, and undertook the full responsibility for the satisfactory performance of the whole project. A complex system of contracts and conditional guarantees was involved and there were other potential complications. Such a situation is fraught with possibilities for misunderstandings but in fact none arose. This can be regarded as a tribute to the quality both of the engineering and manufacturing standards of the Contractors and also of their co-operative and helpful attitude towards the work. The inevitable technical and commercial problems which arose from time to time were always solved in a spirit of mutual understanding and co-operation.

This attitude of co-operation and sense of purpose extended right through to the field staff and in turn to the members of the general public who came in contact with the work as it progressed along the route. There was a sense of team achievement throughout all operations which was in proportion to the magnitude of the work and served to minimise the many difficulties.

In view of this high degree of co-operation and co-ordination it is quite easy to understand that the work proceeded according to the overall time table and that there were no major setbacks. Such a comment may seem inappropriate as any properly directed engineering work should do just this. However the Sydney-Melbourne project was not an ordinary job; it was, both in size and complexity, by far the largest work of this nature ever undertaken in Australia, operations were spread over 600 miles of terrain and there was no previous experience in work of this scale of magnitude and at such a fast rate of installation. Reading the articles particularly concerned with the cable installation, it will be evident that an ever present problem to both the factories and the field staff was the short time interval between the date that the contracts were signed and the terminal dates when the circuits were required to be in service. In spite of these factors and in spite of delays in cable laying in the winter of 1960, one of the wettest on record in the area, work went to schedule. This must be attributed to the skill and enthusiasm of the people concerned assisted in a great measure by the splendid co-operation which was brought to the project by all concerned.

In every respect the Sydney-Melbourne project has been a great one, and it is hoped that the present issue will serve to give readers some appreciation of the project and to record the problems for posterity.

MAIN FEATURES OF THE PROJECT

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INTRODUCTION

Prior to the first settlement of Europeans in Australia with the founding of Sydney (the capital of the State of New South Wales) in 1788, the country was only lightly populated by aboriginals of nomadic habits and, while assimilation is slowly taking place, the aboriginals have not in general accepted European ways or urban life, and in this paper population statistics and their relevance to telecommunications may be taken as referring to "European" population. In any case, the aboriginal population at present does not represent more than about .5 per cent of the total population. In the years that have followed the first settlement a population, mainly of British origin, has spread over the continent with varying degrees of density and, for a number of reasons, including in particular climatic conditions and natural resources, the most densely populated part of Australia is the south-east section which includes Sydney, the Federal capital of Canberra which was founded in 1911, and Melbourne (the State capital of Victoria) which was founded in 1835.

At the present time the populations of Sydney, Canberra and Melbourne taken jointly amount to a total of about 4.7 million persons which is approximately 40 per cent of the total population of Australia. Sydney and Melbourne, with populations of approximately 2.2 millions and 1.9 millions respectively, are the two largest cities in the country. The south-east section of the continent also includes many other important and growing towns and well-developed rural areas. Distribution of population can be illustrated in a number of ways but in view of the subject of this paper, Fig. 1 is appropriate. This figure shows the main long-distance trunk telephone and telegraph routes of the Commonwealth and the relative density of population of the south-east section is indicated by the trunk line network in this area in comparison with, for example, the north-west section of the continent.

The Sydney-Melbourne coaxial cable system to be described generally in this paper and in more detail in associated papers passes through and will serve this south-east section of the country and will therefore play an important part in the governmental, industrial, agricultural and social activity of a substantial proportion of the country's people. Moreover, since, as is also indicated in Fig. 1, the greater part of the eastern section of the continent is also fairly densely populated, with other well-developed areas based on Ade-

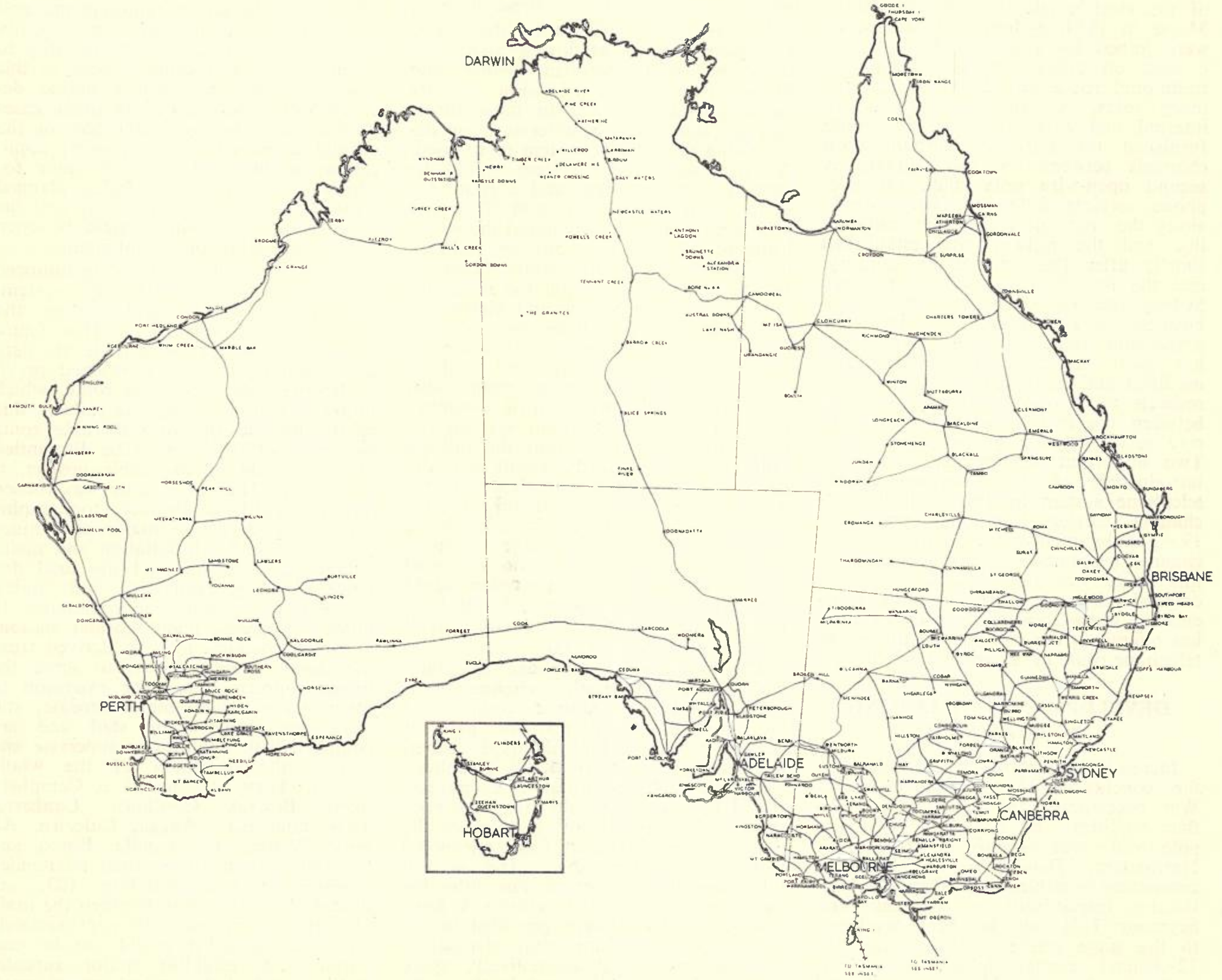

Fig. 1.—Main Telephone and Telegraph Routes of Australia.

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* See page 268.

laide (the capital of the State of South Australia) in the south, and Perth (the capital of the State of Western Australia) in the south-west, the Sydney-Melbourne system will be an important link for these other areas as well, by carrying through trunk telephone and telegraph traffic from (say) Perth to Brisbane. The island State of Tasmania is also connected to the mainland telecommunication system through Melbourne.

Although the south-eastern section of Australia is comparatively well-populated, it also includes areas of rugged mountainous country which are sparsely populated only, and a direct straight line between Sydney and Melbourne (distance 446 miles) would pass through the south-eastern highlands. To avoid this mountainous area, the main well-established route between the two State capitals skirts the highlands on their north-western (inland) slopes. The principal road, rail, and telephone trunk lines, including the new coaxial cable system, follow generally along this traditional route.

Only 14 years after the development of the electric telegraph by Samuel B. Morse in 1844, Sydney and Melbourne were joined by a single telegraph line erected on poles generally along the traditional route just described and for many years, but with improvements in internal and external plant, this route furnished the only telecommunication channels between the two capitals. A second open-wire pole route for telephone services following fairly closely along the route of the earlier telegraph line and the railway was established shortly after the turn of the century, and the first telephone circuit between Sydney and Melbourne was opened for business on 14th June, 1907. Over the succeeding years this telephone route has been increased in capacity and modified and improved in a number of respects to provide additional facilities between the two State capitals and to give service to the intermediate towns. Two important developments were the introduction of the 3-channel carrier telephone system in 1925 and the 12-channel carrier telephone system in 1939. Subsequently the number of 12-channel telephone systems operating on this route was increased to ten. The original telegraph route is still in existence in some areas, but as opportunity has offered in the past, it and the newer telephone route have been combined.

DEVELOPMENTS FOLLOWING WORLD WAR II

Increasing telephone traffic following the conclusion of the Second World War necessitated the provision of further facilities, and a second open-wire pole route was established via Cowra, Narrandera, Deniliquin and Bendigo connecting to cables to Sydney and Melbourne respectively at Blayney and Seymour. This route has been developed to the stage where it also carries ten 12-channel carrier telephone systems and apart from providing the additional channels which were necessary, it furnishes an alternative route as a safeguard against failure of the older route along the railway. It was recognised at the time that the provision of this alternative route via Bendigo and Deniliquin would only furnish sufficient telephone channels for a limited period, and also because the older route was inevitably reaching the end of its useful life with increasing maintenance costs and with technical characteristics inferior to those necessary in a modern telecommunications system, planning studies were undertaken leading to the decision to establish the Sydney-Melbourne coaxial cable system. The planning work which led to this decision had as one of its objectives the provision of a system which could be developed progressively over a considerable period of years to furnish the numbers of telecommunication circuits required, having regard to developments which could be foreseen including the desirability of providing for the relaying of television programmes. The main types of system from which the choice had to be made were radio, cable which could be of the quad carrier type or coaxial type, open wire, or combinations of these systems.

It was mentioned earlier that there are many important towns along the traditional route between Sydney and Melbourne, and the provision of telecommunication services to these towns was an important consideration in determining the type of system to be used. A micro-wave radio system would be attractive at first sight and a route for such a system was considered. This type of system would have required the establishment of radio stations on hill-tops to obtain optical paths from station to station and could provide the necessary facilities between Sydney and Melbourne and to some intermediate towns at relatively low cost. However, provision of services to all towns large and small in the area being considered would also have involved the provision of a number of subsidiary cables, radio systems, or open-wire line routes from the hill-top radio stations, with the result that the cost of the whole complex network would have been considerably greater than the cost of the main micro-wave system itself. A disadvantage of open-wire pole route construction or quad carrier cable was that provision could not be made for relaying of television programmes as can be done with coaxial cable or micro-wave radio.

The numbers of telephone, telegraph and sound broadcasting channels estimated as being required could have been accommodated on one pair of coaxial cable tubes of the type recommended by the International Telephone and Telegraph Consultative Committee (C.C.I.T.T.) and it would thus have been practicable theoretically to furnish the required services (apart from television) with a two-tube cable. (The coaxial tubes are used in pairs, one tube for transmission in each direction.) A four-tube cable would have provided in addition for a television relay channel in each direction or, alternatively, spare tubes which could be used in the event of failure of the first (telephone) pair of tubes and for other maintenance purposes. However, it was shown that the capital and annual costs of a complete six-tube cable system would be little greater than for a four-tube cable system, and since the former would furnish additional facilities either for telephone channels or for television relaying purposes, a six-tube cable was considered to be the best proposition; it will be appreciated that many of the items to be taken into account in comparing costs would be similar for either size of cable as, for example, trenching for cable laying, buildings for associated carrier equipment, power plant, etc.

Exhaustive studies were made of the several types of system which could be considered as possibilities, and after consideration of all factors, including in particular economic comparisons of capital and annual charges of all plant involved, it was decided to establish a six-tube coaxial cable system with, initially, sufficient associated carrier equipment to satisfy telephone and other telecommunication requirements for a period of some five years, and with facilities for readily increasing the number of channels to satisfy requirements estimated for a period of some twenty years. It is stressed that the decision to adopt the coaxial cable system in this case does not mean that a similar decision would be reached in other cases or that there is any preference for the coaxial cable system for general application; on the contrary, each route for which a new system is being planned must be considered individually and the appropriate arrangement could be open wire, radio, cable, or a combination.

Fig. 2 shows the route being followed for this six-tube coaxial cable system; this varies only slightly from the route planned originally. This figure also shows the open-wire route via Bendigo, Deniliquin, etc., mentioned previously; the older telephone route, which follows generally along the railway line fairly close to the coaxial cable route and most of which is to be dismantled on completion of the cable project, is not shown. The cable route was chosen having regard to distance, topographic conditions, service to major and minor towns, access for installation and maintenance, and so on, and the total distance is approximately 600 miles. At intervals averaging approximately 40 miles are located main repeater stations at which channels may be derived from the coaxial cable system to serve the towns concerned and for extension to other places. These major repeater stations are attended by staff and are equipped with facilities to supervise and control the operation of the whole system. They are located at Campbelltown, Bowral, Goulburn, Canberra, Yass, Gundagai, Wagga, Culcairn, Albury, Wangaratta, Benalla, Euroa and Seymour. Intermediate minor unattended repeater stations, totalling 103, are placed along the route between the main stations at intervals of approximately 5.6 miles. Since it would not be economical to establish major repeater stations and derive telephone channels at all towns along the route, separate

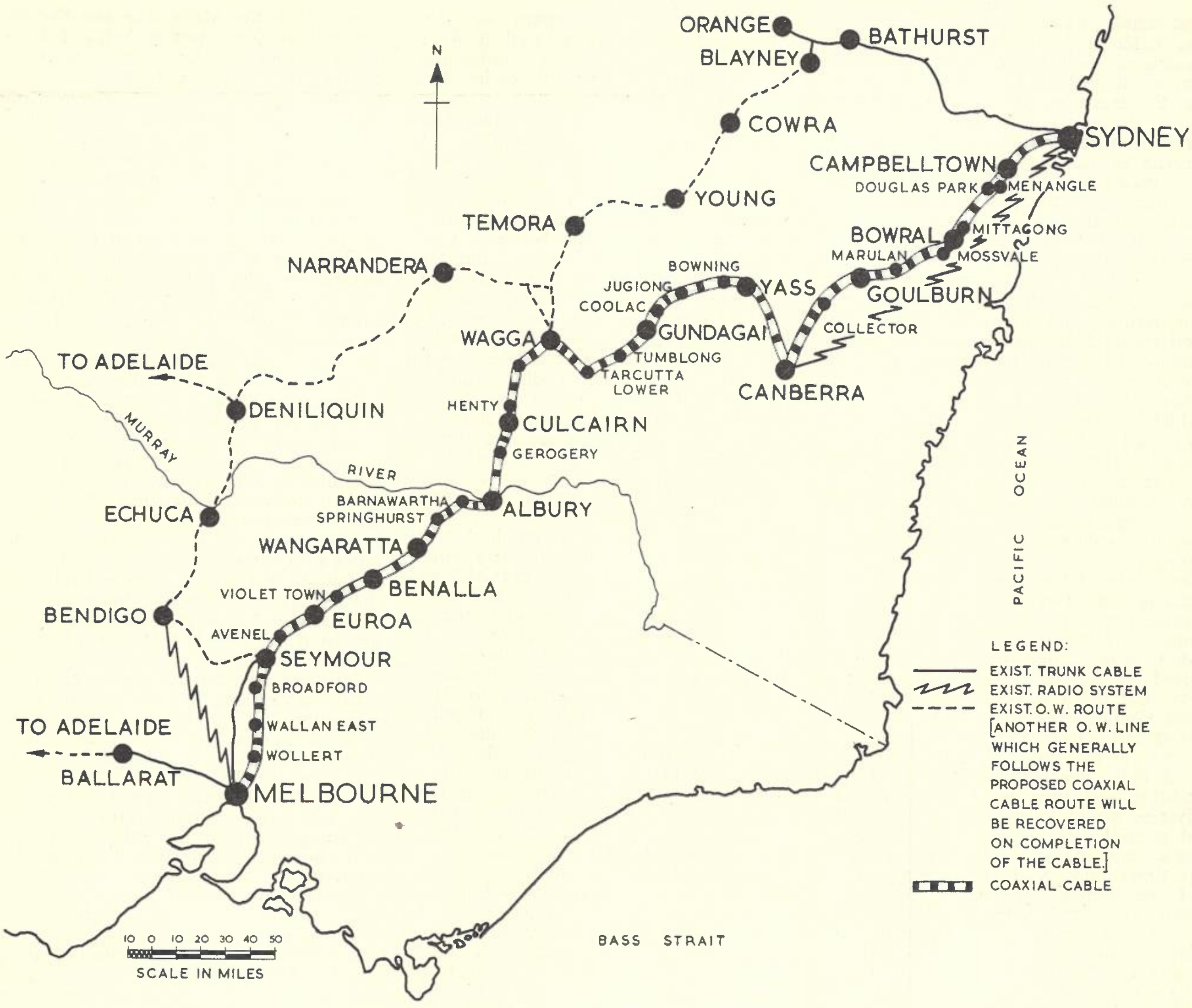

Fig. 2.—Route for Sydney-Melbourne Coaxial Cable System.

minor trunk cables (quad type, loaded) are provided from major stations to other towns and between other towns, the planning of channels from the coaxial system and from the minor trunk cables being integrated. These minor trunk cables were treated as part of the coaxial cable project and were laid with that cable.

ASSOCIATED WORKS

The Australian Post Office has for a number of years been pursuing a policy of mechanising the telephone and telegraph systems and, in common with many other administrations, has long-term plans for the general introduction of subscriber-to-subscriber dialling over long distances. Among other things a trunk dialling system requires a larger number of trunk channels of adequate technical quality than does manual operation of the trunk system.

In conjunction with the provision of the Sydney-Melbourne coaxial cable system, arrangements were made to modernise and extend automatic telephone switching plant at towns along the route as far as it has been practicable to do so having regard to such factors as the age and condition of existing switching plant, availability of funds, etc. A number of installations of automatic switching equipment are being carried out more or less concurrently with the coaxial cable project in conformity with this policy.

To further extend the benefits which will be derived from the establishment of the coaxial cable system, spur trunk line routes from the coaxial cable route to other places are being improved and extended, and provision has been made for improved service to individual subscribers or groups of subscribers, along and in the vicinity of the cable route, by installing cable to connect their premises to exchanges, and by the provision of additional exchange plant.

EXECUTION OF THE PROJECT

Having determined that a six-tube coaxial cable system was most suitable for the purpose, the Post Office invited world-wide tenders for the supply, or alternatively for the supply and installation, of the cable and of the associated carrier and power equipment. After thorough analysis of the tenders, which were received from most of the leading manufacturers of telecommunication plant, it was decided early in 1959 that a contract for supply of the cable with associated accessories such as gas pressure alarm systems, jointing materials, testing instruments, etc., would be awarded to Felten and Guilleaume of West Germany, and that a contract for the supply and installation of the carrier and power equipment would be awarded to Telecommunication Company of Australia. It was also decided that a substantial proportion of the cable would be manufactured in Australia by Olympic Cables Pty. Ltd. as a sub-contractor to Felten and Guilleaume, and that all cable would be installed by the Post Office with its own staff.

It will be appreciated that in view of the size and complexity of the project, a great many other items of plant, large and small, were necessary apart from the cable and the equipment directly associated with the cable, and a most important part of the work of planning for the execution of the project and the actual execution itself has been the co-ordination of all parts, particularly with respect to the carrying out of each part to a predetermined time-table. Of special significance in the planning of the execution of the project were discussions with the principal contractors in May and June, 1959, during which agreement was reached regarding details of the plant to be supplied, the arrangements for testing, and many other technical and contractual matters; a time-table for supply and installation of all major items of plant was developed during these discussions and detailed planning which had been carried out earlier was reviewed and modified where necessary to suit this time-table.

The main features of the arrangements adopted were:—

(i) The coaxial and minor trunk cables for the Sydney-Canberra section of the route together with cable accessories for the whole of the route would be manufactured in Germany by Felten and Guilleaume, whilst coaxial cable and minor trunk cable for the Canberra-Melbourne section would be manufactured in Australia by Olympic Cables Pty. Ltd. as a sub-contractor to Felten and Guilleaume. Initial delivery of coaxial cable from Germany would commence at the end of 1959 at a rate of 12.5 miles per month for the first four months and then increase so that deliveries would be at a rate of 30 miles of coaxial cable per month, with accessories and minor trunk cables delivered at times appropriate to match delivery of the sections of coaxial cable with which they were to be associated.

(ii) Preliminary surveys had been carried out to determine the approximate route of the coaxial cable system and these were followed by a very detailed survey to determine the precise locations of minor repeater stations, the lengths in which cable would have to be supplied, the locations of joints and loading points, and to ascertain the nature of the ground for excavation, and to plan the methods to be adopted in cable laying and similar work.

(iii) The installation of the cable of which the main features are laying of the cable at a depth of 4 feet in trench, hauling of cable into ducts in built-up areas, jointing and testing, would be carried out by the Department progressively from Sydney southwards to Melbourne. This work was planned to be done using mechanical aids extensively, with the staff accommodated in well-equipped caravan camps along the track, Radio communication was arranged between camps, depots and working parties. Transport of cable from the wharf in Sydney (in the case of cable from Germany) or from the works of Olympic Cables Pty. Ltd. in Melbourne (in the case of cable manufactured in Australia) to the points of installation was arranged by the Post Office transport fleet.

(iv) The carrier equipment to be supplied and installed under contract by the Telecommunication Company of Australia would be manufactured in West Germany by Felten and Guilleaume Fernmeldeanlagen and would be installed in four main stages:—

(I) To provide direct telephone, telegraph bearer, and sound broadcasting channels between Sydney and Canberra.

(II) To provide direct telephone, telegraph bearer, and sound broadcasting channels between Canberra and Melbourne and, by extension from Stage 1, between Sydney and Melbourne.

(III) To provide telephone and like services to towns intermediate between Sydney and Canberra with television relay facilities joining Sydney and Canberra, and

(IV) To provide telephone and like services to intermediate towns between Canberra and Melbourne with television relay channels connecting Canberra and Melbourne.

(v) All telephone, telegraph bearer, and sound broadcasting channels would be carried on one pair of coaxial tubes whilst a second pair of coaxial tubes would be equipped for the dual purpose of furnishing a standby bearer for the first (telephone) pair and also for a television relay channel usable in the direction of Sydney to Canberra to Melbourne, and another in the direction Melbourne to Canberra to Sydney. To maintain uniformity and flexibility, repeater equipment for all four tubes was arranged to be of the same type giving an effective transmitted bandwidth of 6 Mc/s. The third pair of tubes would be left unequipped and ready for future development.

(vi) The coaxial cable would, in addition to the six tubes, contain 32 pairs (16 quads) of 20 lbs./mile conductors. Of these, 12 pairs located in the outer interstices between the tubes would be suitable for carrier frequency working, 11 pairs in the inner core would be used for control and supervisory purposes, and the remaining 9 pairs in the core would be used for minor trunk circuits. As previously stated additional minor trunk cables were provided as part of the project where necessary along the route.

(vii) In conjunction with the coaxial cable project, additions to automatic switching equipment and other associated works were planned. For this and other reasons, the Post Office itself arranged to complete connections between the cable channels and switching equipment, to provide some signalling equipment and manual switchboards, and to carry out other similar work (including overall testing) to integrate the coaxial cable system into the Commonwealth telephone network.

(viii) Power plant comprising continuously rotating equipment to give an uninterrupted source of power and normally stationary standby diesel engine alternators with the necessary control equipment would be supplied by McColl Electric Works Ltd. of Melbourne as a sub-contractor to Telecommunication Company of Australia. This power plant was required for all major repeater stations and at the Melbourne and Sydney terminal stations, power being fed to minor repeater stations along the inner conductors of the coaxial tubes.

(ix) The Commonwealth Department of Works on behalf of the Post Office arranged for new buildings or for extension of buildings including building services, air conditioning, etc., at all major repeater stations, the arrangement being that the special equipment for the coaxial system would be accommodated in buildings which were also suitable for other purposes such as housing telephone switching and exchange equipment, other carrier equipment, and so on.

(x) The Commonwealth Department of Works on behalf of the Post Office arranged for the prefabrication and erection on site of the 103 small buildings required for minor repeater stations, these buildings being specially designed for the purpose, including special attention to minimising internal temperature variations.

(xi) In built-up areas, ducts and manholes to a total route length of approximately 50 miles were to be provided by the Department to accommodate the coaxial cable and at the same time make provision for other cables which were foreseen to be required in the future.

(xii) Special attention was directed towards minimising the likelihood of interruptions to service over the system and to ensuring the prompt restoration of service in the event of faults. Security measures included:—

(a) Burying the cable at a depth of 4 feet with additional protection and arrangements to prevent soil erosion or accidental damage at vulnerable points.

(b) Maintenance of an air pressure of 12 lbs. per square inch in the cables with an alarm system to signal loss of pressure to an attended station.

(c) The use of duplicate valves in common transmission (carrier) equipment to maintain service in the event of a valve failure.

(d) Provision of a comprehensive alarm system to signal any abnormal condition to an attended station.

(e) Standby power supply at major repeater stations with mobile power units for use if necessary at minor stations.

(f) Provision of roads and gates to permit ready access along the route of the cable and to repeater stations for patrolling and other staff.

(g) Provision of spare materials, components, and units with comprehensive facilities for testing and repair.

(xiii) The cable contractor, Felten and Guilleaume, guaranteed the physical and electrical properties of the cable when installed, and made available in Australia the services of an experienced engineer to watch the company's interests and to assist the Post Office engineers with the installation. The company also provided three experienced cable jointers to instruct Post Office staff in the jointing of coaxial tubes. The equipment contractor, Telecommunication Company of Australia, guaranteed the

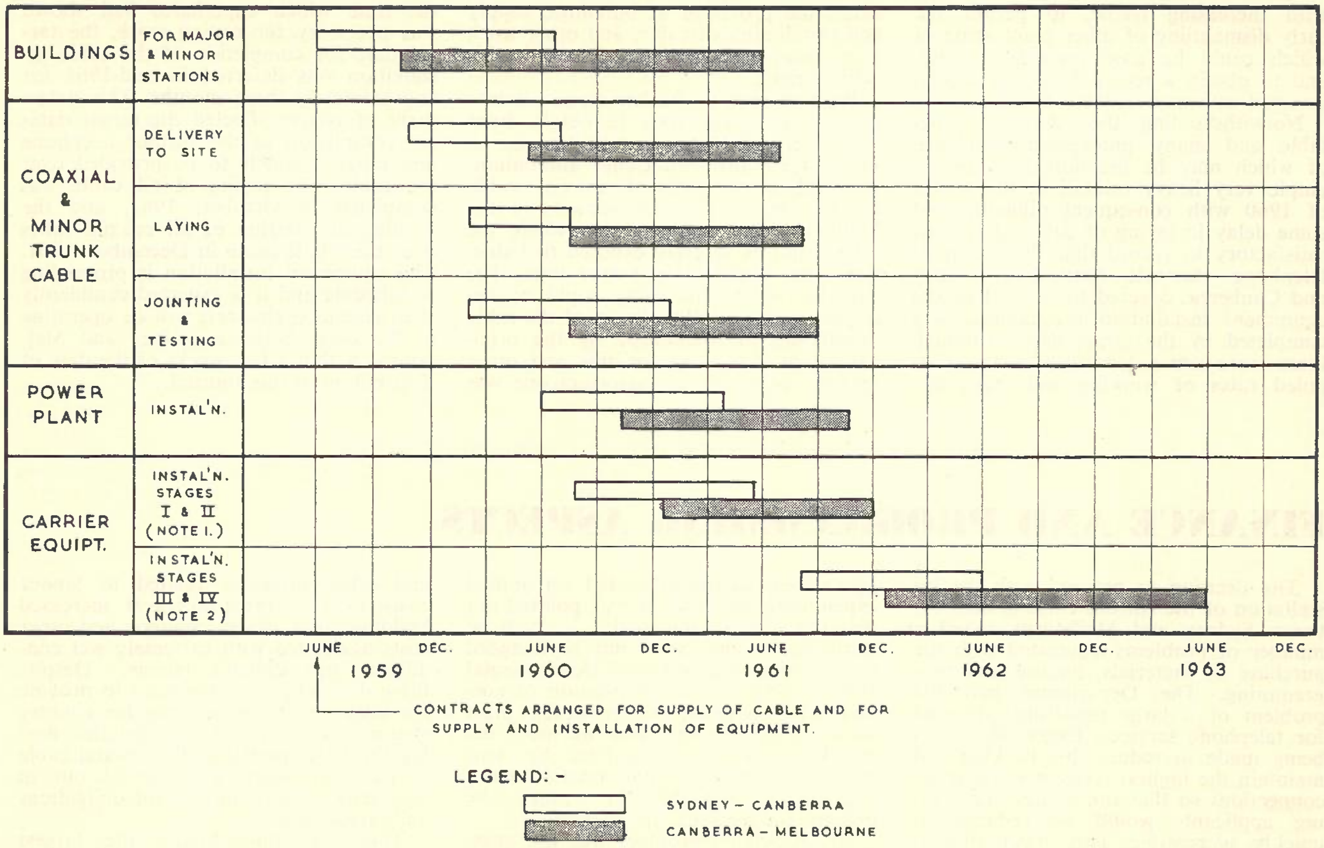

Fig. 3.—Target Programme for Execution of Sydney-Melbourne Project.

Notes:— 1. Stage I (Sydney/Canberra) and Stage II (Extension to Melbourne) are to provide Inter-capital channels for Telephone, Telegraph and Sound Broadcasting Transmission.

2. Stage III (Sydney/Canberra) and Stage IV (Extension to Melbourne) are to provide channels to intermediate towns for Telephone, Telegraph and Sound Broadcasting Transmission and Channels for Inter-capital Television Transmission.

performance of the channels, when operating over the cable.

Other papers in this issue of the Journal deal in more detail with the various parts of the project.

The chart in Fig. 3, which is a greatly simplified version of a type of chart used for planning and oversight of progress, indicates the time-table which was adopted as an objective for some of the more important parts of the project. It is worthy of mention that it was planned to instal cable over a period of approximately 20 months at the very high average rate of at least 30 miles monthly, with the rate of provision of other plant arranged to suit.

With respect to staff organisation for the execution of the project within the Post Office, it was determined that, as a general rule, the responsibility for each aspect would be accepted by the section of the existing organisation normally responsible for the class of work concerned (augmented as to staff strength where necessary and practicable) rather than set up a special organisation. However, because of the unusual nature and magnitude of the project with a very large number of individuals or groups of individuals with a part to play in a co-operative effort, an additional small section of the Engineering Division at Headquarters was established for general oversight of all aspects with emphasis on the co-ordination of the many parts of the work. Field planning, survey, and installation of the cable together with supervision of the contract for equipment installation and for the undertaking of associated works was the responsibility of the Post Office State Administrations of New South Wales and of Victoria respectively, but in each State an engineering group was set up specially to undertake the cable installation. Interchange of plant, staff, and of experience, which was of very great importance because many new techniques were developed as the work proceeded, between the two State groups handling the cable installation was arranged as desirable to achieve maximum output and the planned rate of progress.

Two co-ordinating committees were also set up, one being representative of the principal contractors and of each of the branches of the Department responsible for such matters as finance, stores and contracts, buildings, telecommunications (traffic), transport, public relations, and engineering, and the other representative of the several sections of the Engineering Division concerned in Headquarters and in New South Wales and Victoria. These two committees have held monthly meetings since the early stages of the work and have contributed in a most useful way in resolving points of difference on technical and other matters, in ensuring that no part of the work or of equipment was overlooked, in directing attention and increased effort to any matter which appeared to be lagging behind schedule, and in many other similar ways.

CONCLUSION

The time-table shown in Fig. 3 was agreed in mid-1959 for the main parts of the project and it is mentioned that all concerned at the time realised that the target objectives would be very difficult to achieve. Completion of the project by the earliest practicable date was considered to be necessary because of the need for additional channels to cope with increasing traffic, to permit the early dismantling of other plant some of which could be used on other routes, and to obtain a return from the capital invested without avoidable delay.

Notwithstanding the difficult timetable and many unforeseen problems, of which may be mentioned as an example very heavy rainfall in the winter of 1960 with consequent difficulty and some delay in laying of cable, it is most satisfactory to record that the group of telephone channels connecting Sydney and Canberra, covered by Stage I of the equipment installation programme, was completed by the target date. Although there were some departures from scheduled rates of working and from due dates, the provision of buildings, supply and installation of cable, and other work were completed in time to permit this achievement.

With respect to further stages, it was decided at a late date to obtain from the factory of Felten and Guilleaume in West Germany sufficient aluminium-sheathed plastic-jacketed coaxial cable for two minor repeater sections in the Melbourne metropolitan area where the cable route is severely exposed to induction from high-tension power lines. The date by which this cable could be delivered precluded completion of the cable installation to Melbourne by the original target date, and for this and other reasons, of which an important one was the time which experience had shown was necessary for testing work, the target date for completion of the cable installation was deferred in mid-1961 for approximately three months. This deferment of course affected the target dates for completion of the further telephone and other channels to be provided over the cable. The laying of all cable was completed in October, 1961, and the jointing and testing of all coaxial tubes over the whole route in December, 1961. The equipment installation is proceeding to schedule and it is expected confidently that telephone channels will be operating in the cable between Sydney and Melbourne within a few weeks of the date of distribution of this Journal.

FINANCE AND PROGRAMMING ASPECTS

The decision to proceed with the installation of the coaxial cable system between Sydney and Melbourne raised a number of problems associated with the purchase of materials, finance and programming. The Department had the problem of a large unsatisfied demand for telephone services. Every effort was being made to reduce this backlog and maintain the highest level of subscribers' connections so that the number of waiting applicants would be reduced as quickly as possible. This meant that as much money as possible had to be allocated for the purpose of providing new telephone services. Against this background therefore, it was necessary to obtain some assurance that adequate funds would be available to put such a large project in hand and continue with the project once it had been commenced without prejudice to other facets of the Capital Works Programme.

Advice of the decision to purchase the coaxial cable and equipment was forwarded to the Commonwealth Treasurer before the contracts were let. This advice included detailed reasons for the need of such a system between Sydney and Melbourne, reasons for the decision to procure part of the cable and the equipment from overseas sources, and also details of the estimated net annual expenditure involved. It was pointed out that the costs of the work . . . "will be fairly heavy and could not be financed from within the ordinary Departmental Votes without serious restriction of normal developmental works which must be continuously in hand to meet demands created and expanded by Australia's growth". Additional finance was made available to ensure the orderly progress of the project.

An associated problem was the question of forward ordering authority to enable advance orders to be placed. The Department normally receives approval from the Treasury during a particular financial year to forward order materials required to be delivered in subsequent financial years. Separate authority was obtained for the Sydney-Melbourne project and this enabled the ordering of materials required for the project to proceed without hindrance.

As could be expected with a project of such magnitude covering an installation period of some four to five years, difficulties were experienced from the programming and funding angle because of changes in the cost structure. This was particularly noticeable in relation to wage, travelling and camping allowances and other increases related to labour costs, material price increases, increased building costs, design changes, and other costs associated with extremely wet conditions and difficult terrain. Despite these difficulties and the need to provide for television relay facilities for country stations, which had to be installed during the latter period of the coaxial cable project, the work was carried out in accordance with contractural obligations and target dates.

This was undoubtedly the largest single major work ever handled by the Post Office and notwithstanding the many difficulties encountered during the course of the project, it is considered that the maximum results have been obtained from the money expended and the final result reflects great credit on all concerned.

The total cost of the project and the spread over the financial years is set out below:—

	£m
1958/59	.210
1959/60	1.400
1960/61	2.400
1961/62	1.600
1962/63	1.280
Total	6.890

THE TELECOMMUNICATIONS ASPECTS

*I. S. McDUFFIE.**

INTRODUCTION

The month of June, 1961, marked a most important milestone in the history of telephone communications between Sydney and Melbourne, for it was at this time that the first circuits to be derived from the Sydney-Melbourne coaxial cable project became available for traffic between Sydney and Canberra. This history, however, had its beginning well before the days of coaxial tubes, super groups and carrier systems, to be precise, 54 years previously to the very month when, on 14th June, 1907, the first telephone trunk line between the two cities was brought into service. In those days, the telegraph was the principal means of interstate communication and remained so for many years after the first telephone line commenced operating. The public, too, was far less telephone conscious than it is today and the demand for long-distance telephone facilities was not great. Nevertheless, traffic on the one line built up steadily and was sufficient after World War I to necessitate measures being taken to provide additional facilities.

TRAFFIC GROWTH

Records of the annual development of telephone traffic between Sydney and Melbourne are not available prior to 1922, and to conserve manpower, the records were discontinued shortly after the outbreak of World War II, to be recommenced in 1947/48. However, the traffic figures plotted in Fig. 1 show how the volume of calls has risen steadily over the years. The extremely rapid development since World War II which resulted in the open wire routes quickly becoming inadequate is quite evident. Traffic between Melbourne and Brisbane, as well as traffic between Sydney and the other capital cities obtained through Melbourne, has been included in the graph, since this reflects the increased demands on the route linking Sydney and Melbourne. For simplicity, traffic for Canberra and intermediate centres has not been included.

It is interesting to note that the growth of telephone traffic on the Sydney-Melbourne route appeared to be restricted by the limited facilities available prior to 1925. This undoubtedly was because, even with the operating practices used to secure the absolute maximum effective usage of the lines, it was physically impossible to connect more than 7 or 8 calls over each channel in one hour. This is borne out by the fact that just prior to the first 3-channel carrier system being installed, the average number of calls connected between Sydney and Melbourne in one hour was about 14.8, yet this rose to 23.8 within a month of the lines available being increased from two to five. At the same time the average delay on each call fell from approximately 25 minutes to just over 5 minutes.

Although not strictly pertinent to the story of the development of the Sydney-Melbourne trunk route, the different incidence of traffic in the years before World War II and that of the present day is rather interesting. Prior to 1941 the charging structure provided for half-rate trunk calls at night. This concession was first introduced in 1916 and was extended in 1929 to incorporate an intermediate evening rate. The result was to cause marked peaks of traffic in the evening hours and it was not unusual for the Main Trunk Exchanges to be quiet and slack, with staff waiting for calls, for some time prior to the half-rate period, and working at full pressure immediately the half-rate period commenced. Nevertheless, this spread the non-urgent and social calls to the half-rate period, and meant that considerably more traffic could be handled on the severely congested Sydney-Melbourne route. On the other hand, the sudden surges of traffic created staffing and operating problems which do not exist to nearly the same extent today.

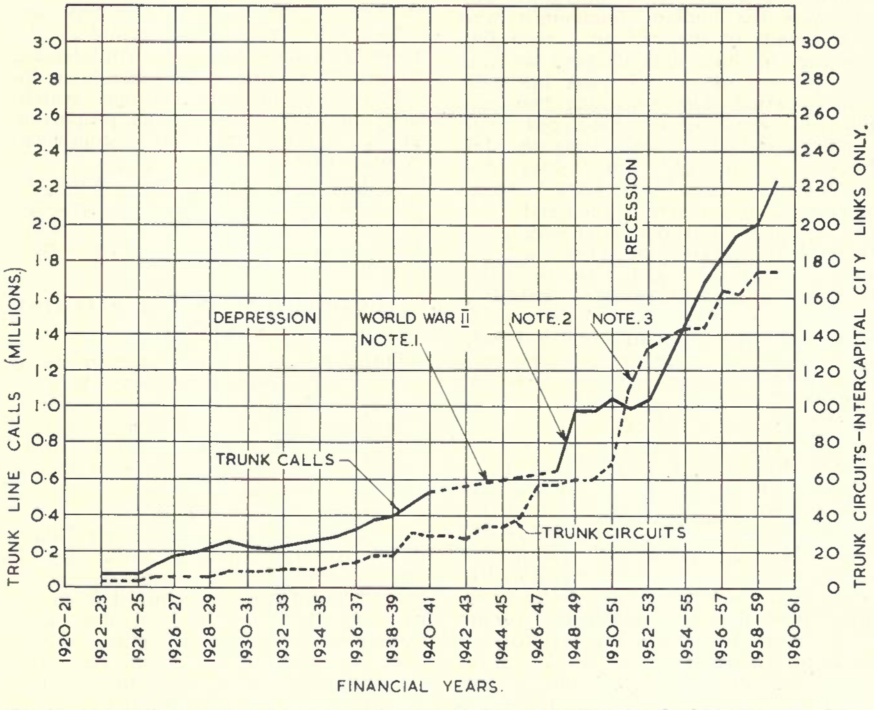

Fig. 1.—Growth in Traffic and Circuits — Sydney-Melbourne Route Inter-Capital City Links Only.

Notes:

1. World War II did tend to repress traffic. Also, many circuits on the route were released to the Armed Services for private lines, hence a slight regression despite the fact that new channels were added. After the War it will be noted that the channels released by the Services caused a sharp upward trend in provision.
2. There was a rapid increase in traffic in the immediate post-War boom years. This tapered off in the somewhat unstable condition of the economy which brought the minor recession of the early 1950's.
3. A rapid increase in circuit provision was apparent with channels becoming available from the newly constructed "back-route". As pointed out, however, relief by this means could not be of considerable duration.

GROWTH OF THE ROUTE

Although the first telephone circuit between Sydney and Melbourne was installed in 1907 it was not until 14 years later that the second trunk line came into service. At this stage the telegraph system was still the more important communications medium and the proportion of telephone and telegraph lines was two to five. In 1925, the first telephone carrier system to be installed outside the U.S.A., where the system was developed, was installed between Sydney and Melbourne and this, a 3-channel system, brought the total telephone circuits in operation to five.

The advent of carrier, which in its time was probably no less significant a change in the concept of telephone development than the coaxial cable is today, ushered in a new era in long-distance communication. Whereas the high costs and limited capacity of open-wire construction had severely restricted the possible development of an inter-capital city telephone network until then, the expansion of the system more in keeping with traffic offering and to provide an improved service to telephone users became a practicable proposition. The depression years, of course, did restrict development to some extent but in spite of this, the second 3-channel carrier system was added to the route in October, 1929, the third in December,

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* See page 268.

1935, and the fourth and fifth in April, and December, 1937, respectively. The first 12-channel carrier system in Australia was installed over the route in November, 1939, at which stage the total of Sydney-Melbourne circuits had grown to thirty. In addition, the establishment of the Nation's capital at Canberra in 1927 had necessitated the provision of trunk line facilities for that centre. These, of course, were additional major circuits on the Sydney-Melbourne route. The first carrier systems to serve Canberra were a 3-channel Melbourne-Canberra system, which was provided in March, 1938, and a 3-channel Sydney-Canberra system provided in September, 1939.

No further significant development occurred until after World War II when the route was expanded rapidly in the post-war boom years. By 1947 the route was carrying 48 Sydney-Melbourne circuits, 4 Melbourne-Brisbane, 12 Sydney-Canberra, 22 Melbourne-Canberra and 4 Sydney-Adelaide — 90 circuits in all, apart from lines serving intermediate country centres. At this stage, the route was near saturation and for this reason, as well as from the security aspect, construction of a second Sydney-Melbourne route was undertaken in 1948. A new pole route was erected between Blayney and Seymour by way of Cowra, Narrandera, Deniliquin and Bendigo, to connect with the existing Sydney-Blayney-Orange and Melbourne-Seymour cables. The new open-wire route, known as the "back-route," had a capacity of 132 "through" circuits but, with the rate of growth then evident, it was recognised even before the channels became available that the additional facilities provided by this means would be inadequate in the long-term. It was necessary, therefore, to plan for the provision of a new main communications system to meet the rapidly increasing needs for telephone facilities and the considerations leading from this realisation to selection of the coaxial system have already been covered in the article by Mr. A. H. Kaye appearing in this issue.

Fig. 1, as well as showing traffic growth, illustrates the development of the Sydney-Melbourne route from its inception to the present date, covering details of all inter-capital city trunk lines provided over the route. Circuits serving provincial centres have been omitted to simplify the illustration. The main factors which operated against the rapid expansion of the interstate trunk system were overcome when 12-channel carrier systems became available in the late 1930's. As previously mentioned, the first 12-channel system was installed between Sydney and Melbourne just after the commencement of the War in 1939. During the War the Defence Services leased a large number of circuits and the withdrawal of lines from the public system accounts for the apparent fluctuations in circuit provision. Had traffic figures been available during this period they would have been depressed as this heavy Defence traffic would not be included. The installation of two 12-channel systems early in 1946 helped to cope with the post-war boom, but the impetus to traffic meant that the relief was short lived. The erection of the back route resulted in one 12-channel system being cut into service in each of the years 1950, 1951 and 1952 with a further two systems becoming available in 1953. A recession in 1951/53 caused a levelling off in traffic and for about two years normal development was lost. More than doubling the number of circuits in three years had an explosive effect on traffic and is reflected in the subsequent unprecedented growth. This continued until impeded by the economic influences late in 1960 which caused a levelling out in traffic.

It will be seen that the Sydney-Melbourne route has been in the forefront of development in trunk telephony in Australia almost since Federation.

OPERATING PRACTICES

In the early days of the Sydney-Melbourne route, and in fact the same could be said for most inter-capital city routes when first established, the costs of providing each circuit were high and new lines could not readily be made available. As a result, it was essential to secure maximum usage from each channel. This led to complex operating procedures and a severely delayed service, which probably would not be tolerated by our more telephone-conscious subscribers of today. Each call was handled by at least three operators. The first was the booking telephonist who took details of the call on a recording position. In those days demand working was unheard of and all trunk line calls were reverted. The remaining two telephonists were those concerned with connecting the call, one being in Melbourne and the other in Sydney. The method of operating was "back to back" working with a docket at each end. Only the very best trunk operators were given the task of working the interstate trunk lines. In fact, these girls were so skilled that two of the Melbourne "specialist" operators in the 1920's were induced to leave the Department to work as P.B.X. operators for private firms at the then remarkable wage of £5 per week. At the time an exchange Monitor's salary was a mere £2 per week.

The operating procedures entailed both called and calling parties being brought to the telephone while a call was in progress, and, as soon as the trunk line became free, their call would be established. This actually meant that the parties to a call would be required to wait on for several minutes until a line was available. For particular person calls it was usual practice to inform a particular person that he would be receiving a call within a certain time, in order to ensure that trunk line time would not be wasted through "particular person unavailable" conditions. Delays were very heavy, especially near holidays, and for many years it was far quicker to send and receive telegrams between Sydney and Melbourne than to make a telephone call. Even after 1925, when 5 channels were available, delays of 2 and 3 hours were commonplace. Although these were reduced as circuit provision began to overtake traffic growth, demand working was not introduced on the Sydney-Melbourne route until 1953, in the Melbourne to Sydney direction. Demand working in the Sydney-Melbourne direction followed in the next year. By this time, of course, the open-wire routes were nearing saturation.

It may be seen that the need to obtain an extremely high occupancy of each trunk line had resulted in the evolution of very efficient operating practices. As a more prompt service could be given when additional circuits were installed, the need to obtain the two parties so far in advance was not so great and subscribers benefited from these alterations. Naturally, the availability of an improving service meant that the interstate trunk line service began to appeal to an increasing number of subscribers. This resulted in greater use of the service by callers other than those from the business section of the community.

Over the years, the need to obtain a high circuit occupancy was greatly reduced through increased economies in providing channels. Moreover, the development of 2VF facilities in 1946, permitting direct dialling by operators into the telephone network of the distant city, enabled the very efficient (in line usage), but cumbersome (in operating procedures), "back to back" working to be eliminated.

Some 90 per cent of calls terminate in the distant city and direct access permitted one operator to complete the majority of these calls with considerable savings in staffing costs. The later installation of automatic "through" switching facilities enabled a high proportion on the "through" traffic to be completed by one operator, for example, a Townsville Telephonist could dial a Victorian subscriber's automatic number directly. Not only were savings in staff made, but the operating times on the connecting links were substantially reduced.

INTRODUCTION OF THE COAXIAL SYSTEM

Once the decision had been made to supersede the open-wire routes between Sydney and Melbourne with a broadband system of the coaxial type, a new concept entered into telecommunications planning. A broadband bearer system is primarily introduced in this country to provide for development when an open-wire route is reaching exhaustion. Whilst the necessary relief is given to all centres between the terminals, about two thirds of circuits obtained from the carrier systems installed in the initial stages will be used to replace circuits formerly obtained on the open-wire route. This is normal when changing from one type of construction to another but the long-term benefits far outweigh any apparent disadvantages. However, an appreciable offset to the cost of the coaxial cable is achieved by recoveries of wire from the aging aerial route and open-wire carrier equipment for use elsewhere. In addition, the particularly high and rising maintenance charges on the existing aerial route will be avoided.

In many instances, however, where large centres of population exist in reasonable proximity along the route or are off the route and served by spur routes, the circuit requirements exceeded the capacity of the pairs of wires in the coaxial cable. It was necessary and economical to provide minor trunk cables to serve these centres. Advantage was taken of the laying of the coaxial cable to effect appreciable savings by laying the minor trunk cables in the same trench.

Considered in its simplest sense, therefore, the primary effect of the Sydney-Melbourne coaxial cable system, so far as the traffic man is concerned, is to provide adequate channels to meet immediate needs for the expeditious handling of calls. Of course, this has always been the planning aim but could not be fully realised as traffic growth outstripped the capacity of the open-wire routes. The other, and perhaps more significant, effect is to make bearer capacity available so that additional circuits can be provided readily, and reasonably cheaply, to meet future needs along this key route which traverses the most populous and rapidly developing area of the continent. However, there are many side effects and developments possible in consequence of the improved position of channel provision.

An advantage of a more indirect nature which will accrue is applicable to routes quite apart from those closely allied with the Sydney-Melbourne route. This will arise as carrier systems are recovered from the open-wire route and become available for installation on minor routes now urgently in need of relief. By this means improved trunk line facilities will be given in areas not receiving any direct benefit from the new system. This factor assumes greater importance when it is recognised that many telephone users in areas much more sparsely settled than those to be served by the coaxial system, tend to take the view that their needs are being overlooked in favour of subscribers in the areas served by the major trunk routes. Naturally the subscriber in the relatively more remote centre, with reasonable justification, takes the view that he, by virtue of his comparative isolation, is more in need of adequate trunk line facilities.

SUBSCRIBER TRUNK DIALLING

Perhaps the most vital feature affected by the coaxial system is Subscriber Trunk Dialling. While introduction of this service is not entirely a function of adequate trunk circuits, as exchange equipment and other features are also relevant considerations, certainly S.T.D. cannot be introduced unless the numbers of trunk lines are sufficient. Provision of S.T.D. between Canberra and Sydney, now that the coaxial cable has been brought into service between those centres, will be effected shortly. Planning is already being directed towards its introduction on calls between Melbourne and Sydney, and Melbourne and Canberra. S.T.D. out of Albury, Wagga, Wangaratta and the many other important centres along the route must be considered feasible as their trunk facilities are improved. Needless to say, the attractions of S.T.D. become apparent on any broad-band route, but are more noteworthy along the Sydney-Melbourne route because of the major nature of this link.

S.T.D. has many results. This is really a separate subject, but brief mention of them could well be made here, insofar as they affect the Sydney-Melbourne route. The characteristics of the interstate traffic will change. Under operator control there is a very high proportion of particular person traffic with long holding times—usually involving P.B.X. operators at each end. Under S.T.D. working it can reasonably be expected that much of this traffic will be dialled direct, with consequent reductions in unpaid holding times. The main trunk exchanges in both Sydney and Melbourne, which are nearing capacity, will be relieved by S.T.D. and this in itself will be a tremendous benefit, for when the capacity, in terms of building accommodation, equipment and traffic-handling capabilities, of the present main trunk exchanges is exhausted there will be a major problem to be overcome. The Departmental objective is to install sufficient S.T.D. equipment to obviate the need to extend the Sydney and Melbourne main trunk exchanges. The alternative, that is, extending the existing exchanges and equipment, would involve enormous effort and heavy expenditure which would not be directed to the aim of the Community Telephone Plan — the provision of a fully automatic telephone service.

Of course, all will not be a bed of roses with the introduction of S.T.D. on the densely populated Sydney-Melbourne route. There will be problems in carrying out subscriber education programmes in large networks, particularly if only part of the network or selected subscribers are given S.T.D. initially. There will also be difficulties in disseminating subscriber education material to all potential users in large P.B.X. installations. Moreover, the differing types of exchange equipment at present in use in metropolitan networks will pose further problems.

Another troublesome feature which will arise under S.T.D. conditions is the question of the extent to which subscribers using the S.T.D. system will require information concerning numbers in the distant network. A large volume of traffic to directory information is expected on this score and at this stage, it is difficult to assess what provision will need to be made to meet it. There are two possible approaches to the problem. One is to have the directory information available from the local exchange and the other is to have it available from the distant network. The ramifications of these methods are being examined.

Similarly for service difficulties, faults and the like, it must be expected that there will be an increased load on repair and assistance positions. Quite apart from the matter of handling the traffic at the originating centre there will also be the added problem of passing details, where necessary, to repair and assistance positions in the distant network.

SERVICE ASPECTS

Ample channels will also bring many service benefits, particularly with operator-controlled calls. Wasteful manual "through" operating should be substantially reduced and the practicability of achieving a high level of demand working will greatly reduce the amount of operator effort per call. The advantages to subscribers of demand working do not need relating.

There can be no disputing that reductions in delays in obtaining calls will achieve a favourable reaction with subscribers. For many years, despite the Departments' aims towards demand working, inadequacy of circuits has produced appreciable delays on interstate channels at certain times of day. Since most calls made over these routes are originated by the business sector of the community, it is logical that the obviating of the present level of delay working, however much this level may be an improvement on the extent of delays in, say, the 1920's, will meet with a favourable reaction. Moreover, delay working requires about 50 per cent more operating effort than demand working. Therefore, about 50 per cent more operators and 50 per cent more positions are required for the same result.

When the Community Telephone Plan was announced, one notable public reaction was an increased awareness of the benefits of automatic facilities. Allied with the Sydney-Melbourne cable project, this led to a deal of agitation for automatic service for centres along or near to the cable route. Although these demands for improved service, mainly by way of automation, cannot be met immediately, the coaxial system does open the way for greater efficiencies in the telephone system, resulting, albeit indirectly, in the introduction of automatic facilities becoming increasingly attractive.

Up to date the shortage of trunk lines has prevented the effective exploitation of S.T.D. The economic benefits from subscriber control of trunk calls are very attractive. Even when the cost of the extra circuits required to introduce S.T.D is included, the capital cost of installing the existing variable rate equipment is recouped within 18 months to two years. Naturally, the savings from automatic working become even more worthwhile and, as a general principle, it is economically sound to convert manual exchanges on broadband routes to automatic. Improved relations with subscribers generally will accrue from the better service. It will be seen, therefore, that the Sydney-Melbourne coaxial system, quite apart from providing an improved trunk line service as a direct result, will bring improved service benefits. It should be realised, however, that the increased prospects of S.T.D. do not alone constitute a case for automatic facilities at any centre. This can be established, and a priority determined, quite independently, but all other things being equal, the possibility of introducing S.T.D. coincident with automatic working is an added attraction.

As with S.T.D., the service picture is not one of total benefit without attendant problems. One outstanding concern is that of security. With a system where so many trunk channels are carried on the one bearer, adequate precautions must be taken firstly to avoid interruptions and secondly to ensure that inconvenience due to unavoidable interruptions is kept to a minimum. To this end, a measure of security is being introduced by having one spare pair of tubes available in the coaxial cable so that a changeover can be made rapidly if a fault develops in the tubes being used. Arrangements have also been made to retain 72 circuits on the back route to permit urgent calls to be connected should the coaxial cable be cut or seriously interrupted. As a policy, continuity of service over coaxial cables on the more important trunk routes will be safeguarded by means of micro-wave broadband radio links and the first stage of these parallelling systems has been achieved by the installation of a radio link between Sydney and Canberra. If necessary, the channelling equipment can be transferred from the coaxial cable to the radio link, but generally the circuits will be divided between the two types of bearer. As these broadband radio systems have a standby channel available to permit an almost instantaneous changeover if the operating radio bearer is faulty, it can also provide additional security for the coaxial cable.

Another, though less exacting problem, will be on the customer education side as automation proceeds at provincial centres. This will to a considerable degree be allied with S.T.D. and will present difficulties more in relation to the volume of work than to complexity.

REVENUE

The Sydney-Melbourne route considered as a whole (that is, interstate channels and the hundreds of circuits linking the many country centres along the route) produces of the order of 20 per cent of the Commonwealth's entire trunk line revenue. This fact in itself is enough to render the route of prime importance in the trunk line network. The high revenue-earning capacity also adds weight to the needs for security mentioned earlier.

There is an undoubted need, because of the high capital costs of the route, for endeavouring to secure added revenue apart from that derived from telephone traffic. This leads to investigations into ways and means of making use of the coaxial tubes in periods when telephone traffic is light. The coaxial cable lends itself well to any form of transmission requiring a wide band width. Television relays are one of these, although the extent to which commercial television will see fit to use the system, particularly in view of the success now being achieved with reasonably cheap video-tape techniques, is problematical. Experience with broadcasting indicates that a very fine balance can exist between the cost of recording and that of relaying live shows. As a consequence the use of the television channels may fluctuate according to the relative costs of video-tape techniques as compared with the rental of the coaxial tube, the importance of the subject in the news sense, and whether the subject matter in question would be suitable for showing at a time subsequent to its actual occurrence.

Other potential sources of revenue are such things as newspaper facsimile transmission at concession rates during slack periods. This avenue is being explored along with that of data transmission. The latter is a field which is opening up rapidly at the present time. As the use of electronic computors and other high-speed data processing equipment expands, it must be expected that there will be an increasing demand for channels to enable data to be transmitted to processing centres and already many enquiries have been received. The demand will probably be for leased channels on both a part-time and full-time basis.

FUTURE DEVELOPMENT

The effects of having a modern, high-capacity system on Australia's largest trunk route are far-reaching. Plans are already in hand for a network of broadband systems linking the capital cities and the large centres of the country's eastern and southern seaboards. Both by virtue of its geographic location and the concentration of population which it serves, the Sydney-Melbourne coaxial system will be the cornerstone of this network. With a broadband network from Brisbane to Adelaide alone, tremendous strides can be made towards the implementation of the Community Telephone Plan, with its aim of a com-

TABLE 1: ESTIMATED FUTURE TELEPHONE TRUNK CHANNEL REQUIREMENTS ON THE SYDNEY-MELBOURNE ROUTE

Circuit Group	Year				
	Existing 1961	1963	1965	1970	1985
Inter-capital city telephone circuits					
Sydney-Melbourne	156	236	255	416	716
Sydney-Canberra	97	114	134	300	447
Melbourne-Canberra	41	41	45	76	134
Sydney-Adelaide	23	36	41	66	116
Melbourne-Brisbane	20	26	29	42	58
Sydney-Hobart	—	—	—	12	19
Total	337	453	504	912	1490
Major Intermediate telephone circuits					
Sydney-Campbelltown	55	69	78	113	226
Sydney-Wagga	26	48	54	85	167
Sydney-Bowral	13	32	40	60	125
Sydney-Goulburn	23	24	29	55	113
Melbourne-Shepparton	24	39	42	59	96
Melbourne-Wangaratta	19	38	44	55	95
Sydney-Cooma	24	22	25	42	87
Melbourne-Seymour	21	25	33	40	67
Wangaratta-Albury	8	18	30	36	61
Goulburn-Canberra	13	22	23	35	60
Wagga-Albury	11	19	20	30	50
Sydney-Albury	9	15	16	25	50
Melbourne-Albury	18	17	20	29	48
Melbourne-Alexandra	9	17	18	27	48
Benalla-Wangaratta	8	17	19	24	42
Goulburn-Crookwell	6	13	13	24	41
Sydney-Camden	15	10	12	20	41
Melbourne-Kilmore	8	11	16	22	38
Sydney-Griffith	7	9	11	18	38
Melbourne-Benalla	9	17	18	21	36
Sydney-Cootamundra	7	9	10	17	35
Cootamundra-Wagga	6	15	16	21	34
Sydney-Young	8	7	10	16	34
Melbourne-Wagga	7	14	15	21	33
Sydney-Narrandera	7	8	9	15	31
Total	361	535	621	910	1696
Total telephone trunk groups on route					
	492	569	562	562	562
Total telephone trunk circuits on route					
	2062	3221	3565	5080	8344
Percentage of above interstate and major intermediate groups in total provision					
	33.9	30.7	31.6	35.9	38.2

TABLE 2: ESTIMATED FUTURE TELEGRAPH CHANNEL REQUIREMENTS ON THE SYDNEY-MELBOURNE ROUTE

Circuit Group	Year									
	Existing 1961		1963		1965		1970		1985	
	VFT bearers	Chls	VFT bearers	Chls	VFT bearers	Chls	VFT bearers	Chls	VFT bearers	Chls
Interstate groups										
Sydney-Melbourne	6	128	10	224	12	270	16	336	20	462
Melbourne-Canberra	2	48	4	83	5	95	6	125	8	163
Sydney-Adelaide	2	48	4	82	5	94	5	110	7	152
Melbourne-Brisbane	1	24	3	54	3	60	4	83	5	105
Sydney-Canberra	3	66	3	66	3	72	4	78	4	78
Total	14	314	24	509	28	591	35	762	44	960
Intrastate groups										
Sydney-Wagga	2	42	2	42	2	42	2	48	3	56
Sydney-Goulburn	1	18	1	18	1	18	1	18	1	18
Melbourne-Shepparton	1	9	1	18	1	18	1	18	1	18
Melbourne-Seymour	—	—	1	18	1	18	1	18	1	18
Sydney-Campbelltown	—	—	1	12	1	12	1	15	1	18
Sydney-Cootamundra	1	9	1	10	1	12	1	15	1	18
Melbourne-Wangaratta	1	18	1	9	1	9	1	18	1	18
Melbourne-Albury	1	9	1	9	1	9	1	18	1	18
Wagga-Albury	1	9	1	9	1	9	1	10	1	12
Total	8	114	10	145	10	147	10	178	11	194

pletely automatic telephone network having both local and trunk line calls dialled direct by subscribers throughout the system.

Beyond these aspects there are those of requirements other than trunk channels. As previously mentioned, there is the new field of data transmission. Planning for the provision of channels must recognise this potential demand. The technical standards to be met insofar as performance of channels for data transmission are concerned forms another subject which will require increased attention by Post Office staff. As the value of centralised electronic data-processing systems such as computers becomes recognised and the possible sources of origination of data increase, data transmission will become an important telecommunication service and in time could equal the public trunk network on main routes. Possible methods of giving this service are:—

(a) Private lines
(b) Telex circuits
(c) Telephone speech circuits
(d) Wide band circuits—of the order of 3, 12 or 60 telephone channel bandwidths.

So far as telegraph circuits are concerned the normal telegraph channels can provide many suitable services but, as more information is to be transmitted, or it is desired to feed sufficient information into a computer to keep the receiving machine operating to input capacity, the need for wider bandwidths and very reliable circuits becomes apparent. More sophisticated transmitting and receiving equipment becomes necessary and at present it is thought that such equipment will be purchased from the manufacturers by the user. This problem is recognised and a brochure on "Facilities for Data Transmission" is being prepared at Headquarters. The brochure will describe the facilities to be provided by the Post Office, the general technical requirements of any private equipment and special technical conditions.

Automatic Telex, another new feature of the telecommunications service, will engender further demands for channel provision as will International Telex. So, too, will the Pacific submarine cable being laid by the Commonwealth countries have a marked effect on the disposal of overseas telephone calls. The section between New Zealand and Australia should be cut into service in mid-1962. Initially, operator-dialling will be available on calls from New Zealand to Australia; operator-dialling in the reverse direction will not be introduced until the installation of the new transit exchange in Auckland some 12 months after the cable is available for the connection of traffic. Naturally enough, it is highly desirable that congestion on internal circuits does not give rise to ineffective holding time on costly international links. Since much of the international traffic will be with Sydney and Melbourne, the coaxial system must also have a beneficial effect on the overseas telecommunications service. As the broadband network grows from the Sydney-Melbourne link, so, too, will this aspect of the benefits increase.

When thinking in terms of future development, perhaps the most important point to bear in mind is, as stated earlier, that the coaxial system does not so much meet immediate demand for additional trunk channels as it provides a means for meeting the demand for many years into the future. Reference to Table 1 will show that there are no less than 492 groups of telephone circuits provided on the route at the present time. This will be expanded to a total of 562. In terms of channels there are now 2,062 trunk circuits on the route and planning envisages that this will rise to 8,344 circuits by 1985. For illustrative purposes, only 25 of the major intermediate groups have been shown in the table, in addition to the intercapital-city channels. Added to the total telephone circuits are 22 circuits now provided as voice frequency telegraph bearers and this figure will be increased to 55 at 1985. Table 2 shows the expected development in telegraph facilities.

The coaxial cable has a nominal capacity of 5,400 circuits using 12 Mc/s working, and on the face of it this does not seem sufficient to provide the total of 8,344 individual circuits estimated to be required in 1985 much less meet all the intermediate needs along this route to 2,010 as is expected. Part of the explanation is that some of the supergroup frequencies can be used to provide intermediate circuits over several sections of the route, whilst the interstitial pairs can provide bearer circuits for carrier systems. As mentioned previously minor route cables will also cater for bulk requirements of circuits over the shorter distances.

However, our grandchildren will still be faced with similar problems to those which arose when the open-wire routes reached capacity. The stage must be reached when the numbers of circuits justified on many of the major groups will reach the level where micro-wave radio links will be an economical proposition. Since radio bearer systems of this type will certainly be justified for both intercapital-city and country television relays, then many of the heavier loaded "long-hop" groups can be transferred from the coaxial cable to a radio bearer, prolonging the life of the coaxial system. Although a radio system was not a practicable proposition when plans were formulated for the coaxial cable, due to the need to meet the large number of intermediate short-haul requirements, the time could well come when the coaxial cable is providing alternate circuits between the major centres, along with the minor and short-haul channels, and radio systems meeting the majority of needs for the longer-distance major links.

Then again, who can tell what new communication techniques will be developed within the next fifty years? Already Time Assignment Speech Interpolation (TASI) has provided an avenue for securing more effective use of communication circuits on long intercontinental submarine cables. The use of waveguide systems to carry hundreds of thousands of circuits is being investigated actively overseas. Science and technology has progressed to the stage where communication through the use of space satellites has become possible. Intercontinental circuits will certainly be provided by this means within the foreseeable future and the long distances between large centres of population in Australia would indicate that this technique might be used here for providing large quantities of circuits for data transmission and other purposes. In years to come the great achievement of the Sydney-Melbourne coaxial cable system possibly will be an historical milestone, just as was the construction of the first open-wire link. There is no doubting, however, that it is the beginning of a new era in Australia's communications history. The vast network of open-wire routes which has been built up to meet the demands for trunk line communications will be gradually transformed from this foundation to a system of untold capabilities. The result naturally must be improved telecommunication facilities overall, providing faster, cheaper and more efficient service for the public.

Justifiably enough, much has been said, and will be said, of the remarkable technical achievement which was carried out by the Post Office in providing the Sydney-Melbourne coaxial cable. A more subjective view, in the light of the thoughts expressed above, is that the project is no less momentous because it is a major feat of Post Office engineering at the present time than because of its tremendous significance in what it will do for posterity.

ACKNOWLEDGMENT

The author wishes to acknowledge the valuable help and guidance given to him in the preparation of this article by Mr. W. D. Rhys-Jones, Assistant Controller, Trunk Line Development and Survey Section of the Postmaster-General's Department Telecommunications Division.

CONTRACT AND SUPPLY ARRANGEMENTS

*J. S. BROGAN**

TENDERS

Contract and supply arrangements for the supply of the new telecommunication system between Sydney, Canberra and Melbourne were commenced with the invitation of public tenders for the project. The invitation to tender was contained in a document which set out in comprehensive detail traffic requirements, geographical conditions along the route, technical stipulations and the commercial and contractual requirements. Although emphasis was placed upon the coaxial cable type of system, suppliers throughout the world were left free to offer systems of other types within the range of their manufacturing capacity and were also permitted the alternatives of tendering for the system as a whole or for specified parts of the work.

On the closing date tenders were received for complete systems, or for part of the work, from Australia, France, Holland, Japan, Sweden, United Kingdom, United States of America and Western Germany. In addition to offers for coaxial type systems, tenders were received for a surface wave transmission line system and for paper insulated carrier type cable with a radio circuit for the television channels.

Considerable effort was necessary to evaluate the tenders commercially. Adjustment of prices had to be made to compensate for variations introduced by tenderers in desired payment conditions, complicated discount arrangements, and normally variable factors such as freight, exchange, labour and materials. Making proper allowance for customs duty and primage (1) on imported materials always presents problems in any work of magnitude, but in this case the task was rendered more difficult than usual because much of the equipment offered had not previously been imported or was not readily identifiable with tariff classifications.

The steps leading to a choice of system and a choice of Contractors are outside the scope of this paper which will be confined to a discussion of some of the contractual arrangements.

THE CONTRACT

Most of what was in the contract documents was concerned with normal relations between the parties to such contracts, but there may be general interest in comment upon conditions relating to guarantees, payments, insurance, patent rights, and progressing arrangements.

Guarantees

From other articles in this Journal, the reader will be aware that about one third of the cable (both coaxial and minor trunk) and the associated cable materials for the entire route were to be supplied by Felten & Guilleaume Carlswerk A.G. and the balance of the cable by Olympic Cables Pty. Ltd., as sub-contractor to the German firm. The installation and testing of the cable was to be carried out by the Department. Telecommunication Co. of Aust. Pty. Ltd. were entrusted with the supply and installation of all carrier equipment and power plant.

It will be seen that, under these conditions, there is a possibility, however remote, of the cable being to specification and being properly installed and the equipment being to specification and properly installed, but the combination failing to provide an efficient telecommunication system. This possibility was eliminated by Telecommunication Co. of Aust. Pty. Ltd. guaranteeing that a system comprising electronic equipment and power plant supplied and installed by themselves and cable and accessories supplied by the cable contractor and installed by the Department to the satisfaction of the cable contractor, would provide telegraph bearer, telephone, sound broadcasting and television channels having overall performance not inferior to that specified.

In turn each Contractor offered guarantees appropriate to its portion of the works. The equipment contractor guaranteed each item of material, apart from normally consumable items, for a lengthy period from the first date the item concerned was used in providing commissioned channels. Normally consumable items were covered by the maker's guarantee. The cable contract contained comprehensive guarantees against physical and electrical defects from the date of completion of testing and commissioning.

General Administration

Those familiar with the administration of contracts of a complex nature and especially those extending over a relatively long period, will be aware that a disproportionate time is usually spent by both professional and administrative staff upon the work of reconciling deliveries and payments.

At the time of writing the whole project is not complete, but it is already clear that the paper work is proceeding smoothly. Within the Department the credit for this belongs chiefly to those administrative decisions which helped promote a unity of purpose in different branches and which gave to one officer each of the Stores and Contracts branches in New South Wales, Victoria and at Headquarters the responsibility and authority for documentation affecting the contract. It is also true that the subsequent smoothness of operation was helped considerably by conscious planning at the negotiation stage. A resume of some of the measures adopted may help those engaged in future large works.

Perhaps the keynote of the approach was a search for the greatest possible simplification of documentation. The approach was two-fold; a reduction in the number of accountable items and the submission of invoices only in unit quantities at the unit prices shown in the contracts.

Payments

Examples of the former approach may be drawn from both contracts. In the cable contract, the price of cable was loaded to eliminate the necessity for accounting for jointing tools and jointing materials. The Contractor accepted a responsibility to supply sufficient of these items to permit training of Departmental staff and for the entire jointing operation, including wastage.

In handling retention money, the necessity for reconciliation of individual invoices was eliminated. An approximation was made of the total amount of the Contractor's money that would be retained by the time all deliveries

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(1)—The principles employed in these calculations are set out in The Customs Act, 1901-1960, Part VIII, Divisions 1 and 2.

* See page 271.

were completed. This sum was divided, according to mileage, to reflect a fixed sum that would be remitted as tests upon each repeater section were satisfactorily completed. When the first repeater section was installed and completed the appropriate fixed sum was remitted to the Contractor out of the reserve of retention money, but without attempt to reconcile invoices for individual lengths of cable, terminal racks, distribution boxes, etc. The same operation was repeated as the second through to the thirteenth sections were completed and tested. Upon completion of the Seymour-Melbourne section the balance of retention moneys will be remitted. The reconciliation will thus be in total rather than in a multitude of invoices.

A similar approach was used in the contract with Telecommunication Co. of Aust. Pty. Ltd. In exchange for suitable securities, the progressive payments envisaged in the invitation to tender were reduced to a single payment for selected materials, and one payment on account and a final payment for the bulk of the supplies. There was a resultant saving in documentation of more than one third on many thousands of items.

Rather than have to account for the great number of items necessary to install the electronic equipment and the power plant at the repeater stations along the route, the Contractor was required to furnish all items necessary to correctly and properly install the equipment and plant. A reasonably accurate assessment of the value of these installation materials was possible and their cost was expressed as a percentage of the unit value of each accountable item. This approach was extended to other aspects of the contract.

The arrangement used to remit retention money to the Contractor could be likened to that employed for the cable contract in that it avoided reconciliation between individual invoices and equipmet installed at particular sites.

Control records of deliveries received and payments made were maintained at Headquarters so that the true overall position could be determined at any time. The following procedures were adopted and, with suitable modifications similar practices were followed in the two States. Contractors prepared invoices in triplicate; two copies going to the State receiving supplies and one copy to Headquarters. Upon receipt of the Headquarters' copy, provisional entries were made on suitable records of the delivery and the liability. When the State concerned authorised its payment, one copy of the invoice, amended as necessary to account for discrepancies and adjusted to the prevailing rate of exchange, was forwarded to Headquarters. From this copy of the invoice final records of deliveries and liabilities were made.

By arrangement, both Contractors invoiced deliveries in unit quantities and at the unit rates shown in the contract documents. Authorising officers made automatic adjustment for exchange variation as each payment was made, but these officers were relieved of the necessity for concerning themselves with the complex price variation formulae relating to movements in the cost of labour and materials. Claims on account of such movements were submitted to Headquarters at regular intervals and, after checking, authorised for payment in a lump sum.

Insurance

Both Contractors were required to take out insurance cover for their employees in the event of their suffering accident, illness or injury while engaged on the works, as well as an indemnity in respect of any liability that the Commonwealth may have should one of its employees suffer because of some action or neglect of the Contractor. Insurance was also required for any injury or damage suffered by a third person or body corporate. Comprehensive insurance policies were specified for the material, that for the cable presenting the unusual feature that it required cover for valuable cable which it was sometimes necessary to store in the open, out of sight of either the Department or the Contractor or, for that matter, out of sight of any dwelling.

Patents

Although the position of the Commonwealth against possible claims arising from infringement of patent rights is safeguarded by the provisions of Section 125 of the Patent Act, particular attention was devoted to the question because of a petition before the High Court of Australia (2) at the time the contracts were being negotiated for an extension of the respective terms of five letters patent relating to coaxial cable.

Progressing

Each Contractor was required to submit monthly a detailed report upon manufacture and delivery, and to bring to notice any possible causes of delay. Progress of the work as a whole was facilitated by regular meetings between the Department and its Contractors, Felten & Guilleaume Carlswerk A.G. being represented by its Australian agents, Electronic Industries (Imports) Pty. Ltd. Although these meetings had no executive authority, they provided a most useful medium for solving problems associated with many aspects of the project.

STATE OPERATIONS

These notes have been confined almost exclusively to Headquarters workings, but an immense amount of detailed work was also necessary in both the Sydney and Melbourne offices. In each office an additional clerical position was provided with the duty of supervising payments and delivery records and co-ordinating Stores Branch work arising from the project, and to solve difficulties as they occurred.

State operations are illustrated by reference to cable deliveries at Sydney, although similar illustrations could be made by considering equipment deliveries at either Sydney or Melbourne or cable despatches from Melbourne. It should be kept in mind (i) that cable for installation between Sydney and Canberra was shipped from Germany, (ii) that cable for installation beyond Canberra was made in Melbourne and transported overland, and (iii) that each of the 3,500 drums of cable was identified by a symbol designed to show its exact position in the route.

Each major repeater section was allotted an identifying code, SC — Sydney/Campbelltown, CB — Campbelltown/Bowral, and so on. The marking "SC1-2/18" indicated that the drum contained the eighteenth length of cable between the first and second minor repeater stations in the Sydney/Campbelltown repeater section. Minor cables were identified by the addition of the letter "M" to the symbol. Because minor cables are not continuous throughout the length of the cable, numbering was arranged so that coaxial and minor cables bearing the same drum reference would be laid alongside each other in the trench.

The principal factors to be considered in preparing State records were the necessity to ensure that:

(i) cable supplied and price paid were in accordance with contract;

(ii) it would be known at all times whether a particular drum had been shipped and, if so, when it was due or whether it was in store or had been delivered to the field; and

(iii) internal costing requirements were met.

The first of these requirements is normal procedure. The second was attended to by a simple record based upon drum numbers and modified for cable beyond Canberra to show only when a drum had passed inspection and was ready for delivery and when it had been delivered to the field. Internal costing was satisfied by the issue of a separate work order for each major repeater section. One requisition was submitted for all the material required for each work order. As each payment was made, appropriate extract requisitions were prepared and the job charged direct.

The physical handling of cable was attended to in the following manner. Upon receipt of shipping documents the field engineers were advised of the expected date of arrival of the particular drums and preliminary plans made for transport from ship to store. When the vessel reached Sydney, the cable was cleared from Customs control and a preliminary inspection was made for possible damage giving rise to insurance claims. Contrary to expectation, shipments on the "Alamak" and "Amerskerk" suffered considerable damage, due, it was later found, to inexperienced stowage in Europe.

Initial thoughts were that it might be practicable to transport cable direct from the wharf to the field but this was decided against because of the desirability of testing gas pressures prior to release to the field and because, for security reasons, it was not desired to

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(2) The reader is referred to a judgment given out of the High Court of Australia on 28th August, 1959.

hold cable in the field for any longer period than necessary. The damage suffered at sea demonstrates the wisdom of deciding upon a marshalling area in Sydney.

Between receipt of papers and the cable at Sydney, the field engineer, using the information relayed from the shipping papers, had prepared a cable delivery advice sheet showing:

(i) the drum numbers required,
(ii) the order in which required,
(iii) the point of delivery,
(iv) the desired date of the first delivery, and
(v) the desired date of the final delivery.

After testing for gas pressure, cable was stored in the marshalling area in its appointed order of delivery. As despatch became due, the field engineer was given at least 24 hours notice of its pending arrival so that he might make arrangements for checking and unloading. Each delivery was accompanied with a consecutively numbered delivery docket. When the last delivery on a particular cable delivery advice sheet left the marshalling area, the delivery docket was endorsed "Last Delivery on Advice No. ....". If all drums were received in the field, a suitable acknowledgment was given, otherwise enquiries were instituted.

A similar procedure was employed for the Canberra-Melbourne section, where drums were marshalled at the works of Olympic Cables Pty. Ltd. and despatch arrangements co-ordinated with the Transport Branch through the Stores Branch, Melbourne.

INCIDENTAL PURCHASES

In addition to obligations arising from the principal contracts, supply arrangements at Headquarters extended to the provision of plant required for the civil engineering. Major purchases were made of motor vehicles, earth moving equipment, tractors, cranes and caravans.

At the State level, purchases were made of a great variety of items including fuel and maintenance parts for the mechanical plant, rabbit-proof gates, concrete gate posts and struts, wire netting, grass seed, superphosphate, explosives, pre-fabricated concrete pits, cement, sand, marker posts and camping equipment. An interesting side-light was the invitation of tenders for the removal of some 5,000 cubic yards of basalt rock from the Epping-Wollert area, near Melbourne.

One of the early problems which arose from these local purchases was the delivery and storage of explosives. The cartage and storage of explosives is controlled by State regulations administered by the Department of Mines. Delivery to country areas by rail is only available on a monthly time-table, and carriage by road is restricted to 100 lb. unless in a special explosives truck. These restrictions made it necessary to arrange storage of explosives along the cable route. Information was obtained from the Department of Mines regarding the holders of magazine licences, particularly State Government and Local Government authorities, and arrangements were made with the various authorities to store explosives on the Department's behalf, to be drawn upon as required. These facilities, so readily extended, were of great assistance.

CONCLUSION

Upon reflection it is clear that the supply arrangements were helped immeasurably by the co-operation between Branches of the Department, a co-operation that would not have been possible had not all concerned been thoroughly briefed upon the project and kept well informed of developments upon all phases of the work. The same measure of co-operation was also shown by all suppliers, large and small, and by many who could assist indirectly.

DESIGN OF CABLE PLANT

*J. F. SINNATT, B.Sc.**

ORIGINAL TENDER SCHEDULE

Schedule C7722 issued in 1957 invited tenders for supply and delivery, and optionally also the installation, of six-tube coaxial cable to A.P.O. Specification 839 between Sydney and Melbourne, together with minor trunk cables to A.P.O. Specification 840 (trunk type) over certain sections.

The main cable was to consist of six coaxial tubes stranded round a centre core of ten trunk type paper-insulated 20 lb. quads. One paper insulated 20 lb. quad was also to be laid up in each of the outer interstices formed by the coaxial tubes.

Coaxial Tubes

The electrical requirements of the tubes were based partly on British Post Office and partly on C.C.I.T.T. specifications, and values were laid down, for both factory lengths and completed repeater sections of breakdown voltage, insulation resistance, impedance, impedance irregularity, attenuation and crossstalk. Impedance irregularity was to be measured on factory lengths by pulse methods, and over repeater sections by both steady-state and pulse methods. Details of actual values specified are given later. The necessity for close control over impedance irregularities is explained in another article in this issue (Ref. 1).

Paper-Insulated Pairs

The 20 centre paper-insulated pairs were to be trunk-type excepting that a lower insulation resistance was permitted. The 12 outer pairs which were not normally used for traffic circuits were allowed to be of lower quality, with a maximum mutual capacity of 0.085 μF per mile, compared with a nominal value of 0.066 μF per mile for trunk type, and with limits set for deviation from mean mutual capacity. Capacity unbalance limits were however to be equal to those of trunk type quads.

The 20 centre pairs were to be V.F. loaded and suitable for unamplified 2-wire, amplified 2-wire or amplified 4-wire telephone channel operation in accordance with transmission needs. To enable 2-wire amplified circuits to be worked at low equivalents and yet remain stable, the balance return loss of these loaded centre pairs over the frequency range 300 c/s to 2,800 c/s was, in accordance with British Post Office practice, to be not less than 28 db for 90% of the pairs and 26 db for 100% of the pairs. The outer pairs were to be used for control or miscellaneous circuits, and to be loaded or unloaded as required. Not less than four of the 32 pairs were to be suitable for the operation of short haul carrier systems to a frequency of 108 kc/s. These could have been chosen from the centre V.F. loaded group of pairs and deloaded later.

Minor Trunk Cables

Where the number of centre pairs was insufficient to provide intermediate circuit requirements in any section, separate minor trunk cables were to be laid. Originally it was intended to lay such cables over 47 route miles in sizes ranging from 28/20 to 104/10, with a total pair mileage of 2,308. These cables were to be trunk-type as the completed circuits were to have the same electrical characteristics as the 20 centre pairs in the coaxial cable.

Installation and Maintenance

Unarmoured cable was to be used in ducts, with steel tape armoured cable in open country and steel wire armoured (S.W.A.) cable at river crossings or in rough ground. The route distance where S.W.A. cable was required was not expected to exceed 11 miles. The loading system was left open as it was thought that tenderers may have offered 66mH coils to gain additional bandwidth, particularly with 2-wire amplified circuits. It was stated however that the Department's present standard system used 88mH coils. Joints were to be in pits or manholes and the tenderer was to furnish details of the jointing and terminating arrangements proposed. The cable was to be protected by a gas pressure alarm system, preferably of the continuous flow type.

THE CONTRACT

Details of certain items in the actual Contract were somewhat different from those called for or envisaged in the Schedule, as further consideration had been given to the matter by the Department, and the standard practice of the successful tenderer had to be taken into account.

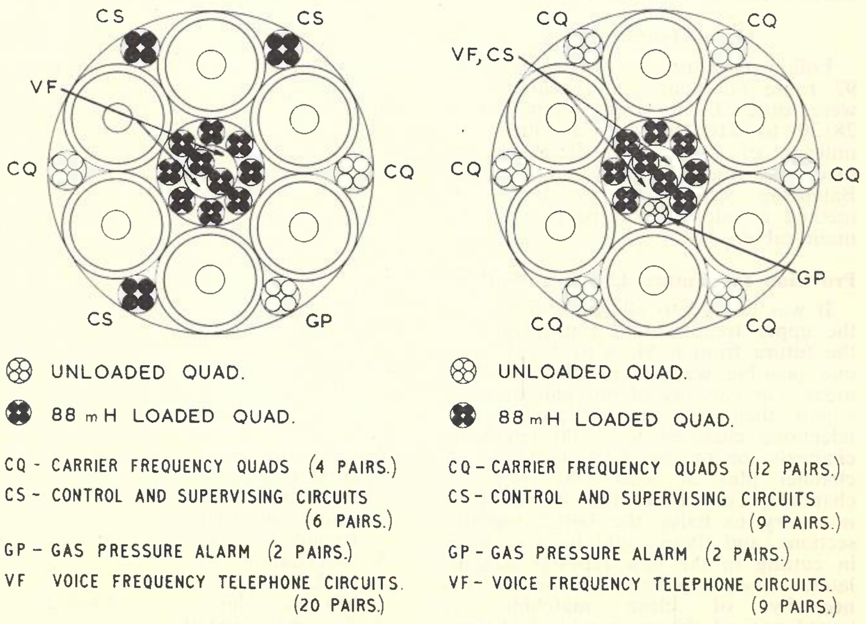
Coaxial Tubes

The dimensions of the tubes were based on Continental practice, with the diameter of the inner conductor, 2.6 mm, and the inner diameter of the outer conductor 9.5 mm. These gave a conductor resistance somewhat higher than that in the Specification. On the other hand the contractor guaranteed better values of certain electrical characteristics than those in the Specification. Final values agreed upon are given in summarised form in Table 1.

Paper Insulated Pairs

The six quads in the outer interstices were to be to C.C.I.T.T. Type 1 Specification, with nominal value of mutual capacity of 0.053 μF per mile, and with capacity unbalances somewhat better than in A.P.O. carrier type cable. Six of the 12 pairs were to be loaded and used for control purposes, and of the remainder two pairs were for the gas pressure alarm system and the other four for future carrier working. (Fig. 1a.)

The loaded control circuits comprised two four-wire order wires, one extending between main stations, and one with the intermediate stations connected, and two pairs for remote supervision of the unattended repeaters. These pairs were loaded as the supervisory system employed V.F. tones. The loading was to be by 88mH Grade 2 coils in 26 coil cases at 6,000 ft. intervals, the spacing applying continuously



(a) Contract Stage. (b) Final Arrangement.

Fig. 11.—Cable Cross-Section.

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* See page 268.

through the intermediate repeaters. The C.C.I.T.T. maximum deviation of ± ½% of the length of any loading section from the average was adopted to assist in achieving the return loss specification for the cable pairs. Building out of the control pairs terminated at the repeaters was not considered necessary. In the Sydney-Campbelltown section, where the V.F. circuit requirements were high and provided for in other cables, and where it was expected that more extensive short-haul carrier working would be required later in the main cable the centre pairs were not to be loaded. This enabled in-joint type coils to be used for the six loaded centre pairs in this section. For manufacturing reasons, all the 20 centre pairs were permitted to have a maximum mutual capacity of 0.071 μF per mile, the upper limit for trunk type cable.

Balancing of the centre group of paper-insulated pairs would be by the German method which features straight-jointing of pairs within a loading section, with addition of correction condensers as necessary. The Contractor had thought that we would prefer our traditional method of inserting crosses at the ¼–, ½–, and ¾– points of the loading section as necessary, with a small number of condensers to correct any residual unbalances, but the German method has certain attractions especially when the cable is of good quality in the first place, and this was considered to be an excellent opportunity to try it out, as the balancing would be under the guidance of experts in this particular method. In practice, the method was found to fit in very well with the jointing and testing organisation, and will most likely be adopted for balancing the paper-insulated pairs in future coaxial cables, but not necessarily in the associated minor trunk cables.

Minor Trunk Cables

Following a review of requirements, 97 route miles of minor trunk cable were ordered, in sizes ranging from 28/20 to 216/10, with a total pair-mileage of 7,665. No alteration was made to the electrical specification. Balancing would be by the same method as adopted for the pairs in the main cable.

Provision for Future 12 Mc/s Working

It was desired to allow for increasing the upper frequency of transmission in the future from 6 Mc/s to 12 Mc/s as one possible way of meeting development. The capacity of one pair of tubes would then be enlarged from 1,260 telephone channels to 2,700 telephone channels, or to one 625-line television channel plus at least 900 telephone channels. To achieve this it would be necessary to halve the initial repeater sections, and there could be a problem in cutting in the new repeater stations later. One important factor is the necessity of close matching of impedances of the main cable laid now, and the tails laid in the future into the new buildings. To overcome this the suggestion was made that a loop be provided in the cable at each future repeater site, and when the new station was to be established the loop would be cut and two ends terminated in the new building. This idea was not however adopted as it would have meant acquiring the additional sites at the outset, and there could have been difficulty in forming the cable loop and recovering it later. Instead it was considered sufficient to specify that, as far as practicable, the end impedances of the cable lengths nearest the mid-points of the original sections (such lengths to be designated on the Cable Drumlength Advices) should be within 0.2 ohms of the nominal value of 75 ohms. This will facilitate matching of the original cable with the new cable tails installed when the additional repeaters are erected.

Installation and Maintenance

It was decided that the use of S.W.A. cable at river crossings was not really necessary, and would complicate impedance matching of the drum lengths, so cable would be supplied mainly in standard lengths of 500 yards plus jointing allowance, as it was expected that hauling lengths of this order into ducts would be quite practicable. Pulling eyes sealed with epoxy resin would be fitted as necessary to lengths at the factory. For ordering purposes the drum lengths were numbered consecutively through a minor repeater section, the minor repeater sections themselves being numbered consecutively through the main repeater section, the latter being designed by the initial letters of the stations concerned. Thus:—

SC : Sydney - Cambelltown main repeater section.
SC 0–1 : First minor repeater section in SC main section.
SC 0-1/1 : First drumlength in SC 0–1 minor section.

This system features designating the intermediate minor repeater stations as SC 1, SC 2, etc., and avoids the necessity of searching maps for possibly obscure place names, although local names are in fact used on occasions. For example one intermediate repeater is referred to locally at "Glenburnie", but this is not a well-known name, and there is no Post Office, exchange, or railway station there. However by using instead the designation SM 4 it is immediately evident without referring to a map at all that the repeater is about 22 miles (4 x 5½) on the Melbourne side of Seymour. The system is possible only because the initial letters of each pair of consecutive main repeater stations form a unique combination.

Jointing would be by the F. & G. method, which uses longitudinally split sleeves for both the inner and outer conductors secured with clamping rings and soldered. Except in the duct sections the joints were to be buried, and both manhole and buried joints protected by cast-iron boxes. At repeater stations the six-tube cable would split at a pothead joint into six single-tube solid dielectric semi-flexible cables of similar electrical characteristics to the disc-insulated tubes and these would terminate on the equipment racks. Three paper-insulated tails would accommodate the centre and interstICial pairs, care being taken to separate the carrier pairs from the VF pairs.

TABLE I.

ELECTRICAL CHARACTERISTICS OF COAXIAL TUBES — LIMITS

	Factory Lengths		*Repeater Sections*	
	Schedule	*contract*	*Schedule*	*Contract*
1. Voltage Test for 2 minutes	3000 V	3000 V	2000 V	2000 V
2. Insulation Resistance (megohm-miles) 500 V for 1 minute)				
centre-outer	5000	5000	5000	5000
outer-earth	100	100	–	–
3. Impedance (ohms) at 2.5 Mc/s	75 ± 1	75 ± 0.5	75 ± 1	75 ± 1
4. Impedance Irregularity (db)				
4.1 Worst echo				
90% of tubes	–	58	–	–
100% of tubes	54	54	54 uncorrected	54 uncorrected
4.2 Mean of three worst echos	55	55	51 (RMS) corrected	51 (RMS) corrected
4.3 Deviation from smooth impedance-frequency curve	–	–	3%	1.5%
5. Attenuation at 2.5 Mc/s (db per mile)	5.6–6.2	5.6–6.2	6.2	6.2
6. Far-end crosstalk ratio (db) 60 kc/s — 12Mc/s	100	120	85	90

TABLE 2.
MINOR TRUNK CABLES

Cable	*Size*	*Length (miles)*
1. Sydney-Canberra Section		
Liverpool-Ingleburn	104/20	7.21
Ingleburn-Campbelltown	104/10	5.44
Campbelltown-Douglas Park	216/10	11.01
Douglas Park-Picton T.O.	150/10	1.07
Douglas Park-Wilton	28/20	5.05
Aylmerton-Mittagong	38/20	3.15
Mittagong-Bowral	150/10	2.85
Bowral-Moss Vale	216/10	5.56
Marulan-Goulburn	38/10	18.64
Sutton-Canberra	28/20	12.81
2. Canberra-Albury Section		
Civic-Hall	28/20	8.81
Yass-Bowning	54/20	8.23
Bowning-Bookham	28/20	12.42
Coolac-Gundagai	28/20	11.71
Ladysmith T.O.-Wagga	28/20	9.65
Wagga-Uranquinty	28/20	10.47
Henty-Culcairn	38/20	10.78
3. Albury-Melbourne Section		
Barnawartha-Chiltern	28/20	5.07
Winton-Benalla	28/20	6.75
Benalla-Violet Town	28/20	15.83
Violet Town-Balmattum East	38/20	6.12
Balmattum East-Euroa	54/20	5.93
Euroa-Creighton's Creek T.O.	38/20	3.74
Creighton's Creek T.O.-Longwood	28/20	5.88
Avenel-Mangalore	28/20	4.42

For the gas pressure alarm system contact manometers using mercury in glass U-tubes were to be installed at 1,000 yard intervals (generally every second joint). The odd-numbered manometers would be connected to one pair and the even numbered manometers to the other. To detect operation of the manometers an automatic supervisory set would be provided at the control station (Ref. 2).

Test Equipment

Instruments for balancing and testing the V.F. and carrier quads, and the coaxial tubes, were included in the main contract.

LATER MODIFICATIONS

Various alterations were made to the details of the scheme as described above, in some cases before work commenced, and in other cases as the job progressed and experience was gained.

Allocation of Paper-Insulated Pairs

As all six quads in the outer interstices were of high quality, and as it was expected from measurements made on the Melbourne-Morwell cable that crosstalk between pairs in different interstices would be negligible, it was decided that all quads in the outer interstices would be reserved for future short-haul carrier working. The control circuits would then be transferred to the centre group of pairs. Moreover an additional requirement was foreseen of two pairs for overall supervision and one pair for a lineman's order-wire—this pair would be connected to spare terminals on the contact manometers and could be used for communication with a repeater station by a lineman attending to a fault. Of the 20 centre pairs, only nine were therefore now available for minor trunk circuits, the final allocation being (see Fig. 1b):

Pairs 1–9 (loaded) minor trunks.
10–18 (loaded) control and supervisory.
19–20 (unloaded) gas pressure alarm system.

Building out of the control pairs to a half section at the repeaters (with capacitance only) was now required by the equipment contractor.

Minor Trunk Cables

A further review of the minor trunk cable provision was made having in mind the reduced number of pairs now available in the main cable, and also the announcement of the Community Telephone Plan. This review resulted in the order being increased to 205 route miles and about 11,100 pair miles, the additional cables being mainly 28/20. The final list of minor trunk cables is given in Table 2.

Installation and Maintenance

The hauling of 500 yard lengths of cable into ducts was not always possible as explained in Ref. 3 and shorter lengths had to be ordered. This caused an increase in the number of joint protection boxes required. After the cable had been laid to Albury, a change was made to the Ericsson solderless rolled-sleeve method of jointing the coaxial tubes (illustrated in Ref. 4). This method is preferred to the F. & G. method and it had in fact been favoured from the outset, but it would have been difficult to obtain supplies of material in time for commencement of the job. As the jointing and testing operations necessarily followed some time after the laying, the holes where the joints were to be made had to be left open and suitably protected. Time was taken baling out water that had seeped into the holes before the work could be done, and it was found desirable to install jointing pits, although the buried type protection boxes were retained. Plastic-jacketed lead-sheathed cable was used in the ducts at the Melbourne end, where an electric traction system was closely paralleled, to give greater protection against corrosion, while aluminium sheathed cable was used in two repeater sections near Melbourne where a severe power induction hazard existed.

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MANUFACTURE OF CABLE

*G. I. B. VERMONT, B.Sc.(Eng.), H.Dipl.Eng.**

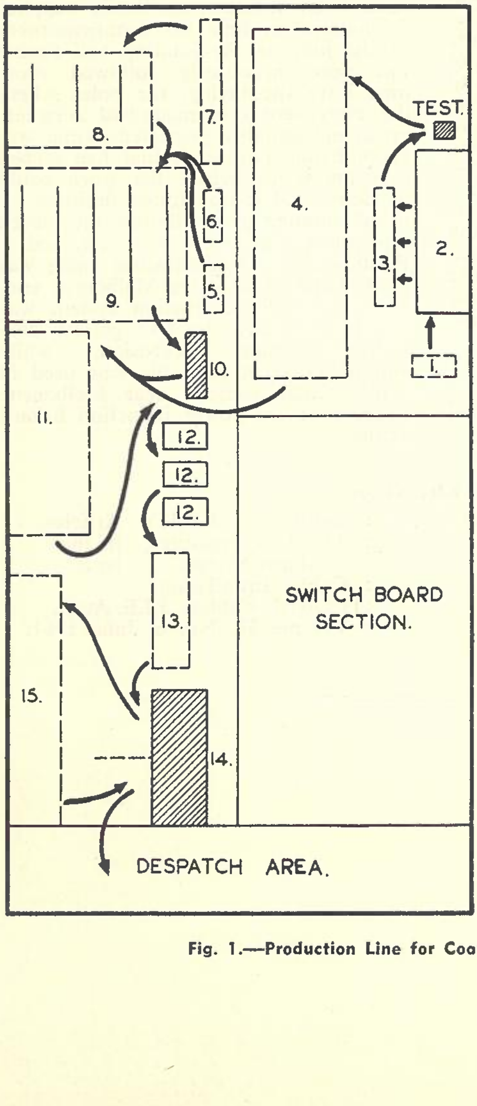
FOREWORD

Olympic Cables Pty. Ltd. as subcontractors to Felten & Guilleaume Carlswerk A/G was set a task to manufacture the Canberra-Melbourne Section (420 miles) of the Sydney-Melbourne Coaxial Cable. The fact of being subcontractors to an overseas firm which had such a large experience in the manufacture of all types of telecommunication cables gave Olympic Cables very valuable assistance on the one hand, but on the other hand also set the types of machinery which were to be used in the manufacture of this cable. The plant has been designed to give an output of approximately 30 miles of 6-tube cable per month, which was the original contractual commitment using average German production figures. It was the policy of Olympic Cables to obtain machinery conforming with German design requirements locally, and import only if a local supplier was not available. However, very many of the plant items required were of special design, with Patent Rights attached to them, and their importation in time created quite a few problems and caused some delay in the plant coming to full production.

PLANT DESCRIPTION

Fig. 1 shows the plant layout, which was designed to give a smooth flow of production. It can be split up into three main divisions, the first which occupies about a third of the available area is the paper cable section, and the second, the coaxial section, with its very specialised equipment, occupying also one third of the area. These two sections meet then in the third to provide the vacuum drying of the laid up cables, the lead sheathing and, if required, armouring.

The paper cable section, as its name suggests, provides the conventional paper covered conductors for local trunk or carrier type cable. At first a string is applied around a copper wire in the lapping room (2) to provide the required air space between the conductor and the paper, then on the same machine a suitably marked paper (numbered one, two, three or four, blue or red striped as obtained from the paper slitting and printing machine) is lapped. The finished conductors are then dried and four conductors laid up in the quadding machine (3) to form the paper quads.



1. PAPER PRINTING & SLITTING.
2. LAPPING ROOM.
3. QUADDING MACHINES.
4. LAY-UP MACHINE FOR CENTRE UNIT & MINOR TRUNK CABLES.
5. STEEL TAPE REWINDING.
6. COPPER TAPE REWINDING.
7. CENTRE WIRE DRAWING M/C.
8. INJECTORS. (3)
9. CRIMPERS. (5)
10. PROCESS TESTING AREA.
11. CO-AXIAL LAY-UP M/C.
12. VACUUM TANKS.
13. LEAD PRESS.
14. MAIN TESTING ROOM.
15. STEEL TAPE ARMOURING M/C.

Fig. 1.—Production Line for Coaxial Cable Manufacture.

The quadders employed in the plant are all of the vertical type capable of producing high quality quads as far as within quad unbalances are concerned. The laid up quads are tested for continuity, resistance unbalance and within quad capacity unbalance before passing them over to the lay up machine (4). The lay up machine consists of three bays with 6, 12 and 18 floating bobbin carriages, and is capable of making a 37 quad (that is 74 pair) cable with further extension possibilities. For the Sydney-Melbourne project this lay up machine provided 420 miles of 10 quad centre units and 129 miles of minor trunk cables, containing 28, 38 or 54 pairs.

The coaxial section is the highest precision part of the plant. To form a high quality tube every single component, that is the centre wire, the disc spacers, the copper tape from which the outer conductor is formed and the steel tape which provides the magnetic screening and mechanical strength, have to be of high quality and of maximum precision as far as dimensions are concerned. To this end, all these components are made or checked in the plant itself. The wire-drawing machine (7) employes a diamond die which keeps the tolerance within 1/10,000 of an inch. The discs are moulded onto the centre wire in the injectors (8) which for every injection provide four wires with 10 discs each, the spacing between each of the discs being absolutely constant (Fig. 2). The centre wire, with the discs moulded on, is then placed at the end of the crimping machine (9) which is the actual tube-forming machine. The copper tape is led through a punching device which forms the teeth on the two edges of the tape. The tape is then passed through a washing apparatus to remove all dust or grease before entering the forming die over a series of rollers. In the meantime, the centre conductor passes inside a high voltage tube to burn off any dust particles attached to it, and over a mechanical device to re-check the disc spacing. Any defect such as incorrect spacing, failure of teeth formation, or high dust contamination causes the machine to stop, indicating on a panel the type of fault. The centre conductor and the outer tape meet in the forming die (Fig. 3). The advantage of this type of tube lies in the fact that the two edges of the outer tape are crimped together by means of the teeth provided, giving a tube diameter on which unavoidable tension variations in the subsequent steel tape will have but little influence. After applying the steel tapes, two further paper tapes are provided to complete the coaxial tube. The coaxial tube is then passed to the testing section (10) where its impedance is measured and the tube is checked for reflections with an impulse echo test set; finally, a high voltage test of 5 kV is applied. This is the stage at which selection for further processing is made,

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*Olympic Cables Pty. Ltd. See page 268.

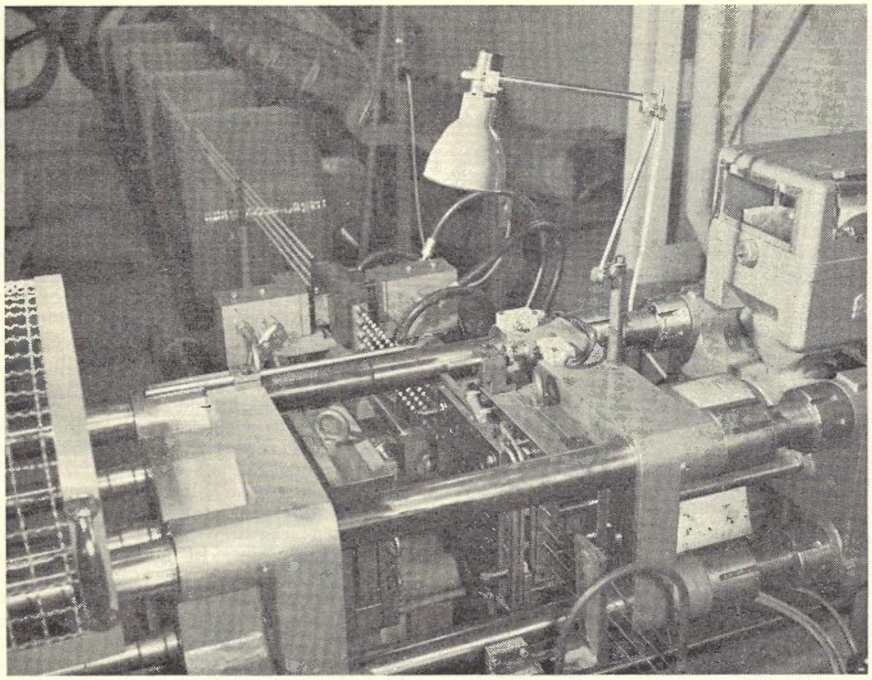

Fig. 2.—Disc Moulding Operation.

depending on the impedance of the tube and on the reflections present.

The selected tubes, together with the 10 quad centre unit and six carrier quads, are then laid up to form the coaxial cable assembly on a large lay up machine (11) which is a masterpiece of engineering (Fig. 4). The laid up cable is re-tested again for impedance and reflections before passing to the vacuum tanks (12), where over a drying cycle a high degree of vacuum is reached. From the tanks the cable is brought to the lead press.

Most of the cables which required steel tape amouring were provided with a plain lead sheath containing 0.1% antimony. This allowed the use of a continuous lead extruding machine (13) which greatly improved both the quality and quantity of production. Each cable could be passed over the lead press without a stop, eliminating the characteristic stop-marks obtained on the ram-type hydraulic presses. Cables for duct use, however, were still required to have Alloy B sheathing, (.85% antimony) and the extrusion time for these cables was approximately three to four times that for plain lead sheath cables, due to charging time and other service stoppages on the lead press.

The lead sheathed cable, if further processing is required (that is steel tape armouring or plastic jacket) is pressure tested and its insulation resistance measured (14). The common protection applied on the Sydney-Melbourne cable was steel tape armouring. The steel tape armouring machine (15) is fairly simple. It provides over the lead sheath two bituminous papers, a layer of jute bedding, two steel tapes, a layer of jute serving with a layer of compound between each of these materials, and finally, white-wash to avoid sticking between adjacent turns on the cable drum.

Steel tape armouring is the last process of manufacture after which all cables are subjected to a comprehensive final test. The process testing during the various stages ensures that the cables reaching this point will meet the specification unless mechanical damage or machine breakdown occurs. After checking the insulation resistance of the cable, the tubes are subjected to a high voltage test. The impedance of the tubes is measured, and a photograph showing the pulse oscillogram of every tube in each cable is taken with a Polaroid Camera. Every tenth cable is checked for attenuation characteristics over the frequency range and the cross-talk attenuation of the tubes measured. The mutual capacitance of both carrier and centre quads is measured as is the capacity unbalance within the quads, and quad to quad unbalances. Cross-talk measurements are made on the carrier quads at 120 Kc/s and the impedance of the carrier quads determined over the frequency range. Finally, the resistance unbalance and conductor resistances are also measured.

When all tests have been completed, the cable is passed into the cable pool awaiting allocation to the field.

PRODUCTION

As mentioned earlier, the plant was designed to produce approximately 30 miles of 6-tube coaxial cable per month to finish production by the end of July, 1961. Various problems such as late delivery of equipment, increased minor trunk cable requirements, with associated raw material shortage and supply difficulties resulted in production starting later than planned as the graph (Fig. 5) will show. Instead of starting full production in June, 1960, the plant did not swing into full operation until mid-September. At one stage, production was some 50 miles behind requirement, and there were some doubts about the possibility of finishing the contract in time. However, the Company put everything into this project, exploring every avenue of increasing production, culminating in an all-time record of 45 miles for the month of March, 1961.

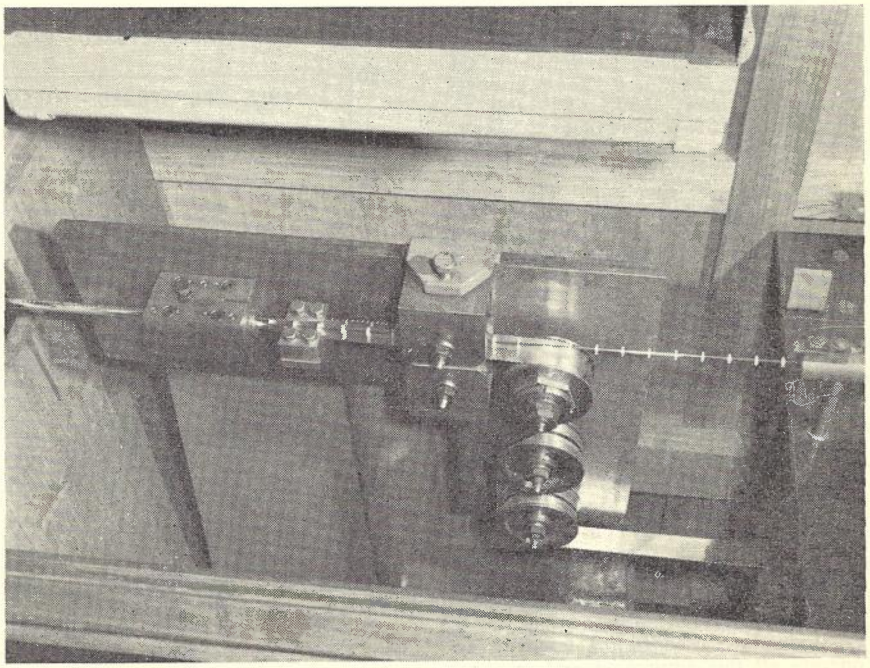

Fig. 3.—Forming of Coaxial Tube.

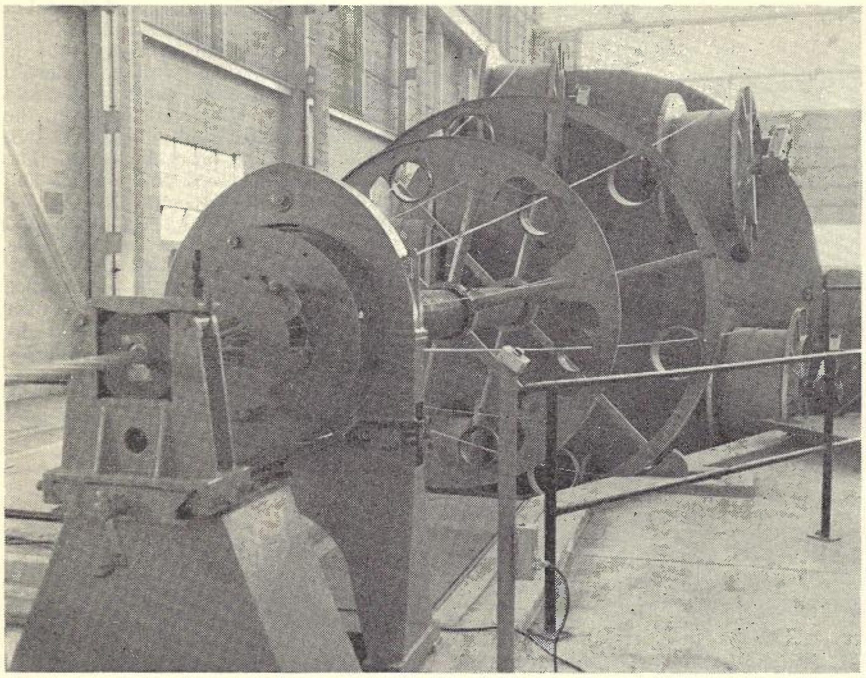

Fig. 4.—Coaxial Lay-Up Machine.

The first time 30 miles was exceeded was in October, 1960, and from then on production never looked back. December and January were the two months when this figure was not reached due to the Christmas close-down of the plant. It should be mentioned that the graph shows coaxial cable production only, and between January and the end of the Contract, an additional 80 miles of minor trunk cables was also produced.

It was not, however, quantity alone which makes this project memorable. Of 1,731 cable lengths manufactured, 97.31% were supplied to the field. Of the remaining 2.69%, 0.52% represents testing allowance, 0.36% loss due to allocation, 0.75% surplus and the rejection figure, caused by faulty material or machine breakdown was only 1.06%. It must also be mentioned that every person associated with this project was new to the job and had to be trained to operate machines which they had never seen before.

TESTING AND ALLOCATION OF CABLES

In the description of the plant, mention was made of the various tests which were required from the start to finish of coaxial cable production. The equipment used for testing is the same as employed by the Postmaster-General's Department for coaxial cable testing. In addition, Capacity Unbalance Bridges and Mutual Capacitance Sets of F. & G. design are used in the factory. To operate all this equipment and to carry out all tests necessary, it was necessary to train personnel who had no background whatsoever in this field. Some learned very fast, but for a long time very great responsibility was laid on the shoulders of the two test-supervisors, both in training people and keeping up with production. By the time production was at its full, 26 people were employed on testing, 9 of whom were fully trained in every field, the others helping in preparing cables for tests, sealing, inserting pulling-eyes and assisting the trained testers to carry out their duties. The Postmaster-General's Department's Resident Inspector had an unenviable job at the beginning, as can well be understood, but it is to the credit of both training personnel and persons trained, that the test results submitted always withstood every scrutiny.

A coaxial cable can meet the factory specification in every respect but that is not the end of the matter. One of the greatest problems is the allocation of repeater sections, where the impedances of the tubes of every cable length have to match those of the cables on either side, with additional restrictions on cables next to a repeater or at the mid-point of a repeater section. Where a section consisted of all standard 500 yard lengths, the allocation was relatively simple, but almost always an odd length was required at the repeaters or at the mid-point. In addition, due to laying difficulties, it was sometimes necessary to provide part of a section out of sequence, which meant that later the remainder of the section had to be matched to cables already in the ground. Also, due to the late start of production, as soon as enough cable was on hand for a repeater section, it had to be allocated as best possible, to maintain the cable laying programme. In consequence, the overall allocation was not the optimum which could have been obtained with more cables available at a time; nevertheless, of 1,032 tube-joints which had to be taken into consideration during the allocation, 90.74% gave a reflection value greater than 58 db and 99.87% greater than 54 db.

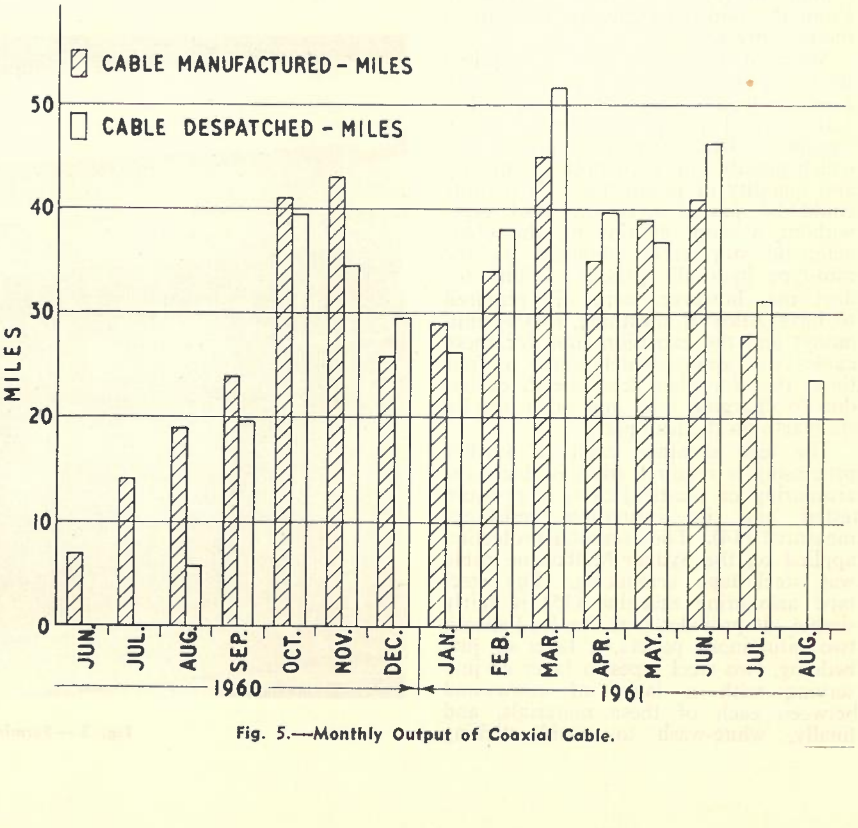

Fig. 5.—Monthly Output of Coaxial Cable.

INSTALLATION OF THE CABLE

D. F. BARRY B.E. and C. H. HOSKING B.Sc., A.M.I.E.Aust.***

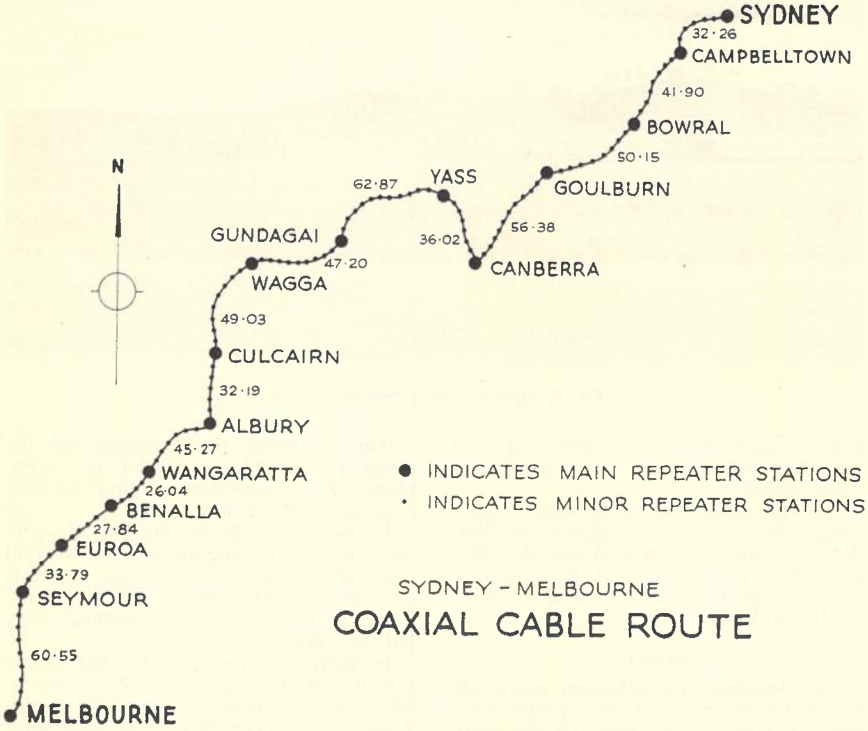

Fig. 1.—Cable Route Showing Main Repeater Stations.

INTRODUCTION

The decision to go ahead with the installation of a coaxial cable between Sydney and Melbourne was made in 1957, with the calling of tenders for the provision of a cable system. A contract for the supply of cable and cable accessories was given to Felten and Guilleaume, West Germany, in June 1959. It was decided that the cable installation would be undertaken by the P.M.G. Department to the satisfaction and under the supervision of the Cable Contractor, who was to be responsible for the performance of the completed cable.

The terms of the associated contract for the supply and installation of carrier equipment required that the cable be completed by September 24, 1961. As the first delivery of cable was not to be made until December, 1959, a particularly fast rate of cable installation was thus required.

The installation in each State was carried out under local Engineering control, but the manipulative staff employed over the whole of the route was drawn from both States. Installation was planned to be carried out from Sydney to Melbourne.

This article describes the selection and survey of the cable route and the installation of the cable.

ROUTE SELECTION AND SURVEY

General

A preliminary route selection had been made in 1950 and it was on this route that tenders were based. In October, 1957, when tenders closed, it was expected that a contract would be placed in February, 1958, and that the actual installation would commence about July, 1958. It was imperative, then, that the detailed route selection and survey which commenced from Sydney in January, 1958, proceed very quickly so as to allow cable drum length advices to be prepared and so that repeater sites could be selected and acquired. Because of the plan to install the cable southwards from Sydney, this haste was not required over the Victorian Section and no attempt to finalise route selection and survey was made in Victoria until considerably later. It will be appreciated, then, that the methods used to carry out the survey in each State differed because of the different circumstances.

Route Selection

The route selected in 1950 was, in general, very good and provided an excellent basis for the final selection. It may be mentioned here that the main repeater stations were chosen before tenders were invited, and in all subsequent planning and tendering these had to be regarded as fixed and definite. There was, therefore, a limitation on the extent to which major changes could be made in the general route. Although numerous small changes were made, the only significant alterations were in the Gundagai-Wagga and Euroa-Seymour sections. Between Gundagai and Wagga the original route was located on the northern side of the Murrumbidgee River via Nangus and

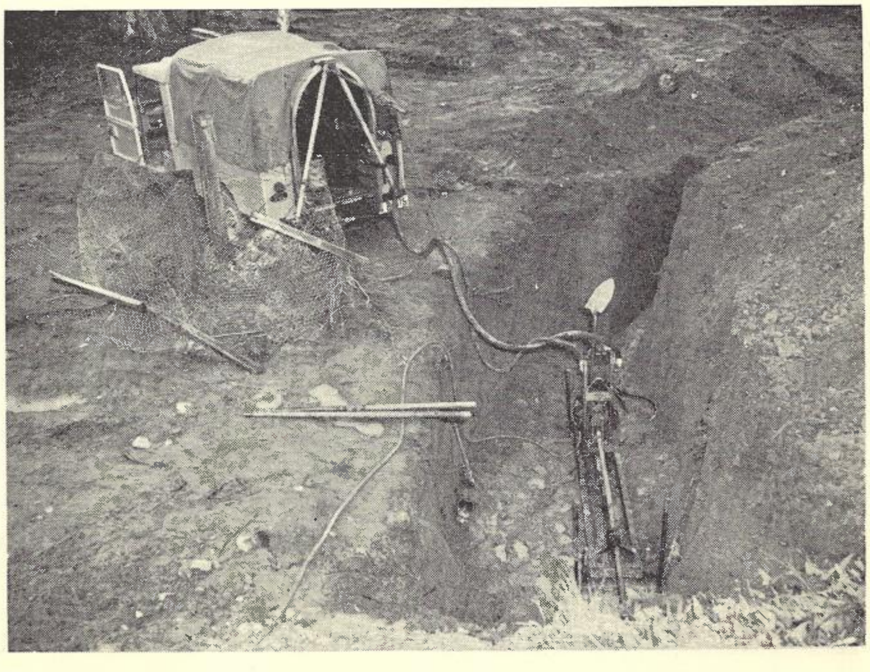

Fig. 2.—Mole Hydraulic Horizontal Borer Showing the Hydraulic Pump Driven by P.T.O. on Land Rover.

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* See page 268.

** See Vol. 12, No. 6, Page 467.

Wantabadgery but was changed to the south side of the river via Lower Tarcutta. This was done principally because the floods of the 1950's showed only too clearly that it was not unusual for some 10-15 miles of the initially selected route to be inundated for periods of a week or more. Between Euroa and Seymour the route was originally selected along the Hume Highway but was changed to follow a secondary road parallel to the Highway and adjacent to the railway line through Longwood and Avenel. It was expected that less rock would be encountered along this road and it passes through towns which had to be served by the cable.

The major portion of the route was selected in reasonable proximity to existing roads and hence presented little difficulty.

On cross country runs it was, in general, possible to select two or more alternative routes from parish or military maps supplemented by aerial photos. The alternatives were then walked over, using compass bearings, examined in detail, and the most suitable route selected. In some sections which were too rugged or too heavily timbered for this, light aircraft were used. Possible alternative routes were plotted on Military Maps and examined as closely as possible from the air. Those considered practicable were then walked over and the best one selected.

The general factors influencing the route selection were:—

(a) The shortest route, consistent with practicability of working, was the most desirable. This was, of course, conditioned by the fact that main repeaters had been previously determined and also by the requirement that the unattended minor repeaters had to be near a formed road for ready access. Consideration had to be given also to the accessibility of the route for future maintenance.

Fig. 4.—Cable Laying and Backfilling.

(b) The cable had to be secure from natural hazards such as floods, erosion, slip, etc., and be so placed that it would not affect or be affected by proposed works of property owners and of other public authorities.

Survey

The detailed route selection was made by an Engineer ahead of a preliminary pegging party which measured the route and placed pegs at every 1,000 feet and at angles. Basic survey plans, 4 chains to the inch, were prepared from these preliminary measurements. Repeater sites were selected and action initiated to acquire these sites. The detailed, final survey followed the selection of the repeater sites. This consisted of a completely new measurement and detailed pegging of the route.

In New South Wales the final pegging involved the placing of one centre and two offset pegs at 100 yard intervals and also at any angles in the route. Joint positions were determined later but not pegged.

In Victoria, where the detailed survey was not started until after cable installation had commenced in New South Wales, pegs were placed at each joint point, angle, cross fence and every 1,000 feet. In open paddock a centre line peg and two offset pegs, 20 feet from the centre line were placed at each such point with the continuous chainage from the main repeater station and the offset distance stamped on the offset pegs. Where the cable route was within 60 feet of a parallel fence only one offset peg was placed and this was located on the fence line. At each peg, which was driven to ground level, a sighter stake was also placed. These stakes were painted with a code to indicate the type of peg, viz., straight line pegs—yellow, angle pegs—red, joint pegs—yellow with red top, loading points—yellow with two red bands.

This increased amount of pegging, as compared with the system used in New South Wales, was adopted in Victoria, as a result of difficulties experienced in New South Wales during the early stages of the cable laying. It was found desirable to facilitate the accurate identification of every point along the route, particularly the joint points. It was necessary to provide for non-sequential laying of cable lengths and it was also essential to ensure that any surplus cable was cut off each drum length rather than be allowed to accumulate and be cut off at one point. This is important to preserve the matching of end impedances of the coaxial tubes at each joint.

Particular care was taken in selecting joint positions in the buried cable sections. Normally, joints were 500 yards apart. However, to facilitate installation, a joint was located imme-

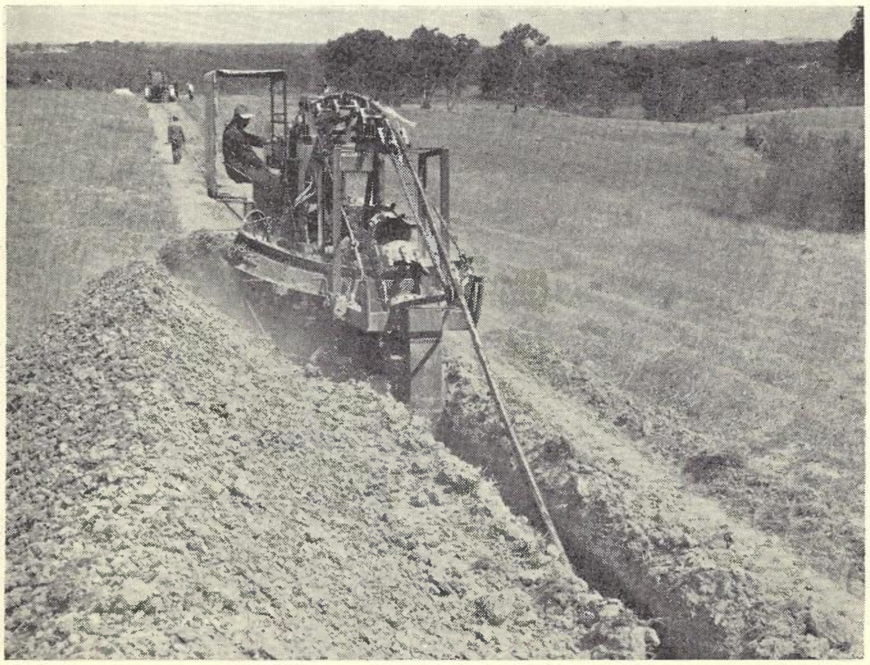

Fig. 3.—B.G. 774 Ditcher Showing Cable Being Laid Out on the Ground Ahead of the Ditcher and Being Run Over the Ditcher Directly into the Trench.

diately adjacent to one end of each proposed pipe crossing so that the minimum length of cable would need to be hauled through the pipe. For similar reasons, a joint was located near one side of each creek crossing and each side of a major river crossing.

In duct sections, joints were positioned so as to keep hauling tensions to a safe limit while allowing the longest possible lengths to be installed. Jointing positions were selected so that angles in the duct route and manholes with significant variations in duct alignment would occur as close as possible to the manhole at which the cable trailer would be placed during hauling.

Following the final survey, detailed route plans (4 chains to 1 inch) in strip form were prepared. Each pegged point with its continuous chainage, was shown on these plans.

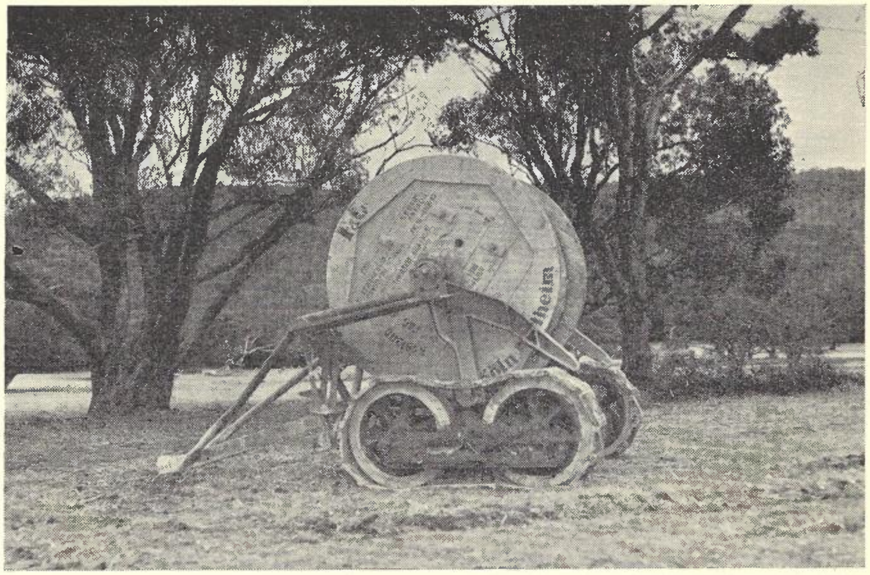

Fig. 6.—Crawler Track Mounted Cable Trailer.

THE CABLE ROUTE

The total route distance between Sydney and Melbourne is 602 miles, 408 miles being in New South Wales and 194 in Victoria. The major portion of the buried cable route is on private property, some 450 individual property owners being involved. The total distance is divided into 14 major repeater sections varying in length from 25 miles in the Wangaratta-Benalla section, to 63 miles in the Yass-Gundagai section. Each major section is itself subdivided into a number of minor repeater sections, the maximum lengths of which are 5.7 miles between Sydney and Gundagai and 5.6 miles between Gundagai and Melbourne.

Between Sydney and Campbelltown the cable is, except for about 4 miles, in ducts. This section is all closely subdivided and settled and offered little difficulty. Approximately two miles of the cable in this section has been installed at a depth of 6 feet to avoid interference by future road work on land that was formerly used for dairy farming but has since been re-zoned as industrial.

The Campbelltown-Bowral section consists almost entirely of softly undulating Triassic Sandstone and shale hills. The shale is generally below the trenching depth of 4 feet but the hard Hawkesbury Sandstone is often on, or very close to, the surface. This area is characterised by very deep, rugged juvenile gorges making access and construction difficult. Some very hard microsyenite was encountered at the base of Mount Gibraltar between Mittagong and Bowral. Large sections of the route through this area are through heavily timbered country, particularly in the Sydney Water Catchment Area.

From Bowral to Wagga along the route the country is mostly devoted to sheep farming and the terrain varies from reasonably flat to steeply undulating. About midway between Bowral and Goulburn the Triassic Sandstones and shales give way to Devonian then Silurian shales and Conglomerates. The route is heavily timbered over many miles and clearing in this area was a major item. South of Goulburn the timber was generally very light except for a few miles near Lake George. The area south of Goulburn through Canberra to Yass, is mostly Ordovician and generally consists of slaty shales underlain by quartz. About 4 miles of granite and about 4 miles of porphyry constituted the main difficulty because apart from the rocks themselves being very hard, when they decompose they produce a treacherous working surface with a hard porous crust for a foot or so with a soft "slop" below. From Yass to Wagga the route crosses the Dividing Range and the area consists generally of steeply undulating Silurian or Ordovician hills of either porphyry or slaty shale. Although there are numerous small creeks and rivers between Bowral and Goulburn, the Murrumbidgee River at Gundagai was the only one to present any real difficulty and then chiefly because six 4" polythene pipes were laid under the bed with the cable.

Fig. 5.—Wheeled Cable Trailer Drawn by Chamberlain Tractor.

Between Wagga and Benalla the country is flat, lightly timbered and almost entirely rock free, consisting principally of deep recent sediments and devoted largely to wheat growing. Some very hard quartzite, over a couple of hundred yards, was taken out near The Rock, and through Glenrowan granite boulders were encountered over about 1 mile.

Between Benalla and Euroa the country is generally flat or gently undulating and mostly of rock-free soil, although about 10 miles south of Benalla there are patches of granite rocks and immediately north of Euroa slightly metamorphosed silurian sedimentary rock was encountered.

From Euroa to Seymour this metamorphic silurian sedimentary rock is in a very hard form almost continuously for 20 miles. The covering soil is mainly

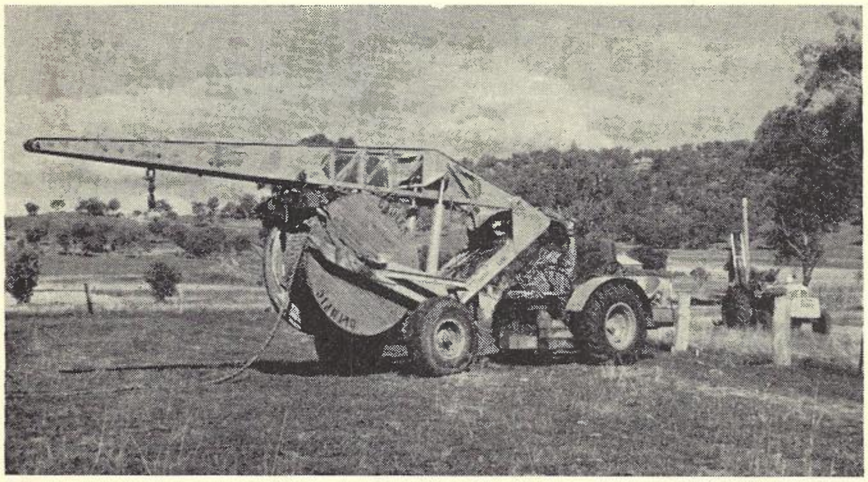

Fig. 7.—8-Ton Cranvel Crane and Cable Transporter Laying Out Cable.

decomposed granite which, when wet, turns into "slop" which will not support crawler track mounted plant. The remainder of this section is mainly rock free, but for some miles there is a layer of decomposed granite near the surface.

Immediately south of Seymour the route crosses the Goulburn River and the river flats which consist of thick alluvial deposits. It then passes through undulating country for about 30 miles, crossing the Dividing Range. Most of the excavation in this section was in weathered silurian siltstone, sandstone and mudstone. Then for the last 8 miles to the end of the ducts leading through the Melbourne metropoliton area there is a deposit of large basalt boulders. For the last 17 miles of the route into Melbourne the cable is in ducts.

JOB PLANNING

Job planning was done by an Engineer who walked over the route and determined the work to be carried out by each of the installation parties. The following points were covered during this inspection:—

(1) The locations for installation of permanent or temporary gates were determined.
(2) The locations for pipe crossings under roads and railways were determined.
(3) The extent of timber clearing and track levelling required was noted.
(4) The required layup of each drum of cable, i.e., whether Sydney or Melbourne end outer was decided. This was normally Sydney end outer as the cable was laid from Sydney towards Melbourne, but creek crossings or pipe crossings sometimes required a reversal in the normal layup. Each drum length in duct sections was considered also from this point of view.
(5) It was decided whether a pulling eye was required on cable lengths.
(6) Points at which special construction difficulties would be encountered were noted and probable job methods worked out.
(7) Soil erosion hazards were noted and control measures planned.

During the job planning walk over, joint positions were checked and test boring was done to check soil conditions and detect the presence of rock.

On the completion of the job planning walk over, cable drum length advices were prepared and other material quantities estimated and ordered. Job instruction sheets were produced and finally a detailed works estimate for each Major Repeater Section was prepared.

ORGANISATION

To carry out the installation, a Project Division was formed in each State, staff had to be recruited and thoroughly trained and material and equipment assembled.

A maximum staff of 250 men, including Engineers, Supervisors, Clerks, etc., as well as the field staff, were employed on the project and these were all recruited from within the Department, being drawn from Country and Metropolitan Divisions in both States.

The total job was organized functionally, and the staff allotted to perform each function were thoroughly trained in the machines and methods that they would use. Machine operation and other skill training was conducted by the Departmental Training Organization and Field Operations Division assisted by the Department of Army. When all skill training had been completed, a week's course in job methods, first aid, clerical work, camp rules, traffic requirements, conduct and rights on private property and other incidental features of the job was given to all staff by Engineers, supervisors and clerks of the Project Division.

The task of equipping a complete Installation Division, not only with their working tools and equipment but also with their living necessities, was stupendous, and involved thousands of individual items ranging from bulldozers to butter dishes.

All members of the field staff were accommodated in caravans and all camp facilities such as kitchens, showers, toilets, offices, etc., were housed in caravans, permitting a high degree of mobility without excessive effort.

As will be mentioned in more detail later, the experience gained between Sydney and Canberra and the change in weather and terrain resulted in a considerable change in organization south of Canberra.

The functional division of the job that was used over the majority of the route was:—

1. Route preparation,
2. Trenching in soil,
3. Trenching in rock,
4. Cable hauling in ducts,

Fig. 8.—Ace Back Hoe Excavating Trench in Rocky Ground After Ripping.

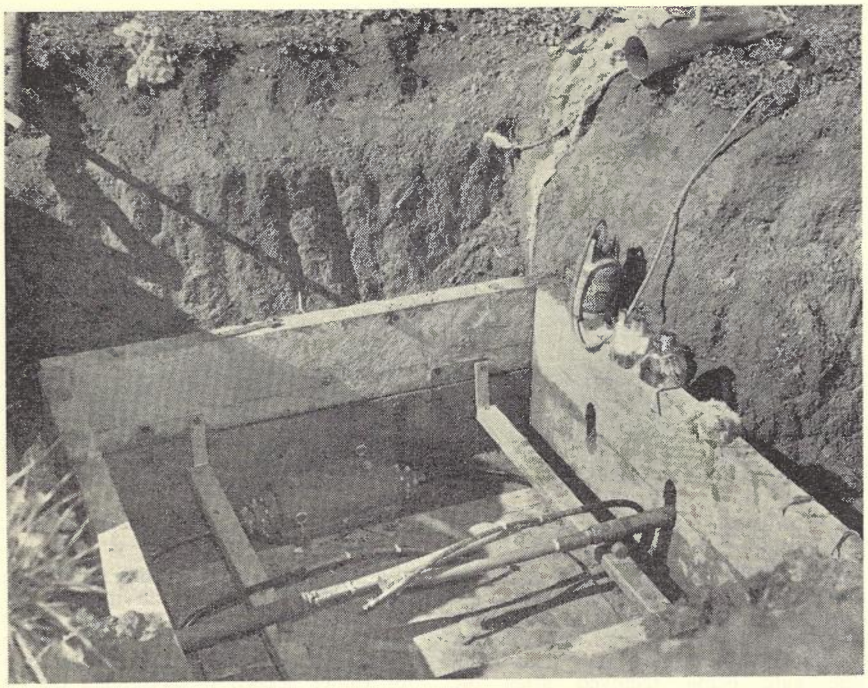

Fig. 9.—Concrete Slab Joint Box Used Between Sydney and Albury.

5. Initial jointing and testing,
6. Final jointing.
7. Final testing.

CABLE INSTALLATION

General

The complete installation programme will be discussed under the various functional headings, recognizing that each function must be closely related to all others in regard to progress rates and organizational control, and that the great variety of terrain and weather conditions coupled with some irregular delivery of cable required a large degree of flexibility in the organization.

Route Preparation

The route preparation covered those parts of the job required to be done on the route prior to the actual cable laying and included such things as timber clearing, gate erection, road and railway crossings and creek and gully access.

Clearing

Between Sydney and Canberra, timber clearing constituted the bulk of the route preparation effort. Allis Chalmers HD. 16 dozers (with torque converters) were used throughout and in the heaviest sections, Bowral to Goulburn, 4 of these machines working in pairs were employed. Tree pushers were not used and many of the trees required two machines pushing at the one time. On the occasions when only one machine was available the larger trees were removed by pulling. The fallen trees were cut up by chain or circular saws. Originally Dayson swing saws with contra rotating blades were provided. These saws were "self propelled" being fitted with a chain drive to one wheel. However, although the contra rotating blades were very effective in eliminating "drag" or "push" the saws were much too heavy to use in the conditions prevailing along the route because of the ineffectiveness of the chain drive. They were replaced, early in the job, by a single bladed circular saw mounted on a wheeled tractor which proved to be both convenient and reliable. "Champion" chain saws were bought for the job but these were unreliable and were replaced by "Danarm" saws which were very satisfactory. Two Macquarie Bush Chippers were obtained for the job to dispose of the smaller branches particularly during the summer months when bushfire regulations prohibit the lighting of fires. Although these machines performed very well, they were found to be impractical on this job because of the required rate of progress and the quantity of timber to be disposed of.

Initially it was thought that a clearing width of some 12-20 feet would be adequate for a working right of way. However, experience soon showed that a minimum width of 30 feet was required to allow unrestricted access to all machines and vehicles during the trenching, laying and back filling operations.

South of Canberra, very little heavy clearing was required, as the route largely traversed private property which had previously been cleared by the land owners. It was no longer necessary to employ a special party on clearing and, with one exception, it was carried out by the trenching parties. Near Chiltern (about 20 miles south of Albury) a section of about 2½ miles of route required extensive clearing which was completed some six months ahead of cable laying by local staff.

Ripping

It was originally intended that the whole route would be ripped to 4 feet ahead of the excavating machines, as part of the route preparation. It was considered that this would considerably increase the trenching rate, particularly for the bucket-wheel ditchers, and would identify sub-surface rock which would need to be handled by pneumatic tools and explosives. This was done over the first 150 miles, some 6-8 weeks ahead of the trenching. However, two very serious disadvantages more than offset the gain derived from the pre-ripping. If any rain fell on the ripped route

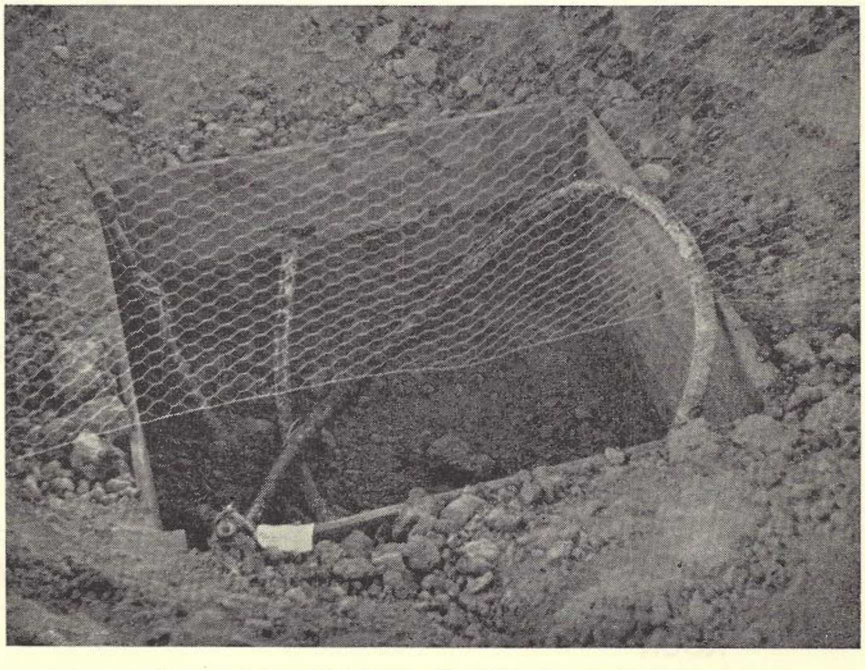

Fig. 10.—Wooden Joint Box used Between Albury and Melbourne.

before trenching commenced the water accumulated in the rip and the route 3-4 feet on either side of the rip became so soft that the trenching machines frequently bogged. It was necessary in many cases to cut the trench some 8-10 feet to one side of the ripped line with a consequent loss of any assistance from the ripping and a reduction in the effective width of the clearing. Even in dry soil of certain types, the ripping disturbed the soil on each side of the ripped line to such an extent that the trench walls collapsed and a large amount of fallback had to be removed after the passage of the ditchers.

Beyond Goulburn pre-ripping so far ahead of the trenching was discontinued. Thereafter ripping was done only in selected areas where it was known some advantage would result and then only just ahead of trenching. This will be described more fully in the section on rock excavation.

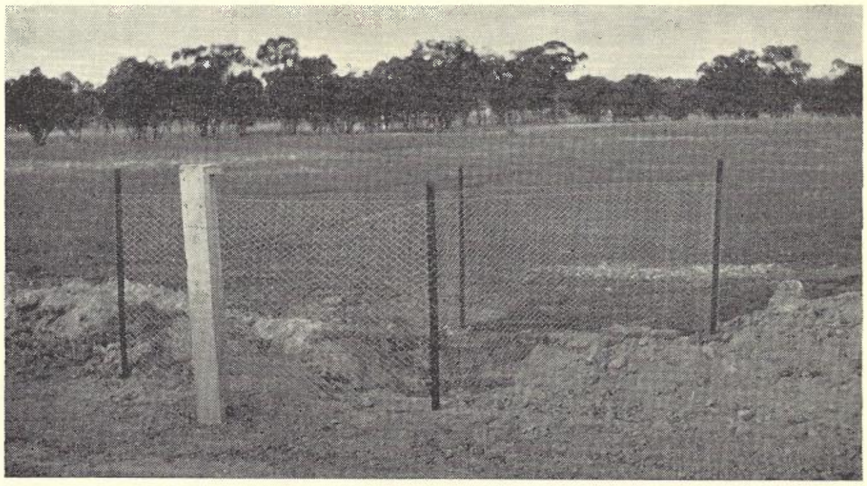

Fig. 11.—Joint Hole Protected by Temporary Fence, showing Marker Post Installed.

Gate Erection

In the early stages of the job two 2-man parties, operating as self contained units, worked in advance of all other parties installing either 13 foot M braced permanent gates or "Mallee" type temporary gates in property fences. The permanent gates were installed so that ready access was available for the jointing, testing and subsequent maintenance parties. 7" x 7" x 7' concrete posts with 4" x 4" x 7' concrete struts were used with permanent gates. It was soon evident that once a trench was cut through the gateway, the trench and spoil heap were so wide as to bar access to the following machines and vehicles. Double 13 feet gates were then used, one gate being removed after the passage of the machines and the trench back filling. This was a cumbersome arrangement and later one or other of the following methods was used. Either a double gate consisting of one permanent and one temporary gate was installed, the permanent gate being just off the trench line, or the gate erection party was attached to the trenching and laying team, the fences being cut immediately before trenching and restored after backfilling, a permanent gate being installed in the most suitable location for future access. It was found that it was preferable not to have a gate immediately over the trench line because of the difficulty of negotiating the disturbed ground in a vehicle in wet weather. A deal of trouble was caused by the movement of the gate posts, particularly in fences that were well strained, even though the posts were

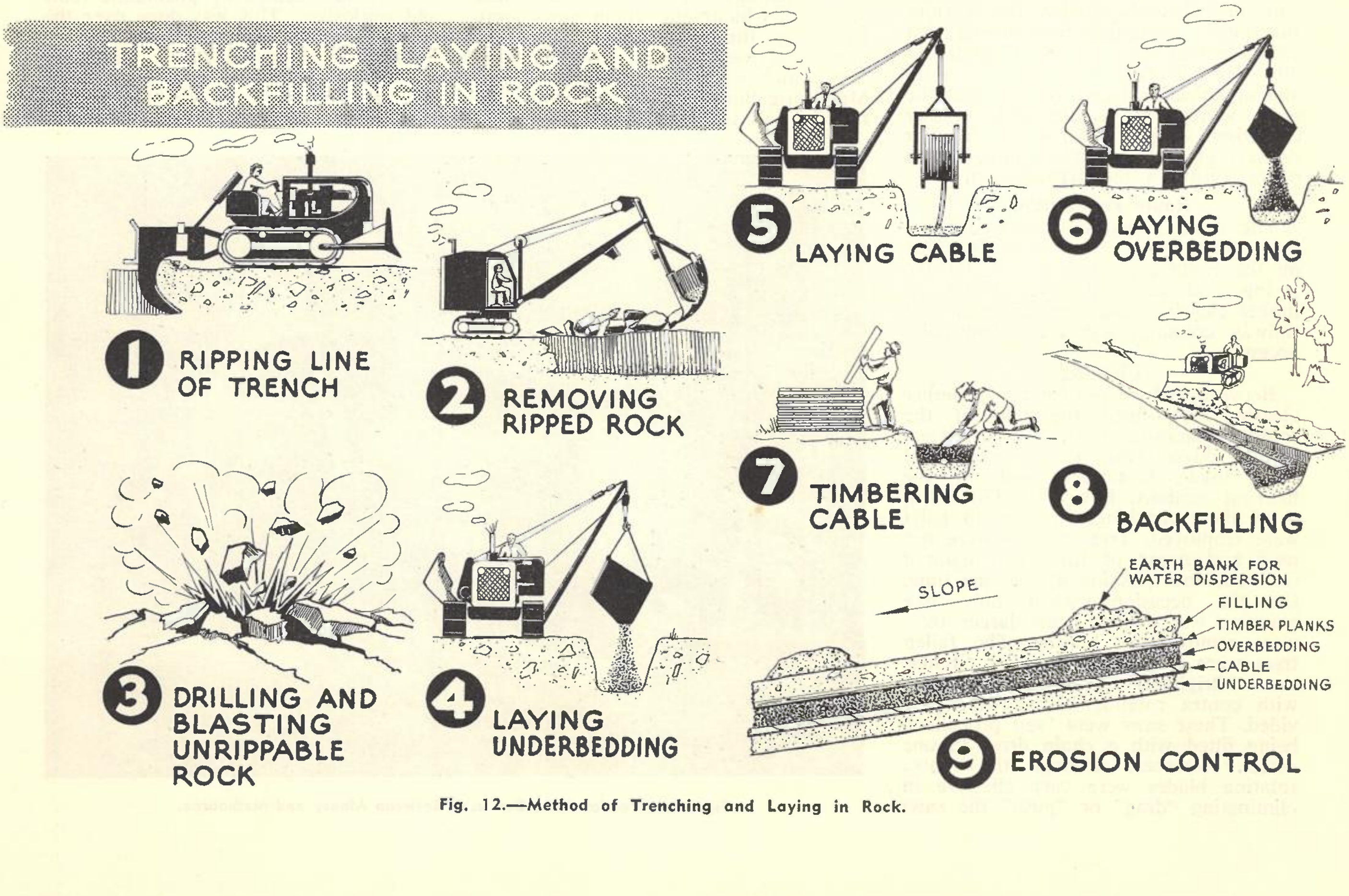

Fig. 12.—Method of Trenching and Laying in Rock.

strutted. The post on which the gate was swung often moved outwards, thereby lifting the other end of the gate and neutralising any previous rabbit proofing. This resulted in complaints by property owners, and to rectify the trouble a third post was provided on quite a few gates as a separate fence strainer post.

In passing, it should be mentioned that a large proportion of complaints received from property owners both during installation and since, concerned gates and fences. The failure of members of the laying, jointing and testing teams to properly close gates on private property, the sagging of temporary gates and the lifting of permanent gates have resulted in numerous complaints that could have been avoided.

Road and Rail Crossings

Except in duct sections, where crossings had previously been installed, all railway and sealed road crossings were made in a single 6" pipe installed in a hole bored under the road or railway. The installation of these pipes was carried out well in advance of the cable laying by a three man party (an extra man was provided as required to operate the grout pump on railway crossings) operating as an independent unit. Either a "Mole" hydraulic borer the hydraulic pump for which was driven off the power-take-off of a Land-Rover, or a Proline horizontal borer was used by this party. Crossing times varied from one day (in good soil conditions) to 12 days (in the case of the Hume Highway Crossing at Governors Hill, Goulburn where some very hard quartzite was encountered).

Access Crossings

Between Sydney and Canberra temporary access across small creeks and gullies was provided by the clearing party, either by battering down the banks or, in the deeper narrow gullies by providing temporary pipe culverts. These culverts consisted of one or more 18" diameter Armco corrugated "nestable" pipes, laid on the creek bed and covered by soil and gravel and in some cases by concrete. In general they were quite suitable for the purpose, but during the wet months they were often partly washed out by floodwaters or the freshly worked soil became a quagmire preventing their use by other than tracked machines. South of Canberra all access crossings were built by the trenching teams when they were ready to use them. For permanent patrol access, it has been found that the 18" pipes are often unsuitable because of the large volume of swift flowing water carried during the wet months and a number of the original crossings are being replaced by 4 feet diameter concrete pipes.

Fig. 13.—HD. 16 Tractor with 4 ft. Ripper Tine.

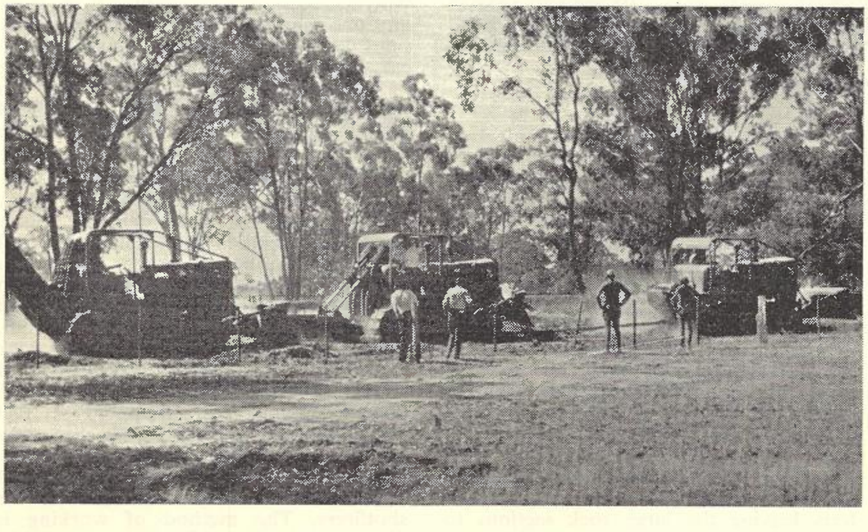

Fig. 14.—Tandem Ripping, one HD. 16 Tractor pushing and one HD. 16 Tractor pulling the Ripping Tractor.

Trenching in Soil

Trenching and Cable Laying: Barber Greene 774 trenching machines were used almost exclusively for the trenching and these machines are capable of digging a 4 foot trench at up to 15-20 feet per minute in good light soil; it is of course, fundamental that advantage be taken of their high digging rate to achieve a high average output. During the early stages of the job however, this was not done. The trenching and laying organisation was controlled so closely by cable deliveries that really efficient production was not possible. Cable lengths were delivered in a very haphazard fashion, resulting in the adoption of a most uneconomical installation organization. As an example trenching was proceeding in the Mittagong area just north of Bowral before lengths in the first sections out of Campbelltown were received, while at this time quite a few lengths in the Goulburn-Canberra section had been delivered. This resulted in a great deal of unnecessary movement of men and machines. Coupled with this was the large amount of rock which could not be ripped and the very wet weather experienced between Sydney and Canberra. Initially, only a small rock party was used with the result that much of the actual rock excavation was done by the trenching party. Pre-ripping to 4 feet, particularly in the Hawkesbury Sandstone areas was more difficult than originally expected. Although isolated downpours caused frequent bogging, rain was not a serious problem until the trenching was proceeding in the Bowral-Goulburn-Canberra Sections between May and October 1960. The wettest winter on record in the Goulburn-Canberra area turned the route into a quagmire and the major part of each day was spent debogging vehicles and machines. The initial downpours of the winter rains washed out about 4 miles of trench overnight in the Bowral-Goulburn Section. This trench was in shale and had been dug by 22RB drag shovels. It was awaiting the removal of small rock outcrops and replacing of

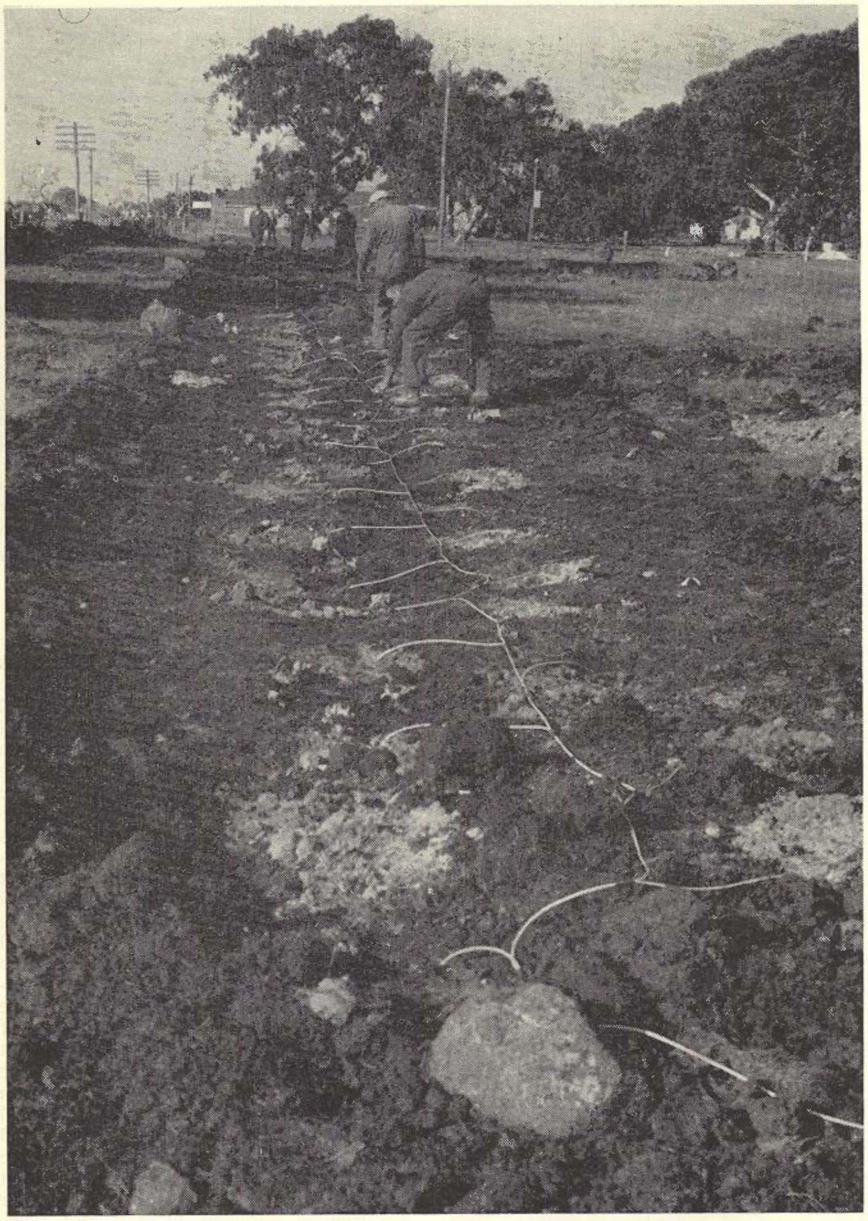

Fig. 15.—Rock Blasting near Wollert, Vic.

bedding before laying the cable. The recovery of this trench was very costly as it had to be done by hand, the machines not being able to approach the vicinity of the trench without bogging. Air Force steel runway matting and timber planking were unsuccessful and even the tracked machines were continually bogged. The most successful arrangement used during the wet season was the fitting of "swamp" shoes to the Barber Greene ditchers. These shoes were 24" lengths of 4" x 2" hardwood, bolted to the tracks, thus increasing the track area. However, the use of the swamp shoes, while allowing trenching in otherwise impossible conditions, did contribute to the large number of ditcher differential failures.

Before Canberra was reached it was obvious that a change in organization was necessary. This re-organization resulted in the reforming of the trenching and laying team into 4 small parties of approximately 12 men. Each party was equipped with a Barber Greene 774 ditcher, Allis Chalmers 45 grader, light back hoe, light dozer, tractor-mounted air compressor, 8 ton Cranvel crane and cable transporter, cable trailer and the necessary vehicles. A heavy dozer for clearing, 22RB dragshovel/dragline excavator for isolated rock and wet soil excavations and for creek and river crossings and a gate erection party were shared by two trenching parties as required. The trenching party worked only in those sections which were reasonably rock free, leaving the large rock sections to the rock party. However, each party did have attached to it a shot-firer and compressor operator to cope with isolated rock outcrops.

South of Canberra, the cable was of Australian manufacture, and was delivered in complete minor repeater sections which greatly assisted organization.

The cable was usually laid over the top of the ditchers, as described in the previous article in this Journal on the Melbourne-Morwell project. The roller fittings on the ditchers were improved, however, sheaves being used instead of the multi roller unit, double sheaves being provided to enable two cables to be laid simultaneously. Short sections, where ditching was not practicable, such as lead-ins to repeaters etc., were taken out by light back hoes.

The maximum daily output from one trenching machine was 2,600 yards, but this was in exceptionally good soil, the normal daily output per machine in reasonable soil conditions being about 1,000 yards.

Joint Holes:

On completion of cable laying a 6' square hole 4' 6" deep was excavated at each jointing point. In New South Wales 5' x 5' prefabricated concrete, and in Victoria 5' x 5' prefabricated pressure treated Radiata pine joint boxes were installed. Temporary fencing of star pattern posts and wire netting were erected around the holes, to protect stock.

Backfilling:

In dry soil the Allis Chalmers 45 graders were used for backfilling. Where conditions are suitable, the grader is the ideal backfilling machine as it combines speed with a neat finish. In wet conditions however, crawler tracked dozers were necessary, the lighter dozers such as D 4, OC 12, TD 6 being most suitable.

Markers:

Seven foot concrete marker posts of substantial cross section were placed at joint positions, angles, hill crests, cross fences, road, creek and river crossings, etc.

Additional markers were erected where necessary to ensure that from any one marker post, the posts on either side were visible. The marker posts carry a plate on the front face, warning of presence of a high voltage cable. On the top of the post a plate was affixed giving details of the location of the cable and joint particulars.

Trenching in Rock

As mentioned earlier the rock sections were the main delaying factor (excluding weather and cable deliveries) north of Canberra. When the teams were re-arranged near Canberra much thought was given to the organization of a rock party capable of smooth, quick, safe progression. A new rock team was established, consisting of about 30 men equipped with HD 16 dozers with tractor mounted 4 feet single tine rippers, 22 RB ¾ yard drag shovels, HD 11 Side Boom cranes, compressors and vehicles. The majority of the staff were compressor operators or shotfirers. The method of working is illustrated in Fig. 13. It was possible, with this organization to average a mile of cable laid per week in rock. Although the specified minimum depth in rock was only 2 feet, the cable was generally laid much deeper and where the ripper was able to penetrate to 4 feet, this depth was used, thus avoiding frequent changes in level. Numerous passes with the ripper, using two HD 16 tractors in tandem, were usually required to obtain full penetration. This was done either with the second machine pushing on a pusher plate forming part of the tine, or towing with a chain attached directly to the ripper tine. On one occasion a train of three tractors was used with one pushing and the other pulling the ripping tractor. Of course, rocks such as porphyry, granite and basalt were, generally, not rippable and these were drilled and blown. All blasting was done by gelignite and cordtex detonating fuse which was convenient to use, and quite suitable because of the shallowness of the trench and because the locations where blasting was required were not in built up areas.

One particularly difficult rock section was encountered near Wollert about 20 miles north of Melbourne where a formation of heavy basalt boulders exists almost continuously over about 8 miles of the cable route. These boulders, weighing up to 8 tons each, are wedged tightly against each other; in many cases they are sometimes visible on the surface and elsewhere covered by soil.

The initial attempt at excavation of this section used the conventional methods used in other heavy rock sections but these proved slow and expensive.

Another method was tried and adopted for the remainder of this section. A pattern of 2 inch holes 5 feet deep in two lines three feet apart was drilled by a crawler mounted wagon drill along the line of the route. The drilling time for a 5 foot hole in solid basalt was about 1 minute. Charges of 2 lb each of 2″ gelignite were used and up to 100 charges were fired at one time. The resulting blast broke up the rock formation so that the line of the trench could then be ripped to further loosen the rock. Drag shovels were then able to excavate a neat trench about 3 feet wide and 4 feet deep. Only very infrequently was a small amount of additional blasting necessary to remove isolated pieces of stubborn rock from the trench bottom.

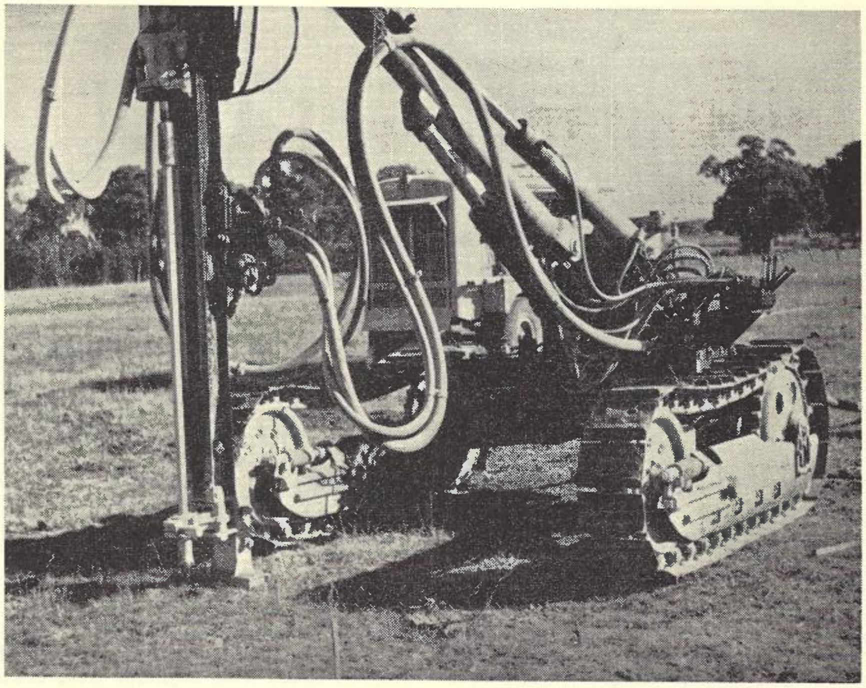

Fig. 16.—Wagon Drill used at Wollert.

To obtain the maximum amount of spoil for backfilling from the excavated material a rock rake was used to sort out the soil and smaller rocks from the larger ones. However, because of the enormous amount of excavated rock which was too large to return to the trench, some 5,000 cubic yards of sand and other filling were required to bed the cable and backfill the trench.

One of the major problems in the rock sections was providing the bedding sand under and over the cable. Generally, the areas where bedding is required are the most rugged and delivering the bedding sand or soil into the trench is difficult. Sand conveyor belts, driven by hydraulic motors, were attached to the rear of 4 wheel drive tipper trucks but were only partly successful. The most successful arrangement, which was developed near Canberra, was the use of a 3-ton hopper carried by the HD 11 side boom crane and this arrangement was used for the remainder of the route.

Lengths of pressure treated 6″ x 1″ Radiata pine were laid over the overbedding to provide greater protection to the cable during backfilling and to avoid any subsequent crushing of the cable due to rocks settling through the bedding during wet weather. Backfilling was done by dozers which also formed up erosion diversion mitres.

In very steep sections concrete checks were placed at intervals along the trench to assist in preventing scour. On the escarpment at Lake George, where a 4 feet trench was cut through the broken quartzite on slopes up to 47°, these checks have been very effective.

Where the rock team installed the cable, they also set prefabricated manholes and marker posts and sowed pasture grasses to help restore the land and prevent erosion.

Creek and River Crossings

Altogether 17 rivers and about 120 creeks and gullies were crossed, the cable being laid under the bed in most cases. Except for two crossings of the

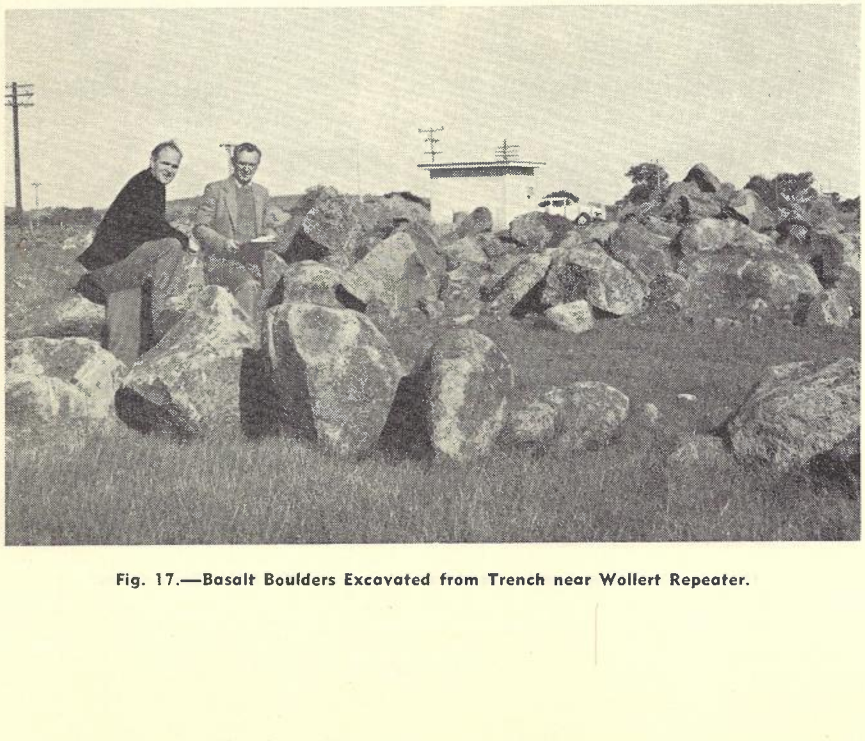

Fig. 17.—Basalt Boulders Excavated from Trench near Wollert Repeater.

Fig. 18.—Excavating Granite Boulders near Canberra.

Nepean, at Douglas Park and Pheasants Nest Pass, and the Murrumbidgee at Gundagai, the crossings were simple and presented no real problem.

A variety of methods were used because of the variety of conditions encountered. Where it was possible to use a dragline this was done, and this applied to most of the large creek crossings and quite a few river crossings.

A number of the crossings such as the Nepean River crossings at Douglas Park and Pheasants Nest Pass were so difficult of access that the use of machines was impractical. Both of these crossings also involved so much rock excavation that hand work was unavoidable. Compressed air was piped from compressors on the banks and all tools and material were taken down the banks by flying fox. The crossing at Douglas Park, in common with a number of other crossings required a good deal of under-water rock excavation, and this was done by a diving contractor. Keeping the sand out of the excavated trench was the main problem with these jobs because of the time taken to remove the rock. At Douglas Park a compressed air lift was used and found to be quite effective. A compressed air attachment was soldered about one foot from the end of a 10-12 feet length of 5" diameter downpipe, and the other end left open. Compressed air was attached and the water and sand lifted up the pipe and blown down-stream from the trench. When the cable was laid in the trench it was covered by bags of cement placed end to end to prevent any damage by falling rocks.

All cable used in river crossings was steel tape armoured, and additional tensile strength where required, such as crossings where large volumes of swift flowing floodwaters were expected, was obtained by the use of a galvanised stranded steel bearer wire attached to the cable and anchored at frequent intervals to rocks.

Some wide crossings, such as those of the Yass River near Canberra and Hughes Creek near Seymour were done by the 22 RB drag shovel. The water flow was slight and it was possible to divert the flow into channels while the remainder of the river bed was being excavated.

A number of dry, shallow or narrow creek crossings was made by a 22 RB or a light back hoe. On steep banks the back hoe was often anchored by dozer or winch truck.

At all crossings measures, such as the construction of concrete or sandbag checks on the banks, were taken to prevent the scouring of the trench. At the Douglas Park crossing, many of these checks, spaced about 10-15 feet apart were installed and to date have proved to be very effective. A graphic example of the effectiveness of the checks was provided at one crossing where the laying party had, for reasons unknown, omitted to build the check bulkheads on one bank of the river. The trench scoured out on this side for some 8 feet while on the opposite bank where a check had been built, no scouring whatever had taken place.

On three major river crossings the cable was installed in pipes supported on road or railway bridges because of constructional hazards involved in underwater crossings. In general, however, above ground pipe crossings were avoided.

Rate of Cable Laying

As previously stated, a particularly fast rate of cable installation was required to achieve the completion date set when the contracts were signed and this required working through the winters of 1960 and 1961. The winter of 1960 was the wettest on record in the Goulburn-Canberra area and had a most serious effect on the rate of, and consequently the cost of, cable laying. From May to October, 1960, the rate of cable averaged only 27 miles per month, whereas from November, 1960, to April, 1961, the average rate was 40 miles per month despite low production over the Christmas holiday period and the fact that some of the worst rock sections were completed during this period. During March, 1961, 60 miles of cable were laid.

Between May and August, 1961, an average rate of laying of 35 miles per month was achieved. This remarkably good rate was made possible partly by the comparatively mild winter in Victoria in 1961, but largely because

Fig. 19.—Depositing Bedding Sand from Hopper on HD.11 Side Boom Crane.

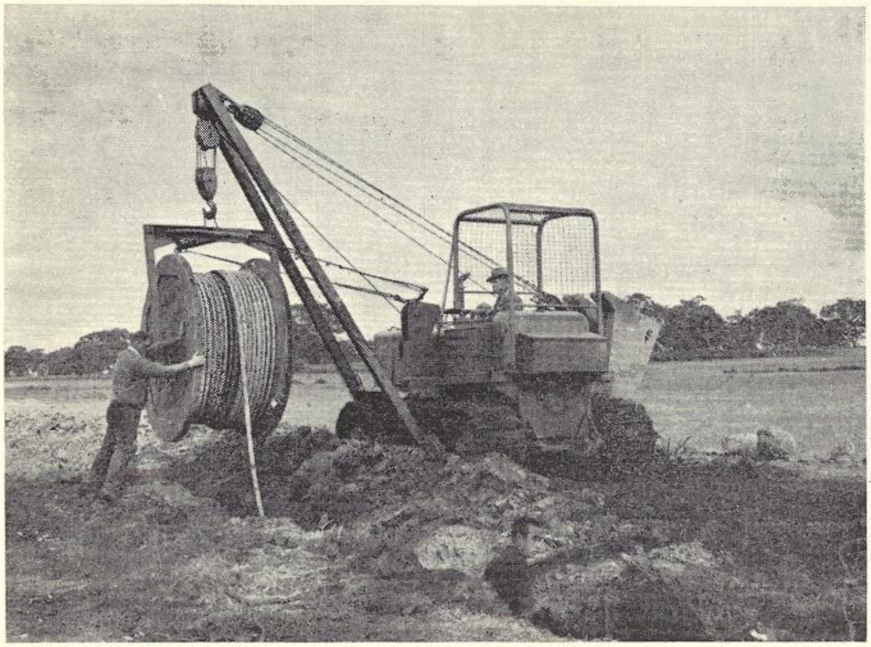

Fig. 20.—Laying Cable with HD.11 Side Boom Crane.

Fig. 21.—Placing Planks on Overbedding Sand in Rock Trench.

advantage was taken of the experiences of the previous winter. When job planning was being done between Albury and Melbourne it was realized that cable laying in two particular sections of the cable route would be most difficult if carried out in wet weather. If the original plan of laying the cable progressively from Sydney towards Melbourne had been adhered to, cable laying in these two sections would have been commenced and completed during the months of June, July and August—normally the wettest months. Arrangements were therefore made to have the cable for these sections delivered ahead of its normal sequence and installation of this cable commenced in January, 1961. These sections were thus completed before the onset of winter leaving the sections less likely to be affected by wet conditions to be done during the wet months.

It is worthy of note that the only phase of the project for which all material was available on schedule, that is, the laying of the buried cable, was completed by the target date, August 20, 1961, despite the abnormally bad weather conditions encountered during the winter of 1960, and the disadvantages suffered during the first nine months due to haphazard cable deliveries.

Cable Hauling

All cable hauling in ducts and tunnels was carried out by a separate party under the control of a Line Inspector. Cable was originally ordered in lengths up to 500 yards to reduce the number of joints, and to reduce the cost of cable installation. A maximum hauling tension of 2,000 lbs. was specified and in the early stages of the job, it was found that although many 500 yard lengths were hauled without exceeding

Fig. 22.—Backfilling Trench on Escarpment at Lake George near Canberra. O.C.12 Tractor which is Backfilling the Trench is Anchored by the Winch Rope of the HD.16 Tractor in the Foreground.

the tension, quite a large number had to be cut because of angles and changes in level in the ducts which substantially increased the hauling tensions.

South of Bowral, the cable was ordered in lengths determined by the conditions of each individual haul and generally did not exceed 300 yards.

In the ducts through the Melbourne metropolitan area P.V.C. jacketed cable was used, to simplify electrolysis corrosion control. Aluminium sheathed P.V.C. jacketed cable was used over a section of 10 miles where a high power exposure exists, the remainder being normal lead sheathed P.V.C. jacketed.

The same methods as were used for the plain lead sheathed cable were used successfully for hauling these types of cable. Because of its considerably smaller unit weight it was possible to haul the aluminium sheathed cable in generally longer lengths, several of nearly 500 yards being installed.

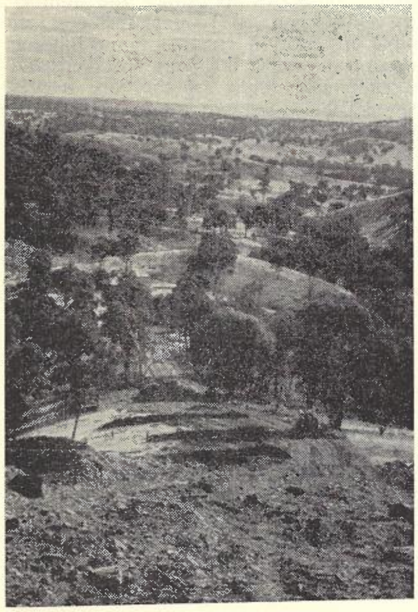

Fig. 23.—Erosion Prevention Measures on Slopes Between Gundagai and Wagga.

A great amount of effort was spent, in the initial stages, on the design of rollers to be used in manholes for hauling around angles and for placing the cable, during hauling, against the manhole walls, but these rollers were not very successful. Meaurement of the increase in hauling tension at each set of rollers in straight-through manholes, caused by the slight bending of the cable from duct mouth to manhole wall and back to duct mouth, showed that the 2,000 lb. limit was exceeded after 3-4 holes had been hauled through. Thereafter the cable was hauled straight through the intermediate manholes, guide funnels being used at the duct entry, the necessary slack being pulled back by hand to house the cable against the walls. Pulling around sharp bends was avoided where possible, and where it was done, the cable was hauled through thick walled polythene tubing which was tied back at a number of points to bolts attached to the manhole wall.

Fig. 24.—Tractor Mounted Compressor and Front End Loader.

Rodding of the ducts was done by the Roductor rodding machine. Hauling was done via the capstan of a normal winch truck to a wire take-up spool. A tension limiting dynamometer was inserted between the capstan and the cable. The dynamometer was a 3-sheave hydraulic ram type with the pressure gauge calibrated to read tension at the end of the cable. A Lockheed pressure switch was inserted in the base of the hydraulic cylinder and adjusted to cut the engine ignition when a tension of 2,000 lb. was reached.

Up to date, there has been no evidence of any faults caused by the hauling of cable into ducts.

After hauling, and placing the cable against manhole walls, the hauling party protected the cable in the manholes by split polythene tubing over which was placed split, articulated, protective, iron couplings.

JOINTING AND TESTING

General

It is common practice to treat jointing and testing as two completely separate entities, but on this job they are so closely related that such a separation is somewhat artificial. However, since a separate paper in this series deals exclusively with the cable testing no detailed discussion of the subject will be entered into in this article.

Jointing

In New South Wales the Felten and Guilleaume jointing method was used

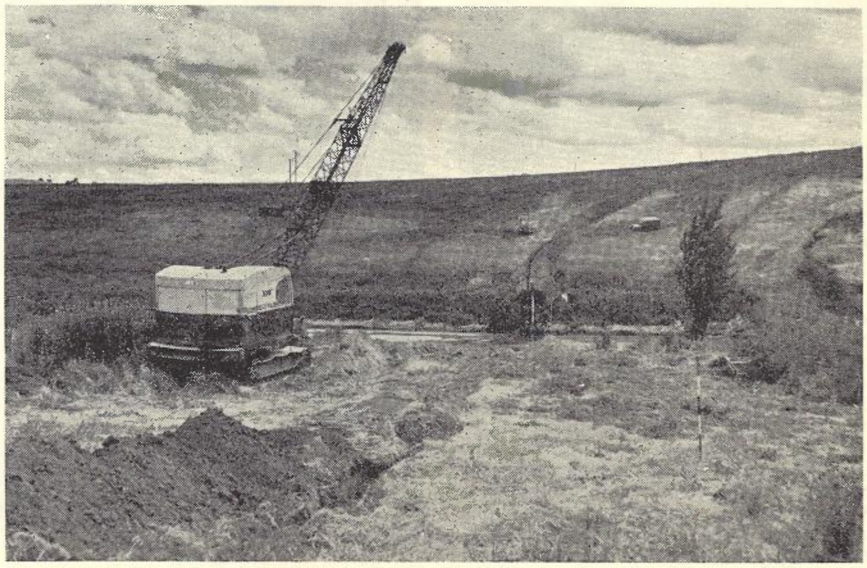

Fig. 25.—22RB. Excavator Rigged as a Drag Line at Jugiong Creek south of Yass.

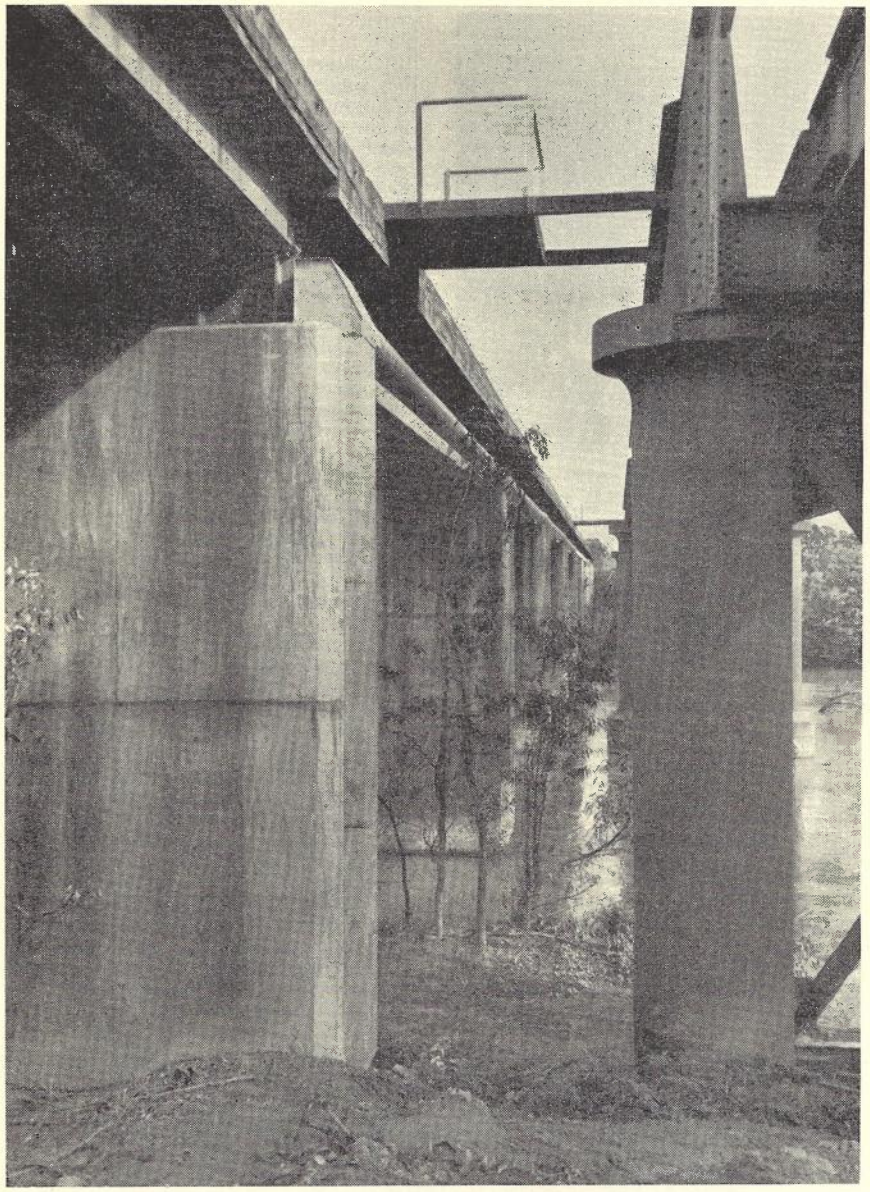

Fig. 26.—Pipe Crossing on Railway Bridge over Goulburn River at Seymour.

Fig. 27.—Laying Polythene Pipes Under Nepean River Crossing at Pheasant's Nest Pass near Campbelltown.

on the coaxial tubes. This method employs soldered connections on both inner and outer conductors, the conductor joining sleeves being split for easy fixing. A bakelite spacer is used to separate the tubes and the paper pairs and this spacer is left in the joint after completion. Copper slip sleeves and tinned copper sleeve ends were used to seal the joints and all joints were protected by cast iron protection boxes. The space between the copper sleeve and the cast iron protection box was filled with petroleum jelly to avoid electrolytic corrosion.

It was normal practice to work jointers in pairs, each pair operating from a Volkswagen panel van. Although some jointers were able to complete a joint in one day it was more usual for the completed job to take 1½ days. Pumping out joint holes, which were almost invariably filled with water and mud, was very time consuming, particularly in view of the unreliable operation of the small portable pumps with which each jointing truck was equipped. Some trouble was experienced in the early sections with the copper sleeve ends, on which the ferrules, through which the cable enters the joint, are butt joined to the end proper, and silver soldered. These ferrules were subject to cracking at the join, and in three cases allowed moisture to get into the joint. The trouble was overcome by having the jointers wipe solder around the butt join before soldering the ends to the cable sheath.

Experience in N.S.W. proved that the Felten and Guilleaume method of jointing the coaxial tubes was appreciably slower and thus more expensive than the Ericsson method used on the Melbourne-Morwell cable. The Felten and Guilleaume method also showed no advantages in quality over the Ericsson method. It was therefore decided to use the Ericsson method of jointing the coaxial tubes from Albury to Melbourne-Morwell cable. The Felten and of completing the joint was the same as used from Sydney to Albury.

It was found that if all the preparatory work, that is, pumping and cleaning out the joint holes, removing the armouring from the ends of the cable and bonding the armouring to the sheathing was done by an advance party, one jointer could then complete a straight joint in the coaxial cable, using the Ericsson method, with reasonable comfort in one day, and therefore in Victoria jointing was organized accordingly. On other jointing operations, however, two jointers worked together as in N.S.W.

Approximately 200 miles of minor trunk cables, ranging in size from 28

Fig. 28.—Trench on the Approach to the Nepean River Crossing at Douglas Park near Campbelltown.

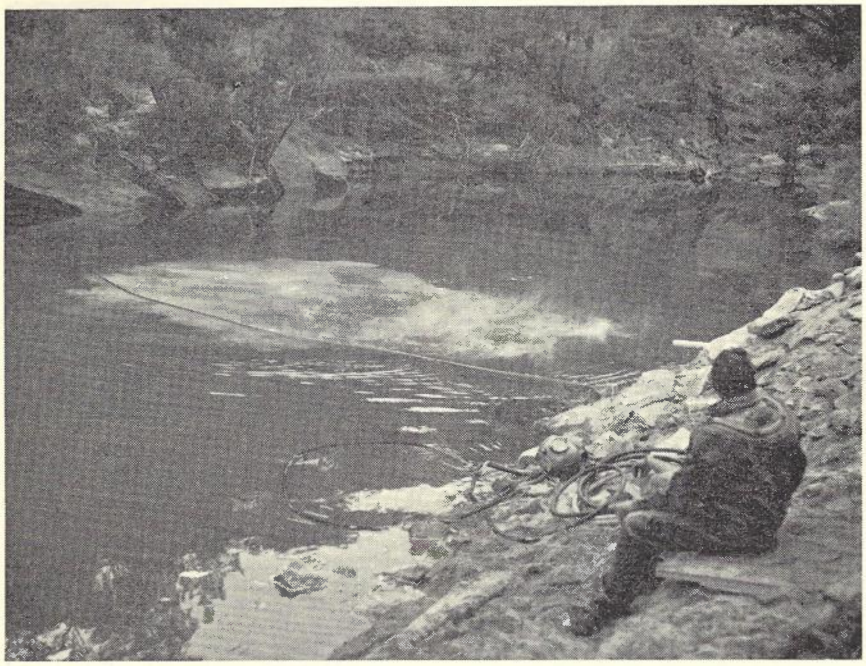

Fig. 29.—Underwater Blasting by Diver in the Nepean River at Douglas Park.

pairs to 216 pairs, were laid at the same time and in the same trench as the coaxial cable. Sleeve ends, slip sleeves and cast iron protection boxes were used on these cables, the sleeve ends and sleeves on the cables from 104 pairs and upwards being of copper as for the coaxial cable and being of lead for the cables below 104 pair.

Between Sydney and Albury, the joints were accommodated in 5′ x 5′ pre-cast concrete slab joint boxes. The joint was supported on galvanized iron channel sections attached to the walls. The box was covered by concrete slabs, additional support for which was provided by steel T-section beams. The boxes were either buried at a depth of 18 to 24 inches or in special cases were installed to the surface.

South of Albury the joints were accommodated in 5′ x 5′ wooden boxes. The completed joint was supported on brick piers constructed on undisturbed ground in the bottom of the joint holes and the hole was backfilled to the top of the wooden box with sand. Two 2 feet square concrete slabs were placed on the sand above the joint and the remaining 18 to 24 inches backfilled with the excavated soil.

Loading

Carrier pairs were not loaded and all voice frequency pairs in the main cable and the minor trunk cables were loaded with 88mH Grade 2 coils at 6,000′ intervals. Buried type loading coil cases were used exclusively in both duct and buried cable sections. The load coil tails were supported adjacent to the load coil case ferrule by bolting a steel strap to the case and binding in the tail. (The straps on which the tails were supported during transportation were ideal for this purpose). In the Sydney-Campbelltown section, where only 6 supervisory pairs were loaded, in-joint type coils were used.

Repeater Terminations

In the repeater station distribution box the main cable is separated into 6 single tube cables and 3-12 pair paper insulated cables. The single tube cables have a solid polythene dielectric, are flexible and in minor repeater stations terminate on the power separating filters of the power feed bay. A gas seal is provided for the coaxial tubes by a glass--metal gland on the top of the distribution box. In the main stations the single tube cables from the distribution box are terminated on a panel on the top of the distribution rack, from which they are connected to the power feed bay. This panel provides an intermediate access and patching point in the major repeater, without unsoldering any coaxial connections. The 12-pair paper insulated cables separate the voice frequency pairs from the carrier pairs and terminate on terminal heads which are fitted either to the distribution rack or an adjacent terminating rack. From the heads circuits may be connected to equipment or linked through the repeater as required. The majority of the terminal heads are filled with a mixture of beeswax and resin following the German practice and an Epoxy resin gas seal is installed where the cable enters the head. Because of the difficulty in achieving a reliable gas seal with this technique, the terminal heads were completely filled with Epoxy resin in the later installations.

Gas Pressure System

The gas pressure system is of the continuous flow type and is described more fully in another article in this Journal. Briefly, 220 cubic feet cylinders of gas are installed at each minor repeater station and permanently connected via reducing valves to the cables on either side of the repeater. The system comprises a supervisory set at each attended station, pressure measuring and regulating equipment at each attended and unattended station and mercury contact manometers at frequent intervals along the cable. The mercury manometers have been a source of trouble and are being replaced by bellows type contactors. In addition

Fig. 30.—Laying the First Length of Cable in the Tunnel from Terminal at Sydney.

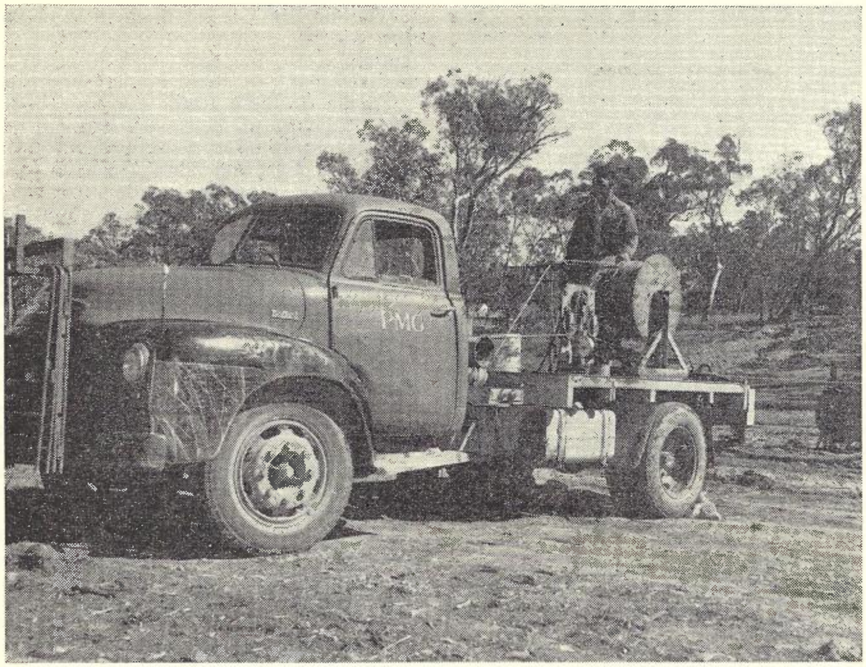

Fig. 31.—Cable Hauling Winch Truck Showing the Dynamometer and Take Up Spool.

to the pressure gauge, flowmeter, drying unit and stop cocks supplied by the contractor, an additional panel consisting of a cylinder alarm gauge for monitoring the contacts of the gas cylinder, pressure relief valves and non-return valves have been installed at each repeater station with provision to feed other cables from the same gas supply.

Organization

The complete jointing and testing programme as applied to this cable included:—

1. High voltage testing of cable lengths after laying.
2. Initial jointing.
3. Prebalancing measurements.
4. V.F. balancing on core pairs and mutual capacity deviation corrections.
5. Load coil installation and repeater terminations.
6. Carrier balancing of repeater lengths.
7. Final acceptance testing of complete repeater sections.

Initial High Voltage Testing: A D.C. voltage of 3,000 volts was applied between inner and outer conductors of each coaxial tube in each length for two minutes as soon as possible after the cable was installed. Any mechanical damage to the tubes due to installation was thus detected and rectified before jointing commenced. This work was done by a jointer using a high voltage source operated by a 12 volt battery and an inverter.

Initial Jointing: After high voltage testing all joints other than load coil joints were made. At balancing points short parallel plastic insulated tails were connected into the joint so that condensers could conveniently be installed during the balancing.

Prebalancing Measurements: On completion of the initial jointing the cable consisted of 6,000 feet loading slings. On each sling the continuity, insulation resistance and resistance unbalance on tubes and paper insulated pairs and the mutual capacity of each pair to be loaded was measured. The mutual capacities of the pairs were then plotted so that the deviations between adjacent sections could be ascertained and later corrected by the installation of condensers.

Voice Frequency Balancing: The unbalances within and between quads on all V.F. pairs were measured and corrected by condensers to achieve the required values of crosstalk. It was normal practice for mutual capacity deviation correction condensers to be installed in conjunction with the V.F. balancing so as to reduce impedance irregularities along the cable and hence achieve the specified values of return loss. The measurements were made by a Senior Technician and the condensers installed by cable jointers as directed by the Senior Technician.

Load Coil Installation, etc.: When the V.F. balancing was complete, the load coils and repeater station terminations were installed so that the cable in the repeater section was continuous from end to end. As carrier balancing still remained to be done over the repeater section, the distribution box (pothead) was not permanently sealed at this stage. As a first step in the carrier balancing, the 1 and 2 legs of each carrier quad were transposed at each V.F. loading position. It was often necessary, then, to insert an additional transposition at the pothead so that each leg of each pair occupied the identical position on the terminal boards at every repeater station. For this reason the pothead was not permanently sealed until after carrier balancing.

Carrier Balancing: It is proposed to use the coaxial repeater buildings to accommodate carrier repeaters and hence each minor repeater section was also a carrier balancing section. All carrier pairs were balanced to 110 Kc/s by a Senior Technician and a Technician. Jointers were used to change the previously inserted trans-

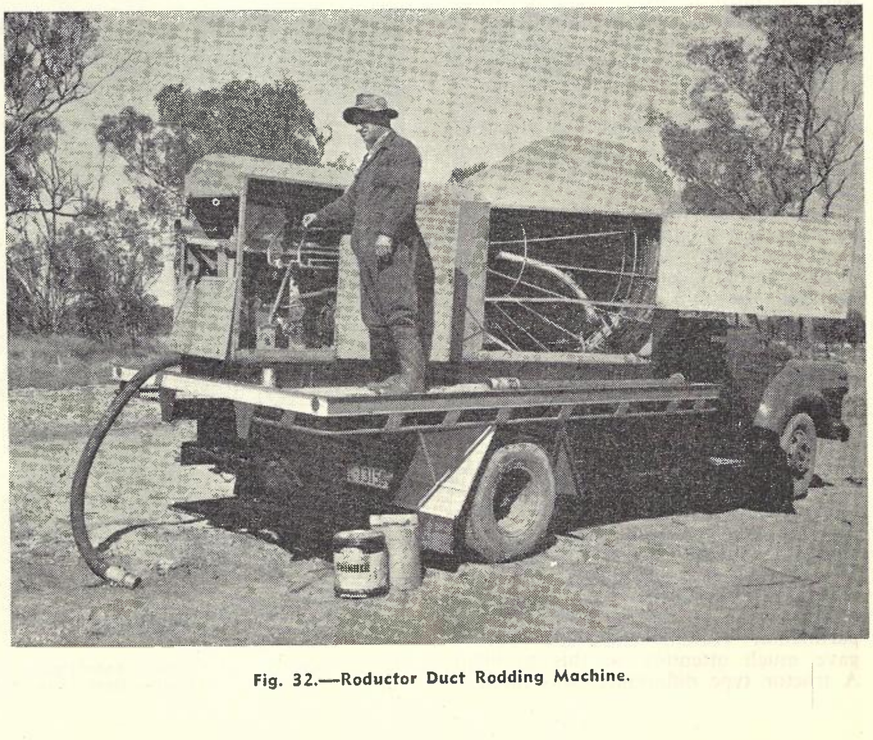

Fig. 32.—Roductor Duct Rodding Machine.

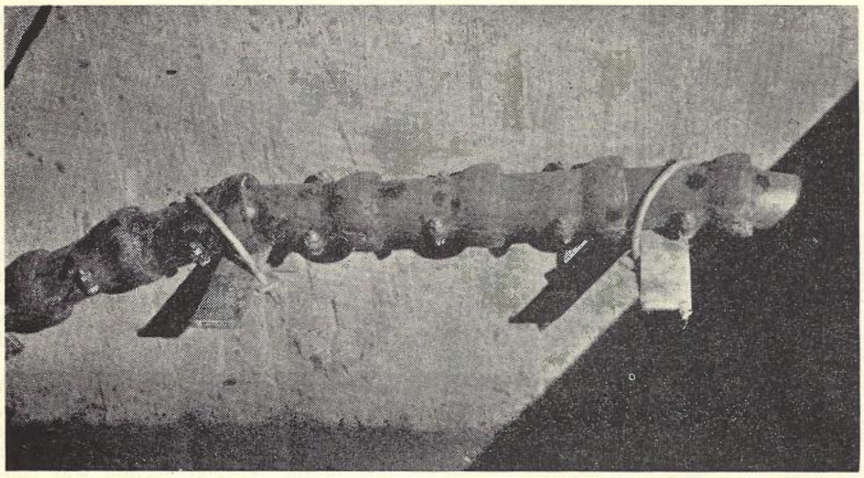

Fig. 33.—Split articulated Cast Iron Couplings Used to Protect Cable in Manholes.

positions of legs 1 and 2 as required and to install any condensers or resistance condenser networks as determined by the Testing Technician. After balancing, the pothead was permanently sealed and the repeater section filled with dry air.

Final Testing: When the carrier balancing was completed, the minor repeater section was acceptance tested and all specified characteristics of the cable measured. When all minor repeater sections in a main section were tested, acceptance testing of the Voice Frequency pairs between main repeaters was carried out. The acceptance testing programme is described in detail in the paper on Testing.

MACHINE MAINTENANCE AND REPAIR

The field maintenance and repair of mechanical plant and motor vehicles were attended to by a team of Motor Mechanics directed and controlled by a Plant Inspector and Foreman Mechanic. The main base field workshop and spare parts store were established at one of the trench and lay camps. Lesser facilities were provided for the outstation mechanics at the other trench and lay camp and with the heavy rock party.

Although all items of plant required continuous attention, the ditching machines, being the key machines and also being the most prone to breakdown required the most maintenance effort. As well as the routine replacement of digging teeth, drive sprockets and digging wheel segment teeth, a great deal of trouble was experienced with the differentials driving the tracks. Approximately 50 differential failures of various kinds occurred on the 7 ditchers employed, the range of failures indicating that the differentials were underdesigned. This was later confirmed by the ditcher manufacturers who agreed to modify the transmissions on all ditchers. Unfortunately, however, their decision was made too late to be of any value on this project. The Departmental Automotive Plant Section gave much attention to this problem. A tractor type differential was fitted to one ditcher as a trial and gave very satisfactory performance. More costly than the actual replacing of the differential was the interruption to organization as a result of the breakdown, particularly in the early stages when the availability of spare parts was very poor. In the later stages of the job the spare parts store carried a good supply of all parts and the mechanics became expert at all types of repairs. They developed a trailer trolley on which a spare differential was mounted and as soon as a breakdown was reported the trolley and spare differential were taken to the site. The broken differential was removed, the trolley wheeled in under the ditcher and the new differential quickly fitted in position.

The Barber Greene ditchers used on the job were fitted with socket type cutting teeth, the tooth end fitting over a male shank or tooth holder. The rate of wear of these teeth was very high. Various types of teeth were experimented with in an effort to achieve a longer tooth life. Cast and fabricated teeth with or without tungsten-carbide tips were tried without any significant improvement. In the latter phases of the job a trenching machine using insert type teeth, was hired while the Departmental machines were being overhauled and it was found that these insert type teeth lasted appreciably longer than the socket type and also that the time taken to change teeth was much less. All of the Barber Greene machines were subsequently modified to take the insert type resulting in longer tooth life and reducing the time for each tooth change on a complete digging wheel from ¾ hour to 10 minutes.

All machine fuelling was done from two 500 gallon 4 x 4 fuel tankers. Daily maintenance was, of course, done by the machine operators and larger services by a mechanic operating a 4 wheel drive service truck.

FIELD COMMUNICATIONS

The provision of telephone services to each camp was essential and the selection of camp sites was made with this as a primary consideration. Field communications between camp, engineers, supervisors, maintenance staff and work parties was by mobile radio systems. Three separate systems were used, two being two frequency type using repeaters and one being a single frequency type operating from a base station. The single frequency system was only moderately successful.

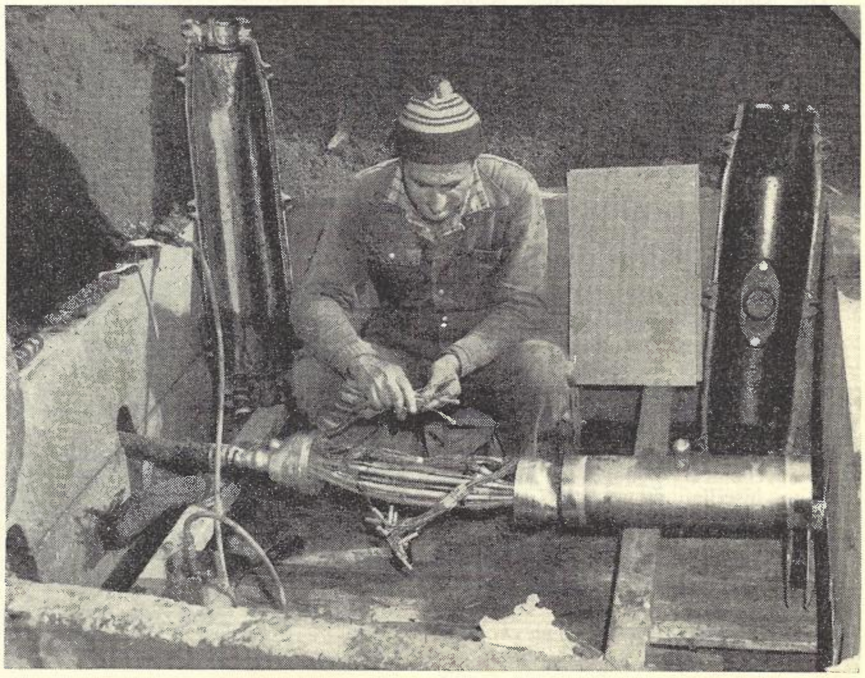

Fig. 34.—Cable Jointer Fitting Balancing Condensers in Joint. This Shows Copper Slip Sleeves, Prefabricated Sleeve Ends and Cast Iron Joint Protection Box.

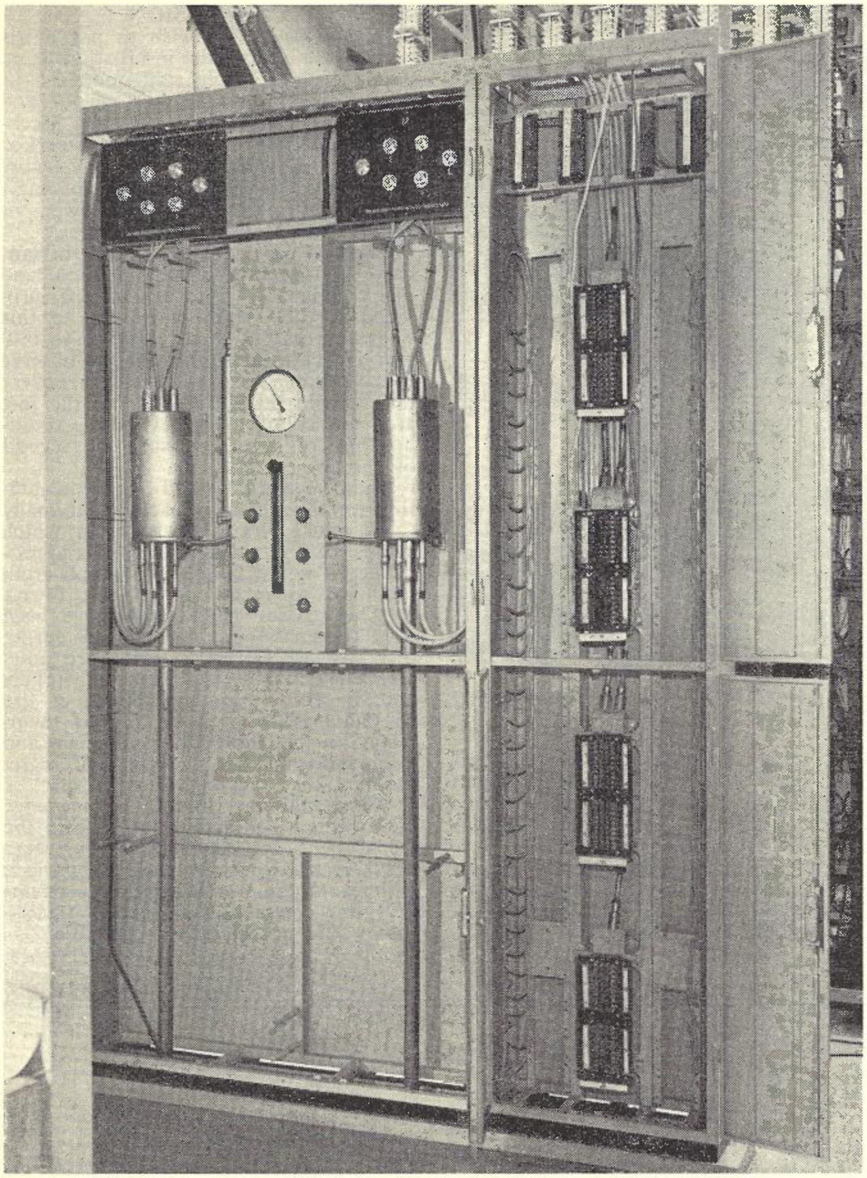

Fig. 35.—Cable Distribution (Pothead) and Terminal Racks in Main Repeater Station, Showing Potheads, Coaxial Terminal Boards, Paper Pair Terminal Heads and Gas Feed Equipment.

The siting of the base station, which was located in one of the camp offices, was often unsatisfactory because of the terrain over which the parties worked. The two frequency systems operated through trailer mounted repeaters which could be placed in the best location for optimum coverage. They were, therefore, very successful. A radio technician was employed on full time maintenance of the three systems.

MATERIAL ORDERING AND DELIVERY

Material supply and delivery was handled very efficiently by the Stores Branch and the Transport Branch who co-operated wholeheartedly throughout the whole project. Before commencing the project discussions were held between Engineering, Stores and Transport Branch officers and a procedure for the ordering and delivery of all materials adopted. Two Inspectors attached to the project Division looked after the whole material and equipment ordering, one concentrating on machine parts and the second on all other material. A central divisional store was established in the two capital cities and regional stores in the camps. The bulk of the delivery from central store to regional stores was done by the Transport Branch. In addition, a divisional stores truck did a continual circuit between camps and central stores. The largest single item was of course, the cable, over 10,000 tons of coaxial and minor trunk cables being handled over the whole job. In addition to the cable, however, thousands of tons of other material such as gates, gate posts, concrete manholes, joint boxes etc., were transported over hundreds of miles.

SOME LESSONS LEARNED

In the space available it would be impossible to set out in detail all the experience gained and the lessons learned. However, it is felt that brief mention in general terms should be made of the most important of these. Some of these lessons are applicable only to the Sydney-Melbourne job but some have general application.

1. On any such project where a high progress rate is required, ensure that a stockpile of *knowledge, material* and *equipment* is on hand before commencing. Undue haste to commence a large project without an adequate supply of these things is most uneconomical.
2. Plan the targets to suit the weather otherwise uneconomical working must be accepted. On this job the cost of laying cable during the wet months was at least twice the cost of laying during the dry.
3. Keep staff morale high by planned organization, by close supervision and by developing in them a sense of personal responsibility and loyalty to the job. There is no substitute for the personal enthusiasm of individuals.
4. Do not stint supervision. Each additional Line Inspector or Engineer costs about £2,000 per year and that amount can be wasted many times over by poor supervision and inadequate direction. Never work teams, no matter how reliable, without close supervision by a senior, capable man.
5. Keep the geographical spread of teams to a minimum. It ensures safer, more economical working and maintains better public relations.
6. Develop in all supervisors the ability to transmit instructions clearly and completely. Time was wasted by failing to clearly tell a party leader, jointer or testing officer precisely what was required.
7. In cable laying encourage party leaders and team members to promptly report all cases of possible damage to the cable whether major or minor. It is much more expensive to discover and rectify the damage during final testing.
8. If the choice is between over-planning and under-planning, choose the former. If the pegging and identification of joint positions, for example, is over-elaborate it will cost much less than stinting on pegging.
9. On cross country jobs, **all** vehicles should have 4-wheel drive and wherever possible tracked machines should have larger than normal size tracks if they are to work through all types of weather and in all varieties of soil conditions.
10. Unnecessary expense can be incurred unless the practical implications of all requirements are properly appreciated in the planning stages of the job. For example, the real requirements for achieving the return loss specification on

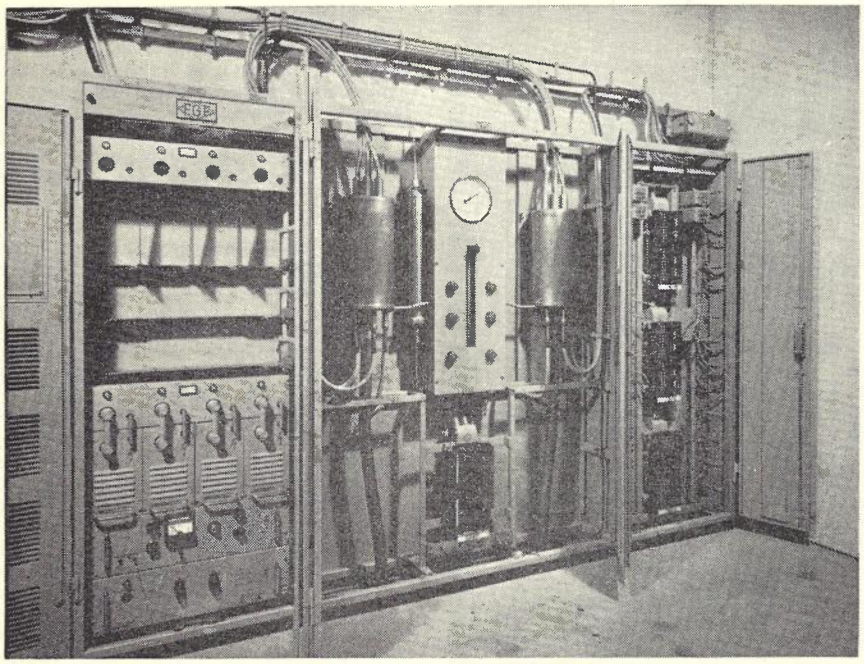

Fig. 36.—Cable Distribution and Terminal Racks at Minor Repeater Station. This also shows Power Feed Rack on the Left.

the loaded V.F. pairs were not fully appreciated when the loading layout was designed and, as a result, an appreciable additional effort by the installation team was needed to achieve this specification.

11. Be guided by the advice and experience of others but do not accept blindly the word of "experts". With a convincing expert it is not easy to tell whether the "experience" behind his advice is first, second or tenth hand.
12. There is no substitute for experience and once the experience is obtained, at considerable cost, it should be utilised.

CONCLUSION

In conclusion, we wish to pay a tribute to the men of the installation team. A particularly high staff morale was maintained throughout the long job and Linemen, Technicians, Motor Mechanics, Supervisors and Engineers worked together in complete harmony, very often under very trying conditions varying from freezing cold and wet, to extremely hot and dusty weather.

There is no doubt that the high standard of camping accommodation and many amenities and concessions provided for the staff contributed to this high morale, but even taking these into account it was most gratifying to observe that, almost without exception, every man was virtually dedicated to the job, and was willing to go beyond the ordinary line of duty to ensure the success of the project.

These men established a high reputation for themselves in each of the many towns along the cable route in which camps were established, and it is appropriate to quote here a paragraph from the local paper of one of these towns. "The coaxial cable gangs have been very good citizens of Gundagai during their ten weeks' stay. They are good competent, solid and honest workers and, in fitting into the pattern of life of Gundagai, they have proved themselves to be thorough gentlemen and keen sportsmen. Gundagai will regret the fact that they are moving on."

We should also like to acknowledge the assistance of many, both within the Department and outside it who were not associated directly with the project, without whose wholehearted co-operation the completion of cable installation would not have been possible.

THE GAS PRESSURE ALARM SYSTEM

*F. J. HARDING A.M.I.E.E.**

INTRODUCTION

The general principles of application of gas pressure alarm systems to coaxial cables have been covered in an earlier article in this Journal (Reference 1). This article describes the experience gained during the installation of gas pressure alarm equipment on the Sydney-Melbourne cable, the difficulties encountered and the remedial action taken which, it is considered, has resulted in the most advanced gas pressure alarm system yet installed in Australia.

THE ORIGINAL SYSTEM

General

The gas pressure alarm system supplied by the Contractor employed mercury U-tube manometers spaced at 1,000 yard intervals which were, essentially, enclosed within the cable and operated on a sealed non-continuous gas flow basis. A 4-wire alarm circuit was employed which, by using 4 different combinations of wires, permitted 88 manometers, each having an identifying resistor associated with it, to be supervised in 4 groups of 22 each. The original layout in unmodified form is shown schematically in Fig. 1. The supervision equipment, located at selected attended repeater stations, consists of an automatic Wheatstone bridge with associated indicating lamps such that any operated contactor out of 88 maximum can be positively identified. At each supervision station, the coaxial and one minor trunk cable may be supervised on each side of the main station up to a maximum distance of 88,000 yards (50 miles). Fig. 2 shows one of the thirteen supervision sets, which are located one at each major station except for Euroa and Culcairn.

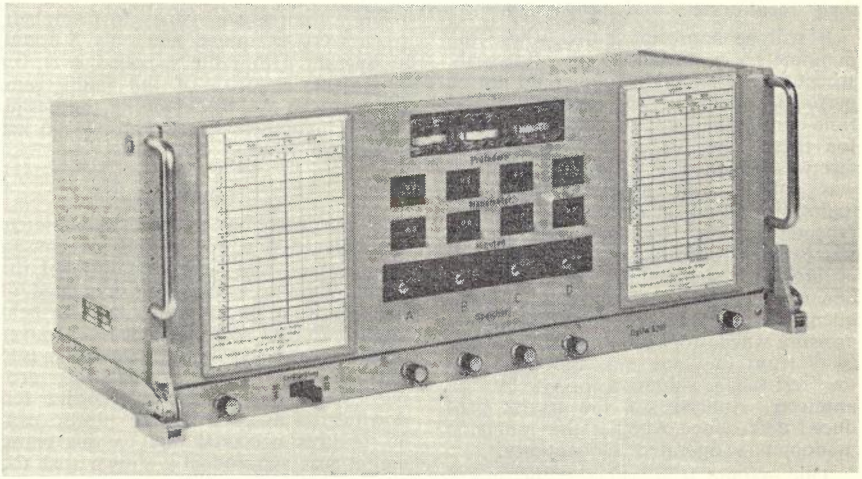

Fig. 2.—Remote Supervision Equipment.

Installation of the mercury manometers in New South Wales followed closely after the installation of loading coil joints and had, in fact, reached The Rock North minor repeater station (about 350 miles from Sydney) before full operational tests could be carried out on the first major repeater section (Sydney-Campbelltown). The delay in carrying out operational tests was inevitable and arose from 3 basic causes:—

(a) The very extensive balancing work carried out on V.F. pairs in the early stages of the project which necessitated the re-opening of many joints and hence loss of gas pressure.

(b) The fact that carrier balancing was the last operation on the coaxial cable and, until it was completed, pot head joints could not be closed and pressure in the cable stabilised.

(c) Difficulties encountered in achieving the very high specified insulation resistance which necessitated repeated gassing and evacuation of the cable over extensive distances.

All these factors conspired to delay the achievement of stabilised gas pressure within the cable and operational tests of the manometers could not, of course, be undertaken prior to the stabilised condition having first been achieved.

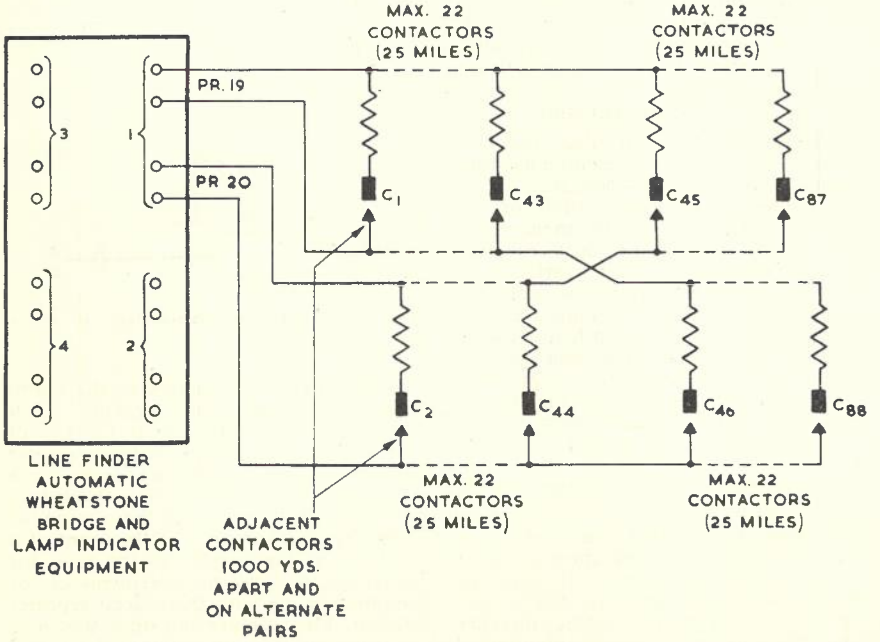

Fig. 1.—4-Wire Alarm Circuit in Original Form.

Acceptance Tests

The designed operating pressure of the manometers is 8 ± 0.1 psig and each manometer was calibrated to this figure, just prior to installation, using the special barometric calibrating equipment supplied.

The first acceptance test was a check made for operation of the individual manometers at their calibrated pressure. Air was released from a neighbouring point on the cable, and by means of a pressure gauge and a local circuit using a battery and voltmeter, the pressure was determined at which the manometer operated. Ready access was available to manometers situated in manholes in the Sydney-Dulwich Hill conduit section, the starting point of these tests, which were later extended from Dulwich Hill to Campbelltown. Six of the ten manometers in the first minor repeater section failed to operate satisfactorily. The manometers were examined and an

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* See page 269.

attempt made to correct their principal defects (see later) by moulding an epoxy-resin support around the manometer U-tube. The manometers were then recalibrated and reinstalled.

It will be appreciated that where the manometers were buried in solid earth, acceptance tests cited above could not be performed without the expensive and time-consuming task of excavation and, for these cases, a different acceptance test was designed. A recording ammeter was placed on each alarm pair (pairs 19 and 20) at one end of a minor repeater section, the alarm pair section was isolated from the supervisory set and an artificial "sheath fault" introduced at one end. The time of make and subsequent break of the manometers as the pressure wave propagated along the cable away from the fault was monitored by the resistance values recorded by the ammeter. Analysis of the charts produced determined whether the contactor manometers operated sequentially.

This method is considered superior to the previous test as:

(i) It emulates fault conditions as they normally occur.

(ii) No errors are likely to be introduced by transient pressure surges.

(iii) It takes account of altitude and temperature variations between different parts of the cable.

The modified manometers in the Sydney-Dulwich Hill Section were subjected to the sequential operation test but correct functioning of all the manometers was still not obtained.

Concurrently with the work on the Sydney-Dulwich Hill section, manometers were individually tested between Dulwich Hill and Campbelltown. So low a percentage of those tested were found to operate within the specified limits that it was decided to remove manometers from the cable for detailed examination.

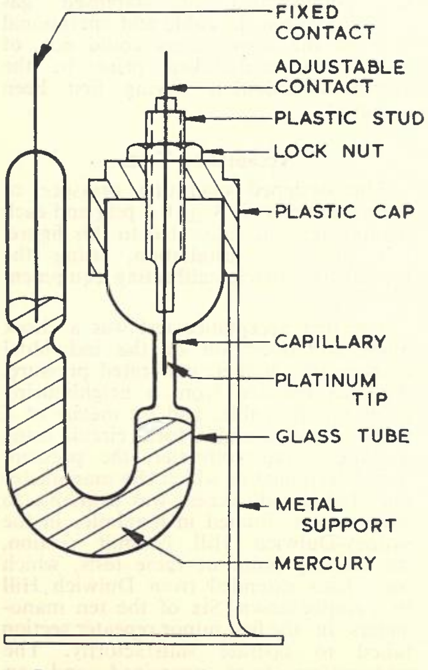

Fig. 3.—Mercury Contact Manometer.

Eventually all 57 manometers in the main section from Sydney to Campbelltown were examined and only 8 found to operate within the specified 8 ± 0.1 psig. The majority of the faults were found to be due to defects in the design of the manometers (see Fig. 3) and are described below.

Faults

The misoperation of the manometers was due to a whole variety of causes, the most obvious being a failure of the resin adhesive holding the open end of the U-tube to the plastic cap. The heat applied during soldering the two halves of the manometer casing together caused the adhesive to lose its bonding properties whereupon the glass U-tube fell downwards away from the plastic cap. 35 failures occurred due to this cause and it was subsequently shown that the resin adhesive was defective.

Another cause of failure worthy of mention was blockage of air inlets to the manometers. The side of the manometer open to variations in cable pressure consists of a threaded plastic stud which screws into the top of the manometer, being secured by a steel lock nut. Air enters the U-tube via the spiral path between the two loosely engaged threads. During soldering of the casing heat caused the plastic stud to deform, in a few cases blocking the air passage down the spiral path.

It will be clear from an examination of Fig. 3 that centering of the adjustable contact on the mercury meniscus is an important factor in achieving accurate calibration. Adequate centering was not possible in some cases due to bent contact pins and in others due to the thread axis of the lock-nut not being at 90° to the face of the nut. Thus, after calibration, securing the lock-nut would move the contact away from its required coaxial location in the capillary tube.

Mercury Contamination

The most serious trouble, observed during the process of examining each contactor for the faults described above, was widespread contamination of the mercury. About 30% of the manometers were found to contain dirty mercury which resulted in a large variation in operating pressure from the nominal. Subsequent investigation indicated that much of the contamination had occurred after the manometers had been installed in the cable. In view of the probable long term unreliability of the system due to mercury contamination over a cable life of at least 40 years, the situation was clearly serious and intensive research investigations were immediately undertaken.

It was found that the cable air pressure at electrical operation could be expected to vary by up to 10% of the nominal operating pressure due to distortion of the shape of the mercury meniscus arising from contaminated mercury adhering to the glass walls of the U-tube. A number of possible causes of contamination were identified as follows:—

(a) The steel wire of the contact probe being immersed in the mercury when the adjusting stud is fully screwed-in (This is the normal condition during transportation of manometers).

(b) The washing of alien substances from the glass walls of the U-tube.

(c) Oxidization of alien metals contained in the mercury.

(d) Particles of plastic falling from the adjusting stud thread into the mercury.

(e) Oxidization of mercury in the presence of moist air at normal temperatures which can occur during transportation.

Operational Difficulties

Other operational service disadvantages had also become apparent due to the method of housing manometers at cable joints (see Fig. 4). The original design provided for access to the alarm pair and the faultman's speaking circuit via a bayonet-fitting cap at the top of the manometer pressure casing, a second similar bayonet cap giving access to a schraeder valve. With joints buried in soil to a depth of 4 feet there is undue difficulty and lost time, in the event of a fault, in gaining access to the joint for either gas pressure measurements or for communicating with the nearest repeater station. Furthermore moisture was able to penetrate the non-waterproof bayonet cap over the alarm and speaking pair

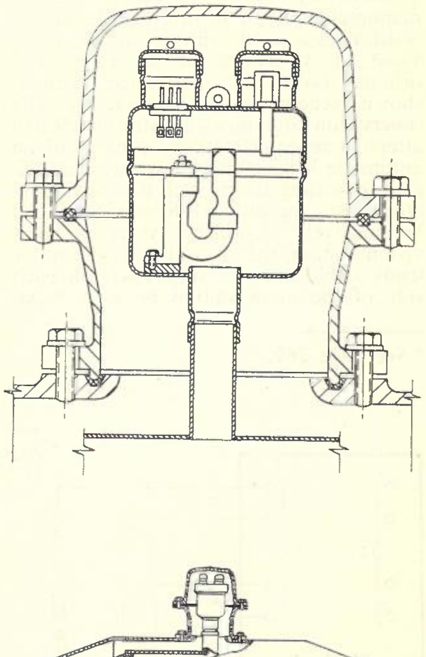

Fig. 4.—Housing of Manometers at Joints.

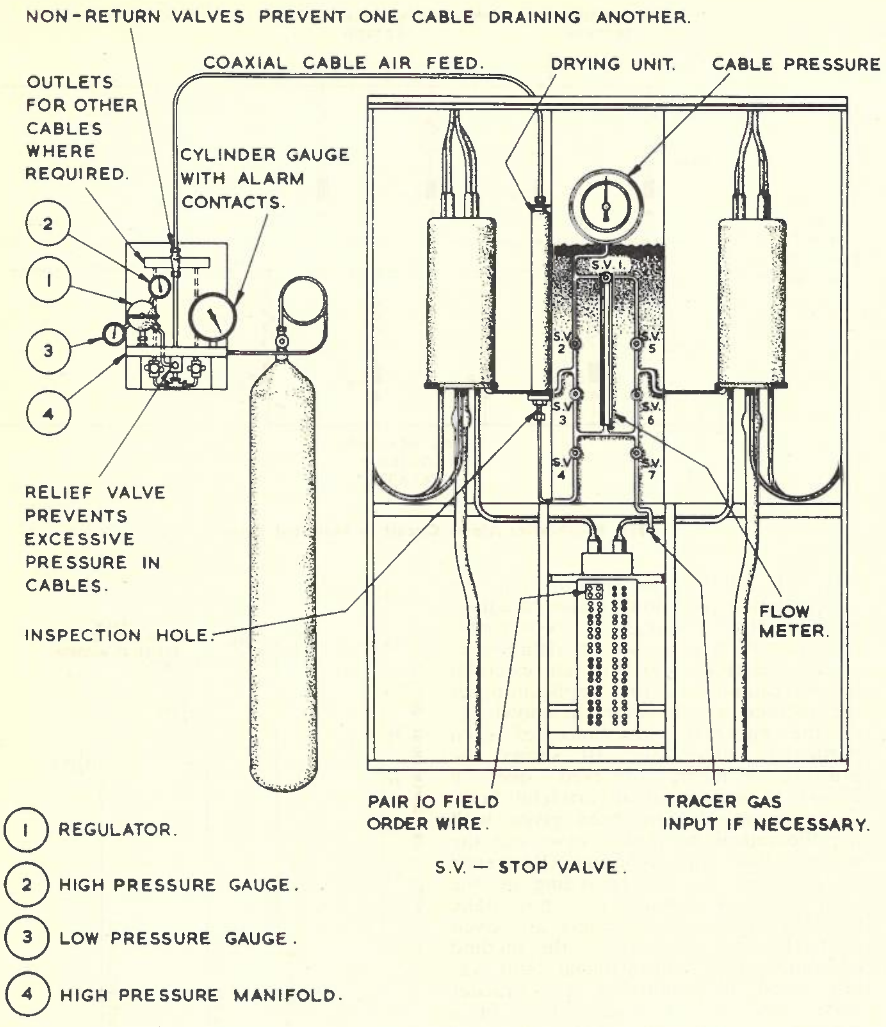

Fig. 5.—Minor Repeater Station Gas Feeding Equipment (Major Stations are similar).

connection pins, causing severe low-insulation on the two alarm pairs and the faultman's speaking circuit. It was necessary to solder the bayonet caps in position to overcome the low insulation troubles thus further increasing the difficulty of access to the circuits.

In recent years there has been an ever increasing awareness of the economic advantages of cathodic protection applied to buried structures where electrolytic corrosion would otherwise be severe. This need constitutes one further important reason for requiring ready access to the cable at reasonable intervals of distance along it.

The only alternative to underground access is above-surface testing facilities which, while practicable, introduce many difficulties of giving adequate mechanical protection and control over the effects of ambient temperature variations.

It will be seen therefore that the need for surface-access manholes at selected joints was becoming increasingly evident almost coincidentally with the difficulties experienced with the mercury contact manometers, and this had an important bearing on the design changes which have been made to the Gas Pressure system.

Remedial Action

At the same time as the research investigations referred to above were proceeding, a full scale field trial of bellows type gas pressure alarm contactors was carried out on one complete gas supervision section of the cable. In addition extensive work was done on the section between Sydney and Campbelltown to modify manometers so as to overcome most of the design deficiencies. This work was carried out urgently because of the special need for gas pressure protection in this section which was known to be the most vulnerable to mechanical damage.

The outcome of these three separate efforts, after discussion with the Company, was the decision to retain the mercury manometers between Sydney and Campbelltown only, on the basis of a long term field trial. By this time most of the faults described had been put right, at some cost, and the system was put into working order over this section. However, serious doubts still remained as to the long term effects of mercury contamination. Because of these doubts, and resulting from the success of the field trial of bellows type contactors, it was decided that bellows contactors would be installed over the full distance between Campbelltown and Melbourne.

MODIFIED SYSTEM

Bellows contactors are being installed at the $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$ points of each minor repeater section in lieu of the 1,000 yard regular spacing originally offered with the F. and G. sealed gas system. At each contactor joint a surface access manhole is being provided; the capital outlay on these manholes, at 3 per minor repeater section, is considered to be well justified in view of the importance placed on rapid access to the cable for testing purposes under fault conditions.

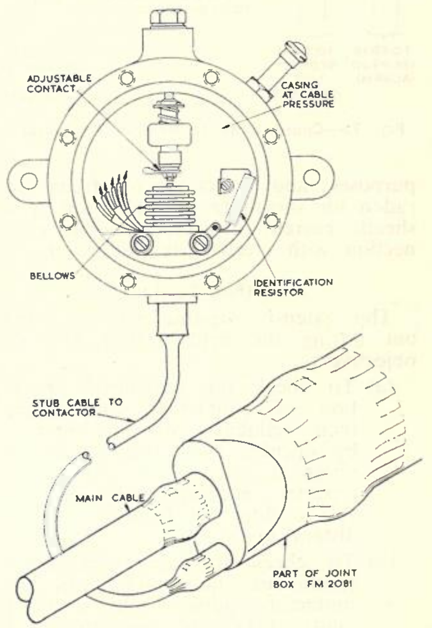

Fig. 6.—Modified Bellows Contactor and Method of Connection to Cable.

At the outset a continuous flow gas system had been decided upon in lieu of the sealed system offered. The problems here were few as the original system included a flow meter, drying unit and suitable control valves for each minor repeater station. The principal addition was a high pressure gauge, fitted with adjustable electrical contacts, and associated with each high pressure air cylinder reservoir. These reservoir gauge alarm contacts are being connected via suitable identifying resistors to the 4-wire alarm circuit, and the remote supervision sets will therefore give a location of low gas reserve in addition to any operated contactors. The gas feeding and control arrangement for each of the 118 repeater stations is shown in Fig. 5.

Fig. 6 shows the general layout of the bellows contactors together with the method of connecting them into joints, Fig. 7 shows the connections and Fig. 8 shows the modified 4-wire alarm circuit. Each contactor, being installed in a surface access manhole, will give ready access to the faultman's speaking circuit on pair 10 of the coaxial cable. In addition ready accessibility will be given for gas measuring purposes and injection of freon or radon for sheath fault localisation, also sheath current measurements in connection with electrolysis protection.

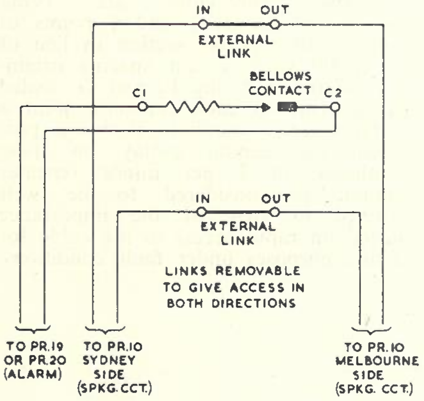

Fig. 7.—Connections to Bellows Contactor.

Further Testing

The extensive testing work carried out during the field trial had three objectives:—

(a) To check the sequential operation of contactors, and hence their reliability of performance, by opening the cable to atmosphere at one end of each minor repeater section and allowing gas to flow out from the sealed distant end.

(b) To check the operation under continuous flow conditions of contactors adjacent to artificial faults of various sizes introduced into the cable and to determine the time delays incurred between the occurence of such faults and receipt of an alarm indication.

(c) To determine the pneumatic resistance of the cable by flowmeter and pressure gauge readings as an aid to future fault localisation by interpretation of gas flow and pressure conditions.

Sequential operation was proved satisfactory in all cases, using a recording ammeter connected to the alarm circuit. Fig. 9 shows the observed results under testing conditions where the cable was opened at one repeater station, closed at the opposite end of the section, and gas allowed to drain from the cable under static flow. In this example the section had a length of 29,602 ft. and the chart shows the location of the contactors and the time elapsed from commencement of the test until operation of each contactor.

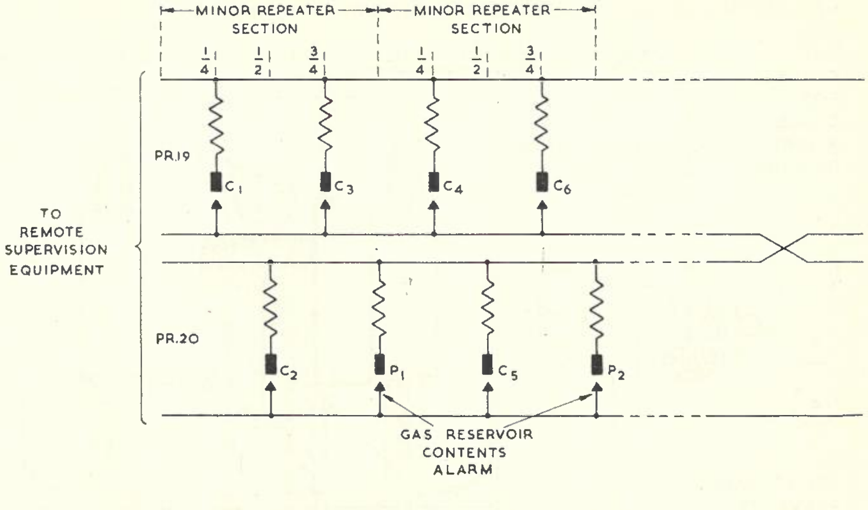

Fig. 8.—4-Wire Alarm Circuit in Modified Form.

The localisation of sheath faults by interpretation of flow meter readings and pressure readings at two points only has been discussed in detail elsewhere (Reference 1), but an essential basic requirement for application of the method is, however, a knowledge of the pneumatic resistance of each particular cable. Fig. 10 shows the pressure gradient observed over a 27,413 ft. section to an artificial fault, a comparison having been given with the theoretical parabolic curve and the straight line approximation (Reference 2). Further work is proceeding on the accurate calculation of pneumatic resistance but interim results are given in Table 1 to demonstrate the method of computation. The artificial fault was introduced by removing a schraeder valve core and drilling a hole in a gas-tight cover nut (hole diameter 0.078 inches) which was screwed into position above the valve holder. Pressure gauge readings were then taken at the flow meter 2,071 ft. from the fault.

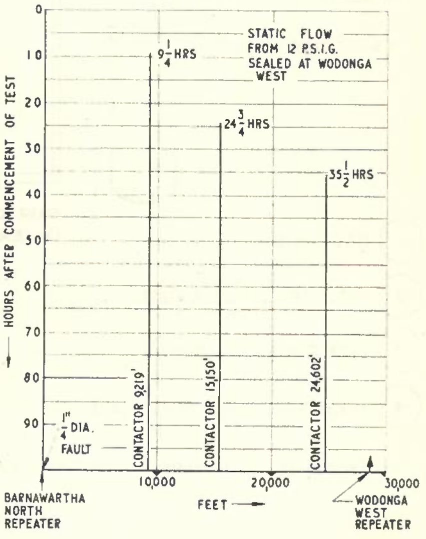

Fig. 9.—Sequential Operation of Contactors.

TABLE I. Calculation of Pneumatic Resistance

Pressure (p.s.i.g.)	Flow meter Readings (cu. ft./hr.)	Corrected flow meter Readings *(S.C.F.H.)	Pneumatic Resistance ⌿
4.10	5.20	4.18	0.0489
3.40	4.35	3.35	0.0483
2.05	2.95	2.10	0.0445
1.17	1.80	1.21	0.0435

* From $F = \frac{Pg + 14.7}{23.52} \cdot Fm$

Where F = corrected flow rate in S.C.F.H.

Fm = observed flow meter reading in C.F.H.

Pg = gauge pressure at flow meter.

⌿ From $R = \frac{Pa^2 - 216}{F \times l}$

Where R = pneumatic resistance in standard units.

Pa = absolute pressure at flow meter

l = cable length in yards.

Preliminary results indicate a pneumatic resistance of 0.044 standard units for the Sydney-Melbourne cable (compared with 0.064 for the Dandenong-Morwell 4-tube cable) although further work is required to verify this result.

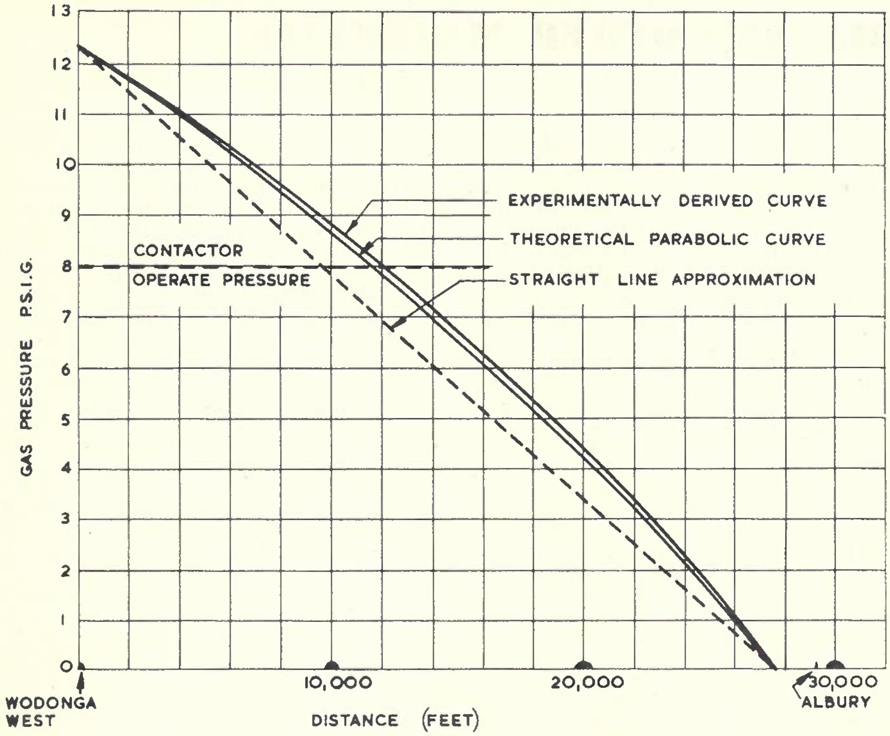

Fig. 10.—Pressure Gradients.

Clearly a stage is being reached in the development of the art of gas pressure protection for long distance telephone cables, where it is possible to foresee such protection without the use of contactors of any kind along the length of the cable. Approximate localisation of faults would be by pressure gauge and flow meter measurements alone applied together with a precise knowledge of the pneumatic resistance of each particular cable, the final accurate fault location being achieved by Radon injection. The remote extension of a gas pressure alarm would, in such a system, depend on an alarm type flow meter (in lieu of contactors or manometers within the cable length as at present) and development work is actively proceeding along this line with a view to application to the Sydney-Melbourne as well as other coaxial cables at some future time.

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2. External Plant Information Bulletin No. 31. "The Theory and Application of Continuous Flow Gas Pressure Alarm Systems to Telecommunication Cables."

TRANSPORT OF CABLE AND OTHER MATERIALS

A. L. FISHER, B.E.,* R. J. CLARK,* AND R. A. COLLINS.*

Delivery of cable to field sites presented a transport project of some magnitude. In the case of the cable delivered from the German works by sea to Sydney, the Transport Branch in New South Wales was faced with two tasks—cartage from wharf to store and subsequently from store to sites between Sydney and Canberra.

At Melbourne, with cable manufactured at the local Olympic plant, it was necessary to decide whether cartage from plant to sites between Canberra and Melbourne should be carried out by the contractor or by Transport Branch. To this end both parties were requested to tender and the Transport Branch tender of £26,000, the lower, was accepted. This price was based on cartage of coaxial cable plus 10% by weight for associated stores. The price was also to include back-loading of empty drums to the Olympic plant as required.

At the outset, it was calculated that the transport task in New South Wales was 300,000 ton miles while in Victoria the commitment was 1,280,000 ton miles ignoring back-loading. The reason for the large variation was that from Sydney cable was carted distances of up to 182 miles while from Melbourne the distances were up to 437 miles.

The existing fleet of semi-trailers required supplementing and tenders were called for six prime movers and tandem-axle semi-trailers capable of carrying 14 ton loads. This was based on an assumed load of 4 drums, each 3 tons 10 cwts. Additional loading would have necessitated tandem-axle prime movers with considerable increase in capital expenditure. Contracts were subsequently placed for International AA182 prime movers and Steco 28 ft. trailers. Five units were for Melbourne and one for Sydney.

An important part of the unit design was the inclusion of quick release couplings and wind down trailer legs which allowed the prime mover to be disengaged from a loaded trailer within a matter of a few minutes only. This was to prove a particular benefit during cable conveyance.

Delivery of the units was unfortunately delayed and commissioning did not take place until May 1960, when the bulk of the Sydney cable had been carted.

Included in the early considerations of the project was the possibility of damage to the cable by vibration and impact during transportation. The Felten and Guilleaume consultants were asked to recommend a maximum permissible speed and after inspection of road surfaces, they informed the Department that the maximum speed should be 35 m.p.h. with a normal average not in excess of 25 m.p.h. A more interesting situation arose with the locally manufactured cable when it was found that the lead sheath would be of lower antimony content than the imported cable, resulting in a greater risk of fatigue damage due to vibration. After obtaining the opinions of various authorities on vibration effects it was decided to reduce vehicle tyre pressures from 75 lbs to 55 lbs. even though such action normally reduces tyre life.

The first shipment of overseas cable arrived in Sydney on the "Moselton" on October 19, 1959, and the last large consignment arrived by the "Alcor" on August 11, 1960. All cable was transported from shipside to the Villawood store for testing and grouping into minor repeater lengths for delivery to the various field sites as required.

Delivery to site commenced on January 8, 1960, with a trip from Villawood to City South Exchange, a matter of 15 miles. Two drums only were involved on this occasion and they were short lengths of 38½ yards. and 91½ yards to provide the leads from the project terminal. The very short haul trips presented no transport problem but as distances increased it was not found possible to use Transport Branch vehicles since they were required to perform considerably longer trips on other intrastate distribution of engineering stores and supplies. Department of Supply vehicles and drivers were, therefore, hired for the bulk of cable cartage from Sydney to Canberra.

In general, cartage was scheduled two weeks ahead and for this purpose the field staff advised both Stores Branch and Transport Branch of their requirements. Transport Branch then arranged with the Department of Supply for vehicles and drivers at particular times. After each despatch, the field staff was advised of the estimated time of arrival in order that a mobile crane could be provided at the dump site for unloading purposes.

On August 29, 1960, the first convoy left the Melbourne Olympic plant en route for Canberra.

The Melbourne transport problem was quite different from that in Sydney for two main reasons. The first, of course, was that the initial distances were high, resulting in round trips of four days. The second was that coaxial cable was accepted in minor repeater lengths of approximately 24 drums, and was usually required in the field as early as possible after acceptance. This resulted in convoys of at least six and up to twelve semi-trailer units and in the main, trips were usually arranged at very short notice. Under ideal transport arrangements a continuous programme would have been preferred but of necessity the requirements of the field staff had first priority.

At this stage, it might be of interest to recount a most unusual incident which occurred during the first convoy trip. All semi-trailers are fitted with a dual vacuum line braking system. From the engine inlet manifold, a short flexible line is attached to a control cock on the scuttle and from this cock there are two vacuum lines to the rear of the semi-trailer. One maintains a partial vacuum in a tank and the other, when opened to atmosphere by a hand control in the cabin, operates a valve connecting the tank with the booster and braking system. The safety feature is that under conditions of breakaway, the trailer brakes are automatically applied.

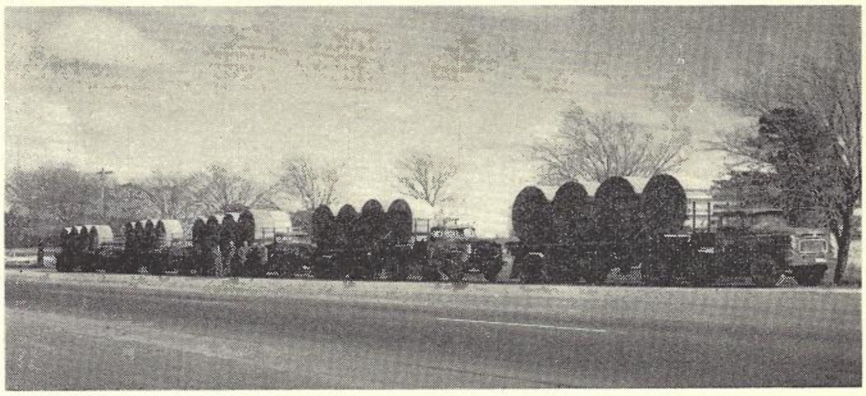

Fig. 1.—24 of the 1814 Drums Carted from Melbourne.

At the summit of a steep hill and prior to commencing the run down, one driver felt for his brakes by the hand control but obtained no response. With a great deal of effort he was able to stop the unit by applying the foot brake which operates on the prime mover wheels only. On the steep downhill slope this would not have been possible. Inspection revealed that the short flexible line had become detached from the engine manifold and during the previous down-hill run, the reserve

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* See page 269.

in the vacuum tank had been exhausted. In order to avoid any possibility of a recurrence, vacuum gauges were fitted to all units on return to Melbourne and drivers then had a clear indication of the vacuum level at all times. The morale of at least one driver was increased considerably.

Before each convoy trip, close attention was given to load distribution so that all vehicles would comply with the appropriate road regulations. In general, the law requires that the road load from a single axle must not exceed 8 tons and from tandem axles 13 tons. In the case of the Internationals the tare at the prime mover rear axle was 2 tons 4 cwts. and at the semi-trailer tandem axles 3 tons 6 cwts. The 14 ton load had therefore to be distributed so that no more than 5 tons 6 cwts. would be thrown on the prime mover rear axle and no more than 9 tons 14 cwts. on the trailer axles. With four normal drums of 500 yards of cable there was no complication since the units had been designed for four drums in line. Unfortunately for Transport Branch, however, many drums contained short lengths. This was the pattern for all large towns and between Canberra and Melbourne there were 1,142 drums of 500 yards and 672 drums of shorter lengths. In order to fully load all units it was necessary to load the lighter drums side by side. A further complication existed due to varying size drums and when drums were to be paired it was necessary to select similar diameters in order that chains could be threaded through the spindle holes. Before every trip, a list of drum numbers, weights and diameters was obtained and after an exercise similar to a jig-saw puzzle, loading plans were prepared. This procedure resulted in considerable savings since underloading would have necessitated the provision of an additional vehicle in most convoys, increasing costs up to £100 in each instance.

As a guide in the actual loading of drums, white lines were painted down each semi-trailer. Single drums were placed approximately 1½ ins. off centre towards off-side of the vehicle and paired drums were placed so that the greater weight was on the off-side. This practice reduced the effect of the road camber. The drums were abutted against each other so that the friction at the contact edges would reduce the tendency for the load to roll forward or back. All drums were chained and as an additional safety measure the end drums were double chained and chocked. No loading difficulties occurred in transit but a number of chains were badly worn by the sharp metal edge at the spindle hole of the locally manufactured drums. Chains were inspected before each loading operation.

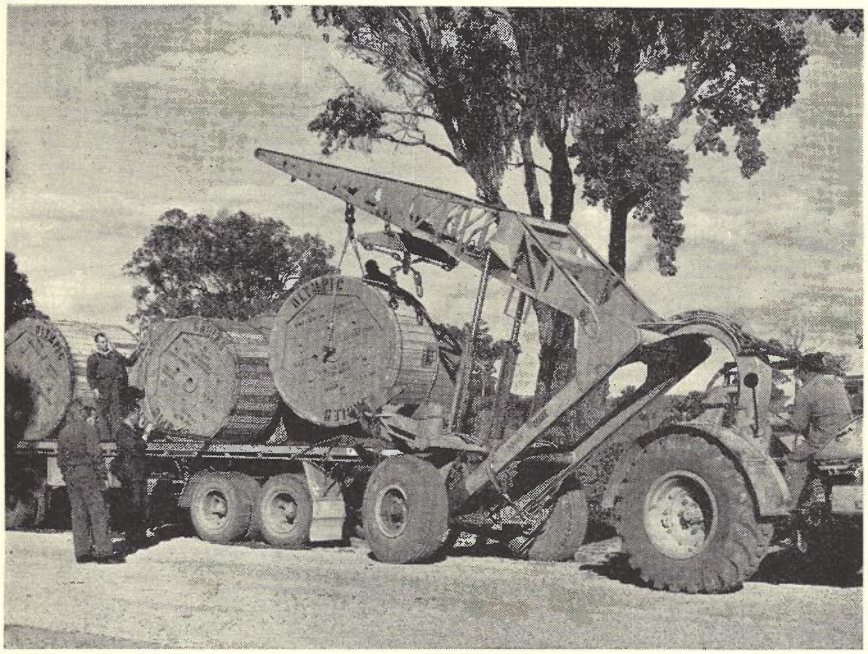
Fig. 2.—Unloading Vehicles in the Field.

One particular driver was selected to take charge of every convoy and he always drove in last position to assist in cases of breakdown, punctures, etc. His vehicle carried jacks, chains and other additional gear.

A number of motor failures occurred through broken valves, probably resulting from high engine speeds when travelling down-hill in a low gear. Engine governors cannot control engine speeds under these conditions. Revolution counters were subsequently fitted and drivers were instructed that vehicles were not to be driven with engine speeds in excess of 3,600 r.p.m. No further valve breakage was experienced. At the time of these failures, the wind-down standing legs and quick release couplings proved their value. The first convoy vehicle which was unloaded at the dump site was able to return to the immobile vehicle, change semi-trailers and deliver the cable with a minimum of delay.

Between August and December, 1960, the demand on vehicles was particularly high because of the long trips involved and the increase in the laying rate. During this period, a special repair staff serviced and checked every vehicle immediately after each round trip and this frequently involved night and week-end work. Mechanical faults which developed on the road were usually rectified locally but on three occasions it was necessary to piggy-back to Melbourne, a prime mover and semi-trailer on two other units.

While this article has dealt primarily with the cartage of coaxial cable, cartage of other materials was an important aspect in the scheme. This included minor trunk cable, jointing pits, repeater equipment, concrete marker posts and gates for private properties. At one stage it was necessary to transport an army Bailey bridge. This was used for crossing the Murray River at Wodonga and four semi-trailers were required to carry the various sections.

Because Transport Branch, Melbourne, had tendered for their section of the cartage, a most detailed account of work performed and costs was maintained. As mentioned earlier the tender price of £26,000 was based on 1,280,000 ton miles or 4.87 pence per ton mile. Final costs were £28,600 for 1,417,000 ton miles or 4.85 pence per ton mile. The increased load resulted from shifting of camps and the transportion of other engineering stores and equipment not originally included as a Transport Branch commitment.

The project was extremely popular with drivers. The long trips into New South Wales provided scenic interest and a challenge to deliver valuable equipment in first class condition. Considerable pride was taken in the fact that not one drum was damaged in transit and at no stage was the field work delayed because of a transport failure. The drivers concerned were well compensated for their efforts since four day trips frequently resulted in week-end penalty payments. Overtime rates were also usual because of the desirability of keeping vehicles on the road for as long a period as possible each day.

An excellent driving record was marred by one vehicle accident but fortunately the vehicle concerned had no load at the time. Nevertheless, one accident only in 250,000 miles of motoring must be regarded as a good result.

THE TESTING OF THE CABLE

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*A. W. SISSON, Grad.I.E.Aust.,**
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INTRODUCTION

The installation of the Sydney-Melbourne coaxial cable was a large project, and methods used in laying were new to this country. More testing was carried out at all stages of installation than is likely on later coaxial cable works in order to gain a technical working knowledge of this new medium, and much of this knowledge will reduce the cost of the later works. The jointing and testing comprised approximately 30 per cent. of the total installation costs.

The testing of this cable, as with any long distance cable, can be divided into three categories:—

(a) Preliminary tests after laying to check that the cable has not been damaged. For this project additional tests were made in the early stages to check that laying methods were satisfactory and to gain familiarity with the testing techniques.

(b) Capacitance unbalance and mutual capacitance measurements of voice frequency pairs, and complex unbalance measurements of the carrier pairs. Tests of this type are normally carried out on long distance balanced pair cables in association with capacitance unbalance and building out procedures; such procedures permit a less stringent purchasing specification in relation to the design requirements of the completed cable installation, with consequent overall economies.

(c) Acceptance tests, which were carried out on the completed repeater sections, to ensure that the cable performance met the design objectives. These tests had a special significance in this project since the installed cable specification is binding on the Department, as cable laying contractor, in relation to the overall system specification. Acceptance tests are also of value in relating the standard of overall performance achieved to the purchasing specification and installation techniques to be employed for future cable systems.

Whilst the coaxial tubes form the principal part of the cable, they do not account for the major percentage of the testing effort and are not involved at all in the category (b) tests (balancing tests).

This article gives a brief summary of the tests carried out, an outline of the testing methods, particularly those associated with tests on coaxial tubes, and an analysis of the results achieved in relation to the design specification limits.

SPECIAL ASPECTS OF TESTING ASSOCIATED WITH COAXIAL CABLE TUBES

There are inherent differences between coaxial cables and unscreened balanced pairs which affect testing methods and procedures; these are due to the differences in construction and the frequency bandwidth transmitted. With balanced pairs the frequency band which may be used is limited by crosstalk, and the controlling factors in installing these cables are related to achieving the best crosstalk conditions possible. However, with coaxial tubes, crosstalk improves with increasing frequency and is not an installation problem. Regularity of impedance is the factor which, more than any other, determines the quality of the cable. Irregularities may be due to variations in the dielectric or in the conductivity of the conductors, but the most usual cause is due to changes in the dimensions of the tube structure. Irregularities occurring after manufacture are mostly due to reductions in the tube dimensions.

The most stringent requirement concerning impedance uniformity arises when the tubes are used for the transmission of television signals. Reflections of signal energy occur at impedance irregularities; each combination of two irregularities produces a twice reflected wave which will arrive after the direct wave. The delay is equal to the time taken for the indirect wave to travel twice the distance separating the two irregularities. The relative amplitude of the echo is equal to the sum of the two return losses at the irregularities plus twice the cable attenuation separating them. A diagrammatic repre-

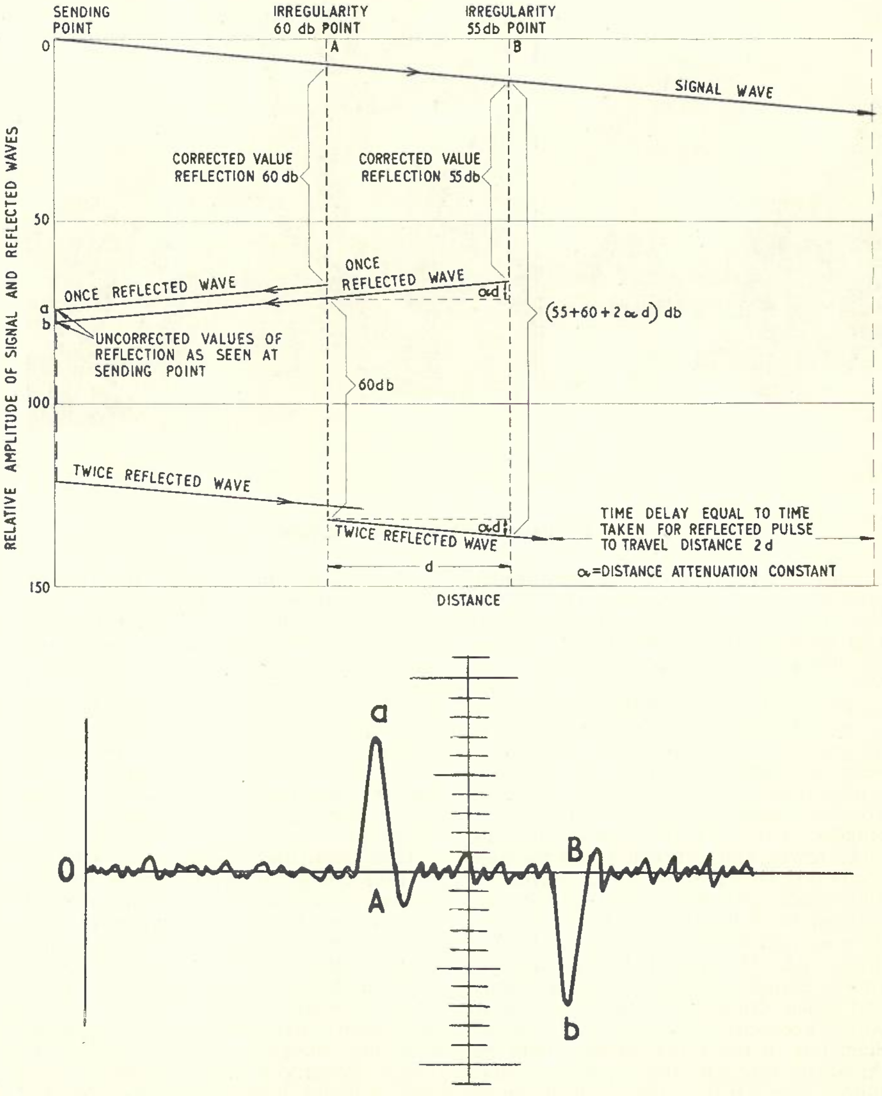

Fig. 1.—A Representation of a Signal Wave and the Reflected Waves which occur at Points of Impedance Irregularity. The Lower Part of the Figure Shows the Type of Trace Seen on a Pulse Echo Tester, Pulse Heights, e.g. a and b Being Measured Vertically, and distances, e.g. OA and OB Being Measured Horizontally.

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* See page 270.

sentation of this feature is given in Fig. 1. Each combination of two impedance mismatches is individually insignificant but with the very great number which exist in a long distance cable a distortion occurs which reduces the picture definition. Irregularities also produce uneven attenuation and phase responses. It is important to realise that the total cable attenuation is nearly 1,000 db at 6 Mc/s for a major repeater section of 100 miles, and ripples in the attenuation characteristic, which are small in proportion to the total attenuation, may complicate the problem of equalisation.

Reflections in the cable near the equipment terminations are the most detrimental since these combine with the terminal mismatch, and suffer only a small cable loss. The return loss which can be achieved between the cable and the equipment is much lower than at any cable irregularity, being of the order of 25 db whilst the cable irregularities are of the order of 50-60 db.

It is theoretically possible to measure the cable impedance and determine the position and magnitude of all irregularities by steady state impedance measurements, but the degree of measuring precision necessary, the number of individual frequencies at which measurements would need to be made, and the subsequent analysis of the measurements which would be necessary, make such a method quite uneconomic. The pulse technique makes it possible to show visually on an oscilloscope, the position and magnitude of all irregularities together with information as to the nature of such irregularities. It also enables accurate measurements to be made of the impedances of coaxial tubes at the ends of repeater sections and drum lengths. End impedance measurements are used for selection of drum lengths to provide optimum matching, and coaxial cable lengths must always be selected and laid in a tailored manner. The pulse echo test set is thus a major aid to coaxial cable testing. A description of this instrument is given in a later section covering testing methods.

PRELIMINARY AND BALANCING TESTS

General

The cable laid comprises six coaxial tubes, 2.6/9.5 mm., a core of ten - 20 lb. per mile trunk type quads and six - 20 lb. per mile interstitial carrier type quads; a diagram showing a cross sectional view of the cable appears in a companion article by J. F. Sinnatt. Over most sections 18 of the 20 trunk type pairs in the core were V.F. loaded with 88 mH Grade II coils at 6,000 feet spacing. The loading of these core pairs at this spacing led to 6,000 feet slings being a convenient unit for the jointing and preliminary testing of coaxial tubes.

Preliminary Tests

Coaxial Tubes: Prior to jointing the coaxial tubes into 6,000 feet slings, they were tested for ionization breakdown with 2,500 volts D.C. between inner and outer conductors applied for two minutes. During this operation the tubes were connected through temporarily using high voltage cables with pin-vice connectors. This test is essential to prove that future breakdown will not occur due to indentations caused during laying or the presence of metallic dust, metal slivers, or other foreign matter in the tubes. Prevention of future breakdown is essential because under normal operating conditions 750 volts A.C. will be applied between the inner and earthed outer conductors of each of two tubes to supply the 1,500 volts A.C. power required for operation of the minor repeaters. After jointing into slings the tubes were again high voltage tested at 2,500 volts D.C., and standard continuity tests and insulation resistance measurements between outer conductor and sheath were carried out. Pulse testing of 6,000 feet slings was done over many sections in the earlier stages of installation but was eliminated later; this testing was used to prove that the laying techniques being employed were satisfactory and to gain a sound working knowledge of the instruments and of impedance variations caused by various laying and hauling methods.

Paper Insulated Conductors: During laying, standard paper pair tests according to well established principles were carried out at frequent intervals. These included continuity and I.R. measurements on both core and interstitial pairs.

Pressure Testing: All lengths of cable were delivered from the factory under gas pressure and were checked before jointing to prove that sheath failures had not occurred during laying and to prove the suitability of the sheath for the satisfactory functioning of the Gas Pressure Alarm System to be installed. All cable joints and plumbing wipes were tested with soap solution to prove that they were gas tight.

Balancing Measurements

Mutual Capacitance Deviation Correction: The core pairs which were to be used for voice frequency purposes between major repeater stations were required to meet a high return loss figure (all pairs better than 26 db from 300-2,800 c/s), and to achieve this result, the impedance of individual pairs needs a very uniform characteristic. This uniformity was achieved by keeping the variation of loading section lengths within fine tolerances, and where necessary building out to a uniform mutual capacitance between adjacent loading sections. The mutual capacitance of each pair was measured in each loading section and plotted on a graph. An additional capacitor was added to reduce the deviation where the difference between adjacent loading sections was greater than 1,200 pF. The mutual capacitance deviation and balancing capacitors were added during voice frequency balancing at the centre of the loading sections.

Voice Frequency Balancing: This was done from the centre joints of the loading sections by a method known as corrective balancing. This means that the core pairs were tailed out from the centre of the joint and all balancing effected by the addition of capacitors rather than the insertion of transpositions. This method allows the jointing of coaxial tubes to proceed unhindered. The unbalances were corrected so that no residual values exceeded 25 pF for a full section and 15 pF for a half section. These figures were designed to meet the far end cross-talk requirement of no values worse than 65 db over major repeater sections. Quad type capacitors containing four single capacitors of equal value in the form of a bridge were used for between-quad balancing where two or four of the unbalances were outside limits.

Carrier Balancing: This was carried out after completion of voice frequency balancing in each minor repeater section and just prior to acceptance testing. This timing was considered necessary because movements in the joints could affect the stability of carrier balance. The balancing was achieved by inserting transpositions during jointing in pair one of each interstitial quad at each loading coil joint and then checking the overall suitability of the circuit by measuring the admittance unbalance within each quad at a number of frequencies between 6 and 110 Kc/s, and calculating the susceptance at each of the measuring frequencies. The need for further balancing was determined from the plotted susceptance-conductance polar diagram. The Sydney-Melbourne cable was balanced so that no value of admittance unbalance exceeded 10 micromhos. This value gives some latitude and means that joints can be disturbed, or short lengths of cable replaced, without rebalancing being necessary to preserve a far-end cross-talk ratio better than 70 db at 108 Kc/s for all combinations. By calculation, a figure of 70 db corresponds to an admittance unbalance of 17.8 micromhos. In cases where further balancing was necessary a balancing capacitor, or a network of resistance and capacitance, was fitted at the centre loading joint of the minor repeater section, or the transpositions inserted at one or more loading coil joints were removed. Generally it was unnecessary to remove transpositions at more than one joint.

ACCEPTANCE TESTS

General

The acceptance tests on coaxial tubes and carrier pairs were carried out over minor repeater sections, an average distance of 5.3 miles. The acceptance tests on voice frequency pairs were primarily carried out over major repeater sections, an average distance of 44 miles, but there were certain standard D.C. tests made on these pairs over minor repeater sections in conjunction with the same tests on the carrier pairs. Such tests are described later. The order in which tests are carried out is important since, should a length of cable have to be replaced, all acceptance tests previously carried out would have to be repeated.

Coaxial Tubes

It was found necessary to make some acceptance tests prior to fitting the solid dielectric semi-flexible single tube cable tails to the potheads. These tests included simple D.C. tests which can readily be performed and reveal possible faults, such as low insulation resistance, which would mean later repetition of more complex measurements. Pulse testing was carried out at the potheads to prevent large reflections near the repeaters from being masked by the much larger reflections caused by the semi-flexible cables.

(A) Tests from Cable Potheads:

(a) High Voltage D.C. — 2KV for 2 minutes.

(b) Insulation Resistance — 500 volts D.C. This was measured between inner and outer conductors, outer conductor to all other conductors and sheath, and all paper insulated conductors to every other conductor and sheath.

(c) Continuity—all conductors.

(d) Pulse Echo Tests—these tests were a measure of the impedance regularity of the tubes, and it was necessary to measure the worst uncorrected reflection* and the three worst corrected reflections from each end. (Fig. 1 shows the concept of these reflections). From these the worst uncorrected value was recorded and the R.M.S. value calculated for the three worst corrected reflections for the section. In addition the end impedance of each tube was measured together with the electrical length in microseconds.

(e) Impedance-Frequency — the resistive component of the impedance of the cable was measured at selected frequency intervals throughout the range 60 Kc/s to 12 Mc/s and a mean smooth curve drawn through the points plotted with frequency as abscissa and resistive component of impedance as ordinate. This test was not carried out on all tubes in sections beyond Canberra but only on those tubes where large reflections occurred near one of the repeaters. On future installations this test will be eliminated and only pulse testing performed.

(B) Tests between Semi-flexible Cable Ends (Permanent Cable Terminations):

After the tests between potheads had been carried out, semi-flexible cables of the same nominal impedance as the cable were jointed to the top of the pothead at both ends of the minor repeater section concerned, and a further series of tests made. These tests were:—

(a) High Voltage D.C. — 2 KV for 2 minutes.

(b) Conductor Resistance — inner and outer conductors of the coaxial tubes.

(c) Pulse Echo Tests—to determine the reflection due to the mismatch between the semi-flexible cables and the main cable.

(d) Attenuation — at 2.5 Mc/s on each coaxial tube and at selected frequencies throughout the range, 60 Kc/s-6 Mc/s, on one tube.

(e) Far-end Crosstalk Ratio — between tubes at frequencies between 60 Kc/s and 12 Mc/s. Crosstalk between tubes decreases with increasing frequency and it was not found possible in the routine measurements to measure above 500 Kc/s because of the very small magnitude of crosstalk and the limits of the instruments used. The far-end crosstalk specification is for values greater than 90 db at all frequencies.

(f) Near-end and Far-end Crosstalk Attenuation — this was measured between each tube and the adjacent carrier balanced quads because the frequencies to be used on the coaxial tubes and the carrier quads overlap in the range 60-108 Kc/s and the direction of transmission is the same for some combinations of tubes and pairs.

Paper Insulated Pairs

(A) In Minor Repeater Sections:

(a) Resistance and Resistance Unbalance —on all pairs.

(b) Far-end Crosstalk Ratio — on the carrier pairs at 108 Kc/s.

(c) Attenuation — on carrier pairs at 108 Kc/s.

(d) Impedance—of carrier pairs at 108 and 60 Kc/s.

(B) In Major Repeater Sections:

Tests were done on all the V.F. loaded pairs over major repeater sections because some pairs were not terminated in a half loading section on both sides of the minor repeaters. These tests were:—

(a) Continuity — This was necessary on those pairs in which rack-mounted loading coils were installed at minor repeaters.

(b) Insulation Resistance — using 500 volts D.C.

(c) Conductor Resistance and Resistance Unbalance—of each V.F. loaded pair looped at the far end.

(d) Far-end Crosstalk Ratio—between all pairs at 1 Kc/s.

(e) Near-end Crosstalk — between all pairs at 1 Kc/s.

(f) Return Loss—on loaded pairs (1-18) over the frequency range 300-2,800 c/s.

Cable Sheath and The Gas Pressure Alarm System

The sheath was tested by completely pressurising the cable with dry air over a minor repeater section, allowing the pressure to stabilise and checking the probability of gas leaks by observation of the pressures in the cable over a period of time. The tests on the gas pressure alarm system were to be carried out successively over all minor repeater sections comprising a major repeater section, by releasing the gas pressure from one end of each minor repeater section and observing the sequential operation and release of the mercury manometers along the length of the cable with the aid of a recording ammeter. However, the tests on the first section revealed serious deficiencies in the proposed system and extensive investigations led to a variation of the method of protection to be applied over the cable from Campbelltown to Melbourne. Details of the proposed system and the problems are covered in the companion article by Mr. F. J. Harding.

THE TESTING ORGANISATION

Testing was performed by specialist groups to permit high staff efficiency to be achieved through concentrated experience, and to achieve the high progress rate of testing required. These groups can be classified as the preliminary testing, voice frequency balancing, carrier balancing, and acceptance testing groups.

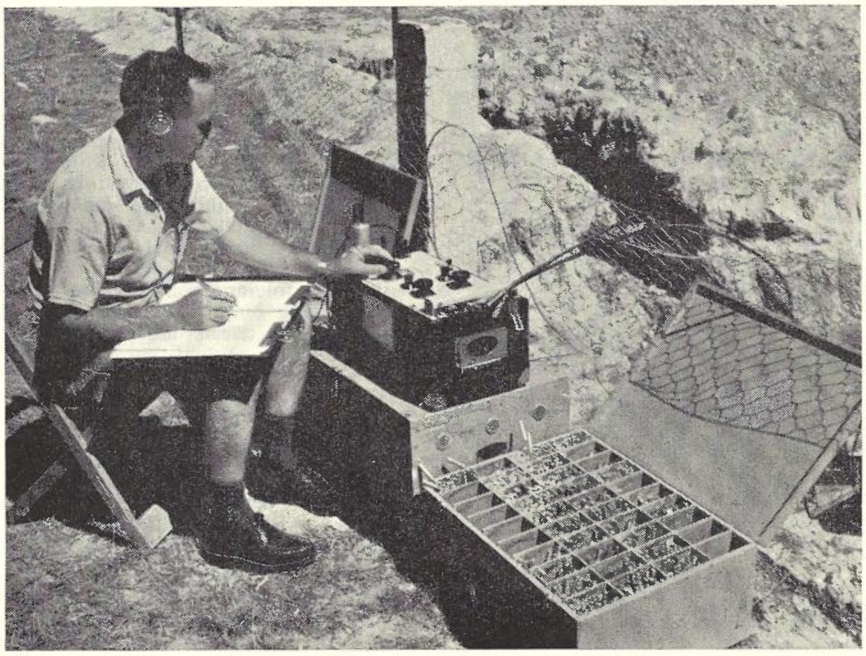

Fig. 2.—Field Balancing of Voice Frequency Pairs.

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*To obtain the true value of each reflection, "correction" is necessary by making allowance for the attenuation of the pulse while travelling to and from each irregularity. However "uncorrected" values as seen from the repeater termination are also of significance, and limits for these are also covered by the specification.

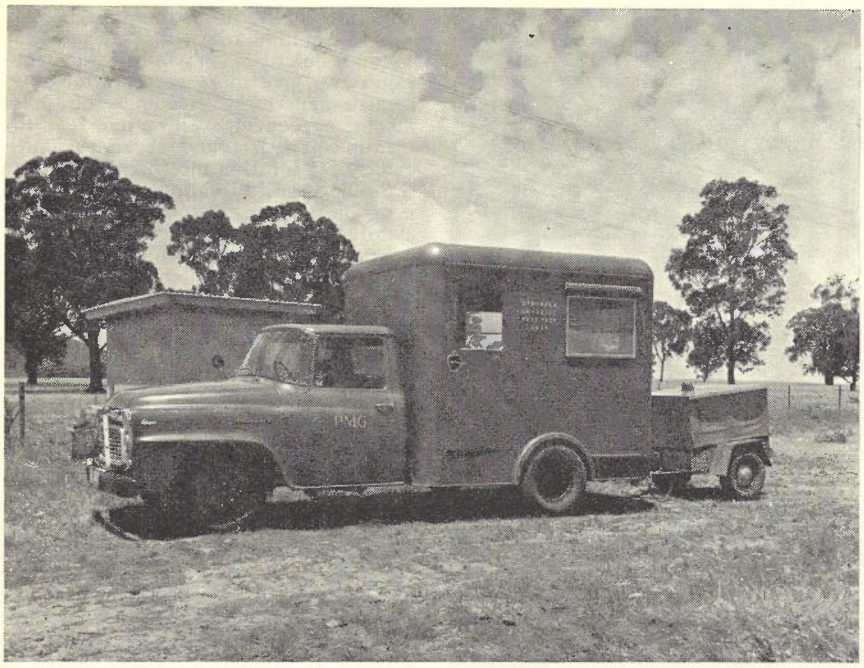

Fig. 3.—Test Van and Mobile Power Supply as Used by Acceptance Testing Team.

It was also found convenient to subdivide the acceptance testing into smaller functional groups and to carry out the major repeater section tests separately from the minor repeater section tests. A small general group was also established to check and repeat tests where errors were suspected or where substandard conditions revealed by previous groups had been rectified.

The preliminary testing and the voice frequency balancing groups were a corporate part of the jointing organisation. They were equipped with light four-wheel drive "jeep" type vans and portable battery and vibrator unit power supplies. Light four-wheel drive vehicles were found essential for working under very wet conditions away from roads as was generally experienced during the winter months of 1960. Fig. 2 is of interest as it shows the conditions under which voice frequency balancing work was carried out in fine weather. The problems which arose in wet weather can be readily imagined.

Most fault location work was performed by the preliminary testing group. The carrier balancing and acceptance testing groups were equipped with 2-ton test vans, some of which were four-wheel drive, and with trailer mounted motor driven power supplies for the latter group. A typical unit is shown in Fig. 3. Battery and vibrator unit power supplies were carried for lighting or in case of breakdowns, and also for those cases where power for testing was required at both ends of a minor repeater section not served with mains supplies. The motor driven generators also provided power for space heating to improve staff comfort in the repeater buildings during the winter months. The heavier vans were used because of the large amount of equipment required for acceptance testing, but the carrier balancing groups could have been equipped satisfactorily with the lighter vans. However, it was found economical to employ available vehicles rather than make new purchases.

TESTING METHODS

General

It is impossible within the scope of this article to cover in detail the testing methods and the principles associated with the various tests made. The methods and principles for the majority of tests however were standard to any cable installation and the most significant feature is the values recorded after installation; these values are covered later. Some limited detail together with comments on problems revealed is given, particularly on tube testing and tube fault location.

High Voltage Testing of Coaxial Tubes

This was a simple test with instruments which require a low power, 240 volt, 50 c/s source, and have a variable D.C. output from 0-5,000 volts. The instruments include current limiting devices which afford some protection, but care was taken when testing coaxial cable tubes to ensure that personnel were not working on the cable at the open end or intermediate points. The test voltage was normally applied for two minutes.

Pulse Testing of Coaxial Tubes

The pulse testing of the Sydney-Melbourne cable was done with Kieler Howaldswerke instruments and the method described here refers primarily to this type. A block schematic of this set is shown in Fig. 4, and it is shown in use in Fig. 5.

The pulse echo test-set consists of a pulse generator, a hybrid bridge with adjustable balance network through which the pulse is applied to the cable, and a cathode ray oscilloscope with which the reflected echo pulses are amplified and displayed on the screen, shifted in accordance with their transit time. The height and position of the reflected pulses indicate the magnitude and distance of the cable irregularities; the shape of the reflections gives information as to the type of irregularity.

The pulse generator produces a pulse of approximately cosine squared shape. Such a pulse is well suited to cable testing since the energy contained in the pulse is mainly confined to a discrete band of frequencies, the upper limit of which can be set by choosing a particular pulse width; the narrower the pulse the higher is the upper frequency limit.

The pulse is applied to the hybrid, to which is connected the cable under test, the adjustable balance network, and the oscilloscope, so that the pulse is absorbed by the cable and the network. The only signals reaching the oscilloscope are those due to the unbalance between the cable and the network (which is adjusted to a minimum) and those reflected at points of mismatch in the cable. The time base of the oscilloscope is synchronised with the reception of the generated pulse and the vertical deflection is then a measure of the amplitude of the reflected signals returned from impedance irregularities within the cable.

The gain of the video amplifier is adjusted by means of a calibrated attenuator so that a mismatch of 0.15 ohms gives a pulse height of 1 centimetre. A mismatch of 0.15 ohms causes a reflected pulse which is 60 db below the level of the transmitted pulse and corresponds to 0.1% of the voltage being reflected from the irregularity. The values of the reflected pulses can

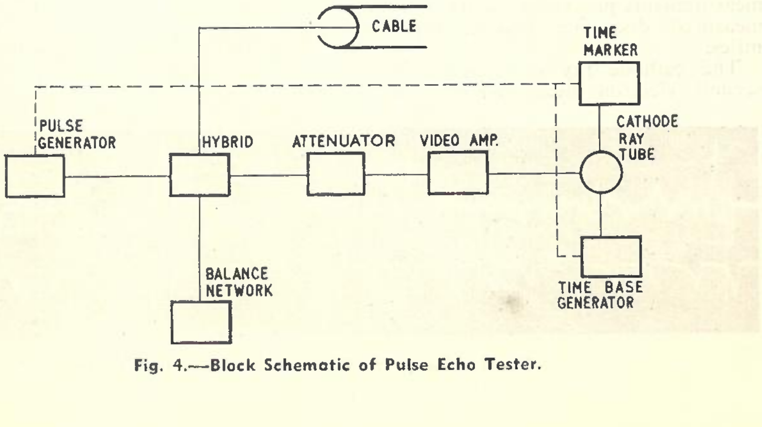

Fig. 4.—Block Schematic of Pulse Echo Tester.

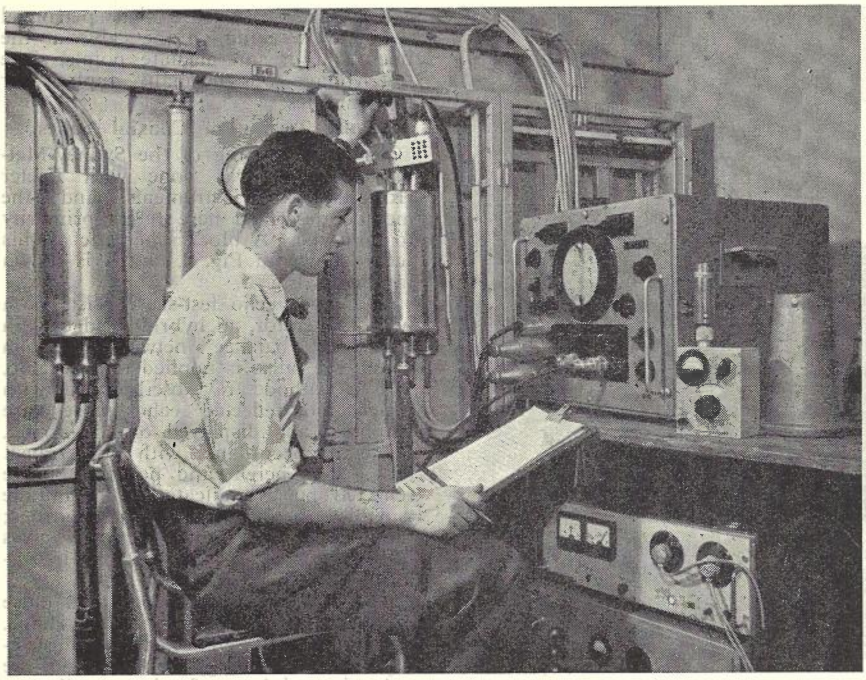

Fig. 5.—Pulse Measurement — Adjusting the Balance Network at a Minor Repeater Station.

best be determined by adjusting the gain so that the height of the deflections is one centimetre; the variation in magnitude from 60 db is then calculated from the difference in gain setting from that for the 60 db calibration.

As indicated previously, the pulse is attenuated while travelling to and from each irregularity and allowance for this may be made in determining the magnitude of the irregularity. The terms "corrected" and "uncorrected" indicate whether or not allowance has been made for the attenuation. The pulse attenuation is not linear with distance; this is because of the change in pulse shape which occurs due to the greater attenuation of the high frequency components of the pulse. A concept of the type of trace occurring on the oscilloscope and caused by cable irregularities is given in Fig. 1.

The end impedance of the cable is determined by adjusting variable components of either the network which balances the cable at the hybrid, or the network which terminates the distant end of the cable. Greater accuracy is generally obtained with distant end measurements providing the length being measured does not exceed, say, two miles.

The cathode ray oscilloscope has a second electron beam which can be controlled independently from the main beam and which shows a series of time marking pulses, the interval between each time pulse being accurately adjusted to 1.0 microsecond. These time markers can be shifted horizontally and if the beginning of the transmitted pulse is made to coincide with the beginning of any particular time mark, then the position of an irregularity can be measured by observing the number of one microsecond intervals between the transmitted and reflected pulses. A control is provided to allow a time mark to be brought to exact coincidence with the reflected pulse, this control being calibrated in hundredths of a microsecond. If a pulse echo tester is used on a cable of known length then the velocity of propagation of the transmitted pulse in the cable can be calculated by observing the time interval between the transmitted pulse and the pulse reflected from the far end. This velocity can be used to determine the location of bad reflections in a coaxial tube by observing the position of the reflection (in microseconds from the measuring end) and multiplying this value by the velocity of propagation.

When using the pulse echo test set for magnitude measurements, it was found important to remember that the visual scale for measuring percentage reflection is only linear to approximately ± 15 millimetres (.15%), and the method described previously was considered to give more accurate measurements than direct readings of pulse height. Frequent calibration of the instruments was found necessary, particularly for location measurements where the time base calibration is very dependent on voltage and source frequency stability.

The semi-flexible cable which was used for termination purposes at the repeaters is a solid dielectric tube and has a different velocity of propagation from the standard tube. This had to be taken into account for location measurements made from the ends of these cables. Better accuracy can be obtained by removing the semi-flexible cable, particularly where the fault is close to the repeater.

The pulse testing of repeater sections was carried out with an 0.1 microsecond pulse. It is interesting to note that the specification for factory lengths requires the use of an 0.05 microsecond pulse, and because of the difference in the centre of gravity frequencies of these two pulses, an impedance variation can give different reflection values with each pulse width. In such a case an irregularity which passed the factory length specification, but was close to the limit, could be outside the repeater section specification limit even though it had not deteriorated during laying, and vice versa.

Fig. 6 is a composite picture compiled from four photographs of adjacent sections comprising a full repeater section. The amplifier gain was readjusted for each section to compensate for tube attenuation. This compensation is clearly shown by the superimposed lines defining the pulse height for a reflection of 60 db, that is to say, the trace is corrected. The 1 microsecond timing marks also appear in the picture. The reduction in the resolving power of the trace, for small variations, as a function of distance from the measuring end can be seen. As mentioned previously this is due to the relatively greater attenuation of the high frequency components of the pulse.

Impedance-Frequency Measurements

The specification required that the resistive component of the measured impedance at any frequency should not deviate from a smooth curve by more than ± 1.5%. These measurements were made with an impedance bridge of type suitable for measuring only the restricted range of impedances encountered in standard coaxial tubes. Precautions were necessary when it was required to produce accurate readings

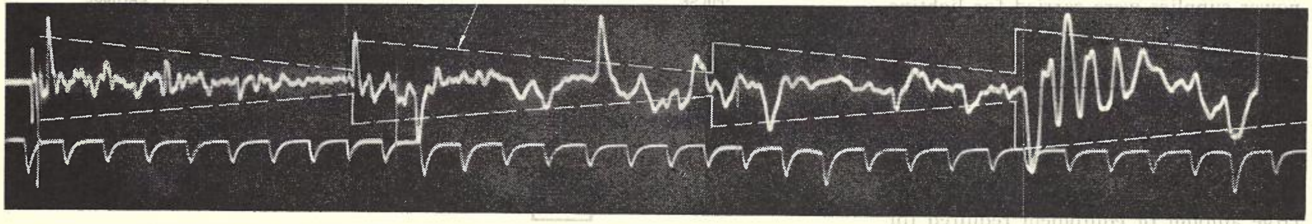

Fig. 6.—Composite Trace of Four Sections of Typical Tube as Seen on Pulse Echo Test Set.

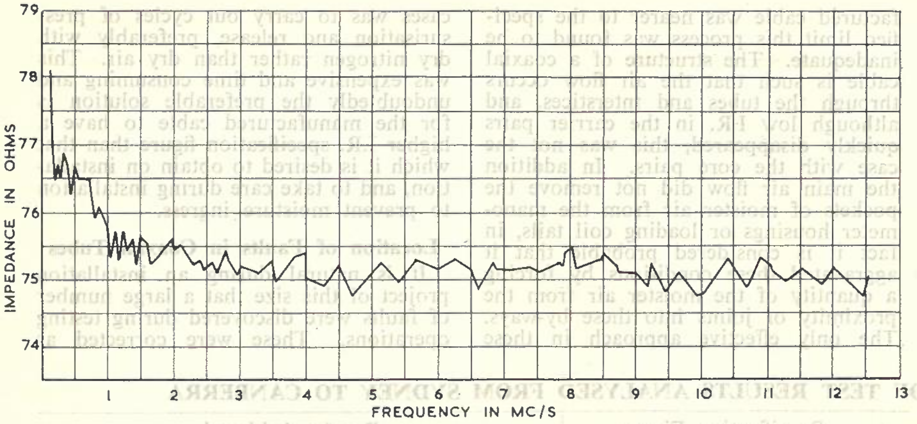

Fig. 7.—Impedance—Frequency Curve for Typical Coaxial Tube.

of the "absolute" value of the cable impedance because of inaccuracies introduced by the solid dielectric test leads. The method adopted to obtain these "absolute" readings was to balance the bridge in the normal way, then substitute for the cable at the pothead a network designed to match the cable impedance characteristic and containing a variable resistance element. This network was adjusted to produce a balance on the bridge. The network impedance was accurately measured in the laboratory to determine the cable impedance at the frequency concerned after appropriate allowance for resistance variation with temperature was made. However, it was found that measurements made directly with the bridge could be used to determine the deviation from the mean curve, even though the mean curve was generally displaced by up to 0.5 ohm from the "absolute" value. Fig. 7 illustrates the impedance frequency curve for a typical tube.

Far-end Crosstalk Measurements between Tubes

The specification requirements for the far-end signal to crosstalk ratio between coaxial tubes was 90 db minimum over the frequency range 60 Kc/s to 12 Mc/s, this frequency being the permissible upper frequency of operation when at a later stage the repeater spacing is halved by the installation of additional repeaters. The attenuation of the present repeater sections at 12 Mc/s is approximately 74 db, and a facility to measure crosstalk attenuations up to 164 db. is required to confirm by measurement on present sections that the specification requirement is met. This is beyond the capacity of the normal testing instruments, which were adequate up to approximately 500 Kc/s only. Measurements below 500 Kc/s indicated that the specification was met over this range and since crosstalk attenuation increases with frequency, it could reasonably be assumed that satisfactory values pertained throughout the frequency range. However in order to check the crosstalk over the whole frequency range a special low noise amplifier was built which, in conjunction with the normal T.M.S., enabled crosstalk attenuation measurements to be made to approximately 140 db, this being an adequate range up to 2 Mc/s. A further measurement was made at 11.2 Mc/s, sending +40 dbm from a 10 watt radio-transmitter, which extended the range to approximately 170 db. This figure represents the limit of measurement set by the basic noise, but since the reading on the receiver did not increase when the transmitter was connected to the interfering tube, it is estimated that the actual crosstalk attenuation is better than, say 190 db, equivalent to a signal to crosstalk ratio of 116 db. For routine acceptance testing, measurements were made only to 500 Kc/s; since the values obtained on all sections were reasonably consistent it can be assumed that they are satisfactory over the complete frequency range.

Return Loss Requirements on the Voice Frequency Loaded Pairs

The specification called for certain values of return loss over a frequency range when the pairs were terminated against a network having "an impedance frequency characteristic similar to that of the average smooth mean impedance-frequency characteristics of the pairs in the same group at the termination at which the measurement is being made". A set of measurements over the frequency range on all pairs was very time consuming and in many cases repeat return loss measurements and impedance measurements were necessary before the optimum network could be determined. Then again, some of the pairs involved had rack mounted building out and loading units fitted at minor repeater stations to allow termination at these points for supervisory purposes, and the effect of the large capacitance build-outs without resistive components reduced the values of return loss achievable and the requirements had to be relaxed for the supervisory pairs concerned. It became obvious that great care was necessary on several points if all return loss values were to be better than 26 db. Briefly, these points were that section building out should be kept at the practical maximum distance from the point of measurement, that correction for mutual capacitance deviation should if possible be based on actual measurements and not ones calculated from length variations or theoretical data, that at the outset the cable pairs should have only small deviation from the mean mutual capacity, and that the network against which the pairs were measured and terminated should be carefully designed to match the type of cable.

Fig. 8 illustrates the improvement on return loss following the insertion of resistive build-out in conjunction with a large capacitance build-out. It is possible that higher values of return loss could have been obtained in some cases had the pairs been measured against a network designed specifically

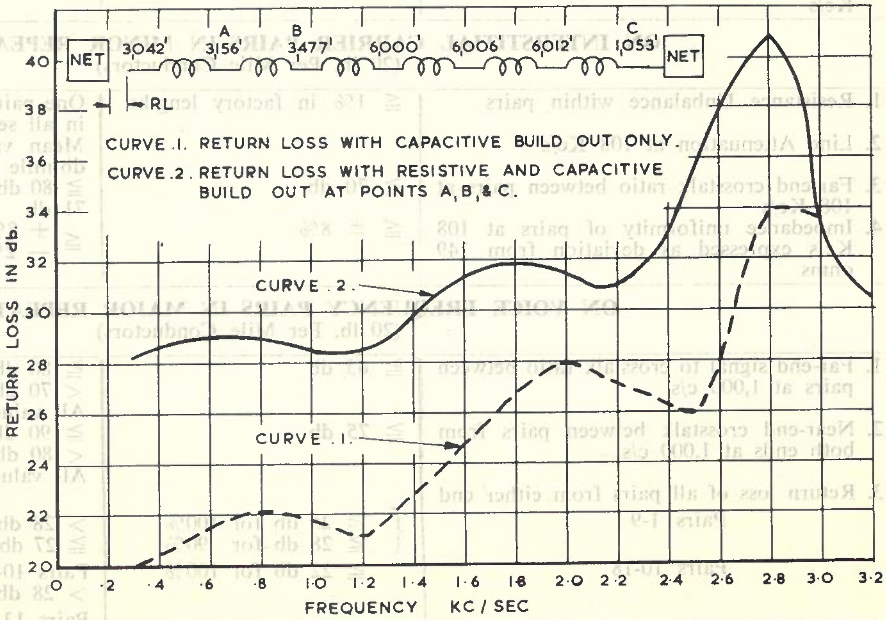

Fig. 8.—Illustrating the Improvement in Return Loss on Voice Frequency Pairs with Resistance Build Out of Loading Sections.

for that group as was permitted by the specification.

Insulation Resistance Specification

Problems were experienced in achieving the I.R. values specified for the installed cable, primarily because the specification for I.R. in factory lengths was the same as for the installed cable, namely 5,000 megohm miles. Little trouble occurred where the manufactured cable was much better than specified (of the order of two to three times); any deficiencies after laying could be overcome by passing dry air through the cable. However, where the manufactured cable was nearer to the specified limit this process was found to be inadequate. The structure of a coaxial cable is such that the air flow occurs through the tubes and interstices, and although low I.R. in the carrier pairs quickly disappeared, this was not the case with the core pairs. In addition the main air flow did not remove the pockets of moister air from the manometer housings or loading coil tails, in fact it is considered probable that it aggravated these conditions by forcing a quantity of the moister air from the proximity of joints into these by-ways. The only effective approach in these cases was to carry out cycles of pressurisation and release, preferably with dry nitrogen rather than dry air. This was expensive and time consuming and undoubtedly the preferable solution is for the manufactured cable to have a higher I.R. specification figure than that which it is desired to obtain on installation, and to take care during installation to prevent moisture ingress.

Location of Faults in Coaxial Tubes

It is natural during an installation project of this size that a large number of faults were discovered during testing operations. These were corrected as

TABLE I. SUMMARY OF TEST RESULTS ANALYSED FROM SYDNEY TO CANBERRA

Characteristic	Specification Figure	Results Achieved
ON COAXIAL TUBES IN MINOR REPEATER SECTION—AVERAGE LENGTH 5.33 MILES		
1. Resistance D.C. of Centre Conductor	5.22 ohms/mile nominal	Mean value 5.18 ohms/mile Range 5.08-5.36 ohms/mile
2. Resistance D.C. of Outer Conductor	3.50 ohms/mile nominal	Mean value 3.36 ohms/mile. Range 3.22-3.50 ohms/mile
3. Characteristic impedance at 2.5 Mc/s	75.0 ± 1.0 ohms	All tubes within specification
4. Uniformity of impedance as deviation from respective smooth curve from 60 Kc/s to 12 Mc/s	≦± 1.5%	All tubes within specification
5. Echo attenuation of 0.1 micro second pulse		
(a) Any single reflection without correction for attenuation	≧ 54 db	Arithmetic mean for all tubes in all sections, 60 db. 90% of all values better than 57 db. Worst value 53 db.
(b) R.M.S. of the three worst reflections after correction for attenuation	≧ 51 db	Arithmetic mean for all tubes in all sections, 56.5 db. 90% of all values better than 54 db. Worst value 51.5 db.
6. Line attenuation at 2.5 Mc/s	≦ 6.2 db/mile at 60°F.	Arithmetic mean for all tubes in all sections, 6.1 db/mile. Range of values over sections 5.9-6.2 db/mile.
7. Far-end signal to crosstalk ratio between tubes over frequency range 60 Kc/s to 12 Mc/s	≧ 90 db	Arithmetic mean for all tubes in all sections, 99 db. 90% of all values better than 98 db. Worst value 95 db.
8. Far-end crosstalk attenuation between tubes and carrier pairs at 60 and 108 Kc/s	—	See Fig. 15
9. Near-end crosstalk attenuation between tubes and carrier pairs at 60 and 108 Kc/s	—	See Fig. 15
ON INTERSTITIAL CARRIER PAIRS IN MINOR REPEATER SECTIONS (20 lb. Per Mile Conductors)		
1. Resistance Unbalance within pairs	≦ 1% in factory lengths	One pair in one section 0.48%. All other values in all sections ≦ 0.1%
2. Line Attenuation at 108 Kc/s	—	Mean value 5.42 db/mile. Range from 5.3-5.5 db/mile
3. Far-end crosstalk ratio between pairs at 108 Kc/s	≧ 70 db	≧ 80 db for 90% of all values. Minimum value 71 db
4. Impedance uniformity of pairs at 108 Kc/s expressed as deviation from 149 ohms	≦ ± 8%	$\leqq \begin{smallmatrix}+8\%\\-2\%\end{smallmatrix}$, or 153 ohms ± 5%
ON VOICE FREQUENCY PAIRS IN MAJOR REPEATER SECTIONS (20 lb. Per Mile Conductors)		
1. Far-end signal to crosstalk ratio between pairs at 1,000 c/s	≧ 65 db	≧ 80 db for 86% of the pairs < 70 db for 6% of the pairs All values in this 6% occurred in pair 10.
2. Near-end crosstalk between pairs from both ends at 1,000 c/s	≧ 75 db	≧ 90 db for 90% of the values < 80 db for 3% of the values All values in this 3% occurred in pair 10.
3. Return loss of all pairs from either end		
Pairs 1-9	{ ≧ 26 db for 100% ≧ 28 db for 90%	> 28 db for 98%. > 30 db for 70% ≧ 27 db for 100%.
Pairs 10-18	≧ 22 db for 100%	Pairs 10-12: > 28 db for 95% ≧ 27 db for 100% Pairs 13-18: > 25 db for 67% ≧ 22 db for 100%

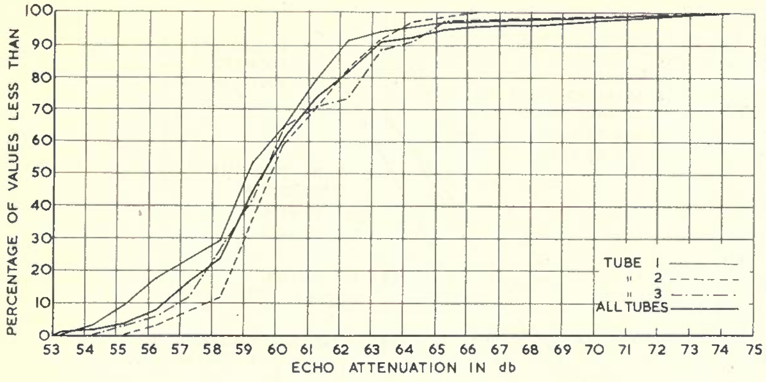

Fig. 9.—Distribution of Worst Uncorrected Values of Echo Attenuation in Minor Repeater Sections.

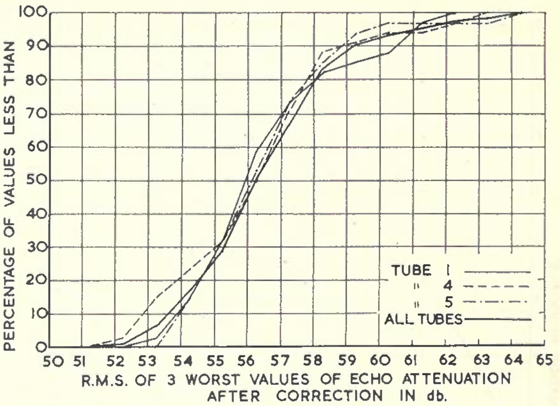

Fig. 10—Distribution of R.M.S.'s of Three Worst Values of Echo Attenuation after Correction in Minor Repeater Sections.

soon as possible to prevent dislocation of the progressive testing of the cable. Many faults were similar to those on normal paper pair cables, for example, short circuits, etc. The four main groups of faults and the methods of location employed are summarised below.

(a) **High Voltage Faults:** High voltage breakdowns in a length of cable present rather a difficult problem in accurate location of the fault. The instrument used was a special High Voltage Varley Bridge incorporating a current limiting device. A D.C. voltage is supplied to the bridge from a high voltage source and the voltage gradually increased until the faulty tube breaks down intermittently. The bridge is then balanced and the distance to the fault calculated.

(b) **Impedance Discontinuities:** These were located by the pulse echo tester and may occur due to mismatch at a joint, or due to damage during laying operations such as crushing or draw-down with hauling tension, or to deterioration at a previously existing unstable irregularity. The method of location is covered in the section on Pulse Testing.

(c) **D.C. Faults:** The most accurate method of locating a short circuit on a coaxial tube was found to be by a three wire test using conventional D.C. methods. Three measurements are required in this test involving the use of two good wires free of earth. The gauge of wire of these good conductors is not important. The pulse echo tester and tone type cable locator were also employed for locating these faults.

(d) **Open Circuit Faults:** These were located with the pulse echo tester or by a comparison of the mutual capacity of the tube with the mutual capacity of an adjacent good tube. This latter method, while not being very accurate, does give a measurement which can localise the position of the fault.

ANALYSIS OF TEST RESULTS

The testing of the whole project was not completed at the time of preparation of this article and it has not been possible to provide an analysis of all sections. As a result the analysis given is of the sections from Sydney to Canberra, approximately one third of the total. An analysis summary is shown in Table I.

The uniformity of coaxial tube impedance, as seen from the echo attenuation figures, was such that the two values below 54 db for the worst single reflection without attenuation correction in a minor repeater section were accepted without concern. In addition, because of matching difficulties, it may be inadvisable to attempt to eliminate one reflection just outside a specified limit by replacing a section of the cable, particularly where the other tubes do not contain marked reflections in the section to be replaced. If a section is replaced it is probable that all tubes would contain reflections, quite a number of which would be significant, at the joints at the ends of the replaced section, and that the total effect of these reflections would be worse than that initially pertaining even though individually none was outside the specified limit. Graphs of the distribution of recorded values for echo attenuation are shown in Figs. 9 and 10.

As mentioned earlier in the section on Testing Methods the measurements of impedance at various frequencies were not those of "absolute" value of the tube and Table I shows these characteristics as being simply "within specification". However, Fig. 11 shows the range of the values of impedance as measured in tubes and the degree of uniformity is apparent. Fig. 12 shows the distribution of the measured values

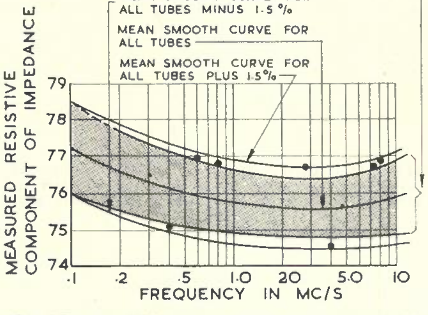

Fig. 11.—Limits of Impedance—Frequency as Measured on All Tubes in All Sections from Sydney to Canberra.

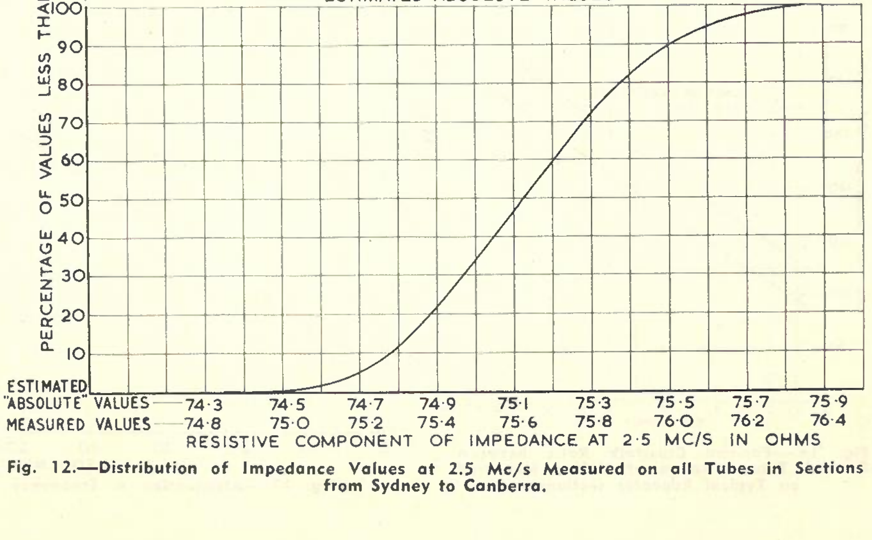

Fig. 12.—Distribution of Impedance Values at 2.5 Mc/s Measured on all Tubes in Sections from Sydney to Canberra.

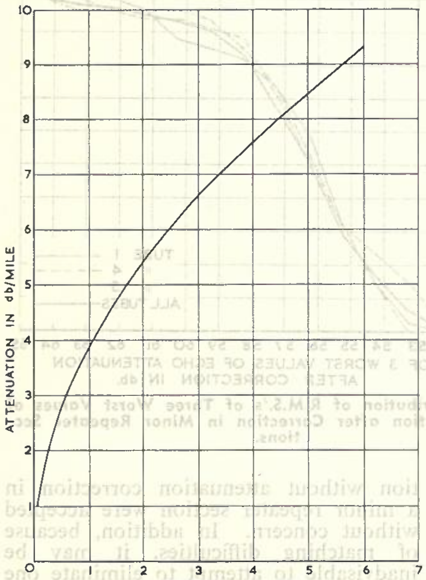

Fig. 13.—Average Value of Attenuation v. Frequency for Coaxial Tubes.

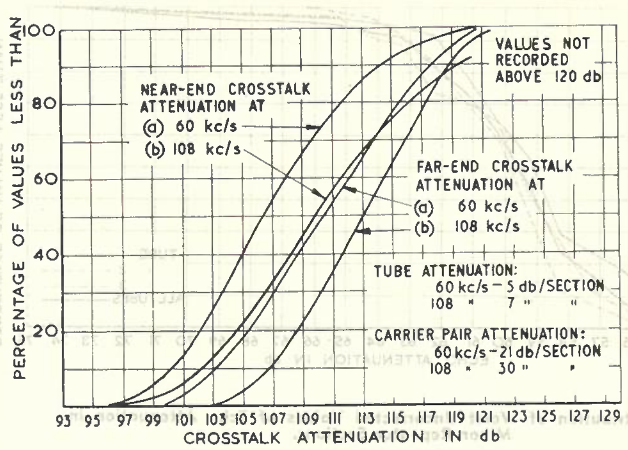

Fig. 15.—Crosstalk Attenuation between Coaxial Tubes and Carrier Pairs at 60 and 108 kc/s from Values Recorded between Goulburn and Canberra over Minor Repeater Sections.

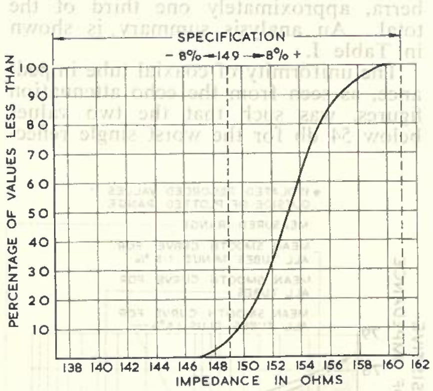

Fig. 16.—Distribution of All Values of Impedance at 108 kc/s on Carrier Pairs in Minor Repeater Sections between Sydney and Canberra.

of impedance at 2.5 Mc/s and correlates these with the estimated "absolute" values, assuming an 0.5 ohm difference at this frequency.

The range of values given for line attenuation of coaxial tubes is probably wider than the true value because of the limits of measuring accuracy at a particular frequency and the limits of accuracy of length measurements which were used to convert section measurements to the unit of "db per mile". The attenuation of all tubes in any one section at the selected frequency was always very uniform (within 0.15%) and it may be assumed that a greater uniformity than that shown actually exists between different sections. A curve of the attenuation-frequency characteristic of the coaxial tubes for this cable is shown in Fig. 13, and this may be taken as a more representative measure of the tube attenuation at different frequencies.

The far-end crosstalk ratio between tubes can be seen to be very much better than specification throughout the cable and throughout the frequency range. As mentioned earlier all of the values quoted occurred at the lower frequencies as measurements were not generally made above 500 Kc/s. The range of values measured on typical tubes in 5.5 mile repeater sections is shown in Fig. 14.

An examination of the far-end and near-end crosstalk attenuation of tubes to carrier pairs, as shown in Fig. 15, reveals that all pairs could be quite suitable for carrier operation. It should be noted that the far-end crosstalk shown is expressed as the crosstalk attenuation, that is the ratio of the power received on the disturbed circuit to the power sent on the disturbing circuit. All other values of far-end crosstalk in this analysis are the ratio of the power received on the disturbed circuit to the power received on the disturbing circuit.

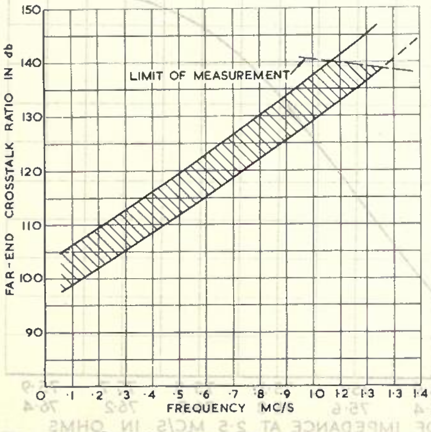

Fig. 14.—Far-end Crosstalk Ratio between Coaxial Tubes (Range of Values Measured on Typical Repeater sections).

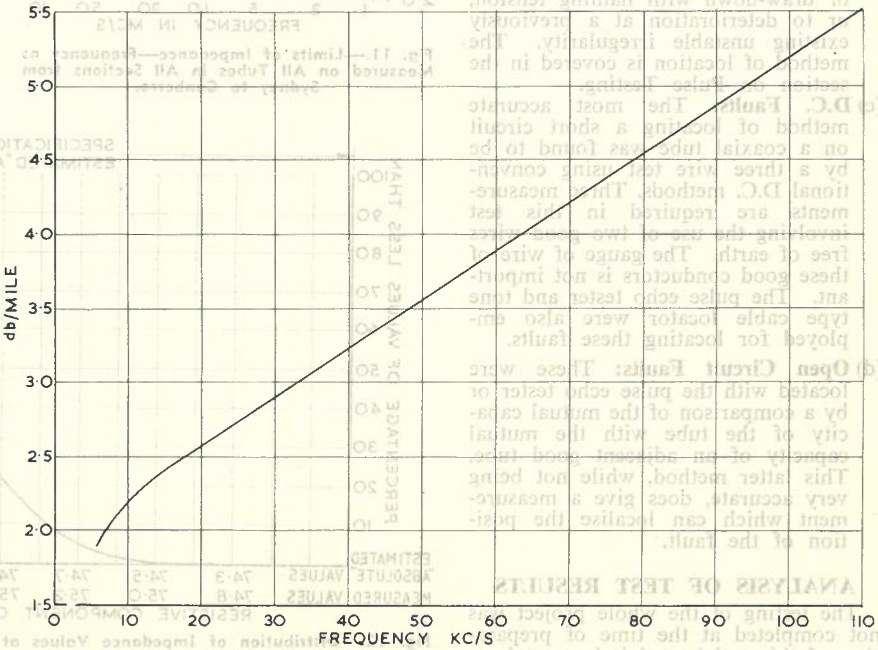

Fig. 17.—Attenuation v. Frequency of Carrier Pairs in Interstitial Quads.

This distinction has been made because of the different attenuation characteristics of the circuits and the different system levels concerned when dealing with crosstalk between coaxial tubes and carrier pairs. It is interesting to note that the values obtained for far-end were better than for near-end crosstalk attenuation.

For the carrier pairs in the outer interstices the characteristics were again much better than specification. It is probable that the isolated value of resistance unbalance which is greater than 0.1% is due to a field or factory joint. In the case of the impedance uniformity of pairs at 108 Kc/s, the range of values is well within limits and is shown in Fig. 16; the higher mean value arises from the mean mutual capacity of the pairs being lower than the specified nominal—this was an advantage rather than a disadvantage because it also resulted in a lower line attenuation figure. Fig. 17 shows the attenuation-frequency characteristic of a typical carrier pair. The values examined so far beyond Canberra have shown that the cable manufactured in Australia has an even lower mean mutual figure, and the repeater section specification for these sections has been amended to a nominal impedance of 156 ohms at 108 Kc/s rather than to increase the mutual capacitance. Here again the range is approximately ± 5%. The far-end crosstalk ratio achieved demonstrates the suitability of the method of carrier balancing employed and its application.

For the voice frequency pairs the values of crosstalk, which are very much better than specified, suggest that the limits of residual unbalance to which capacitance balancing was carried out were probably more stringent than actually necessary. The only values approaching the specification limit occurred in pair 10, the field order-wire pair which loops into all manometer housings along the route. The return loss values have been summarised in three groups because of alterations to the circuit layout in later stages of the contract. Initially interstitial pairs were to be loaded and used for supervisory purposes, but this was later changed to the loaded voice frequency pairs. The initial specification was relaxed on pairs 10-18 to a figure not worse than 22 db for 100% of the pairs. As can be seen the supervisory pairs 13-18, which terminated at minor repeater stations and contained extensive building out with the installation of rack-mounted loading coils, are the only pairs which failed to meet the initial specification. These pairs could have been improved by the inclusion of resistive build-outs, but this was not considered economically justified on these pairs. The problems associated with achieving the quality demonstrated by the results has been mentioned in preceding sections of this article.

It will be seen that the results recorded indicate a cable of uniformly high quality. Testing is almost completed on the remaining sections of the cable and the results so far recorded confirm that this quality will be applicable throughout the whole cable.

BUILDINGS

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INTRODUCTION

If you drive from Melbourne to Sydney along the Hume Highway, leaving it to pass through Culcairn and Wagga on the Olympic and Sturt Highways and Canberra via the Federal Highway, you will, if you are observant, notice what appear to be small "concrete block houses." These are the unattended repeater stations referred to in other articles in this series, and appear generally as shown in Fig. 1. When all reinstatement has been completed, they will form almost the only external visible evidence along the whole route that the coaxial cable has been provided. There is a total of 103 buildings in all, each accommodating the repeater equipment essential for the operation of the cable. This equipment is auxiliary to the main repeater equipment which is housed in communication buildings in the larger country centres and are referred to as main repeater stations.

Main repeaters are located at Campbelltown, Bowral, Goulburn, Yass, Gundagai, Wagga Wagga, Culcairn and Albury in New South Wales and Wangaratta, Benalla, Euroa and Seymour in Victoria. Terminal equipment is accommodated in existing exchange buildings in Sydney, Canberra, and Melbourne. The greatest distance between main repeater stations occurs from Yass to Gundagai and involves approximately 63 miles of cable and 11 unattended repeaters, and the shortest distance occurs between Wangaratta and Benalla, involving some 26 miles of cable and 4 unattended repeaters.

MAIN STATIONS

New buildings were required at most centres but in general it could be said that design of main station buildings presented few problems as they were similar in requirement to other communication buildings erected throughout Australia. They were all designed to accommodate local subscriber exchanges and other trunk line equipment as well as the coaxial cable equipment. Plan form consists of two equipment areas arranged either adjacent to one another or in two storeys with adjoining ancillary areas for power supply and air treatment plant. Amenities and office space are provided in the fronts of the buildings. In each building the coaxial cable main repeater equipment is accommodated in the common trunk line equipment room. There was, however, a new introduction to Australian communication building design in the provision of no-break and normally stationary diesel plant rooms which has in effect replaced the emergency power room requirements, and these rooms require a much higher degree of finish than was previously necessary in the old emergency power rooms.

In all cases the buildings were designed for normal solid masonry construction, and work commenced well in advance of the dates by which it was estimated that the cable-laying team would reach them. As cable laying commenced in Sydney and proceeded southwards, the buildings nearer to Sydney were in general commenced earlier than those situated further along the route. The buildings, or certain areas in the buildings, were required by predetermined dates for cable termination and equipment installation respectively. In all cases completion was effected on time although some problems were encountered during the progress of the work. This was to be expected in a project involving so many buildings and contractors and for which only comparatively short construction periods were available.

It was possible in a number of cases to provide the required cable equipment accommodation in extensions to existing buildings, and in the terminal buildings at City South, Sydney, and City West, Melbourne, and in the main repeater stations at Canberra internal alterations only were necessary. With these projects, too, similar problems associated with a shortage of construction time had to be overcome before the accommodation was made available on time.

Illustrated in Fig. 2 is the Campbelltown communication building, which is typical of the single-storied type erected on the route, and in Fig. 3 is the Bowral building.

UNATTENDED REPEATER STATION SITES

Sites had to be obtained very quickly for all but two of the 103 unattended buildings as selection was dependent upon the cable survey, and this left very little time between site availability and anticipated building operations. In fact, the contract for the buildings between Sydney and Albury was let before the site survey had been completed. In view of this the Department of the Interior, which is responsible for acquisition, took the precaution of obtaining permissive occupancy for all sites for which details were known in advance of site acquisition, to avoid the building contractor being held up for want of access.

The New South Wales and Victorian Branches of the Postmaster-General's Department carried through successfully a very tight programme of site selection and owner interviews. The respective Branch Offices of the Department of Interior quickly undertook and completed the necessary site survey work and formal acquisitions and leases.

UNATTENDED REPEATER BUILDINGS

The design and construction of the unattended buildings posed some problems for both Departments, and it is probable that no structure designed by the Department of Works for the Postmaster-General's Department has received such close technical co-ordination as these small but very important buildings. To ensure an end result which would under all physical and climatic conditions prove satisfactory for the housing and operation of the coaxial cable equipment, the various technical resources of both Departments were fully utilised. In this connection "thermal-electrical analogues" were used suc-

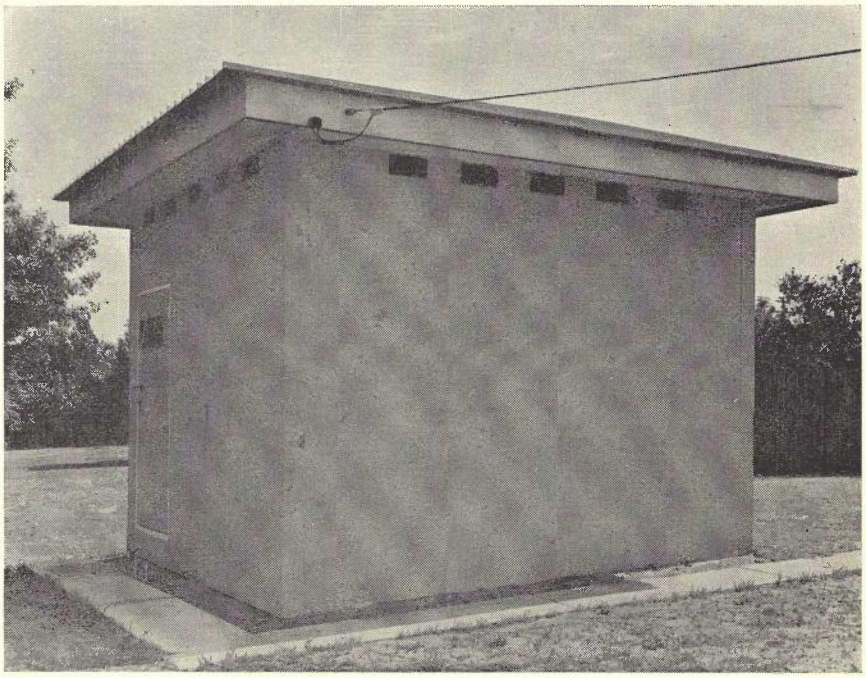

Fig. 1.—Typical Unattended Repeater Building.

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* See page 270.

cessfully in determining the degree of effectiveness that might be expected from the various materials and building structures and plan form of the basic design. The methods adopted in the use of these analogues were described in an article by Macdonald, Harnath and Tyrer which appeared in the February, 1961, issue of this Journal.

Once the route and the sites had been fixed by the Postmaster-General's Department, this information was provided to the Department of Works and a detailed survey of each site was then undertaken with the objective of determining in particular the nature of the ground in relation to foundation design, local flood levels and local conditions generally, and conditions of entry to the site for the building materials.

The brief prepared by the Postmaster-General's Department to cover the design of the buildings provided, inter alia, that the "buildings should provide the maximum of security from vandalism, fire, flood and dust and should require the minimum of maintenance . . . and reasonable temperature stability." Good thermal characteristics and behaviour of the buildings was a matter of major importance and design was directed towards achieving this. The maximum allowable temperature for the air inside the building was set at 115 degrees F. This figure was based on equipment performance guarantees of some manufacturers and was to apply even with 600 watts of heat being generated continuously by repeater equipment for a fully equipped six-tube cable. With regard to temperature stability, it was decided to adopt as the design objective for the building a maximum variation of 7 degrees F. over an extreme 10-day cycle or roughly a maximum variation of 3 degrees F. over an extreme daily cycle.

The buildings were required to be constructed ahead of the cable laying and it was therefore important that contractual arrangements for their erection should be such as to ensure that there would be no weak spots in the construction chain. In view of this it was decided by the Department of Works to adopt prefabrication design techniques and to formulate a contract which would require both prefabrication and construction to be undertaken as one single contract.

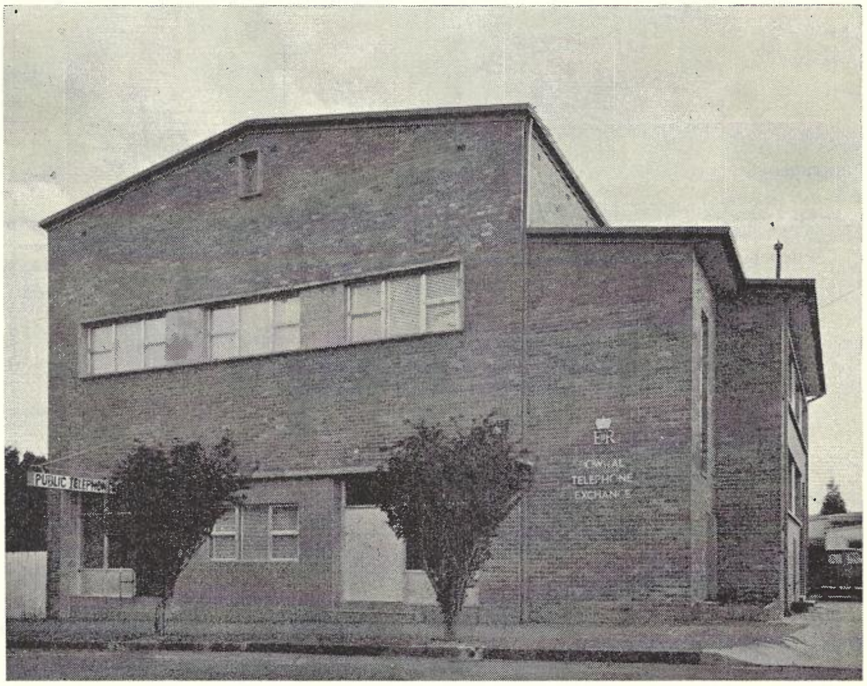

Fig. 3.—Bowral Communication Building.

During the early stages of the design, consultation took place with a firm specialising in the manufacture of concrete products. Consultation took place with the view to ascertaining the general potential of that type of industry to handle such a project and to assess design and construction limitations. These discussions proved to be quite valuable. Discussions on design and expected performance characteristics also took place on many subsequent occasions between relevant officers of both Departments, at Head Office and at Branch levels.

Subsequently, a point was reached at which design factors became more fully established and it was possible to have prepared a preliminary design which enabled further study being undertaken in regard to the thermal capacity likely to be achieved (in this connection the work done with thermal electrical analogues was of considerable assistance) and general suitability for housing of the coaxial cable repeater equipment.

At this stage further consultations took place between the Departments enabling the design to be firmly settled and a decision reached that any contractual arrangements entered into would be on the basis, as previously mentioned, of supply and erection of the component parts as one single contract.

Tenders were invited and subsequently a contract was entered into by the Department of Works with Concrete Industries Ltd., of Sydney, for the buildings required between Sydney and Albury. This firm was subsequently also successful in obtaining a contract for the provision of identical buildings between Albury and Melbourne, and later between Brisbane-Southport and Tweed Heads-Lismore.

The buildings are 14 feet by 12 feet outside dimensions with an internal floor to ceiling height of 8 feet. They have a lobby-type entry arrangement in one corner with two heavy steel-clad doors. The lobby was designed to minimise the change of air inside the building during staff entry and to act as a dust trap for air ventilated through the lobby vents. The ventilator in the outside door was for this reason placed high towards the door head and the internal door ventilator in the lower part of the door. The buildings are orientated to face south or south of east to exclude or minimise the amount of sunlight that could enter through the lobby into the equipment space if both doors happen to be left open by visiting

Fig. 2.—Campbelltown Communication Building.

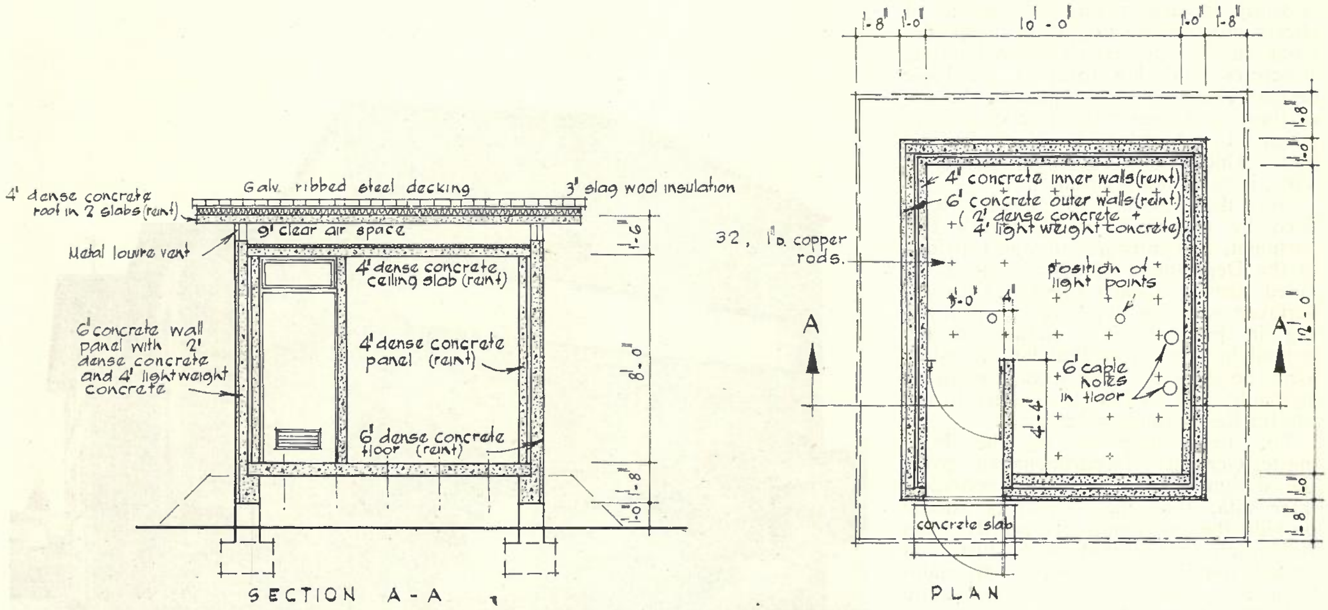

Fig. 4.—Sydney-Melbourne Unattended Building Design.

maintenance staff. Fig 4 illustrates the building design.

Construction consists of a number of prefabricated units comprising the floor, walls and roof. The roof is covered with galvanised ribbed steel decking over 3 inch insulation placed on top of the concrete roof slab. A 1 inch layer of glass wool insulation is provided also over the ceiling. In order to achieve the required temperature level within the structure, a free air space is provided between the ceiling slab and the roof slab, both of which are 4 inches thick and consist of high-density concrete. The walls are constructed of two separate inner and outer leaves with an air space between. The outer leaf consists of a 6 inch composite high and low-density concrete with reinforcing located in the high-density section, and the inside leaf consists of a 4 inch reinforced high-density concrete slab. All panels are mastic jointed at all intersections and are held together with galvanised iron bolts. The buildings are supported on pre-cast concrete piers set on a foundation of concrete poured in situ and of a size necessary to conform to the bearing capacity of the ground at each site. Height of the floors of the buildings above ground level was determined for each particular site and pre-cast concrete piers of required height were used. For some sites it was found necessary to raise the buildings above local flood levels and where this was done a perimeter wall was constructed to support the buildings in place of the piers. A typical building of this type is shown in Fig. 5. On normal sites an earth bank surrounds the building and consolidated earth under the floor slab provides contact with natural ground. In order to dissipate the heat from the repeater equipment 32 1 inch diameter 4 feet 10 inches long copper rods are provided and these pass through the floor slab and into the ground below. These rods were dispensed with in those buildings in which the floor levels are 4 feet above ground level and these have solid surrounding walls which serve the same purpose of dissipating internal heat from the structure. The under side of the floor slab is coated with hot bitumen ⅛ inch thick. This was applied to the upper surface of the floor slabs after setting in the moulds, the surface in contact with the mould forming the eventual upper surface of the floor.

Fig. 5.—Unattended Building in Area Subject to Flooding.

Provision has been made in the buildings to enable electricity supply to be connected where this is available.

The Contractor was required to erect a prototype building which was inspected and approved before he was permitted to proceed with his bulk prefabrication. The prototype offered both Departments the opportunity of close scrutiny with the objective of ensuring that all design and technical requirements were satisfactory. A further contractual condition was the completion of six buildings per month, and this rate was not only successfully maintained but considerably improved upon with the result that the buildings were completed well ahead of cable laying. Towards the end of the project the buildings were being completed at the rate of two a week and even faster over the last few weeks.

CONSTRUCTION

The order of construction consisted of pouring the foundations (Fig. 6) followed by the placing of four corner columns and then the assembly of the outside leaves (Fig. 7). The floor was then lowered down between the walls until it rested on the beam section of the external wall leaf (Fig. 8). The internal leaves which were shorter than the external walls were then lowered and placed in position (Fig. 9) and the ceiling slab seated on them (Fig. 10). The first layer of glass wool insulation was placed, and the roof slabs were then seated on the external leaves (Fig. 11) leaving 9 inch air space between the insulation and the ceiling slab. Finally, the roof was covered with 3 inches of glass wool insulation and the heavy gauge hot dipped galvanised steel deck and the doors, etc., fitted.

The project was constantly under supervision by the staffs of the Directors of Works, New South Wales, and Victoria, in their respective States. Construction proceeded most satisfactorily and was indicative of the general contractual arrangement.

Equipment is at present being installed in the buildings and recording tests are being carried out to determine the thermal efficiency of the buildings. To date, these tests have indicated that the buildings will in fact behave as the designers expected and as predicted by the thermal-electrical analogue test results.

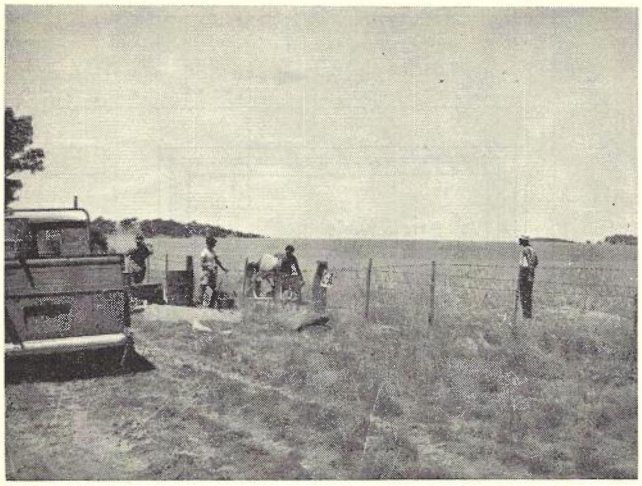

Fig. 6.—Pouring Concrete Footings on Normal Level Site (Table Top).

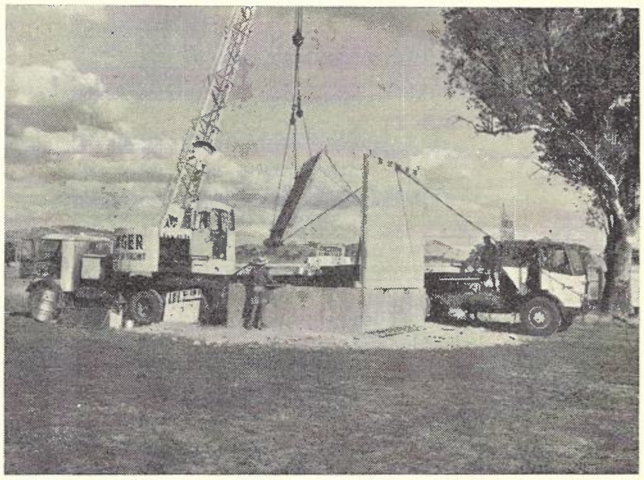

Fig. 7.—Erection of Second External Wall Unit on a Raised Site (Willie Ploma).

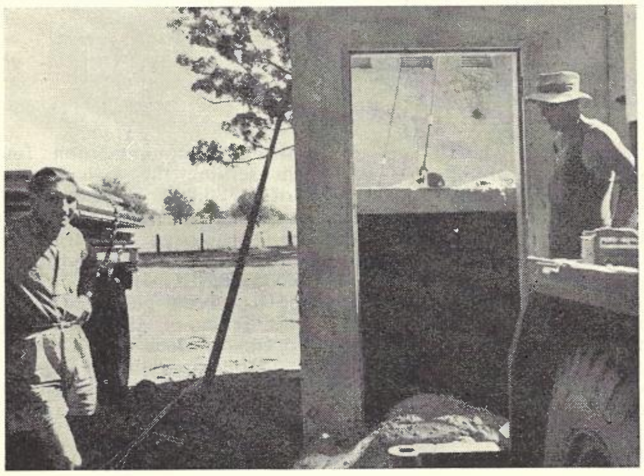

Fig. 8.—Lowering Floor Unit Into Position.

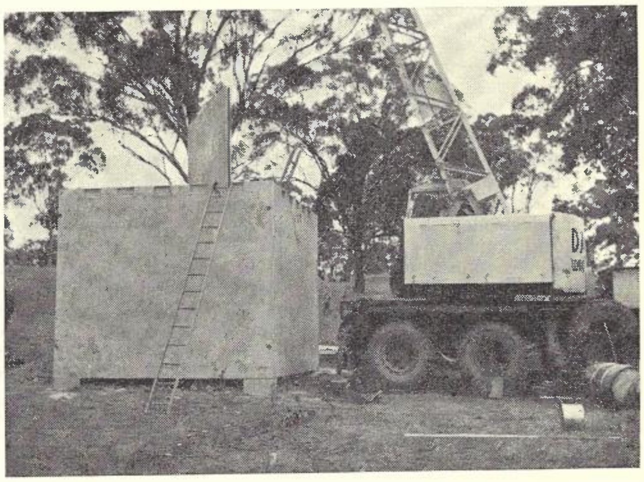

Fig. 9.—Lowering Internal Wall Unit Into Position (Nanima).

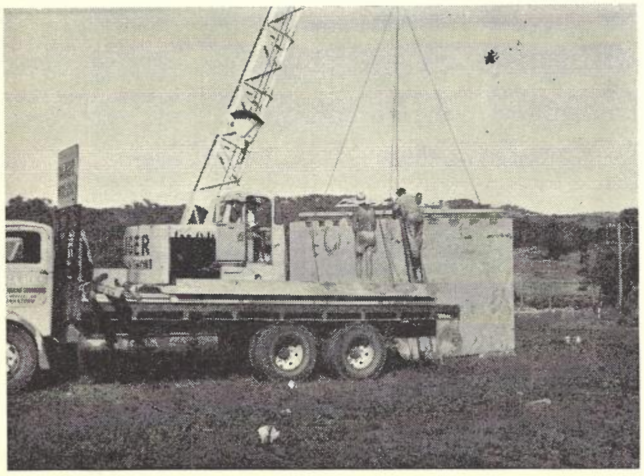

Fig. 10.—Placing Ceiling Section Into Position (Connors Creek).

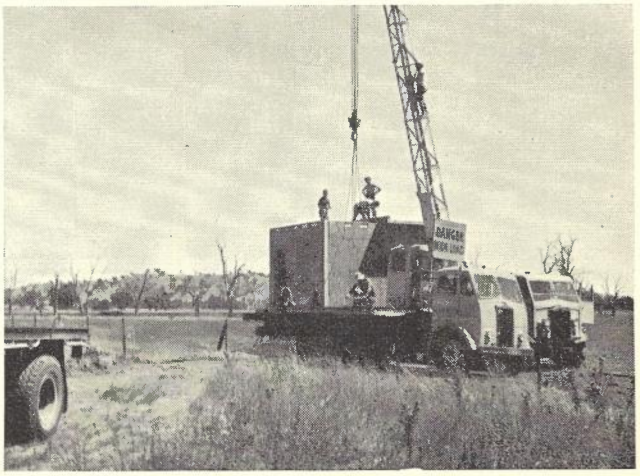

Fig. 11.—Placing First Section of Roof Unit Into Position (Willie Ploma).

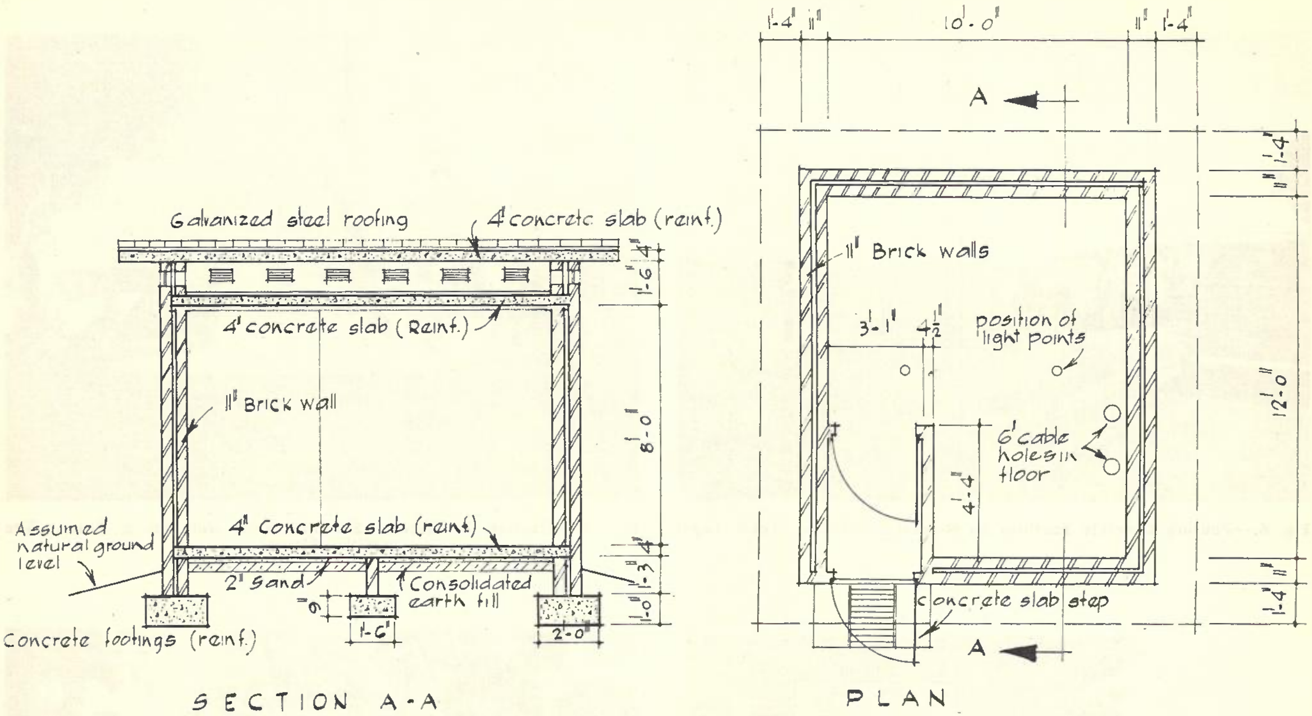

Fig. 12.—Design for Alternative Brick Building.

Subsequently, an alternative design was prepared by the Director of Works, Victoria, which specifically caters for short routes such as the Dandenong-Frankston-Dromana system, for which it would be uneconomical to set up construction equipment for the precasting of heavy concrete units which proved so satisfactory for the longer systems. This design, illustrated in Fig. 12, is basically the same as for the Sydney-Melbourne building, differing mainly in floor construction which consists of a slab and foundations poured in situ and in the wall material which is of brick. On site construction work is mainly "wet" including roof and ceiling slabs and takes much longer than the prefabricated building to erect, which tends to render it unsuitable for construction on long routes in which strict scheduling is required. However, it is expected that thermal characteristics will prove to be much the same as those of the Sydney-Melbourne building.

The Sydney-Melbourne unattended buildings were erected at a cost of approximately £2,000 each and the overall cost of providing accommodation for all equipment serving the system was in the order of £380,000. The Commonwealth Department of Works was responsible for the design, construction and supervision of all building projects.

ACKNOWLEDGMENTS

This paper has been published with the kind permission of the Director-General, Postmaster-General's Department and the Director-General, Department of Works. The authors wish to thank all those concerned with the project for their ready assistance.

GENERAL FEATURES OF TELEPHONE TRANSMISSION EQUIPMENT

*N. M. MACDONALD, B.Sc., M.I.E.Aust.**

INTRODUCTION

From the viewpoint of an administration concerned with the operation of a trunk telephone network, the main purpose in providing a coaxial cable system is to obtain relatively large quantities of reliable communication circuits, which will enable traffic demands on the route to be met readily and which can be operated economically. This general objective dictated the main technical requirements of the transmission equipment for the Sydney-Melbourne project. There were, however, other important considerations. In particular, as this was the largest coaxial cable installation likely to be undertaken in Australia, and would be the fore-runner of many similar projects, it would largely set the technical standards for the whole future trunk network. It was therefore most desirable that the transmission equipment as well as the cable should be of an advanced design and could be expected to remain in service for many years without becoming obsolete. It was also essential that the system should be flexible and readily extendible to meet future growth. Considerable emphasis was given to the reliability of the system as for some years it was expected to carry the main traffic on the route without backing by another parallel broadband system.

It is the purpose of this article to give a brief outline of the main technical requirements of the Sydney-Melbourne cable telephone and broadcast programme transmission equipment and its integration with other trunk line plant. Further information on the installation of the equipment and some of its interesting design features is given in other articles in this issue, and detailed aspects of television transmission equipment, the actual performance of the system, and maintenance, will be covered in later issues.

EQUIPMENT CONTRACT

As the Sydney-Melbourne project involved a considerable capital expenditure, and the type of plant was new to the Australian network, it was natural that the Postmaster-General's Department was anxious to make certain that all channels furnished would be of the desired technical standard, and that the work would be completed and revenue produced in the minimum time practicable. The contract for the transmission equipment and power plant was placed with Telecommunication Company of Australia in such a way that the contractor carried the full responsibility for the technical performance of the whole system and for its completion on time, and gave adequate guarantees to the Department in these respects. These guarantees were of necessity made subject to the cable itself being supplied and installed to the mutual satisfaction of the equipment contractor and the Department, and to the Department providing on time certain other essential items such as building accommodation. As indicated in the article by Mr. Kaye in this issue, the design and manufacture of the transmission equipment was undertaken mainly by Felten and Guilleaume Fernmeldeanlagen G.m.b.H. of West Germany and the supply and installation of the power plant by McColl Electric Works Ltd. as sub-contractors to Telecommunication Company of Australia. Nevertheless, the latter company as contractor carried the full responsibility for all this equipment as far as the Department was concerned.

The technical requirements of the equipment contract were concerned primarily with safeguarding the performance of the individual circuits derived from the cable, although important aspects of the general system design were also covered. The transmission equipment was designed primarily to meet the recommendations of the International Telegraph and Telephone Consultative Committee (C.C.I.T.T.) and these recommendations were used as contract specifications for much of the equipment. However, it was still necessary to cover separately a number of other requirements related mainly to the integration of the system with other items of Departmental plant, to performance aspects for which no C.C.I.T.T. recommendations existed, and to instances where some tightening of C.C.I.T.T. limits was practicable and desirable in the interest of securing the most modern design. The contract specifications in these instances were determined jointly by the contractor and the Department. The contractor was given the maximum freedom practicable in the general design of the system, and certain design aspects were also not covered firmly in the contract, but rather determined informally by joint discussion.

CIRCUIT QUANTITIES

An indication of the quantities of main circuits involved on the route was given in the article by Mr. McDuffie on the telecommunications aspects of the cable, which appears in this issue. The quantities of equipment units to be supplied on the main contract were sufficient to meet the requirements at 1967 (five years after the average expected date of completion) as estimated at the time the contract was placed in June, 1959. Since that time, however, the estimates of future traffic have been increased to take into account developments in subscriber dialling along the route, and the channels being provided under the contract are now expected to meet requirements for only a few years after provision. The main contract will not be varied to meet the increased requirements, but additional equipment will be added to the system by the Department as required. The quantities of main telephone circuits to be provided initially are summarised in Table I. A relatively large number of 2-way carrier broadcast programme circuits is also to be provided and the quantities of these are shown also in Table I.

Details are given in the article by Mr. Sinnatt, in this issue, of the locations and sizes of separate voice-frequency cables laid for minor trunk purposes. Most of the circuits provided by the loaded pairs in these separate cables, and from the paper-insulated loaded pairs included in the main coaxial cable, will be operated as two-wire unamplified circuits, but some will be amplified four-wire and others two-wire using negative-impedance repeaters. Table II shows the numbers of circuits being provided initially in each category.

In addition to the circuits to be provided on the coaxial tubes and on the voice-frequency pairs, a relatively small quantity are being provided using 12-channel two-wire carrier systems which will operate on the interstice or core pairs in the main cable over certain sections of the route. These systems are being provided separately by the Department under its normal works programme.

TABLE I — MAIN THROUGH CARRIER CIRCUITS

Through Circuits	Facilities Provided Between Terminal Stations			
	Total Supergroups (Capacity 60 Channels)	Total Groups (Capacity 12 Channels)	Telephone Circuits	Programme Circuits
Sydney-Melbourne	5	23	252	8
Sydney-Canberra	3	12	126	6
Canberra-Melbourne	1	4	48	—
Sydney-Campbelltown	1	5	60	—
Sydney-Wagga	2	9	99	3
Albury-Melbourne	1	3	36	—
Wagga-Albury-Melbourne	1	3	33	1
Multi-office (See Note 1)	2	44	513	5

Note 1: These circuits are to be provided on Supergroups 1 and 2 between the various main repeater stations. Some of the groups involved are through-connected to other groups in the cable.

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

TABLE II — VOICE-FREQUENCY CIRCUITS

Circuit Category	Total Number of Circuits
Two-wire Unamplified	312 (See Note 1)
Two-wire Amplified	86
Four-wire Amplified	70

Note 1: The figure shown covers quantities included in the contract only. The Department is also placing in service several hundred additional voice-frequency circuits in the separate minor trunk cables.

TECHNICAL REQUIREMENTS OF COAXIAL TELEPHONE CIRCUITS

General

As indicated previously, the general design of the system was based largely on C.C.I.T.T. recommendations and the performance of individual circuits will follow these recommendations as a minimum requirement. A brief summary is given in the following paragraphs of the more important requirements of the individual circuits and the reasons for supplementing the C.C.I.T.T. recommendations where this was done.

C.C.I.T.T. Recommendations

The recommendations of the C.C.I.T.T. are evolved by a process of continuous review having regard to needs made apparent by the experience of operating and manufacturing organisations, to the state of technical development which progresses continually, and to the state of development of the various international networks. In order to enable the equipment design to be finalised quickly, the contract specified that the relevant recommendations were those applying at the end of 1958. The more important of these were:—

Circuit Noise: The general noise objective for long distance circuits up to 2,500 km or 1,600 miles in length which can form part of an international connection, is that the total circuit noise (including non-linear crosstalk) measured by a C.C.I.T.T. psophometer at the end of the circuit should not exceed an average value corresponding to a psophometric e.m.f. of 2 millivolts, measured at a point of relative level of —7 db. This value corresponds to about 10,000 picowatts or —50 dbm (weighted) at a zero relative level point. To enable the design of a 4 Mc/s coaxial cable system to proceed, a hypothetical reference circuit shown in Fig. 1 has been established, and as a design objective, the total noise of 10,000 picowatts is allocated 2,500 picowatts to the terminal and modulating equipments, and 7,500 picowatts to the high frequency line. The high frequency line noise includes intermodulation noise. In general the noise contributed by the different repeater sections of the cable adds on a power basis although certain odd order intermodulation products tend to add over a number of sections on a voltage addition basis. To take into account this last factor, the noise contributed in any circuit by the high frequency line, including repeaters, should be less than 3 picowatts per kilometer or 4.7 picowatts per mile. The noise produced in the terminal and modulating equipment due to various causes (thermal noise, intermodulation, crosstalk, power supplies, etc.) has been allocated, as a guide, as shown in Table III.

TABLE III — ALLOCATION OF NOISE PRODUCED BY MODULATING EQUIPMENT

Equipment Items	Noise
1 Pair of Channel Modulators	200-400 pW
1 Pair of Group Modulators	60-100 pW
1 Pair of Supergroup Modulators	60-100 pW

From this information, the maximum value of the mean noise can be calculated for any circuit in a 4 Mc/s coaxial cable system if the circuit length and the numbers of the different types of modulating equipment included in it are known. These values apply in the contract as limits for any circuit over 125 miles in length and located in the line frequency band below 4 Mc/s. The other circuits are subject to other considerations and will be dealt with in a later paragraph.

Other Characteristics: These characteristics are summarised in Table IV.

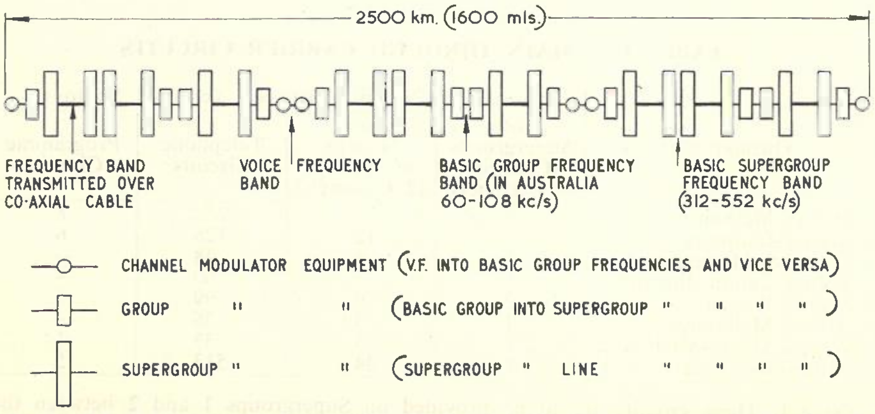

Fig. 1.—C.C.I.T.T. Hypothetical Reference Circuit for a 4Mc/s Coaxial System. This Circuit Includes Three Pairs of Channel Modulators, Six Pairs of Group Modulators and Nine Pairs of Supergroup Modulators in the 1,600 Mile Link.

Other Contract Requirements

Circuit Noise: For circuits in the 5 supergroups located in the line frequency range between 4 Mc/s and 6 Mc/s, no C.C.I.T.T. recommendation exists. Circuits in this range are in effect "bonus" circuits obtained by the use of 6 Mc/s line equipment and in the Sydney-Melbourne cable can be used readily in the future for additional short distance requirements, for example between Sydney and Canberra. Because the basic design of the 6 Mc/s system was determined mainly by requirements for television transmission, repeater spacings are very similar to those of a 4 Mc/s system for telephony and the noise performance of the higher frequency circuits cannot be expected to be as good as that of the circuits in the lower range. The degradation expected is of the order of 4 db compared with a normal circuit. The objective agreed to was that a circuit 620 miles in length (the Sydney-Melbourne route length) would give the same performance as the C.C.I.T.T. reference circuit. In practice this would result in the worst Sydney-Canberra circuit having a mean weighted noise level of about —54 dbm at a zero relative level point, which should be quite satisfactory.

For circuits less than 125 miles in length, the noise is controlled mainly by crosstalk in the channel modulator equipment and the normal Departmental noise specification, established some years ago, is for a limit of —60 dbm which should not be exceeded for more than 1% of the time. This type of specification is more applicable to small groups of circuits and is desirable on the Sydney-Melbourne cable as a number of the short distance groups will be extended on small capacity spur systems. It was agreed to for all circuits less than 125 miles in length which are located in the frequency range below 4 Mc/s.

Frequency Response: The frequency response or attenuation/frequency distortion limits recommended by the C.C.I.T.T. for an international circuit are shown in Fig. 2. These limits have been established for many years and are somewhat generous for modern equipment. The C.C.I.T.T. have recognised this and recommended recently that the limits should be made more stringent; the question is at present under active investigation and is complicated by the number of channel modulator equipments, through group filters, etc., in a given circuit. Moreover, with the expansion of the international network at present taking place as a result of the development of intercontinental submarine cables, the numbers of links connected in tandem in long distance connections are increasing, and an improvement in the frequency response of individual circuits

TABLE IV — MISCELLANEOUS CIRCUIT CHARACTERISTICS COVERED BY C.C.I.T.T. RECOMMENDATIONS

Characteristic	Limit for Overall Circuit
Group delay (t)	t ≤ 150 ms and preferably ≤ 100 ms
Phase distortion (relative to the group delay, t)	tm —tmin ≤ 20 ms, tM — tmin ≤ 10 ms where m = nominal minimum frequency transmitted and M = nominal maximum frequency transmitted.
Maximum variation of equivalent with time	± 1.74 db.
Frequency difference at two ends of a circuit	≤ 2 c/s.

is most desirable. The contract limits determined finally for the Sydney-Melbourne route are shown also in Fig. 2. In addition to the limits for the overall circuits, other more stringent limits were placed on individual equipment units such as channel modulator equipments; these limits were based mainly on German Post Office specifications.

Overall Equivalents: The overall nominal equivalents of the circuits, switchboard to switchboard, were specified in the contract, but have since been varied slightly as a result of finalisation of the general transmission plan for the Commonwealth. The new values and the reasons for their adoption have been described in a previous article in this Journal (1).

Circuit Terminations: Typical terminating arrangements for the circuits are shown in Fig. 3. The fixed reference levels of —13 db and +4 db respectively at the modulator input and demodulator output points are the standard Australian levels which were determined many years ago when earlier types of equipment of Bell System design predominated in the Australian network. These levels have been retained despite later changes to the American standards and other developments overseas, since distances between carrier terminal stations and trunk exchanges are short in Australia and the levels in use allow an adequate margin for losses in four-wire cable extensions. The use of the standard reference levels at the four-wire points has a number of advantages, particularly for maintenance and in allowing losses in signalling and switching equipment, cabling, etc., to be compensated for while still retaining a uniform arrangement. Fig. 3 shows, in addition to the facilities used with two-wire and tail-eating switching, those which will apply when crossbar exchanges with true four-wire switching are introduced shortly.

When tenders for the Sydney-Melbourne equipment were invited, the standard terminating arrangement for all except very small offices, included centralised "V.F. Test and Mon." four wire test boards, located in carrier terminal offices at the modulator input and demodulator output points and used for channel line-up and patching purposes. However, as the channel modulator racks offered by the contractor provided similar and reasonably concentrated facilities, and new offices were also required at all stations, they are not now being used on the Sydney-Melbourne and other similar installations. A brief description of the signalling equipment will be given in a later paragraph. It should also be mentioned that the arrangements for adjusting transmission levels in the terminations, which allow for 3 db switching pads or their equivalent to be in circuit when the adjustments are made, were determined only after an investigation had been made of the speech levels at Australian trunk switchboards (2); the actual speech levels in the carrier equipment with the arrangements shown are still below the nominal loading levels recommended by the C.C.I.T.T.

An important requirement, from the viewpoint of echo and stability in the trunk network with two-wire switched connections, is the return loss at the ends of the two-wire circuits. From the viewpoint of the contract, the end of each circuit was the first distribution frame on the exchange side of the 2/4-wire terminating set, and the minimum return loss specified at this point was 22 db in the frequency range 500-2,400 c/s, 18 db in the range 400-3,000 c/s and 14 db in the range 300-3,400 c/s when the distant end of the circuit was terminated at the two-wire point in 600 ohms plus 2 microfarads.

Non-Linear Distortion: The harmonic distortion of a circuit is not covered by C.C.I.T.T. recommendations, and the C.C.I.T.T. limit recommended for the variation of equivalent as a function of absolute power level on the circuit allows limiting at a somewhat lower value than is generally achievable in practice. The limits specified in the contract are shown in Table V.

Unwanted Modulation Products: Modulation products in the frequency range above 4 kc/s appear at the

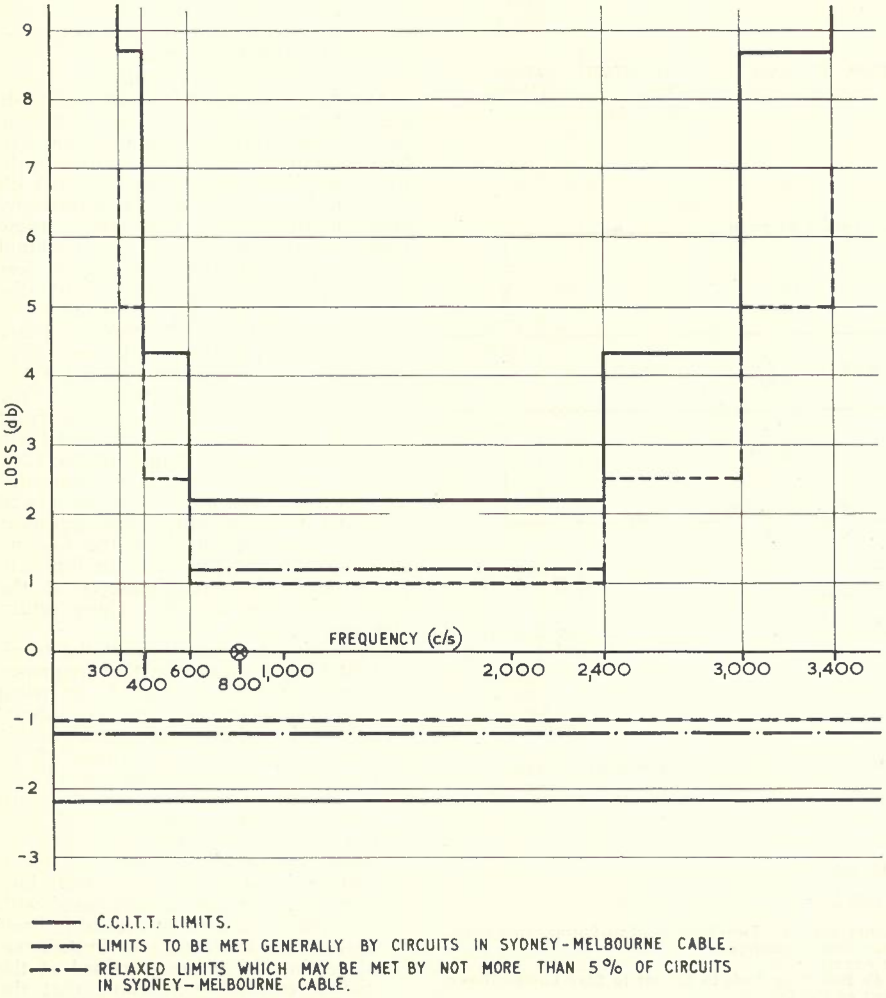

Fig. 2.—Limits for Variation, as a Function of Frequency, of Equivalent of Telephone Circuits with respect to Value at 800 c/s. The Limits for the Sydney-Melbourne Circuits shown Exclude the Measured Effects of Group Modulating Equipment and Group Connecting filters at Intermediate Stations.

demodulator outputs, and if they are not suppressed sufficiently can produce interference in other carrier circuits to which they are switched, particularly if the modulation scheme is different for the two circuits. This aspect was investigated with the contractor, and although no limits were set under the contract, the performance will be satisfactory except in a few unusual circumstances when corrective action will be taken by making slight modifications to the carrier circuits not associated with the Sydney-Melbourne route.

TECHNICAL REQUIREMENTS OF VOICE-FREQUENCY CIRCUITS

Four-Wire Circuits

The four-wire voice-frequency circuits are used only between trunk switching centres, and where pad switching or equivalent facilities are installed, will have a nominal overall equivalent of 0 db. The technical requirements for these circuits are identical with those of the shorter coaxial telephone circuits (below 125 miles in length) except the frequency response limit applying is the higher quality limit shown in Fig. 2. This should be achievable without difficulty with the loading arrangements described in other articles in this Journal, since the length of any circuit is limited to about 35 miles.

Two-wire Circuits

The two-wire voice-frequency circuits are used only between trunk switching centres and terminal exchanges, and will have a nominal equivalent of 3 to 6 db for unamplified circuits and 3 to 5 db for circuits which are amplified by negative-impedance repeaters; these repeaters are located at the terminal exchanges to improve the return loss at the trunk centres. Very short distance circuits are built out to the minimum loss of 3 db. Transformers are also provided at the trunk centres to give a nominal impedance of 600 ohms.

The technical requirements of the two-wire circuits differ somewhat from those of the four-wire circuits, the main differences being the limitation to 3,200 c/s of the frequency band transmitted, because of difficulties associated with the negative impedance repeaters in the region approaching the loading cut-off point, and the need for limits to cover return loss requirements at the trunk switching centres. These return loss requirements are:—

(i) A minimum return loss at the trunk switching centre over the frequency range 300-3,000 c/s of 5 db when the distant end is open or short-circuited. This requirement mainly ensures the proper adjustment of the negative impedance repeater.

(ii) A maximum degradation of return loss at the trunk centre of 2 db over the frequency range 500-2,500 c/s when measured through the terminating transformer against 600 ohms plus 2 microfarads as compared with the value measured at the cable itself against its characteristic impedance, a termination being provided at the distant end of such value that the return losses are of the order of 10 db. This requirement ensures mainly the proper matching arrangements at the trunk centre.

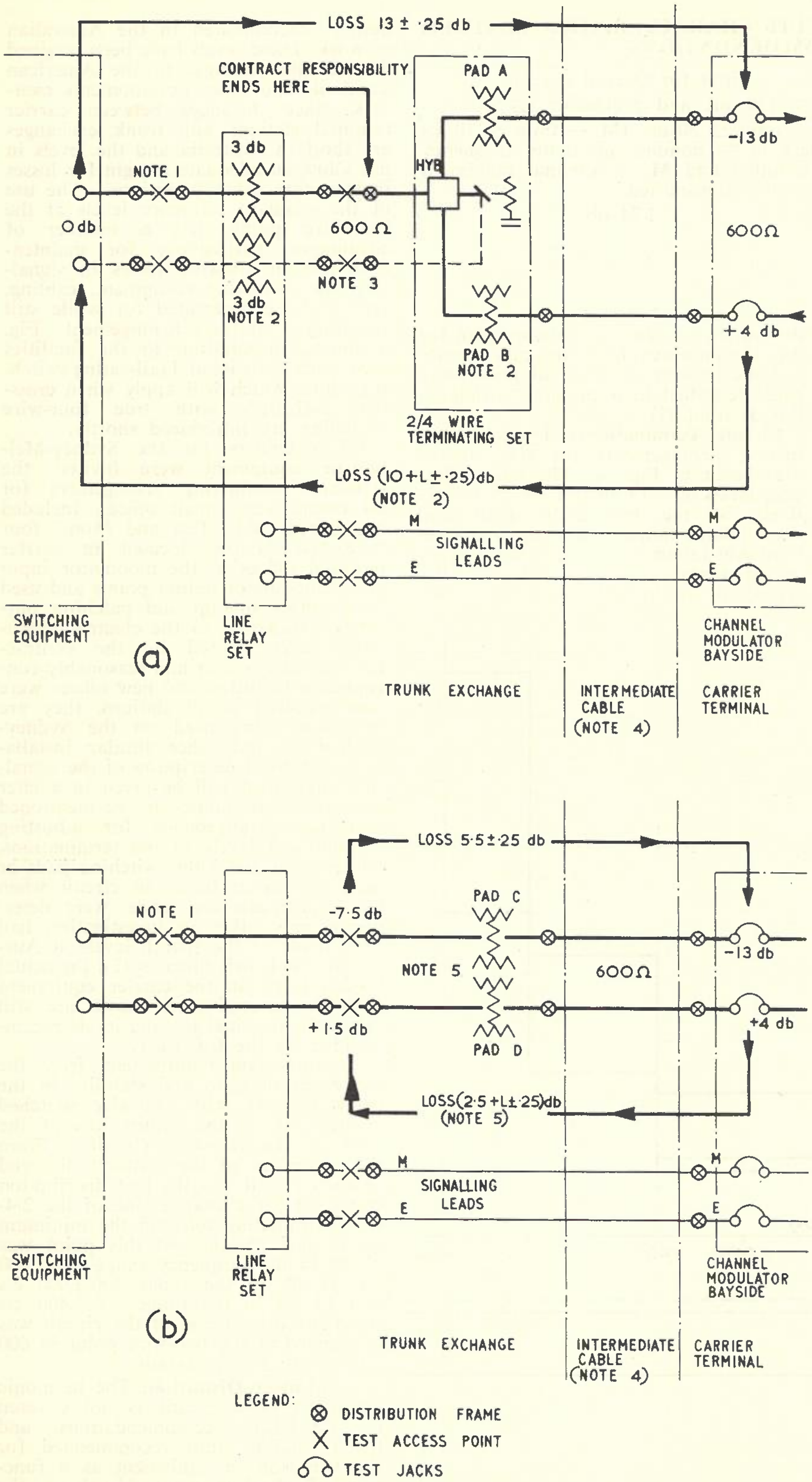

Fig. 3.—Typical Circuit Terminating Arrangements for (a) Two-Wire or Tail-Eating Exchanges and (b) True Four-Wire Exchanges.

Notes: 1: Provided only where Automatic Test Access Used.
2: Pads A and B are Adjusted with 3 db Switching Pads in Circuit to Give Losses Shown in figure. L is the Nominal Equivalent of the Circuit.
3: Wiring Shown Dotted Provided Only in Tail-Eating Exchange.
4: In Most Centres, Exchange and Carrier Terminal are in the same building and no External Cable is Required.
5: Pads C and D are adjusted to give Losses shown in Figure. L is the Nominal Equivalent of the Circuit.

TABLE V — CIRCUIT NON-LINEAR DISTORTION

Characteristic	Limit
Harmonic distortion (% of fundamental)	Total distortion 5%, 800 c/s at + 5 dbmo. Second harmonic 3%, 800 c/s at 0 dbmo. Third harmonic 1%, 800 c/s at 0 dbmo.
Linearity (800 c/s power at point of zero relative level)	± 1 db, 0 dbm to + 6 dbm. Peaks of up to + 35 dbm limited to not more than + 14 dbm.

TECHNICAL REQUIREMENTS OF BROADCAST PROGRAMME CIRCUITS

A relatively extensive network of broadcast programme circuits under the control of the Postmaster-General's Department has existed in Australia for about 30 years. This network has developed largely on the American pattern and provides facilities for many national and commercial broadcasting stations. The technical standards for the circuits have evolved over a period of time and have been agreed to by the stations, the Australian Broadcasting Control Board and the Department. The standards differ somewhat for historical reasons from those of the C.C.I.T.T., but it is nevertheless undesirable to change them because of difficulties with existing plant and agreements.

Broadcast programme circuits are provided on the Sydney-Melbourne cable by the substitution of one circuit for three normal telephone circuits, and a summary of the technical standards which differ from those of the C.C.I.T.T. is given in Table VI.

TABLE VI — REQUIREMENTS OF BROADCAST PROGRAMME CIRCUITS

Characteristic	Limit
Input and Output Levels	+ 8 v.u.
Input and Output Impedance	600 ohms, return loss against nominal greater than 20 db over frequency range 50 to 10,000 c/s.
Attenuation Distortion	± 2 db relative to that at 1,000 c/s for frequency range 50 to 10,000 c/s.
Harmonic Distortion	Not less than 28 db below fundamental with + 17 dbm at any frequency within transmitted range applied at input.
Linearity	Loss difference for input powers of + 16 dbm and —22 dbm to be less than 1 db.

One aspect which could not be decided completely before the contract was placed was the limit to be applied to circuit noise. There are fundamental difficulties in achieving the C.C.I.T.T. noise limit for programme circuits with normal repeater spacings on a coaxial cable system, and the problem is described more fully in the paper by Mr. Walklate appearing in this issue. It was also not desirable to use compandors on the circuits because of the large number of links which can be connected in tandem in the network, or to reduce the repeater spacing merely because of the programme circuits. The C.C.I.T.T. noise limit was therefore taken as an objective rather than a contract limit, but subsequent experience has shown that it should actually be met on all programme circuits in the cable.

GENERAL SYSTEM DESIGN

The general system is a 6 Mc/s system. This type has been standardised for Australian use because it permits the patching under emergency conditions between bearers used for telephone and television purposes, simplifies maintenance and reduces the holding of spare repeater units when television and telephone facilities are required on the one route, and moreover enables an additional 300 circuits to be obtained from a pair of tubes at a relatively small extra cost compared to that of a 4 Mc/s system. The telephone system is effectively divided into two separate systems at Canberra to assist in obtaining the maximum circuit capacity from the available frequency spectrum, and also to improve the system noise by preventing the transfer of certain intermodulation products which tend to make a relatively greater contribution as the route length increases. Initially the system will not use frequencies above 4 Mc/s, but the traffic growth will require these frequencies to be used within a few years. At about the same time as this stage is reached it is probable that a parallel radio bearer system will also be available over the whole route, and at a still later stage, conversion of at least part of the system to 12 Mc/s operation will be required. A more detailed description of the design is given in Mr. Walklate's article in this issue which covers among other things, repeater spacings, channel drop-out facilities, the design of the line equipment, and the allocation of the frequency band.

One aspect of the design in which the Department was interested was in ensuring the possibility of connecting 12-channel groups from spur open-wire and cable systems to the main system, and of extending the channel capacity of the main system at a later stage with equipment of different manufacture, if this was found to be necessary. For this reason, some consideration was given to the boundary conditions at the basic group and supergroup points of the system. Individual specifications for all sub-units of equipment, for use mainly in factory testing, were agreed to between the contractor and the Department and these covered adequately the extension aspects. The basic group frequencies used are 60-108 kc/s (the C.C.I.T.T. Group B) which are used in all systems in Australia made up of 12-channel groups. Consideration was also given in the early stages of the system design to the retention of the previous Australian standard levels and impedances at the basic group points, namely —42 db and —5 db, 135 ohm balanced. However, having regard to the relatively self-contained nature of the Sydney-Melbourne route, and the need to carry out major additions on most spur routes radiating from the main repeater stations, it was more economical to change to the standard German levels and impedances, on which the coaxial system was already designed, and to use German type systems on the spur routes.

EQUIPMENT RELIABILITY

Considerable attention has been given at the design stage to ensure that equipment will be as reliable as practicable and will require a minimum of maintenance attention. All equipment using frequencies up to 108 kc/s is fully transistorised and all components used have been selected only after extensive life tests. All valves used will be of special reliable types and lives of the order of 5 to 8 years are expected. Contacts on plugs and sockets associated with plug-in units and coaxial U-links will be gold-plated for reliability reasons, except where the contacts carry power feeding voltages and will not be liable to contact troubles. Other special measures such as the use of parallel valves in repeaters and the duplication of power feeding equipment are described in the article by Mr. Walklate in this issue.

SIGNALLING

Coaxial Circuits

For a number of years, it will be necessary to terminate many of the telephone circuits derived from the coaxial tubes at established trunk exchanges, for example in the case of the Sydney-Melbourne circuits provided at the outset. As these exchanges include 2 V.F. signalling facilities, it was necessary to use this form of signalling on many of the cable circuits. The noise requirements of the circuits are to be met using this type of signalling.

However, new exchanges are being provided at many centres along the route and subscriber dialling is being introduced between many centres. Exchanges provided in the future will be of the crossbar type and a new trunk network is being set up in parallel with the present operator-controlled network. The general pattern of future development has been described in a recent article in this Journal (2). 2 V.F. signalling will be restricted in future to the operator-controlled network and as the main trunk exchanges at a number of centres such as Sydney and Melbourne are nearing the limit of their capacities, there will not be an appreciable growth in this field. Outband signalling is in use on a proportion of the circuits provided in the cable at present, and will be used on most circuits added in the future. To take care of future developments and to standardise channel modulator units, all circuits being provided will be equipped with outband signalling facilities, whether they are operated initially with 2 V.F. signalling or not.

At the present time only one supergroup of 60 circuits between Sydney and Canberra is equipped with outband signalling. A "high level" system with a signalling tone power of —4.3 dbm at a point of zero relative level is used with pulse-type signalling relay sets. This is an interim arrangement only and within six months conversion of all channel modulator units to a "low level" system with a signalling tone power of —18 dbm at a zero level point will commence. This system was developed by Felten and Guilleaume Fernmeldeanlagen G.m.b.H. to permit the use of a "continuous" tone system on the "compelled sequence" principle which has been standardised by the Department; tones which are transmitted almost continuously must be applied at a low level if the intermodulation performance of the system is to be satisfactory. With the new standard method, breaks in the circuit can be detected both in the idle period or during conversation and the circuits either busied automatically or released. Release during very short breaks is prevented by a 300 milliseconds time delay feature, and breaks in individual circuits can be distinguished from complete group failures by observing whether they have occurred simultaneously on four sample circuits in each group. If a group failure occurs, the circuits are released only after a delay of about half a minute in order to avoid the need for a large number of connections to be set up again for relatively short breaks. The new relay sets have been designed by the Department and are being provided independently of the Sydney-Melbourne contract. It is hoped that a more detailed description of this system will be given in a later article in this Journal.

Voice Frequency Circuits

Originally, signalling on the amplified voice frequency circuits was to be A.C., 50 c/s for the two-wire circuits and 2,280 c/s for the four-wire. This was proposed in order to enable the inclusion of isolating transformers in the circuits for protection against voltages induced under fault conditions in power transmission lines in the vicinity of the cable route. A more detailed investigation of the exposure conditions made subsequently showed that the voltages to ground likely to be induced into the voice frequency pairs would not be as high as was expected originally, and a D.C. signalling system is now being provided on all voice frequency circuits. A D.C. system is more economical, particularly when account is taken of the need to transmit metering pulses during conversation. The voice frequency pairs are being protected by the use of gas arrestors having an operating voltage of 350-400 volts. The signalling relay sets were again designed and are being supplied by the Department.

MECHANICAL CONSTRUCTION

The equipment is of the German Post Office standard "Type 52" construction and is illustrated in the photographs in other articles in this issue. The racks or bays are 23.6 inches wide, and at the main repeater stations are 8 ft. 7 inches high, while at the unattended stations short racks 5 ft. 1 inch high are used. Although the normal Departmental standard rack is 20¼ inches wide and 10 ft. 6 inches high, the problems of integrating the two types of construction which occur in established offices were minimised by the use of separate areas for each type. This was possible as new buildings were involved in almost every case, and this aspect is discussed further in the next paragraph.

LAYOUT OF EQUIPMENT

Main Stations

The general designs of the buildings in which the terminal and main repeater equipment is located vary from station to station along the route, being dictated principally by site considerations and accommodation requirements for plant other than that associated directly with the cable. The carrier equipment rooms also vary considerably in dimensions as a result, but nevertheless it was possible to standardise on two general types of space allocation, one for "wide" rooms over about 30 feet in width and one for narrower rooms. The general arrangements adopted are shown in Fig. 4.

The "narrow" room layout was used at smaller centres, and was applied at Campbelltown, Bowral, Yass, Gundagai and Culcairn. At Canberra an additional separate room was available for German type equipment only, and the existing installation was retained for other types of equipment. There were also slight differences from the "wide" layout shown in the figure at the very large main terminal stations of Sydney and Melbourne due to special circumstances. Naturally the relative areas of each block of equipment varied at each station due to different requirements in the quantity of each class of plant.

Within the areas allocated for "German" type equipment, individual layouts were established, and a typical one (Albury) is shown in Fig. 5. The design of the layouts and the allocation of individual rack spaces were dictated by many different factors and therefore vary also from station to station. The general objectives in determining the number of spaces reserved for each type of rack were to provide a balanced growth for the whole installation over the period of its life, and make provision for any likely future developments such as spur cables, 12 Mc/s operation and parallel radio systems. The allocation of individual types of racks to individual spaces was governed by cabling considerations, access for maintenance purposes, and the need for flexibility to avoid expensive re-arrangements at a later stage. As far as cabling is concerned the lengths of some runs, particularly those associated with the high frequency line, were very critical. The spacing between row centres for "German" type equipment is 5 ft. 6 inches at all stations except Sydney and Canberra where floor loading considera-

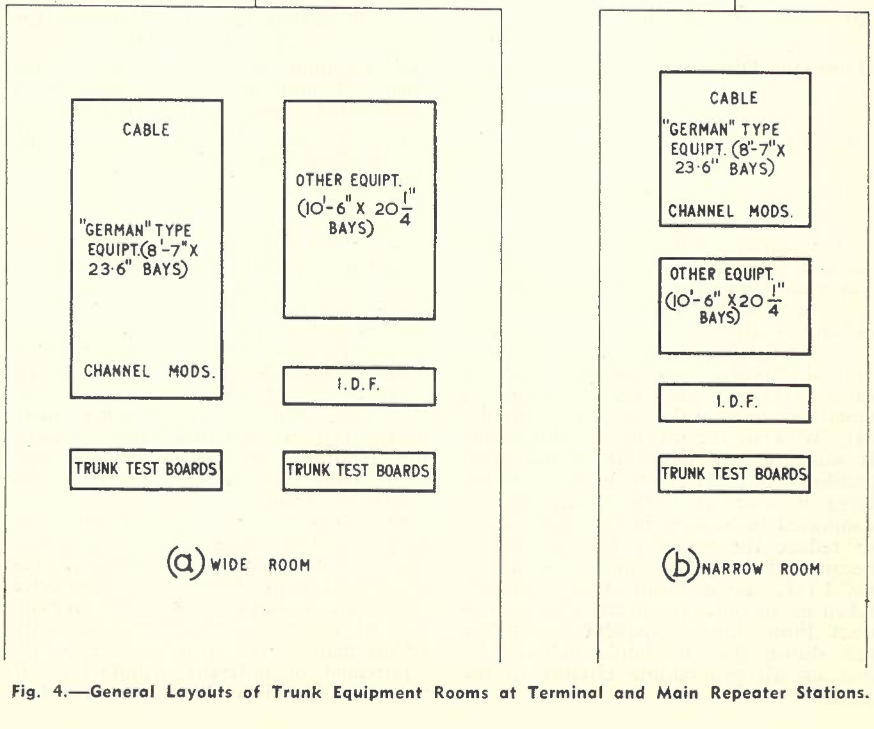

Fig. 4.—General Layouts of Trunk Equipment Rooms at Terminal and Main Repeater Stations.

tions dictated a wider spacing. A spacing of 4 ft. 0 inches is used with equipment constructed to normal Australian standards, and the increase to 5 ft. 6 inches has been made in this case because of the bulk of the testing equipment required and the slightly greater depth of the racks.

Unattended Repeater Stations

The layout used at the unattended repeater stations is shown in Fig. 6.

An alternative layout with the line amplifier racks located along the shorter wall was possible, and would have been preferable from the viewpoint of providing better access to the equipment and simplified cabling. However, the arrangement shown was adopted as it provided slightly better temperature conditions in the building (4). As a result of experience, consideration is also being given to the location of the gas cylinder in the alcove instead of the position shown in the figure in order to avoid opening the interior door relatively frequently for cable maintenance purposes.

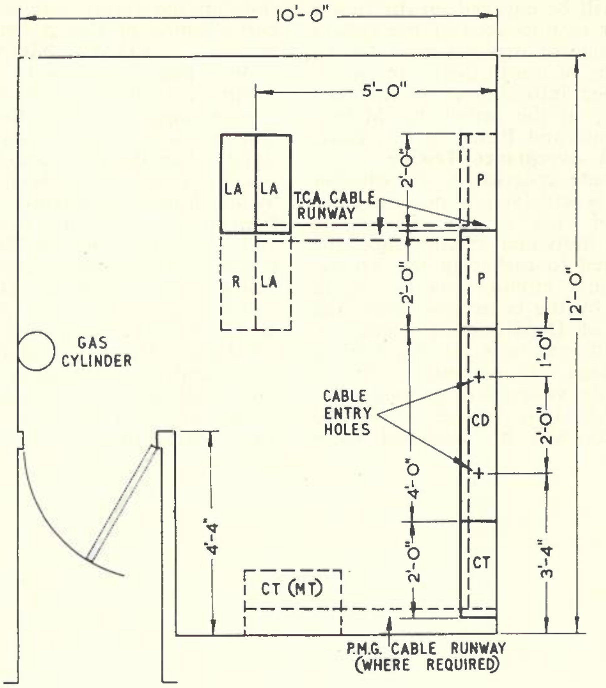

Fig. 6.—Layout of Unattended Repeater Station. Rack designations are as follows: CD-Cable Distribution, CT-Cable Terminal, P-Power Feeding, LA-Line Amplifier, CT (MT)-Minor Trunk Cable Terminal (where required), R-Short Haul Repeater (where required).

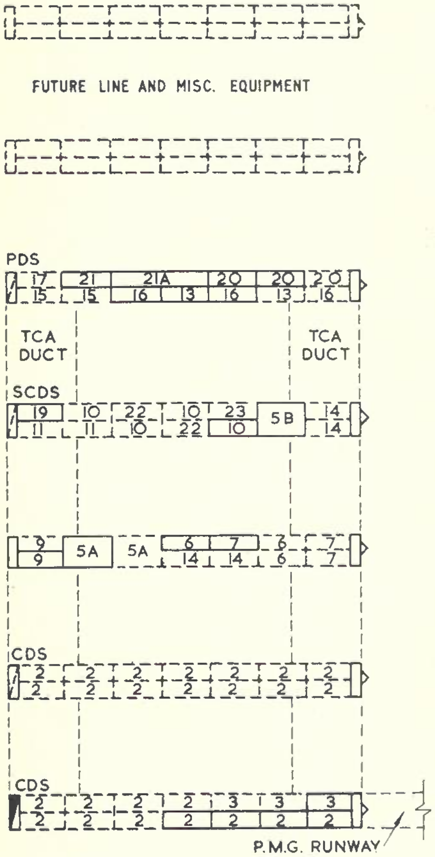

Fig. 5.—Detailed Layout of German Type Equipment at a Typical Centre (Albury). Rack designations are as follows: 2-Channel Modulator, 3-Programme Terminal, 5A-Group Distribution, 5B-Supergroup Distribution, 6-Group Pilot, 7-Group Modulator, 9-Channel and Group Carrier Supply, 10-Supergroup Modulator, 11-Supergroup Carrier Supply, 13-Branching, 14-Through Filter, 15-Line Amplifier (T.V. Terminal), 16-Line Amplifier (Telephone or T.V. Repeater or T.V. Receiving), 17-T.V. Distribution, 19-Auxiliary, 20-Power Feeding, 21-Cable Terminal, 21A-Cable Distribution, 22-Supplementary Supergroup Modulator and Carrier Supply (for S.G. 17-21), 23-Supergroup Pilot, C.D.S.-Channel and Group Carrier Distribution Strip, S.C.D.S. —Supergroup Carrier Distribution Strip, P.D.S. —Pilot Distribution Strip.

EQUIPMENT TESTING

General

In order to safeguard the Department's investment in the system, a comprehensive schedule of testing was established and is carried out at all stages of manufacture and installation of the equipment. The need for this may be appreciated from the fact that the overall system is made up of many individual racks of about 25 different types which house hundreds of different types of panels which are arranged in different ways at each of the 15 main stations and the 103 unattended stations. All these items must interwork together and with the cable in such a way as to give the required performance of the individual circuits. If any unit is faulty, either in regard to design or to manufacture, considerable delay and disorganisation would result if the trouble were detected only during the final testing of the circuits. Manufacturing and installation programmes, if they are to be efficient, also require work to be carried out on similar units in batches, and this generally prohibits the connection of main units together for testing before installation. For both design and testing reasons, therefore, individual specifications were prepared for each sub-unit of equipment, and each sub-unit is tested to the specifications at appropriate stages. As considerable time and expense is involved in testing, it is necessary to ensure that the optimum compromise is achieved in the amount of testing undertaken. As far as the contract was concerned, particular care was taken to avoid duplication of testing by the manufacturer, the contractor, and the Department which would add to the cost and prejudice the smooth progress of the work.

Factory Testing

A very comprehensive testing procedure is used by the manufacturer of the transmission equipment to ensure the quality of equipment manufactured for other users, such as the German Post Office. The procedure involves testing at all stages of production, from the receipt of components to the dispatch of units from the factory. It was not found necessary by the Department to arrange for separate tests in the factory, but an arrangement was made for the testing specifications of the main units to be determined by joint agreement. Factory testing of components, sub-units, etc., is carried out by the manufacturer to his normal procedure, following which each unit is tested finally to the agreed specification, and certified test results forwarded to the Department. In practice this arrangement has worked very smoothly, and despite troubles which may be introduced by transport over the distances involved, very few faults have been encountered in the equipment during installation.

Testing During Installation

All testing during installation is again carried out by the contractor, but Departmental inspectors are present during many of the tests and must certify that the equipment racks are satisfactory before final payment is made for their installation. Most of the inspectors will be engaged on the future extension or maintenance of the system and gain valuable experience in testing which will be of use in their later work. More detailed information on the testing is given in the article by Messrs. Peacock, Boyd and Beard in this issue.

Final Acceptance Testing

The ultimate criterion as to whether the system is satisfactory or not, from the point of view of the contract, is whether the individual circuits meet the limits referred to earlier in this article. The individual circuit tests are again carried out by the contractor under the supervision of Departmental inspectors. Certain additional tests are required at the final stage of the installation to ensure that the system will operate satisfactorily when fully loaded. This and other aspects will be discussed more fully in the future article covering the performance of the system.

CONCLUSION

Any final conclusion regarding the quality and performance of the transmission equipment and the overall system is somewhat premature at this stage, when the only coaxial circuits in operation in the cable are the direct Sydney-Canberra circuits, which have been in service for just over six months, and the direct Sydney-Melbourne and Canberra-Melbourne circuits currently being placed in service. However, there is little doubt from the progress made so far that the equipment will be very satisfactory from the Departmental viewpoint, and it is confidently expected that this prediction will be borne out in the future article referred to in the previous paragraph.

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DESIGN OF TRANSMISSION EQUIPMENT

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INTRODUCTION

This article describes the main design features of the transmission equipment of the Sydney-Melbourne coaxial cable system, with particular reference to telephony transmission over the coaxial tubes. The basic performance specification of this equipment together with that for voice frequency circuit provision on paper insulated pairs of the cable is covered in the associated article by Mr. Macdonald, and aspects related to television transmission on the coaxial tubes will be discussed in a later article.

The coaxial transmission equipment is installed along the 600 mile Sydney-Melbourne route in a total of 118 stations. Fifteen of these are defined as "attended" stations where telephone channels are derived from the coaxial line frequency band, and where supplementary coaxial line equalisation is employed and No-Break A.C. power plant provided. The attended stations on the route are Sydney, Campbelltown, Bowral, Goulburn, Canberra, Yass, Gundagai, Wagga, Culcairn, Albury, Wangaratta, Benalla, Euroa, Seymour and Melbourne. The equipment may be considered in two main categories, namely the "line" equipment which is associated with the coaxial tubes at all stations to form the bearer circuit, and the "terminal" equipment at the attended stations only which assembles the information to be conveyed into suitable form for transmission over the bearer circuit.

The line equipment of the Sydney-Melbourne system is of Type V.1260 employing a bandwidth of 60 Kc/s to 6.2 Mc/s in each direction on a pair of coaxial tubes, and caters for transmission thereon of 1,260 telephone channels or of two uni-directional 625 line television programmes in accordance with Australian television standards. The telephone terminal equipment is limited, however, in the initial installation to 960 channel working.

LINE EQUIPMENT — GENERAL

The basic function of the line equipment is to provide amplification and equalisation for the attenuation which the broadband signal undergoes in transmission over the cable. For a specified noise performance the intervals at which this is necessary is determined, from considerations both of thermal noise and intermodulation noise, with appropriate use of pre-emphasis, by the amplifier output level and inter-modulation performance that can be practicably and economically achieved.

The Sydney-Melbourne equipment being supplied will allow a nominal repeater section length of 5.8 miles of "German standard" cable at the route mean cable temperature of 17.5°C. This length is slightly greater than was expected with the initial equipment design at the time when the contracts for the project were being placed, and when the locations of the repeater sites had to be finalised. At that stage it was necessary to specify a nominal repeater section length of 5.60 miles, but with allowance between Sydney and Gundagai for lengths up to 5.70 miles provided 5.64 miles was exceeded in not more than 13 sections and 5.60 miles exceeded in not more than 16 sections. The later improvement in equipment design provided a margin of safety in the Canberra-Melbourne section of the route, in case the attenuation of the Australian cable, although within C.C.I.T.T. limits as required by the cable specification, should exceed that of the German standard cable. The improvement in equipment design was also aimed at improved system performance in relation to broadcast programme channels as will be further discussed later in this article.

Automatic regulation along the route is necessary to maintain the desired noise performance and attenuation distortion characteristics. To cater for variations in cable temperature in a repeater section, which were calculated to be up to ± 9°C., automatic regulation is provided at every station using a pilot frequency of 4,092 Kc/s. Further automatic regulation using pilot frequencies of 60, 308 and 6,200 Kc/s is provided at Sydney, Canberra, Wagga, Wangaratta and Melbourne to cater for valve ageing and variations in equipment ambient temperature. These five stations are designated "main" attended stations and at the other attended stations, designated "minor" attended stations, supplementary equalisation only is provided.

Remote power feeding, supervision and order-wire equipment is also regarded as part of the line equipment. A separate power feeding system is required to be associated with the transmission equipment for each pair of coaxial tubes, but the remote supervision and order-wire equipment installed initially is common for the route. Power feeding in one or both directions is effected on the Sydney-Melbourne route from 10 of the attended stations and these stations also supervise their respective power fed unattended stations. A short haul order-wire circuit is provided between each pair of adjacent attended stations giving communication to each unattended station in the section. There is also provided over the whole route an overall remote supervision system and a long haul order-wire circuit linking up all the attended stations.

The layout of line equipment over the route is shown in Fig. 1.

LINE AMPLIFIER EQUIPMENT

Station Arrangements

Block schematics of the line amplifier equipment configurations at terminal, main attended, minor attended and unattended stations are shown in Figs. 2, 3, 4 and 5 respectively. The functioning of this equipment is amplified in the following descriptions of the various units involved. For telephony, the equipment for both directions of transmission on one pair of tubes is housed in the one rack at each type of station as illustrated in Figs. 6 and 7. For television transmission, the equipment at unattended

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* See page 269.

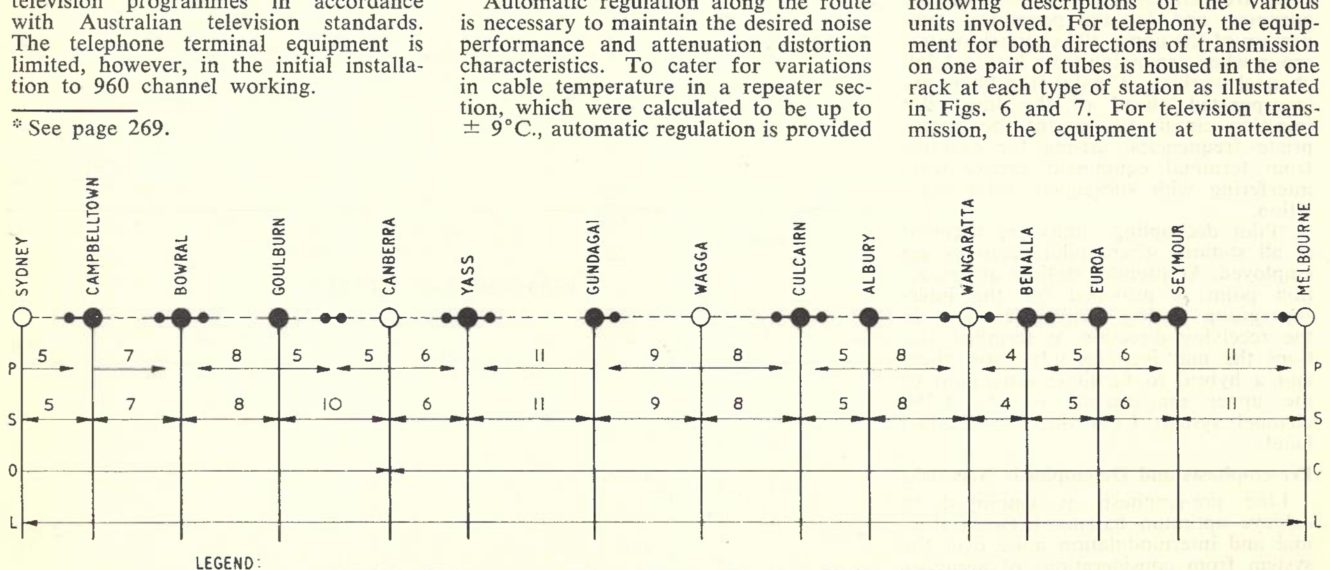

Fig. 1.—Line Equipment Route Layout.

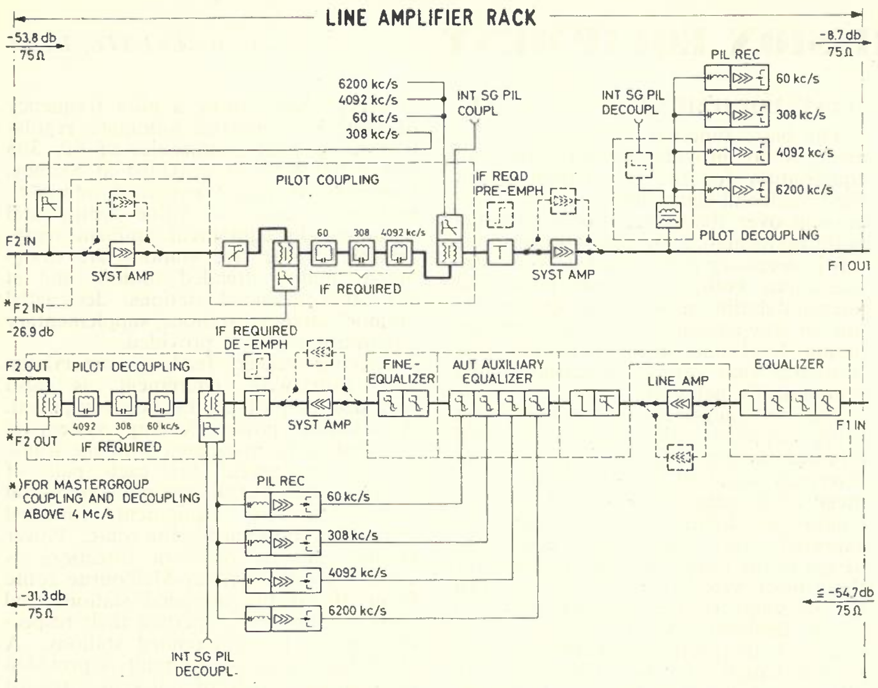

Fig. 2.—Terminal Line Amplifier Equipment—Block Schematic.

stations is identical to that for telephony but an additional rack is required at terminal stations and at those intermediate main attended stations where phase and echo equalisation is employed.

Pilot Coupling and Decoupling Units

The "pilot coupling" unit is used in the transmitting direction at terminal stations for the injection of the line pilot frequencies 60, 308, 4,092 and 6,200 Kc/s. The pilots are injected into the line frequency band at a level of -10 dbmo. The unit is also designed to allow the insertion of inter-supergroup pilot frequencies for in-service testing purposes, and for the permanent connection of the upper 300 channel mastergroup when expanding from 960 to 1,260 channel working. Crystal stop filters are incorporated ahead of the line pilot injection circuit to prevent the appropriate frequencies, arising for example from terminal equipment carrier leak, interfering with subsequent pilot regulation.

"Pilot decoupling" units are required at all stations where pilot receivers are employed. At attended stations an extraction point is provided for the inter-supergroup testing frequencies, and in the receiving direction at terminal stations the unit includes pilot stop filters and a hybrid to facilitate separation of the upper mastergroup of the 1,260 channel system from the 960 channel band.

Pre-emphasis and De-emphasis Networks

Line pre-emphasis is employed to achieve optimum balance between thermal and intermodulation noise over the system from considerations of amplifier design, repeater section length and system loading. The attenuation characteristic of the pre-emphasis network at a transmitting terminal falls linearly over the frequency range 60 to 5,564 Kc/s with a difference in attenuation of 10 db between these frequencies. The basic attenuation at 5,564 Kc/s is 1.74 db. A complementary de-emphasis network is employed at a receiving terminal.

System Amplifier

"System" amplifiers are employed for flat level compensation at all attended stations. The amplifier has three stages with negative feed-back and provides a gain of 34.7 ± 0.17 db over the frequency range 60 to 6,200 Kc/s. The amplifier output level per channel where used as a transmitting amplifier at attended stations is -8.7 db.

Pilot Receivers

Two types of pilot receivers are employed in association with motor controlled equalisers at unattended and minor attended stations and with electronically controlled equalisers at main attended stations.

The input of the pilot receiver for motor controlled equalisers comprises a selective filter followed by a three-stage negative feed-back amplifier. The output voltage from this amplifier is rectified and applied to an indicating meter and to one winding of a polarised relay which has an opposing reference voltage applied to its second winding. When the pilot level deviates by more than ± 0.7 db from nominal the relay is operated and its contacts apply earth to relays in the "equaliser" unit. If the pilot level drops suddenly by more than 5.2 db alarms are operated and the control voltage to the equaliser is interrupted.

In the pilot receivers for electronically controlled equalisers the rectified pilot voltages are amplified and applied directly to the "automatic auxiliary equaliser" unit.

Equaliser

The "equaliser" unit at unattended stations comprises an artificial line, temperature equaliser and basic equaliser. At attended stations an adjustable attenuator and system equaliser are also included, but at main attended stations the temperature equaliser is not included and a different type is provided in lieu in the "automatic auxiliary equaliser" unit.

The artificial line (all stations) is for building out short repeater sections to

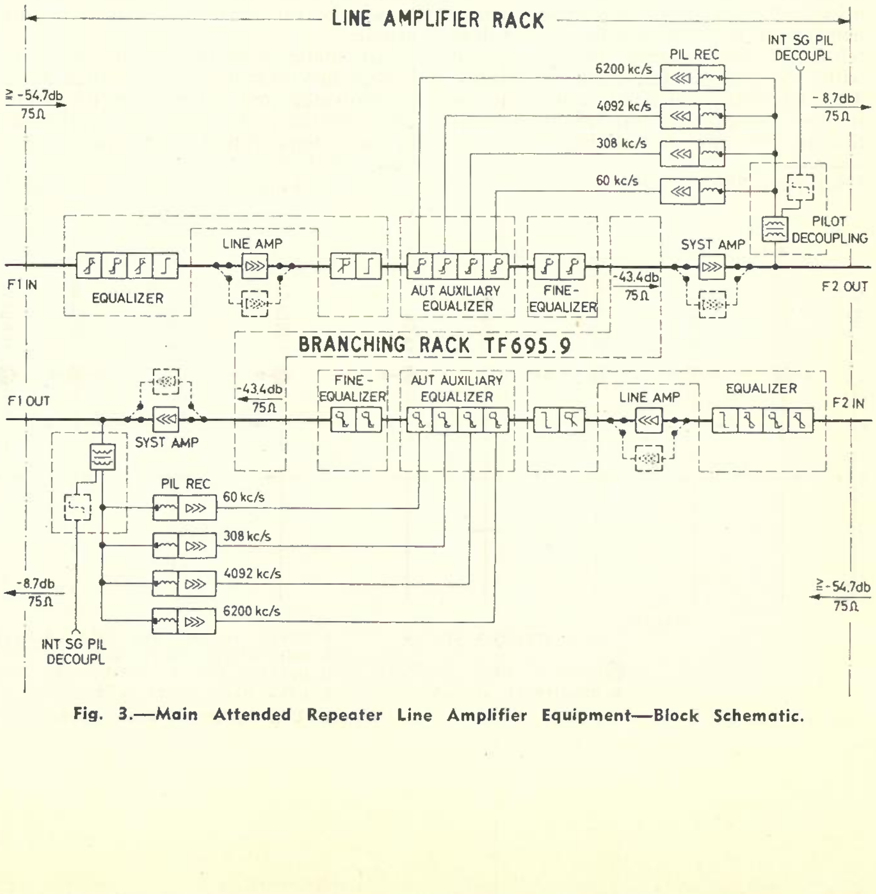

Fig. 3.—Main Attended Repeater Line Amplifier Equipment—Block Schematic.

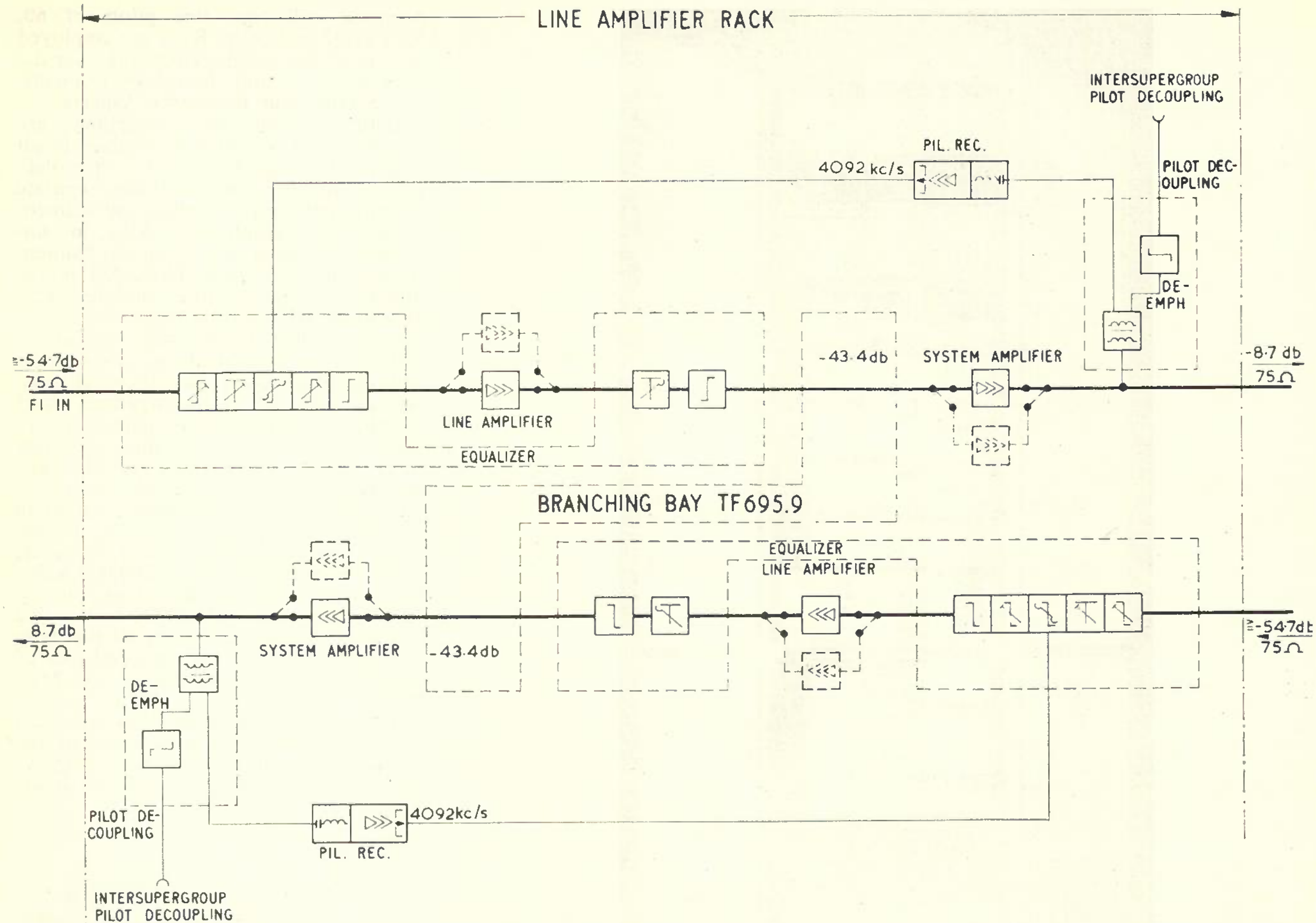

Fig. 4.—Minor Attended Repeater Line Amplifier Equipment—Block Schematic. (**Note: Fine Equaliser also included at certain stations.**)

the nominal length within ± 25 meters using sections equivalent to lengths of standard coaxial cable at temperature 10°C. A "coarse" sub-assembly provides for up to 2.4 km in steps of 200 meters, by allowing for three units each equivalent to lengths of 200, 400 or 800 meters to be inserted in any combination. A "fine" sub-assembly comprising units of 200, 100 and 2 x 50 meters allows for addition of up to 400 meters adjustable in steps of 50 meters by means of soldered straps. The fine sub-assembly also includes two pads of 0.44 db for level adjustment. If building out beyond 2.8 km is required, an additional unit equivalent to 2.4 or 4.8 km may be employed.

The temperature equaliser (unattended and minor attended stations only) compensates for changes in cable attenuation over a single repeater section due to variations in cable temperatures of up to ± 12°C. It is automatically controlled via the 4,092 Kc/s pilot receiver but may also be manually operated. The equaliser is operated by a 25-position stepping switch which is driven by a synchronous motor with separate windings for clock-wise and anti-clock-wise operation. The respective motor windings receive their operating voltage by the operation of an appropriate relay when it is in turn operated by the application of earth from the polarised relay in the pilot receiver. An alarm is operated if the temperature equaliser is driven to either end position.

The basic equaliser (all stations) is a fixed unit required in conjunction with the line amplifier to correct overall repeater section equalisation in the frequency range below 1 Mc/s.

The adjustable attenuator (attended stations only) is employed for level adjustment depending on the number and type of equalisers used. It comprises a "coarse" unit with seven steps each of 4.4 db and a "fine" unit with 11 steps each of 0.44 db.

The system equaliser (attended stations only) is specially designed and inserted on site, after initial line-up measurements, to take care of the summation that may occur of small systematic design and manufacturing deviations in unit characteristics from their nominal values.

Line Amplifier

The "line" amplifier provides the gain and basic equalisation compensation for the loss over a repeater section. The amplifier gain is sloped from 16.2 to 57.8 db over the frequency range 60 to 6,200 Kc/s and is 48.2 db at 4,100 Kc/s. The nominal output level per channel at 4,100 Kc/s is -8.7 db. The unit has three valve stages with negative feedback and is illustrated in Fig. 8.

Fine Equaliser

The "fine equaliser" is employed at main attended stations, and at certain minor attended stations, namely Bowral, Gundagai, Albury and Euroa, for cor-

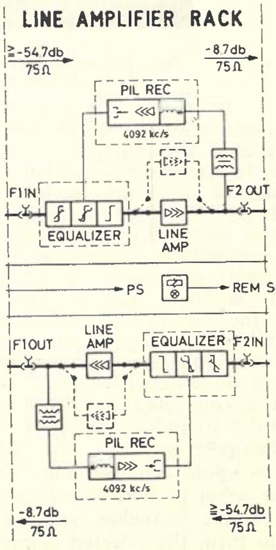

Fig. 5.—Unattended Repeater Line Amplifier Equipment—Block Schematic.

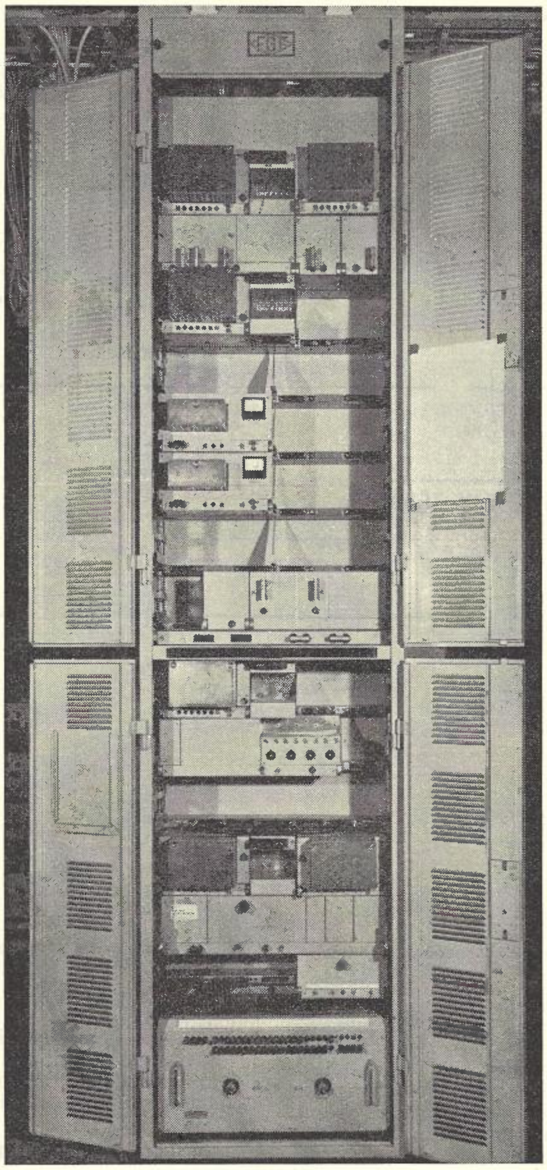

Fig. 6.—Attended Station Line Amplifier Rack Partly Equipped for Terminal Application.

recting odd deviations of an unsystematic nature in the amplitude frequency response. It comprises a number of networks each of which may be built up as required on site to provide a single attenuation maximum or minimum at a selected resonance frequency with a chosen flank steepness. This can be achieved without mutual interaction between the networks. Two types of sub-assemblies are employed.

The "fine equaliser with attenuator' consists of three networks ahead of each of which is connected an 8.7 db attenuator in order to reduce reflection caused by the two-pole equaliser. In each network a two-pole equaliser may be connected to either or both the longitudinal and transverse branches and in each branch in turn, the selected components may be either series or parallel connected as desired.

The "transistorised fine equaliser" can comprise up to four plug-in equaliser networks each of which has associated with it a five-position attenuation switch and a transistorised amplifier. The latter improves the return loss and allows zero basic attenuation to be attained where the network is used to produce an attenuation maximum. If the attenuation switch is in the zero position an equaliser network can be removed during system operation.

Automatic Auxiliary Equaliser

The automatic auxiliary equaliser is used at main attended stations for correcting automatically, changes due to variation in cable temperature over the preceding repeater section and accumulated changes due to valve ageing and variations in equipment ambient temperature. All four line pilots of 60, 308, 4,092 and 6,200 Kc/s are employed to control the equaliser networks via the pilot receivers and thermistor elements.

Service and Reliability Aspects

Both line and system amplifiers are equipped with semi-parallel valves in all stages. The anodes of the "parallel" valves are interconnected but separate screen supply, grid coupling and filament circuits are employed. Also in unattended stations the separate filament circuits are fed from duplicated power supply units in the line amplifier rack. Maximum reliability is thus provided in cases of valve failure due to loss of emission, filament breakage, grid current and electrode open and short circuits, excluding the effect of an anode short circuit. Separation of the anode supplies would not assist the latter since an anode short circuit is generally of the low resistance type and would affect the other valve via the magnetic coupling of the output transformer. The probability of an anode short circuit, however, is of the order of one in 200,000 valve failures and this is equivalent, on the basis of a guaranteed 10,000 hour valve life, to less than one failure of this type in 100 years on a fully equipped pair of coaxial tubes between Sydney and Melbourne.

The above arrangement has considerable advantages over alternative means of achieving reliability such as employing completely separate amplifiers inter-

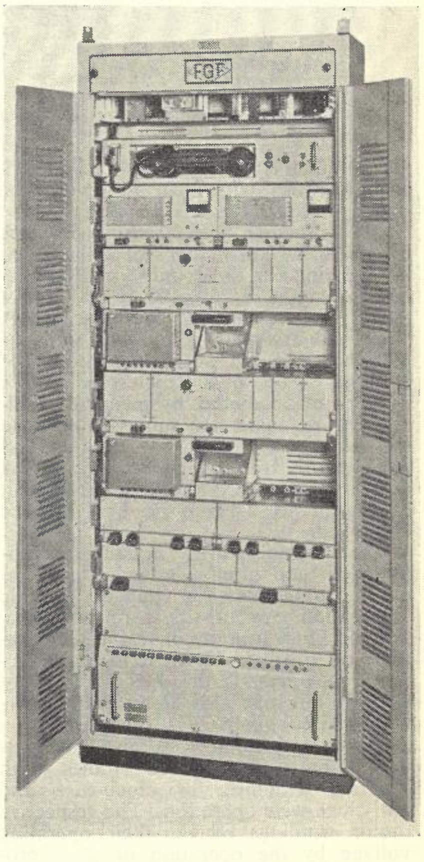

Fig. 7.—Unattended Station Line Amplifier Rack.

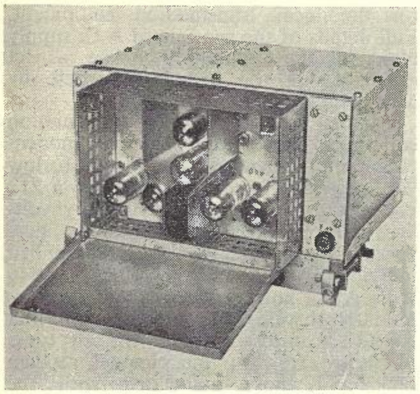

Fig. 8.—Line Amplifier.

connected at input and output hybrids, or semi-separate amplifiers between common input and output transformers. The first alternative of completely separate amplifiers would adversely effect the system design in that the hybrid losses would have to be compensated for by a 3 db higher amplifier gain, with a corresponding reduction of feedback and worsening of intermodulation, and, due to the input hybrid, there would be a 3 db increase in noise power from the amplifier input stage. Failure of either amplifier due to failure of any valve therein would reduce the overall gain or power handling capacity by 3 db. The second alternative of semi-separate amplifiers would overcome most of these disadvantages but a reduction in power handling capacity would still occur on failure of any valve. The arrangement of semi-parallel valves employed reduces this effect to the output valves only.

Provision is made in all line amplifier racks for "no-break" manual change-over within not more than 2 ms from working to spare line and system amplifiers. The spare amplifier is not normally housed in the rack but when required it is plugged, together with a change-over unit, into the spaces provided. During normal equipment operation the connections from the rack to the working amplifier do not pass through any relay contacts but are made by a by-pass plug whose contacts are gold-plated, as are those of all other plug-socket components in the equipment excluding those carrying remote power feeding. To effect a change-over the spare amplifier and change-over unit are first plugged in and the operation of the spare amplifier checked by means of an inbuilt coupler and the pilot receiver. As no amplifier itself regulates, no adjustment of the spare amplifier is required. The by-pass plug is then removed from its normal position and plugged into a socket in the change-over unit. In so doing a pin on the plug operates a high speed change-over relay, the contacts of which are again by-passed on re-insertion of the plug. If it is desired to recover the change-over unit at that stage, the procedure must be repeated in reverse with a further spare amplifier to revert to the normal working position.

TELEPHONY SUPERGROUP ALLOCATION AND DROP-OUT FACILITIES

Intermediate Drop-Out Arrangements

Generally on long distance coaxial cable systems only a proportion of the capacity of the system is required for end to end circuits, and this is the case on the Sydney-Melbourne route where the communication network involves the 15 attended stations of the system itself, plus extensions at carrier or voice frequency from the system at these stations to many other stations both along and off the route.

The dropping out of telephone channels at attended stations of a coaxial system is most simply and economically achieved by means of a branching hybrid arrangement whereby the complete line frequency band is split into two directions, and the particular supergroups and groups thereof required at the drop-out station and the remote station are selected at those locations by the filters in the appropriate terminal equipment. With this arrangement, which is shown in principle in Fig. 9, the same portions of the line frequency band cannot be used independently on both sides of the drop-out station, except in the case of supergroups 1 and 2 for which band stop filters are available for insertion in the through line frequency path. Use of the branching method is therefore limited by the overall circuit capacity which the system has to provide. When this limitation becomes effective it is necessary for the complete line frequency band to be demodulated to the basic supergroup stage at the intermediate point and basic supergroups connected through as required via steep walled through-supergroup filters. With through supergroup working the line pilots are not connected through, and the arrangement becomes in effect a tandem connection of two independent line systems.

On the Sydney-Melbourne system the initial circuit requirements are such as to require through supergroup working being established at Canberra. Branching, including selected use of supergroup 1 and/or 2 stop filters is adequate at all other intermediate attended stations.

Branching Equipment

At all intermediate attended stations excluding Canberra a "Branching" rack is employed to accommodate firstly the branching hybrids, supergroup 1 and/or 2 stop filters, and system amplifiers required for level compensation. This

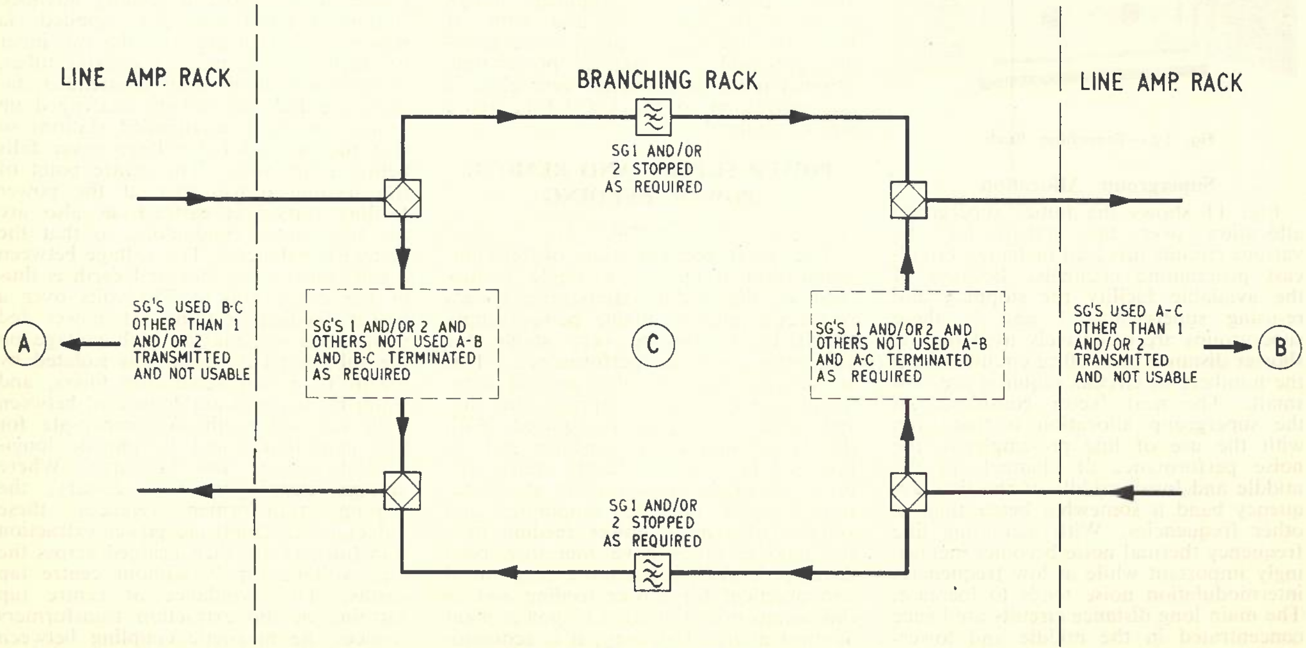

Fig. 9.—Branching Principle.

branching rack can also accommodate the supergroup modem and carrier supply equipment for terminating up to four supergroups. The rack is illustrated in Fig. 10.

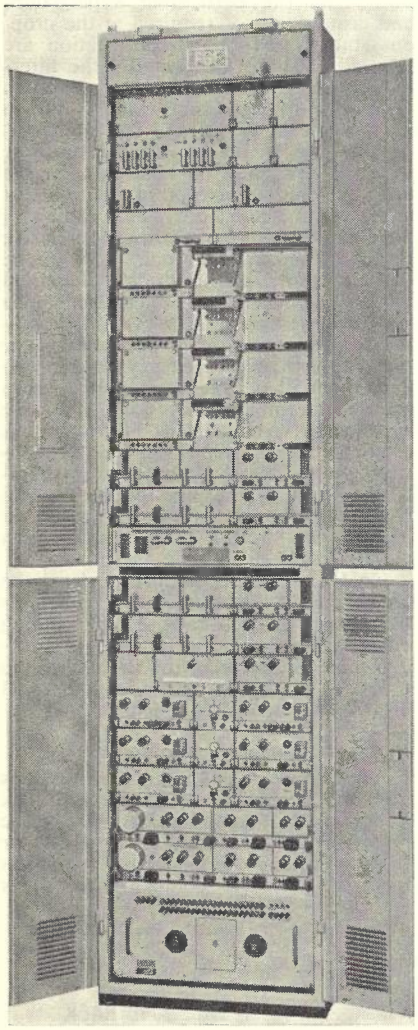

Fig. 10.—Branching Rack.

Supergroup Allocation

Fig. 11 shows the initial supergroup allocation over the system for the various circuits involved including broadcast programme channels. Because of the available facility for stopping and re-using supergroups 1 and 2, these supergroups are extensively used for the shorter distance inter-office circuits where the numbers of circuits required are also small. The next factor considered in the supergroup allocation is that even with the use of line pre-emphasis, the noise performance of channels in the middle and lower-middle of the line frequency band is somewhat better than at other frequencies. With increasing line frequency thermal noise becomes increasingly important while at low frequencies intermodulation noise tends to increase. The main long distance circuits are hence concentrated in the middle and lower-middle of the band and the higher supergroups are used for the shorter distance circuits where traffic requirements exceed the capacity of supergroups 1 and 2. A further factor which may lead to an exception to the latter is that no broadcast programme channels are operated higher than supergroup 10, that is a line frequency of about 2.5 Mc/s, and also no more than three programme channels are operated in any one supergroup.

The large number of broadcast programme channels required to be operated on the Sydney-Melbourne system imposed a problem. The system is basically designed to meet the C.C.I.T.T. requirements for telephone channels and firstly the high peak volumes associated with broadcast programme channels increase the system peak loading such that, with the number of programme channels involved, the possibility had to be investigated of this resulting in excessive intermodulation noise in the telephone channels as well as in the programme channels themselves. Secondly the greater bandwidth of a programme channel compared with a telephone channel and the difference between the C.C.I.T.T. programme and telephone psophometric weighting curves results in it being fundamentally impossible, from thermal noise alone, without using compandors, to meet the C.C.I.T.T. requirements for noise on a programme channel over a system which would only just meet the C.C.I.T.T. requirements for telephone channel noise. These two aspects are related by the balance between thermal and intermodulation noise and a small improvement can be obtained by the use of pre-emphasis on the individual programme channels themselves as well as on the overall line system.

It is now expected, however, that with the positioning adopted for the programme channels in the line frequency band, and with the system pre-emphasis and improved line amplifier design referred to previously, and with, if necessary, the use of programme channel pre-emphasis, that a programme channel noise performance very close if not equivalent to the C.C.I.T.T. figure will be attained.

POWER SUPPLY AND REMOTE POWER FEEDING

General

The great concentration of telecommunication traffic on a single facility such as the Sydney-Melbourne system requires a highly reliable power supply which must also be very stable for satisfactory system performance. This is not provided by the normal commercial A.C. mains supplies so that specialised power plant is required. With the large number of repeater stations involved in a coaxial cable system the provision of this power plant at all stations would not be economic, and systems of remote power feeding over the coaxial tubes have therefore been developed. A.C. is the more economical and practical for power feeding and as this means provision of A.C. power plant at most attended stations, it is economical to employ the same A.C. supply also for the local transmission equipment. Full details of the specialised A.C. supply plant for the Sydney-Melbourne project are given in the associated article by Mr. Hannah.

Almost all the coaxial transmission equipment except the channel modem racks employs valves, which require low voltage A.C. filament supplies and a 212 volt D.C. anode supply. Auxiliary voltages are also required for alarm purposes. These voltages are all supplied individually to each rack from a 240 volt A.C. power supply unit accommodated therein. This power supply unit is of standardised design for all types of racks excluding the channel modem rack and those associated with the remote power feeding. The channel modem rack is transistorised and consequently could be operated directly from a battery supply, but as the incremental power requirement due to its low consumption is small for any station, it has been retained on A.C. operation to simplify station power supply arrangements.

The method of 240 volt A.C. power distribution within the stations is described in the associated article by Messrs. Peacock, Boyd and Beard.

Remote Power Feeding—General Design

The remote power feeding system on the Sydney-Melbourne route caters for feeding the line amplifier equipment on one pair of coaxial tubes at up to 11 unattended stations. For the maximum number of fed stations approximately 2.7 KVA is fed to line from the power feeding station. This can, however, be increased to 3.7 KVA if it is desired to supply power at the unattended stations to repeaters of short haul carrier systems on the paper insulated interstice pairs of the cable.

A simplified schematic of a power feeding section is shown in Fig. 12. Power is fed from a feeding attended station at 1,500 volts A.C. applied via power separation filters to the two inner conductors of a pair of coaxial tubes. Where more than seven unattended stations are fed the voltage is stepped up at one or more unattended stations so that the onward fed voltage never falls below 1,200 volts. The centre point of the feeding transformer at the power feeding station is earthed, as also are the tube outer conductors, so that the system is balanced. The voltage between a tube inner-conductor and earth is thus in the range 600 to 750 volts over a power feeding section. At power fed unattended stations the high voltage on the tube inner-conductors is isolated by means of power separation filters, and shunt inductances are connected between each leg and earth to compensate for line capacitance and to impede longitudinal current flow to earth. Where voltage stepping-up is necessary, the step-up transformer replaces these inductances. Duplicate power extraction transformers are then bridged across the high voltage supply without centre tap earths. The avoidance of centre tap earthing of the extraction transformers reduces the magnetic coupling between the two tubes and so facilitates fault

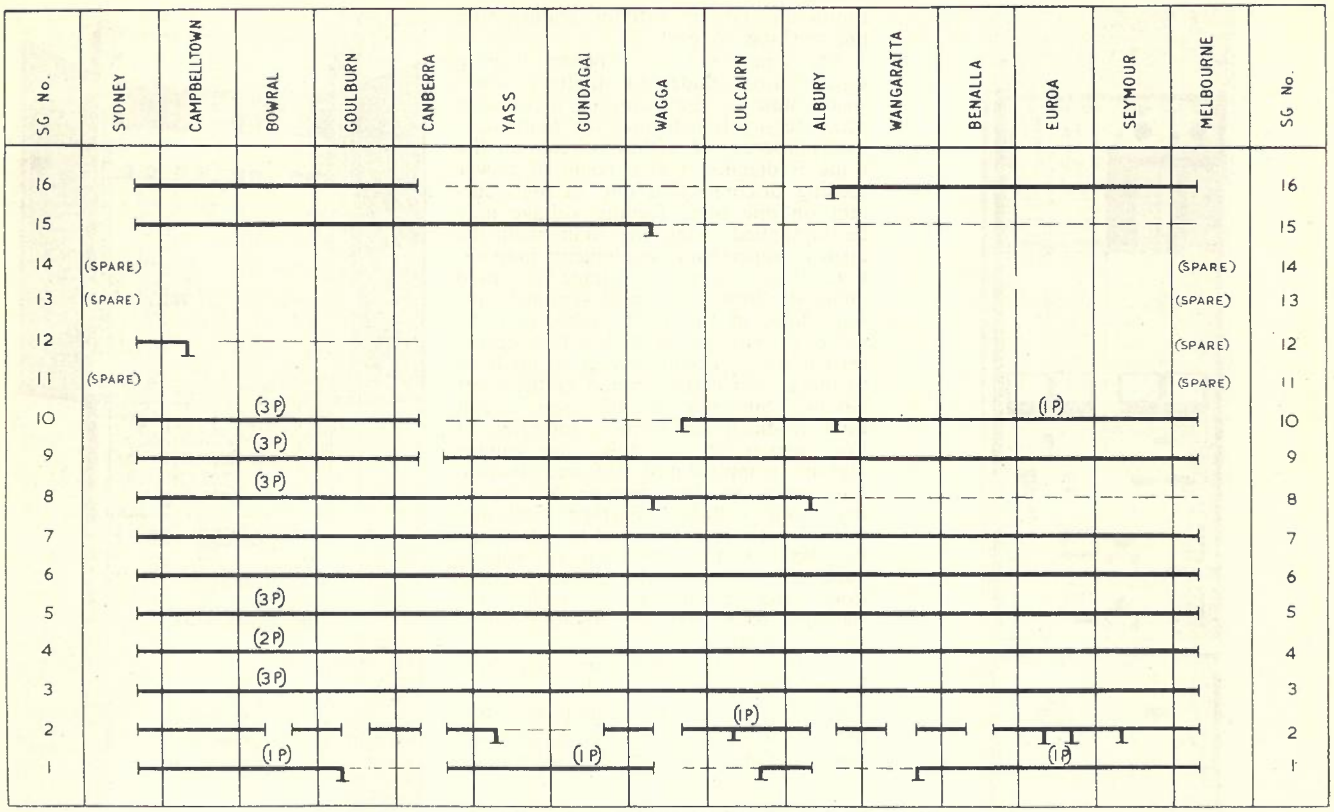

Fig. 11.—Telephony Supergroup Allocation, including Programme Channels.

location under short circuit fault conditions. Duplicate power extraction transformers are provided to further increase the system reliability resulting from the use of parallel valve amplifiers and of duplicate line amplifier rack power supply units at the unattended stations.

The above design at unattended stations is such that it would be theoretically possible, with more than one tube-pair equipped, for the duplicated power outlets to be so distributed that the parallel valves in each line amplifier are fed from two independent power feeding systems. This arrangement would add considerably to the system complexity, however, and its possible implementation on the Sydney-Melbourne route will depend on the reliability experienced with the overall system, including the cable, as initially installed.

Power Feeding Equipment Arrangements

The power feeding equipment at the attended and unattended stations is housed in "Remote Power Feeding" racks.

At the attended stations three types of remote power feeding rack are employed. The first type caters for feeding on one pair of tubes in one direction only and is used at Campbelltown, Gundagai, Benalla and Seymour. The second type, illustrated in Fig. 13, accommodates equipment for two independent power feeding systems on two pairs of tubes in the one direction, or on one pair of tubes in both directions. It is employed in the first application at Sydney and in the second application at Goulburn, Canberra, Wagga, Albury and Euroa. The third type of rack accommodates power separation filters only at those attended stations from which power feeding is not employed. This rack has a capacity for 12 filters and is installed at Bowral, Yass, Culcairn, Wangaratta and Melbourne.

The one type of remote power feeding rack is installed in all unattended stations and accommodates all equipment for one pair of coaxial tubes on both sides of the station. This rack is illustrated in Fig. 14.

It should be noted that power separation filters are still installed on cable sections where there is no power feeding. This is mainly to protect the transmission equipment from longitudinal voltages that may be induced in the cable due to near-by power line faults or lightning strikes and also maintains standard conditions for line equalisation and cable termination.

Heavy U-links are employed on all racks for the connections to the power separation filters from the line sockets at which are terminated the flexible coaxial leads from the cable pot-heads.

Power Feeding Supervision

At a power feeding station there is inbuilt for each power feeding system a voltmeter and ammeter which are switchable to either tube of the pair. These allow observation, as required, of the values of voltage and current being fed to line on either tube. Furthermore, continuous automatic monitoring is

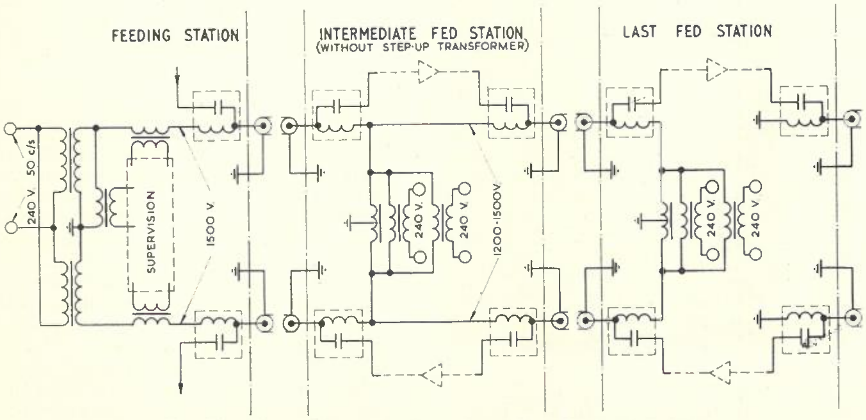

Fig. 12.—Power Feeding Section—Simplified Block Schematic.

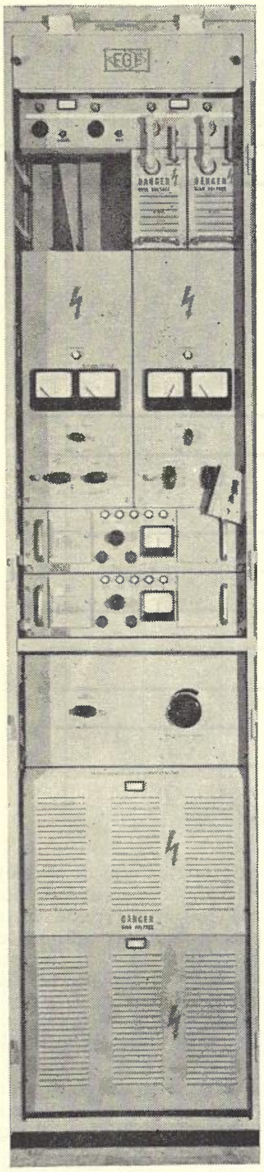

Fig. 13.—Attended Station Remote Power Feeding Rack Partly Equipped for 2 Power Feeding Systems.

effected on an impedance supervision basis whereby the ratio of feeding current to feeding voltage is measured independently for each tube. If the current changes in relation to the voltage by more than a pre-set percentage, an alarm is operated and if the change exceeds double this pre-set amount, the remote power feeding is automatically disconnected after a delay of one second. The limit at which alarm/disconnection occurs is set to 10/20%, 20/40% or 30/60% depending on the number of unattended stations being fed, a higher sensitivity being required with an increase in the latter. Alarm lamps indicate the particular tube involved and whether the condition is due to high or low current. The supervision equipment is so designed that its operation may be checked by means of an inbuilt fault simulation circuit without endangering the working system.

The equipment at a power feeding station also includes an auxiliary supervision unit in the form of a variable ratio step-up transformer for fault location purposes. If a short circuit on the route is diagnosed as a result of power feeding disconnection due to high current on one tube, feeding voltage may be re-applied using this unit with the normal supervision equipment inoperative. The re-applied voltage is raised manually from zero until nominal current flows in the faulty tube, and the value of voltage at which this occurs then allows a calculation to be made as to the approximate location of the short circuit. Similarly if an open circuit fault is diagnosed from a condition of low current on one tube, the voltage may be re-applied manually and observation made of the current flowing at maximum voltage. Further confirmation of the results obtained in either case is given by the operation of voltage dependent relays in the unattended stations, the conditions of which are signalled back over the Remote Supervision system.

In the unattended station rack there is an inbuilt meter for observation of the 240 volt output from the power feeding system, and measuring sockets are provided for the onward feeding voltage. The latter is also relay supervised as referred to above.

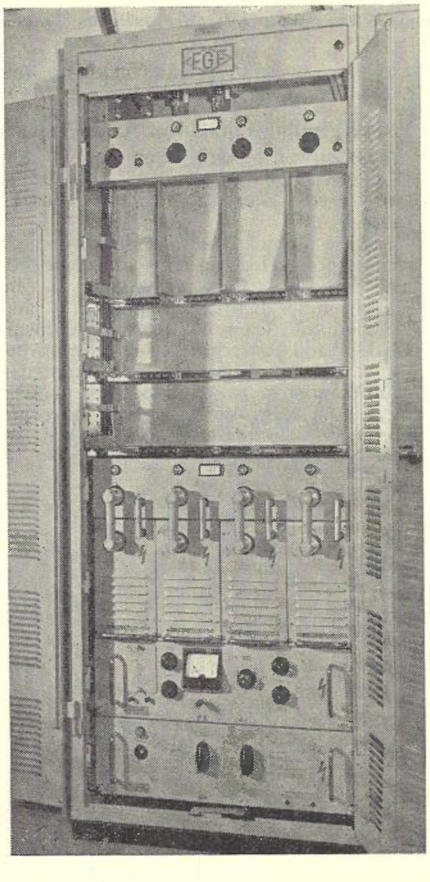

Fig. 14.—Unattended Station Remote Power Feeding Rack Equipped for 1st of 2 Pairs of Tubes.

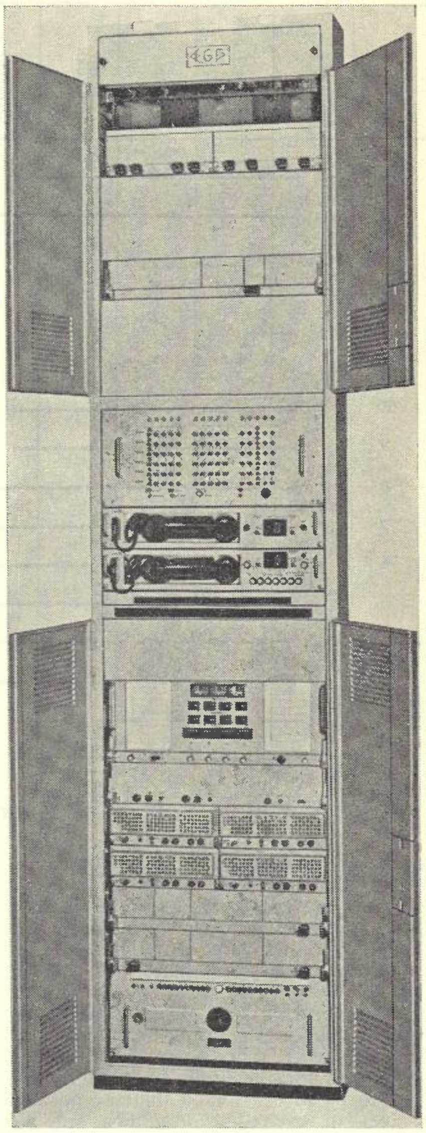

Fig. 15.—Auxiliary Rack.

Mobile Power Feeding

The requirement for mobile power feeding plant for use at unattended stations during cable repair operations is discussed in the associated article by Mr. Hannah in which details have also been given of the actual power plant involved, the dummy loads required when normal power feeding is disconnected at an intermediate unattended station, and the special vehicles designed for carrying this plant. The mobile power feeding vehicle also accommodates remote power feeding equipment virtually identical to that at a normal power feeding station except that it is mounted on short racks to ease accommodation requirements in the vehicle, and that facilities are incorporated for remote control from within an unattended station. One rack accommodates equipment for feeding on one pair of tubes.

The unattended station remote power feeding racks have been designed to provide full co-ordinating facilities for use with the mobile plant to allow no-break change-over from normal to mobile power feeding and vice versa. It is also possible where commercial A.C. mains supply is available at all unattended stations concerned for the line amplifier equipment to be operated therefrom under emergency conditions.

Power Feeding Safety Features

On all remote power feeding racks, all doors and units where high voltage may be present are appropriately signwritten or marked with a red "lightning" symbol. Removal of the cover from a high voltage transformer during operation results in automatic disconnection of power and an alarm. At the heavy U-link connections between the power separation filters and the rack line sockets, the plug/socket design is such that on removing a U-link, the connection of the earthed outer conductor remains closed until after the inner conductor, which is recessed in the socket, is broken. Above each power separation filter a neon lamp is provided to indicate whether or not high voltage is applied to the coaxial tube concerned. Although it might at first appear that for maximum safety this neon lamp should be connected directly to the line socket, such connection would lead to difficulty in obtaining valid results from insulation-resistance testing of the cable, after a fault. This testing at unattended stations can only be carried out from this line socket if technically undesirable unsoldering at the cable pot-head is to be avoided. The neon lamps have accordingly been connected to the rack connection points at the low pass drop of the power separation filters, and it is considered that equivalent safety features are obtained with this arrangement. The doors of unattended station racks are lockable in such a manner that the key cannot be extracted unless the doors are closed and the lock operated.

When the remote power feeding is disconnected for cable repair operations, it is essential for the safety of the linemen concerned that all practical steps are taken to render the re-connection of power impossible while the line work is in progress. A number of the above features assist to this end but a number of additional special features have been incorporated in this connection as set out in the following paragraphs.

For each power feeding system at an attended station a second switch, separate from the power feeding "on/off" switch, is provided for disconnection of the power circuits from the low pass drop of the power separation filters and for the application of earth thereto. This earth provides a safety connection to the coaxial tube without affecting high frequency line transmission. A mechanical interlock is provided between the two switches. The "cable disconnect/earth" switch is also provided with an auxiliary contact in the "earth" position which closes a D.C. loop to the terminal strip at the top of the rack. These loops for all equipped pairs of coaxial tubes in the cable on a particular side of the station are then wired away, in series with a battery supply, to a "cable safe" lamp, which lights when all switches concerned are operated to the "earth" position. If power is to be disconnected from an adjacent cable section, the lineman can thus note whether all neon lamps for tubes on that side of the station extinguish and observe if the "cable safe" lamp lights. To guard against re-connection of power, a small keyed metal plate is then applied over the "power on/off" switch knob and the lineman fixes this in position with his own padlock; the rack doors cannot be locked at attended stations as independent power feeding systems for opposite directions from the station may be accommodated on the one rack.

In the unattended stations a similar "disconnect/earth" switching principle is incorporated in the equipment, and a "cable safe" lamp is provided for each direction. In this case, however, the complete rack doors are locked and the keys deposited in a wall mounted box in the station which the lineman then locks with his own padlock.

ORDER WIRE AND REMOTE SUPERVISION FACILITIES

General

The Sydney-Melbourne system includes order wire facilities for providing service communication over the route between all stations, and remote supervision facilities whereby fault indications are transmitted from unattended to controlling attended stations and from attended stations to the route master control stations. These facilities are provided over paper insulated 20 lb per mile core pairs of the cable and fully electronic equipment is employed. To provide maximum reliability under fault conditions, when these facilities are most important, active units of this equipment in the unattended stations are not powered from the coaxial remote power feeding system but are power fed independently at low voltage D.C. over a phantom circuit of the paper insulated pairs. At attended stations all equipment, as required, is accommodated in an "Auxiliary" rack as illustrated in Fig. 15. In the unattended stations the equipment is housed in the first-in line amplifier rack.

Short Haul Order Wire

The short haul order wire circuit is provided at voice frequency between each adjacent pair of stations to give

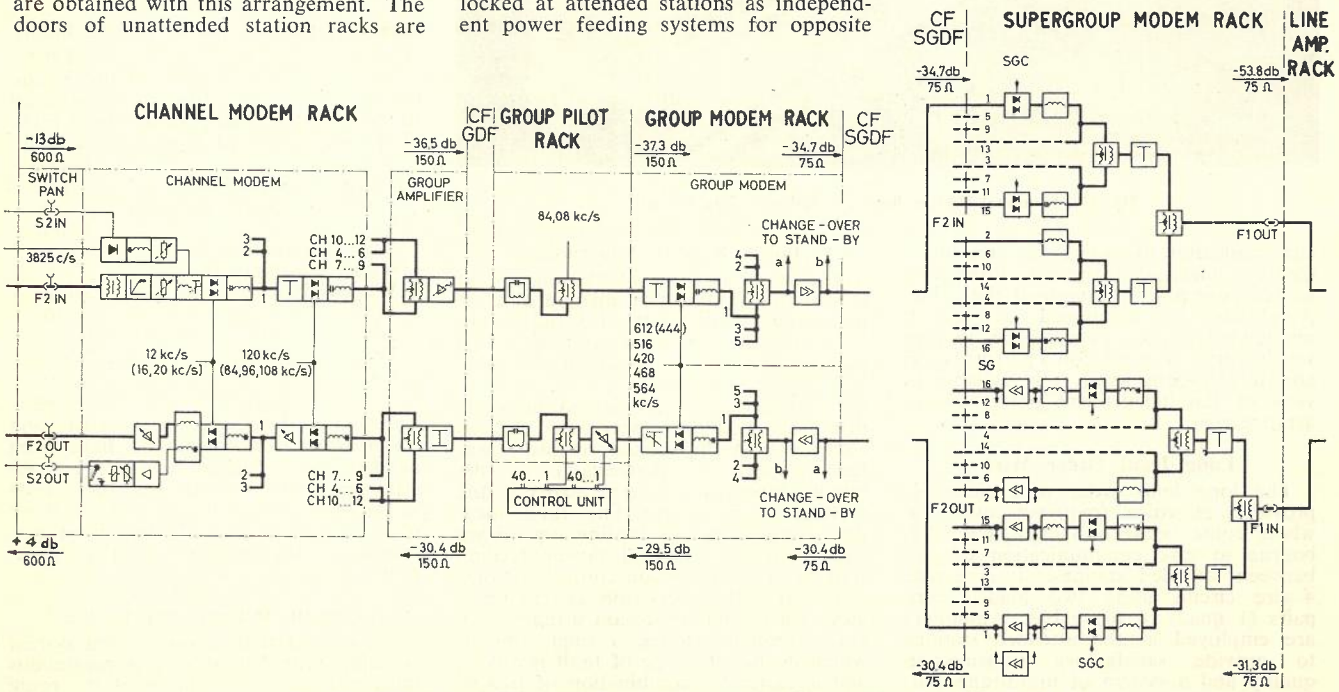

Fig. 16.—960-channel Telephone Terminal Modulation Equipment—Block Schematic.

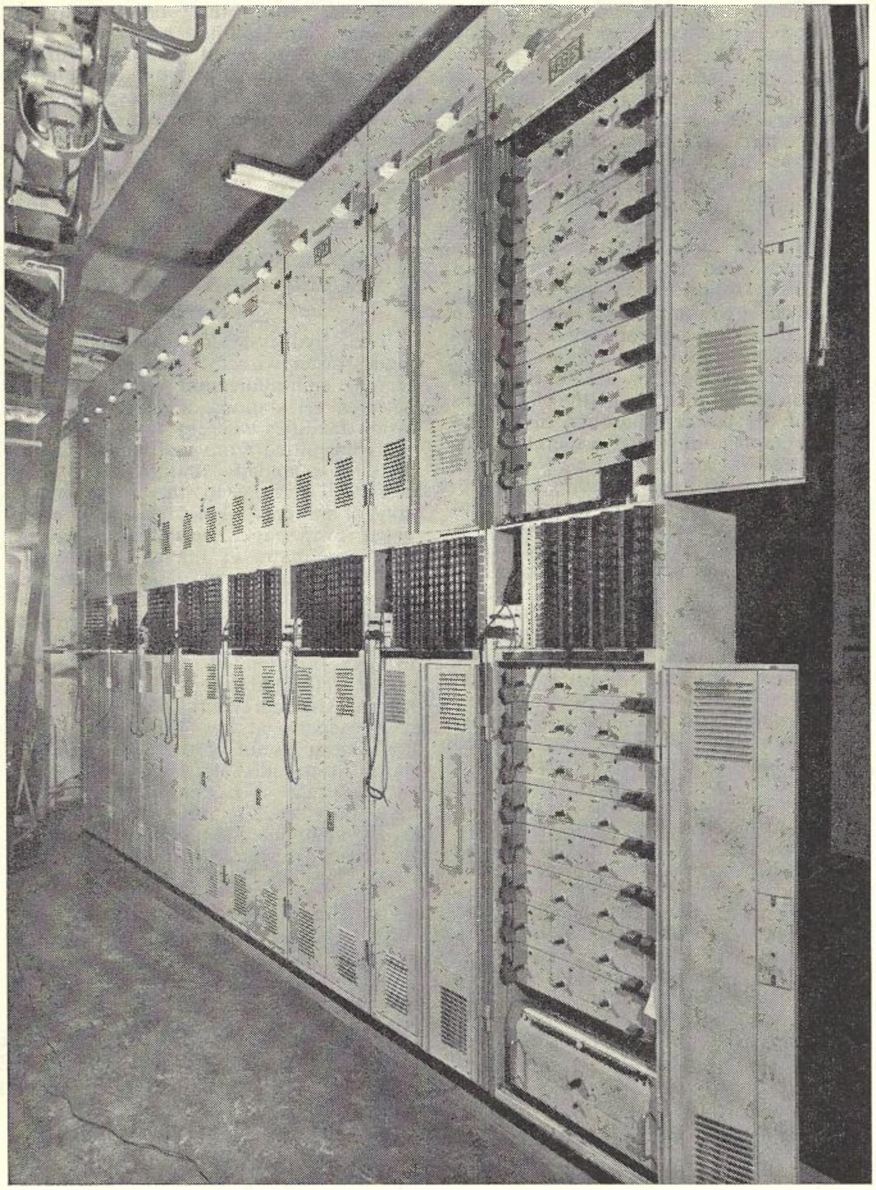

Fig. 17.—Channel Modem Racks at Sydney (City South).

communication to and between the intermediate unattended stations, using two loaded core pairs (1 quad) of the cable. Amplifiers are employed at certain unattended stations as necessary to give satisfactory transmission performance, and this is considered fully reliable in view of the independent power supply arrangement.

Long Haul Order Wire

The long haul order wire circuit is provided at voice frequency over the whole route between Sydney and Melbourne to give communication to and between attended stations. It is a true 4-wire circuit using two loaded core pairs (1 quad) of the cable. Amplifiers are employed at the attended stations to provide satisfactory transmission quality and a system of multi-tone calling is incorporated.

Local Remote Supervision

The local remote supervision system is provided for the transmission of fault indications from unattended stations to a controlling attended station. Two loaded core pairs (1 quad) of the cable are employed. From service considerations it has been considered desirable that the remote supervision sections coincide with the coaxial remote power feeding sections, particularly as the remote supervision system assists in the method available for line fault location using the power feeding supervision equipment. All coaxial power feeding stations are thus section control stations.

The remote supervision system operates in a particular section using 5 or 6 voice frequency tones, a single one of which defines the type of fault involved, and a particular combination of two of which defines the particular unattended station concerned. The 5 or 6-tone system is thus employed to supervise up to 10 or 15 unattended stations respectively. In the attended control station a "control unit" transmits to the unattended supervised stations, over the "calling" cable pair, successive combinations of 2 out of the 5 or 6 frequencies generated in the control unit, using two electronic selectors switched by a pulse generator. The "repeater unit" of each unattended supervised station responds in turn to its particular 2-frequency code and connects to the "answering" cable pair a local 5 or 6-frequency tone generator which operates so that if there is a fault, the particular frequency corresponding to that fault is not transmitted. The return signals on the answering line are received at the attended control station by its "indicator unit" which also receives the unattended station code transmitted on the calling line. Both signals are decoded by the indicator unit and any fault is registered on a rectangular array of visual indicators which shows the unattended stations horizontally and the types of fault vertically.

The following types of fault are indicated by the signals transmitted from an unattended station:—

Signal 1: Building door lock contact open or Order wire answering key not in "off" position.
Signal 2: Tube failure in a line amplifier or Anode currents in a line amplifier show excessive departure from normal.
Signal 3: Pilot failure in A-B direction or Temperature equaliser at extreme upper or lower limit in A-B direction.
Signal 4: Pilot failure in B-A direction or Temperature equaliser at extreme upper or lower limit in B-A direction.
Signal 5: Coaxial power feeding failure on one or more tube pairs.

The distribution of use of the 5- and 6-tone systems over the route, referred to the attended control stations and route directions concerned, is as follows:—

Sydney (South)	5-tone
Campbelltown (South)	5-tone
Goulburn (North & South)	6-tone
Canberra (North)	5-tone
Canberra (South)	5-tone
Gundagai (North)	6-tone
Wagga (North)	5-tone
Wagga (South)	5-tone
Albury (North & South)	6-tone
Benalla (North)	5-tone
Euroa (North & South)	6-tone
Seymour (South)	6-tone

Although both directions north and south from Canberra could have been handled by a single 6-tone system, two separate 5-tone systems are being used so as to achieve the desired break-up of the route for overall supervision purposes, as discussed in the next paragraph.

Overall Remote Supervision

An overall remote supervision system is being provided to give a continuous indication of the condition of the route to master control stations Sydney and

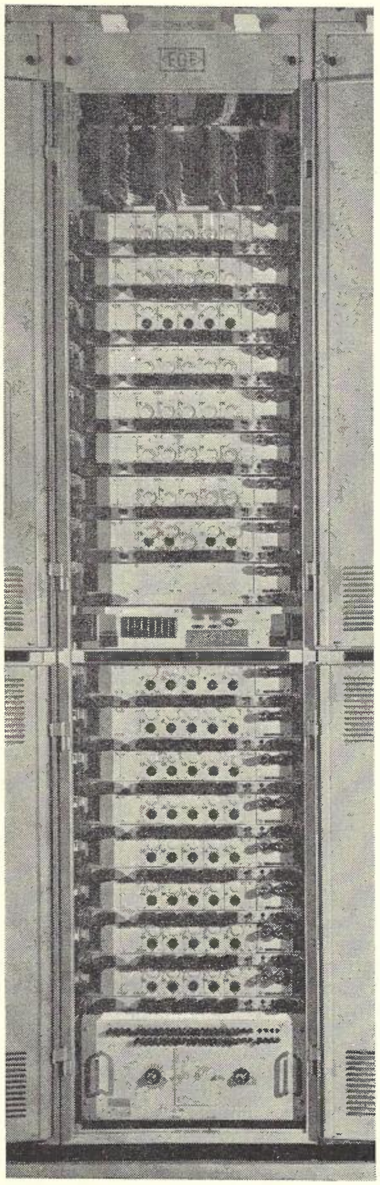

Fig. 18.—Group Modem Rack.

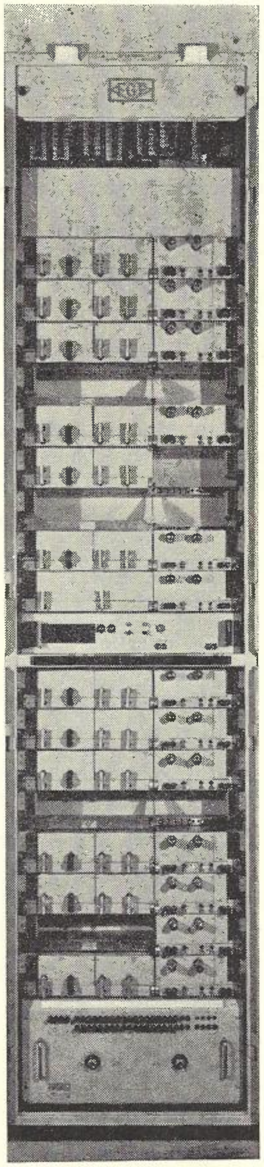

Fig. 19.—Supergroup Modem Rack (Partly Equipped).

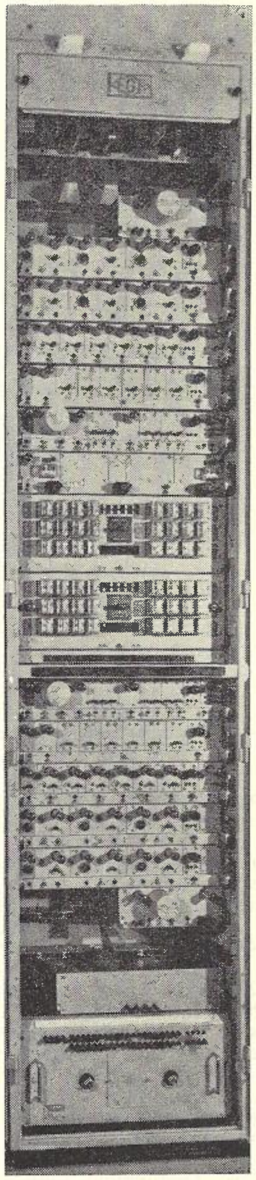

Fig. 20.—Channel and Group Carrier Supply Rack.

Melbourne. The method of operation of this system is to be identical to that of the local remote supervision system, with two loaded core pairs (1 quad) of the cable being employed, and with the intermediate attended stations being considered as analogous to the unattended stations in the local system. As Canberra constitutes for telephony a back-to-back terminal connection of two coaxial line systems, the overall supervision system is to be divided there between the line equipment on the two sides of the station, with the northern system supervised from Sydney and the southern system from Melbourne. This arrangement requires a second auxiliary rack at Canberra. The 5-tone system is to be used for Sydney-Canberra while the 6-tone system is required for Melbourne-Canberra. The fault indications to be transmitted are not yet finally determined but will include extensions from both the local remote supervision indicator unit, where such is employed at the attended station concerned, and extensions from the attended station local alarm system.

TELEPHONE TERMINAL EQUIPMENT

General

The telephone terminal equipment comprises all equipment necessary to effect the transformation in both directions between individual 2-wire circuits and the multi-channel line frequency band. The 2-wire telephone circuits from the Departmental switching equipment are converted by 4-wire terminating sets into 4-wire circuits, and then pass through a series of modulation stages according to a scheme recommended by the C.C.I.T.T. As in most long distance carrier systems, single side-band suppressed carrier amplitude modulation is employed to achieve maximum utilisation of system bandwidth and minimum power loading of line equipment. Stages of channel modulation producing 12-channel basic groups in the frequency band 60-108 Kc/s, group modulation producing 60-channel basic supergroups in the frequency band 312-552 Kc/s, and supergroup modulation producing the 960-channel line frequency band 60-4,028 Kc/s are employed. A simplified block schematic of the complete terminal modulation equipment for 960-channel working is shown in Fig. 16, which sets out the basic equipment units and the levels, impedances and carrier frequencies employed. The group pilot equipment shown is used on groups that transverse a distance over the system

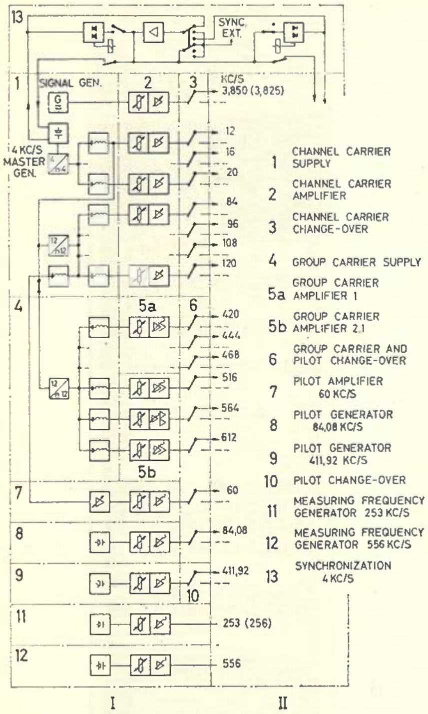

Fig. 21.—Channel and Group Carrier Supply —Block Schematic.

exceeding 125 miles. To increase the system capacity to 1,260 channels a further set of 5 supergroups is added after the supergroup modulation stage, this being known as a 300-channel mastergroup and comprising supergroups 4 to 8 occupying the frequency band 812-2,044 Kc/s. This mastergroup is further modulated and combined with the 960-channel band to produce the 1,260-channel band of 60-5,564 Kc/s.

Performance aspects of the terminal equipment have been covered generally in the associated article by Mr. Macdonald. Other interesting features of the equipment are set out briefly in the following paragraphs.

4-Wire Terminating Equipment

This equipment comprises for each channel a plug-in unit housing a hybrid transformer, solder-strap adjustable attenuators in both 4-wire send and receive directions, and a simple receive low pass filter for increasing the immunity of the speech channel to the 3,825 c/s signalling tone. Two types of rack are employed for accommodating this equipment, namely a "4-wire terminating" rack of capacity 120 units, and a "Voice Frequency" rack of capacity 60 units together with amplifiers and hybrids for voice frequency circuits in the cable. The 4-wire terminating rack is installed at Sydney, Canberra, Wangaratta and Melbourne, the voice frequency rack at Campbelltown, Bowral, Yass, Gundagai, Culcairn, Benalla, Euroa, Seymour and both types at Goulburn, Wagga and Albury.

Channel Modem Equipment

The channel modem equipment for each 12-channel basic group comprises four pre-group slide-in chasses plus a group amplifier plug-in unit. This equipment is fully transistorised and extensive use is made of printed circuits. The "Channel Modem" rack illustrated in Fig. 17 accommodates channel modem equipment for 4 basic groups together with a monitoring set, 800 c/s test oscillator and level meter, and a central jack panel providing test and monitoring access for each 4-wire speech channel and for the inbuilt signalling control leads. The levels at the 4-wire voice frequency input and output test points have been modified by the manufacturer to the Australian standard by incorporating pads in the wiring of the jack panel.

Group Modem Equipment

The group modem equipment for each 60-channel basic supergroup comprises for each direction, a single slide-in chassis which incorporates a supergroup amplifier as a plug-in unit. At the larger stations Sydney, Goulburn, Canberra, Wagga, Albury, Wangaratta and Melbourne such equipment for up to 8 basic supergroups is accommodated in a "Group Modem" rack as illustrated in Fig. 18. In this rack a centralised spare supergroup amplifier is provided complete with facilities for it to be manually switched into service in place of any working amplifier with a change-over time of not more than 2 ms. In the smaller stations a "System" rack is provided which will accommodate group modem equipment for up to 4 basic supergroups together with channel and group carrier supply equipment.

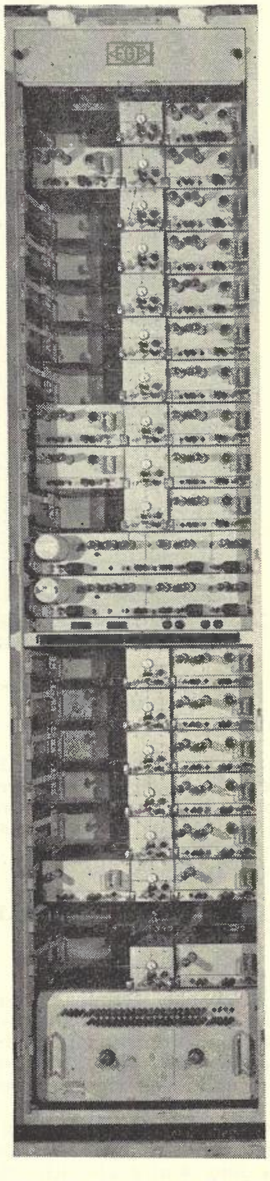

Fig. 22.—Supergroup Carrier Supply Rack (Partly Equipped).

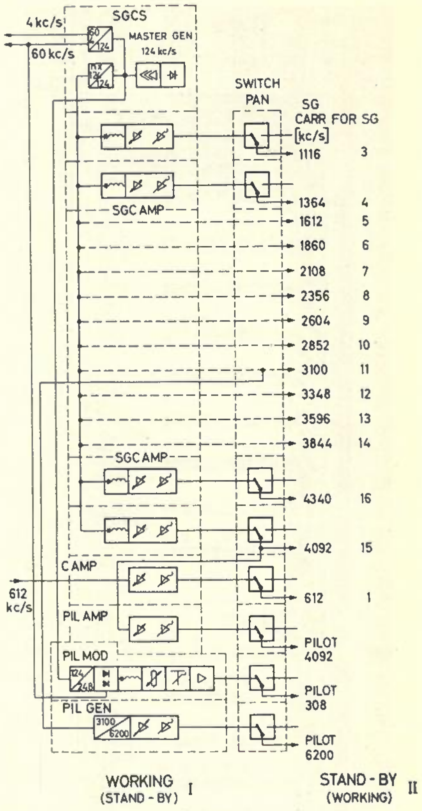

Fig. 23.—Supergroup Carrier Supply—Block Schematic.

Supergroup Modem Equipment

The supergroup modem equipment comprises a common supergroup coupling unit plus for each supergroup a single modem unit and a supergroup receiving amplifier unit. At the larger stations Sydney, Canberra, Wagga, Albury and Melbourne a "Supergroup Modem" rack as illustrated in Fig. 19 is employed, which has capacity for the complete supergroup modem equipment for one 960-channel terminal. As for the Group Modem rack a centralised spare supergroup amplifier with manual change-over facilities is provided in this rack. At the smaller stations all supergroup modem equipment required initially for the system can be accommodated in the Branching rack referred to previously. To avoid re-adjustment of levels

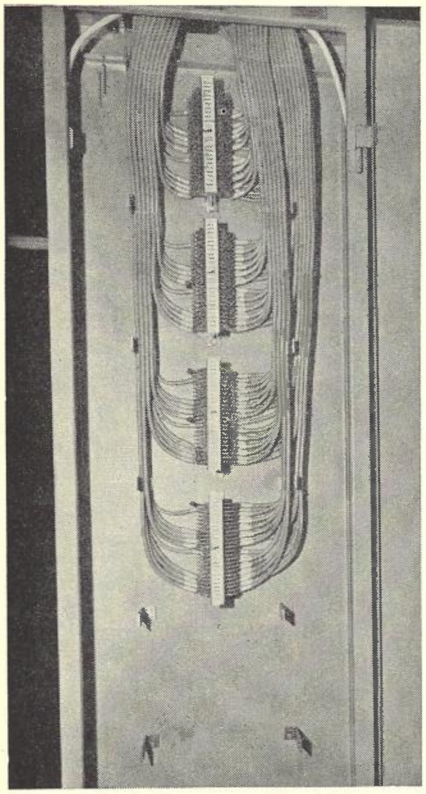

Fig. 24.—Channel Carrier Supply Distribution Strip.

in the supergroup modem equipment when additional supergroups are provided in the future, imitation supergroup modem units are being installed initially to provide the full number of correct terminations to the supergroup coupler unit.

Carrier Supply Equipment

At the larger stations Sydney, Goulburn, Canberra, Wagga, Albury, Wangaratta and Melbourne all carrier frequencies for channel and group modulation, together with the 3,825 c/s signalling frequency and, excluding Goulburn, the 84.08 Kc/s group pilot frequency, are generated in a "Channel and Group Carrier Supply" rack which is capable of supplying these frequencies for eighty 12-channel groups. This rack is illustrated in Fig. 20 and a simplified block schematic is shown in Fig. 21. The channel and group carrier frequencies are generated from a 4 Kc/s master oscillator which has a long term frequency stability of 1 in 10^6. All equipment is duplicated and facilities for both automatic and manual change-over between working and spare units are provided. At the smaller attended stations similar equipment, but on a smaller scale and excluding the group pilot supply, is accommodated on the System rack referred to previously.

At stations Sydney, Canberra, Wagga and Melbourne a "Supergroup Carrier Supply" rack is installed to provide up to all the 15 carrier frequencies required for supergroups 1 and 3 to 16. No carrier is required for the basic supergroup 2 and amplification only is provided for the supergroup 1 carrier 612 Kc/s which is also a group carrier frequency and is available from the channel and group carrier supply. At the terminal stations Sydney, Canberra and Melbourne units are also included for supplying the line pilot frequencies for the 6 Mc/s line equipment. The rack is illustrated in Fig. 22 and a simplified block schematic is shown in Fig. 23. Each frequency is supplied at sufficient output power to feed up to 5 terminals. All frequencies are generated from a 124 Kc/s master oscillator of long term frequency stability 1 in 10^7. All equipment is duplicated and facilities for both automatic and manual change-over incorporated. At the smaller attended stations all supergroup carrier supply equipment provided initially for the system can be accommodated in the Branching rack referred to previously.

Facilities are provided on the two carrier supply racks for synchronisation between them at a frequency of 4 Kc/s. Distribution of the carrier frequencies to the modem racks concerned is effected at "Carrier Distribution Strips" located at one end of the equipment rows. These are illustrated in Figs. 24 and 25.

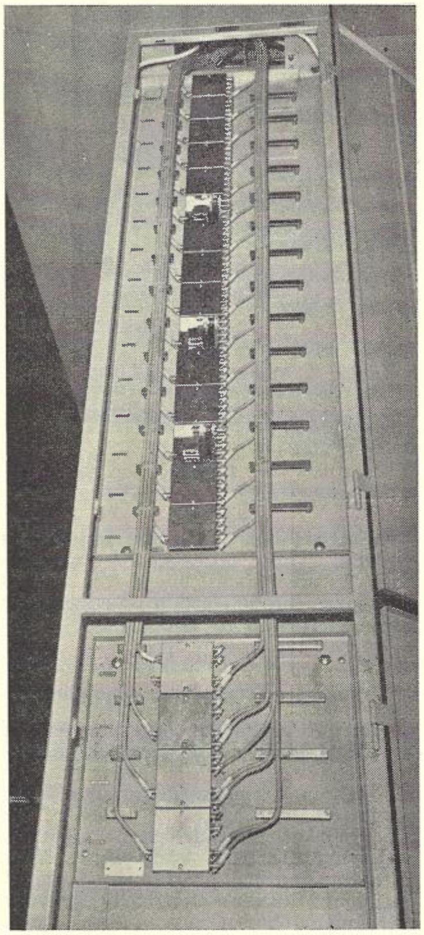

Fig. 25.—Supergroup Carrier (Top) and Line Pilot (Bottom) Distribution Strips.

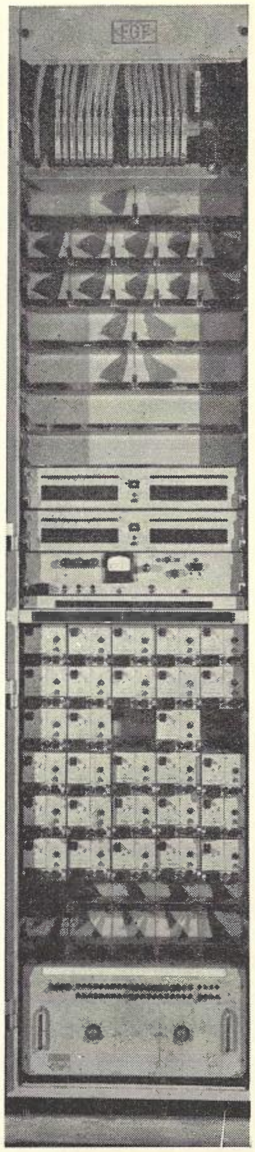

Fig. 26.—Group Pilot Rack (Partly Equipped).

Group Pilot Equipment

Where required for circuits exceeding 125 miles in length, group pilot equipment for up to forty 12-channel groups is housed in a "Group Pilot" rack as illustrated in Fig. 26. The plug-in unit for a single group comprises an injection circuit consisting of an 84.08 Kc/s crystal stop filter and combining hybrid, and a receiving circuit consisting of a transistorised control amplifier, a separting hybrid and stop filter. The stop filters are necessary to avoid interference between the 84.08 Kc/s pilot and the nearby 3,825 c/s signalling tone at group frequency 84.175 Kc/s. The receiving outputs from the group pilot units are scanned at a rate of one per 4 seconds by one of two pilot supervision units, each of which scans 20 group units, and connected in turn to a common pilot

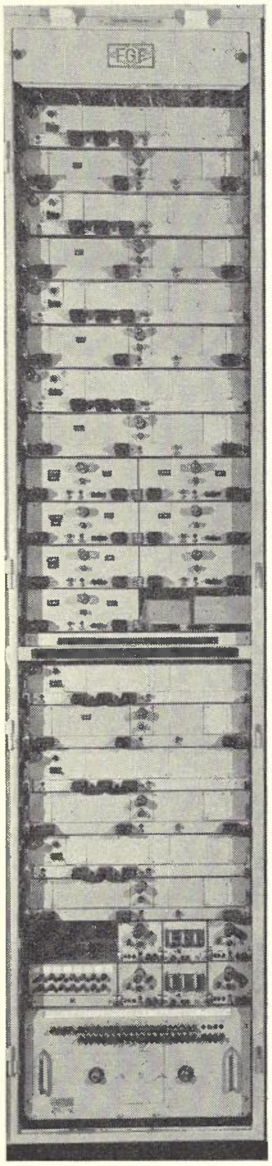

Fig. 27.—Programme Terminal Rack Fully Equipped for 7 Transmit Terminals.

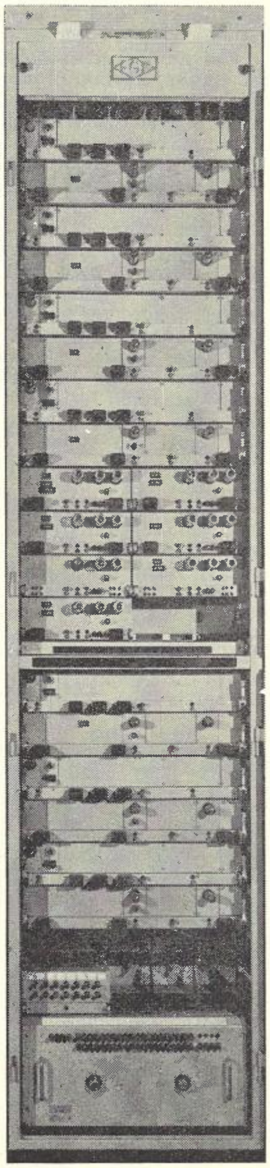

Fig. 28.—Programme Terminal Rack Fully Equipped for 7 Receive Terminals.

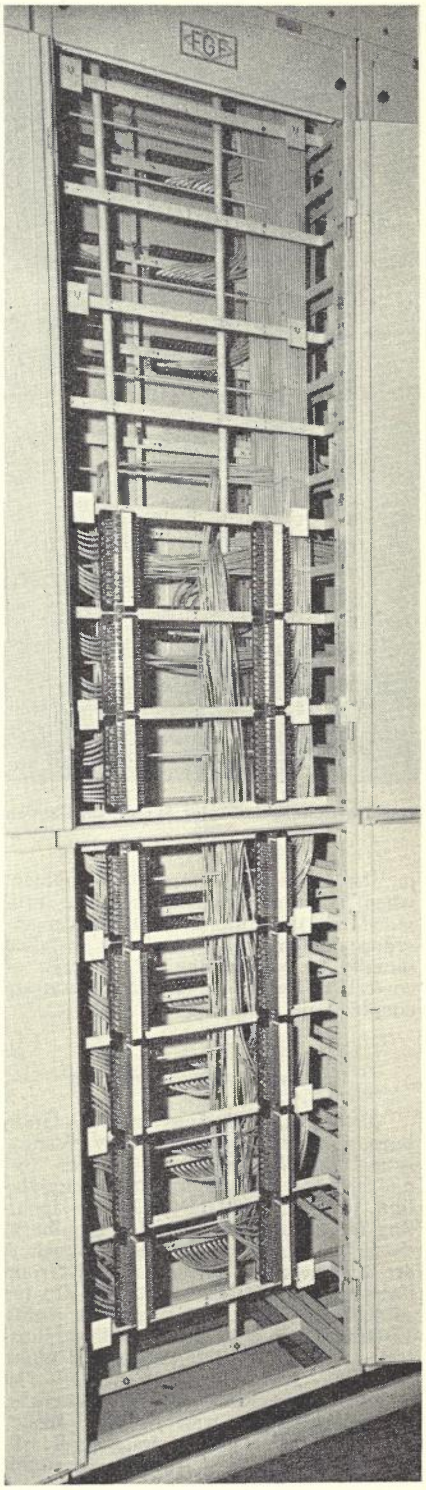

Fig. 29.—Group Distribution Frame.

receiver which if necessary sends a corrective pulse to the control amplifier concerned. Level regulation occurs in steps of 0.1 db on a group if its incoming pilot level deviates by more than ± 0.5 db from nominal, up to a maximum deviation of ± 2.6 db. Different types of alarm are indicated for deviations exceeding ± 2.6 db and exceeding -6.1 db.

Group pilot racks are installed at Sydney, Canberra, Yass, Wagga, Albury, Wangaratta and Melbourne. At Yass, where no channel and group carrier supply rack is installed, the group pilot rack also accommodates the duplicated 84.08 Kc/s pilot generators.

Through Filter Equipment

To cater for through connection of basic groups and/or basic supergroups, "Through Filter" racks are installed at Sydney, Canberra and Melbourne. This rack accommodates up to 16 sets of filters for through group or supergroup connection in both directions.

Broadcast Programme Equipment

Facilities for the transmission of broadcast programme channels of 10 Kc/s bandwidth may be incorporated in the terminal equipment at the basic group (60-108 Kc/s) stage in lieu of the pre-group of three telephone channels occupying the band 84-96 Kc/s. This is effected using programme terminal equipment located electrically between the channel and group modem equipment. In this equipment for a transmitting terminal, a physical programme channel of bandwidth 50 c/s to 10 Kc/s is modulated, by a two stage process using carrier frequencies 24 Kc/s and 120 Kc/s, to the band 86-96 Kc/s. This band is then combined with the remaining nine telephone channels of the basic group via a filter and coupler unit, and the composite group finally amplified to restore the basic group level to its former value. Similar processes occur in reverse in the receiving terminal.

All necessary equipment including that for deriving and amplifying the carrier frequencies from the 12 Kc/s and 120 Kc/s frequencies available from the channel and group carrier supply, are accommodated in a "Programme Terminal" rack. This rack, which is illustrated in Figs. 27 and 28, can house equipment for up to seven terminals in any combination of transmitting or receiving directions. Programme terminal equipment is installed at Sydney, Goulburn, Canberra, Wagga, Albury, Wangaratta and Melbourne.

Distribution Frames

"Distribution Frames" are installed to facilitate interconnection of equipment at the basic group (60-108 Kc/s) stage and at the basic supergroup (312-552 Kc/s) stage. A distribution frame occupies the space normally occupied by two equipment racks back-to-back and is arranged with connecting strips horizontal on one side and vertical on the other side. The horizontal side generally terminates cables from the F1 (line) side of equipment racks while the vertical side terminates cables from the F2 (station) side of equipment racks. Normal type tag blocks are used for group distribution but shielded terminations are necessary for supergroup distribution. The arrangements employed are illustrated in Figs. 29 and 30.

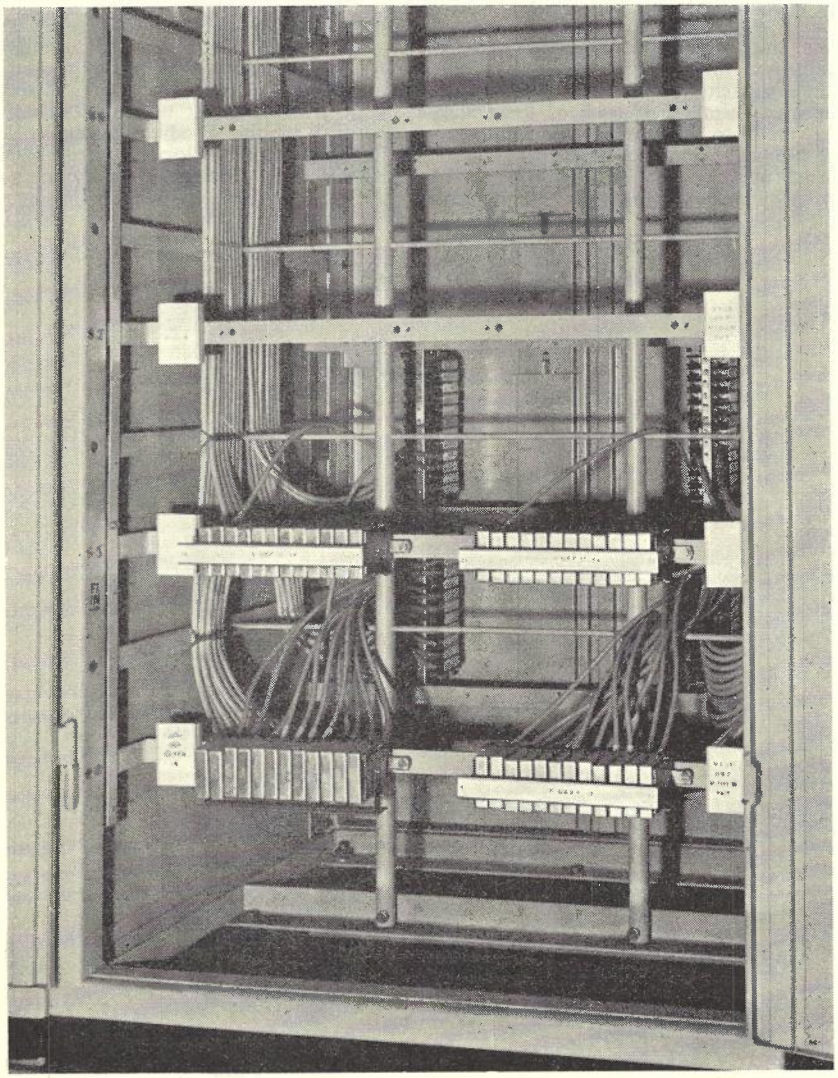

Fig. 30.—Supergroup Distribution Frame (Part only).

The capacity of a distribution frame is 120 basic groups or basic supergroups when installed for separate application in large stations, as has been done at Sydney, Canberra, Wagga, Albury and Melbourne. At the smaller stations a combined frame of capacity 20 supergroups with 100 groups is installed.

Other aspects relating to cabling and mechanical arrangements are described in the associated article by Messrs. Peacock, Boyd and Beard.

EQUIPMENT FOR VOICE-FREQUENCY CIRCUITS

The transmission equipment involved in the provision of voice frequency circuits on paper insulated core pairs of the composite coaxial cable and on separate minor trunk cables along the Sydney-Melbourne route is very similar in principle to that normally installed by the Department for this type of application. All units are designed on a plug-in basis and all active equipment is transistorised and suitable for 48 volt battery operation where installed at other than attended stations of the coaxial system.

The equipment for 4-Wire amplified circuits, comprising amplifiers and hybrids, is accommodated in the Voice Frequency racks referred to previously at both coaxial attended stations and at other trunk switching centres along the route. The negative impedance repeaters for 2-Wire amplified circuits are located only at small terminal exchanges along the route where they are accommodated in small frames for wall or rack mounting, each frame having a capacity for 8 units.

CONCLUSION

A brief overall survey has been given of the main design features of the Sydney-Melbourne transmission equipment and of its application over the route. On present indications the equipment appears to be of very high standard in all respects. Aspects of the system design relating particularly to television transmission will be covered in a later article in the Journal.

ACKNOWLEDGEMENTS

The author wishes to acknowledge with thanks information made available by the equipment contractor for the project, Telecommunication Company of Australia Pty. Ltd., and by the equipment manufacturers, Felten and Guilleaume Fernmeldeanlagen G.M.B.H. and N.V. Philips Telecommunicatie Industrie.

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J. R. Walklate, "Broadband Telecommunication Systems. Part 5 — The Transmission of Telecommunication Traffic over Broadband Bearers", The Journal of the Institution of Engineers Australia, Vol. 33, No. 6, page 224.

INSTALLATION OF TRANSMISSION EQUIPMENT

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A. M. BOYD, Assoc.I.R.E.Aust.[*]
and W. G. BEARD, B.E., A.M.I.E.Aust.[*]

INTRODUCTION

The installation of the transmission equipment for the Sydney-Melbourne Coaxial Cable Project is a major work calling for the mechanical installation, cabling, testing and commissioning of equipment in fifteen attended stations and 103 unattended minor repeaters. The problem is additionally complex because of the diversity of suppliers, as the carrier and line equipment associated with the telephone channels is manufactured in Nuremberg, Western Germany, by Felten & Guilleaume Fernmeldeanlagen, G.m.b.H.; the programme and television terminal equipment in Holland by N.V. Philips Telecommunicatie Industrie, Hilversum; the power plant principally in England with some control apparatus being manufactured in Melbourne by McColl Electric Works Ltd.: and test instruments in Western Germany, Holland, Switzerland and the U.S.A.

The equipment used on the project incorporates the most advanced techniques applicable to the field, and this creates difficulties in the training of staff. Furthermore, the fact that the 600-odd mile route passes through some sparsely populated areas introduces unique problems of transportation and housing.

This article is intended to indicate some of the most important considerations in the early planning for the installation, in the organisation and training of the field staff, with details of some of the salient points of mechanical erection of the equipment, cabling and testing.

INSTALLATION PROGRAMME

Mr. Kaye's article elsewhere in this issue of the Journal indicates that the installation of the equipment is taking place in four stages. At first sight this may seem a most inefficient procedure, as it necessitates repeated visits to each station with resultant loss of time and additional travelling. However, the installer is not the only party to be considered, and thought had to be given to the requirements of the Department and of the equipment manufacturers.

Firstly, it is most desirable that the Department's capital investment in the system becomes revenue producing at the earliest possible date, and this is clearly best achieved by progressive commissioning in stages.

From the manufacturers' viewpoint, it would be simplest to manufacture all units of a particular type in one continuous production run, but for the complete installation of each station in sequence, so many different items would be required at the one time, that production capacity would have to be increased to an impossible figure if any reasonable time table were to be realised. The breaking down of the project into four stages provides a reasonable compromise. keeping the size of the production series economic, and avoiding a large build up of stock and work in progress. Yet another advantage of progressive completion lies in the fact that information derived from measurements on the actual route in the early stages can be "fed back" to the manufacturer's laboratory to permit the incorporation of final refinements in the design for subsequent stages.

Having decided to adopt the four basic stages for the installation, dates for the conclusion of each were determined (primarily limited by production capacity), and a further detailed study was made of each of these stages in turn, to determine the number of technicians required to carry out this work in the available time, and the way in which they could be best deployed to reduce waste and travelling time to a minimum. This required a great deal of consultation with the manufacturers on possible alternatives to their order of production in order to arrive at the best possible plan for each stage. These general plans for each stage were recorded on a line chart of which Fig. 1 is typical.

This chart is self-explanatory and has enabled a close survey of progress during the various stages to be made.

STAFF ORGANISATION AND TRAINING

General Organisation

In order to carry out the installation, testing and commissioning of the equipment on the 600 mile route, a special field group was set up under the direct control of the Product Manager, Line Telephony, who is located in the administrative headquarters of the Company in Adelaide. This group consists of:—

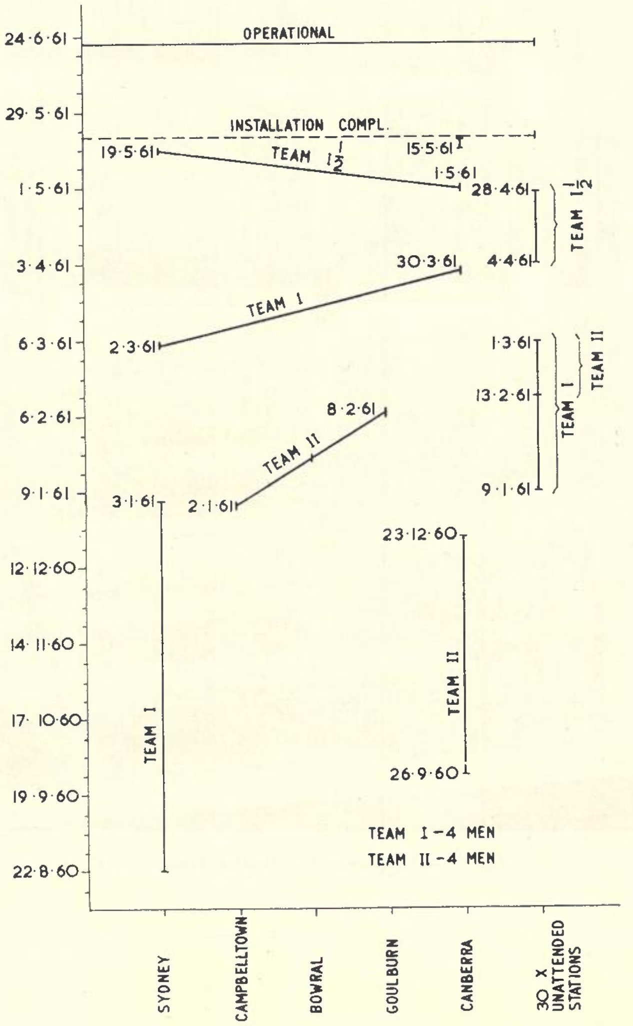

Fig. 1.—Installation Timing Chart showing Proposed Deployment of Staff for Stage I (since completed).

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[*] Telecommunication Company of Australia Pty. Ltd. See page 271.

1. Project Manager
2. Male Secretary/Clerk
3. Installation Engineer
4. Testing Engineer (Terminal Equipment)
5. Testing Engineer (Line and Television Equipment)
6. Eight Installation Technicians
7. Transport Driver.

The Project Manager is responsible for the co-ordination of the whole team, the oversight of finances, liaison with other parties to the contract, and the day to day administrative problems associated with an organisation of this nature.

Installation and cabling of all the equipment is carried out by the eight technicians under the direction of the Installation Engineer who also supervises the distribution of the equipment over the route.

It was decided to divide the testing functions under two basic categories. One engineer was to be responsible for alignment and testing of the terminal equipment up to and including the supergroup stage, and the other the television and line equipment. On the other hand, it was realised that these two engineers must work in close collaboration with one another and combine forces to overcome any lag in one side or the other. This arrangement was to be supplemented during periods of peak loading, with additional engineers from the manufacturer in Western Germany, and additional technicians who could be made available from the installing company's factory and branch offices.

Training

The equipment for the project is new to Australia, and it was considered much better to send Australian engineers overseas to obtain the necessary knowledge and experience rather than to import engineers who would subsequently return to their homeland taking their experience with them. To this end a team of four engineers, headed by the Company's Product Manager for Line Telephony, went to Europe to study the design, manufacture and testing of equipment at the factories of the associate companies in Western Germany and Holland. Arrangements were also made for some of these engineers to spend periods on installation and testing of smaller systems, using similar equipment, for the German Post Office. The total time spent on overseas study by this group amounted to four man years.

In addition to this, the Installation Engineer spent some time studying Australian Post Office methods of cabling and mechanical installation to ensure that the methods adopted for the project were compatible with existing Departmental practices. A technicians' training school was subsequently established in Sydney to train those selected in the special techniques of installing equipment for the coaxial cable system.

Field Organisation

Referring back to the line chart of Fig. 1, it can be seen that the basic team consists of four technicians, but it is sometimes necessary to break these down further into groups of two. (As the teams spend a great deal of time in relatively remote areas, it was decided that for safety reasons no technician should work alone). It was also envisaged that these teams would be far more flexible if they were independent of country hotels and cafes, hence it was decided to provide caravan accommodation for team members. This principle was extended to include all members of the field staff. Accordingly, a fleet of aluminium-sheathed caravans, equipped with L.P. bottled gas for operating gas stoves and refrigerators, was purchased. Each van was supplied with all crockery, cutlery, cooking utensils, etc., required for normal living, the occupants providing their own linen, blankets and other similar items. Fig. 2 shows one of the caravans. This organisation results in four completely independent two-man teams, giving the very high degree of flexibility necessary on an installation of this nature.

Five station sedans and two panel vans, for the transportation of installation and testing teams, their tool kits, instruments and the smaller pieces of installation materials and a 3.8 ton load capacity truck for distribution of the equipment along the route, were made available. All were fitted with draw bars for attachment to the caravans. Arrangements were made for the carrying out of repairs and supply of petrol and oil on requisition to a chain of service stations along the route. This fleet of vehicles was to be supplemented from time to time by "drive yourself" cars and use of staff's own cars as demanded by circumstances.

Kits of frequently used hand tools were supplied to each technician on a personal basis, and the heavier items such as electric drills, ladders, etc., were supplied in tool kits to each of the four-man teams, while specialised kits for the testing engineers were made up on an individual basis. Power is not available at many unattended stations, so four portable 500 watt petrol generating sets were made available for use of either installation or testing teams.

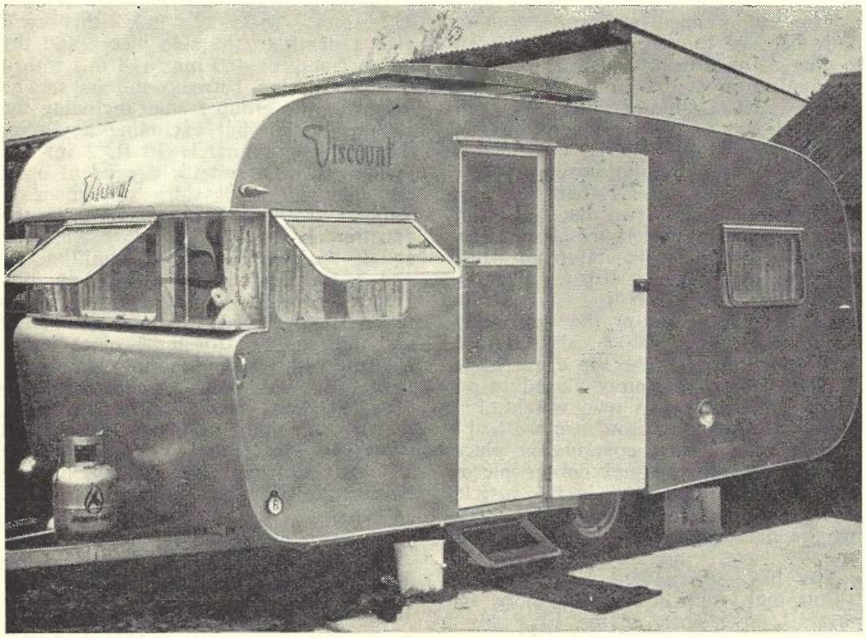

Fig. 2.—Aluminium Sheathed Caravan as Used by the Field Staff along the Route.

SOME ASPECTS OF THE INSTALLATION

General

The installation of equipment at various stations along the Sydney-Melbourne coaxial cable route has, wherever possible, followed standard Departmental practices but obviously, where new and modern equipment is installed, new techniques and procedures are required. The main departure will nearly always be the mechanical construction with less significant changes within the cabling procedures. This has been found so with this project and a description of some of the details of the mechanical equipment, cabling and methods of installation is given with emphasis on the variations.

Mechanical

The mechanical construction of an installation is governed by the type of equipment used within the installation. For the Sydney-Melbourne project a modern construction employing single-sided bays has been chosen. This construction is of the so-called type 52, and to support this equipment the bays are housed in a group frame. The group frame consists of two end pieces housing power and carrier distribution as well as the aural and visual alarm display equipment, and two angle irons running the full length of the suite. A typical arrangement is illustrated in Fig. 3 and shows four group frames and several bays in position.

The angle irons are pre-drilled to accommodate the bay head brackets and frame covers and, to complete the frame and form a bay cable duct, the angle

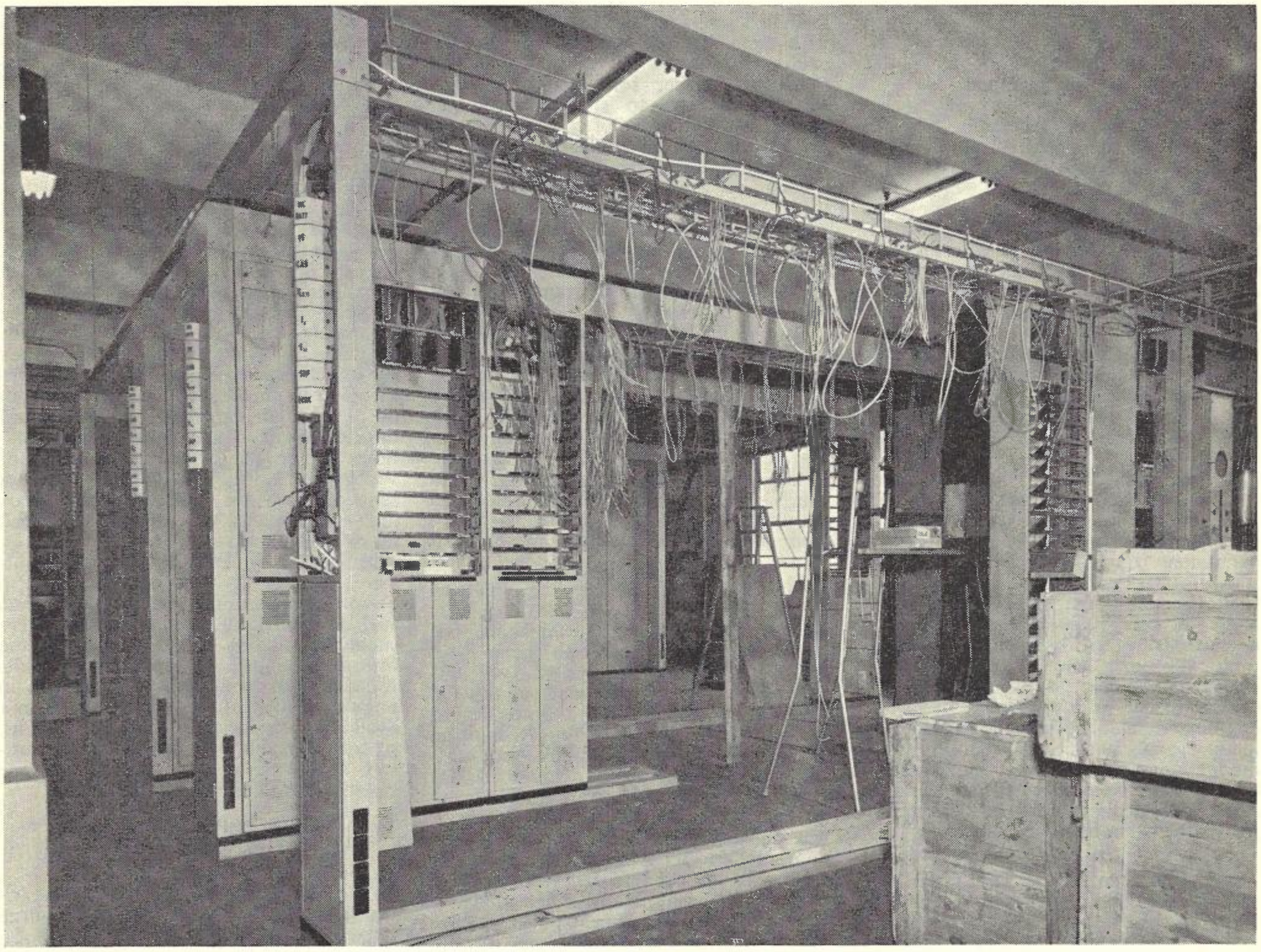

Fig. 3.—Typical Arrangement of Group Frames and Bays.

iron is spaced by cable slats which are screw fixed every 20 centimetres (8 inches) along the angle iron length. These details can be seen in Fig. 4 which also shows the cable-positioning rods and their clamps as well as the frame cover stand-offs. The positioning rods are designed to reduce the amount of lacing which is required when blocking the cables within the frame duct. Between the cover stand-offs can also be seen the pre-drilled holes for the bay head brackets.

Once the bays have been installed the group frame is self-supporting and does not require any additional wall or ceiling braces; however, within certain stations, wall braces have been used but they are of a temporary nature only, forced upon the installation staff because of the erection of large group frames and only one or two bays housed within. At some future date, when additional bays are installed, these braces may be removed if so desired.

The installation is braced from one suite to another by means of channel iron run on both sides and at right angles to the group frame and also bolted at the top of the end pieces. The suites are further mechanically connected by station ducts which also run on both sides of the group frame adjacent to the channel iron, and are stayed to the angle iron of the group frames. The station duct facilitates inter-suite cabling and cabling to equipment external to the installation, that is, intermediate distribution frame, station earths, etc. The station ducting is rather simple in construction having two flat bars running its length to which are clamped the "U"-shaped cable slats and from which hang the corner piece stirrups. The side covers are hung over the end of the cable slats and held at the bottom by the corner pieces which also support the bottom covers. The top cover has a shallow lip and is simply placed in position and held by its own weight. Fig. 5 shows the channel iron in place and a portion of the duct covering in place, that is, side covers and corner pieces. Fig. 4 (and Fig. 8 later in this article) also show details of the method of staying the flat bars of the ducting in position.

The bays are placed back to back within the group frame and since the physical dimensions of the bays are a height of 2600 mm. (8 ft. 7 in.), a width of 600 mm. (2 ft.), and a depth of 222 mm. (8-25/32 in.), this will give a depth to the side pieces and the group frame of 480 mm. (18 in.) with a 6 mm. spacing between the bays. The height of the group frame, including the station ducting but excluding any plinthing, is approximately 10 ft. 2 in. and the length of a suite is dependent upon the number of baysides as shown in Table I. Table I is computed from the equation $L = 216 + 606N$ where L equals the overall length in millimetres and N the number of bays in any row.

Because of the variation in height between standard Departmental equipment and that supplied for the project, it has been necessary when cabling external to the Sydney-Melbourne equipment to provide special racking pieces to bridge the two equipments. Such a piece is shown in Fig. 6 and is supporting the VF cables from the channel modem bays to the IDF.

Cables

The cables and wires used can be divided into the following groups:

1. Voice Frequency Cables.
2. Carrier Frequency Cables including Jumper Cables.

TABLE I

Title	AB252.3	AB252.4	AB252.5	AB252.6	AB252.7	AB252.8	AB252.9	AB252.10
"N"	3	4	5	6	7	8	9	10
Overall Length Metric	2034	2640	3246	3852	4458	5064	5670	6276
Overall Length British	6′ 8½″	8′ 8½″	10′ 8½″	12′ 8½″	14′ 8½″	16′ 8½″	18′ 8½″	20′ 8½″

3. High Frequency (Coaxial) Cables including High Voltage Types and Jumper Cables.
4. Miscellaneous — Earth, Power, Alarms.

There are two sizes of VF cables used on the project, a 48-wire cable for use between the IDF and Channel Modem Bays and a 12-wire cable used to carry various alarm conditions from the bay heads to the alarm frames. The colour code for the above two cables is blue, yellow, green, brown and black with pairs 1-5 having blue/white mates, pairs 6-10 yellow/white, pairs 11-15 green/white, etc. Both cables have an outer casing of relatively hard grey thermoplastic followed by a thin white plastic covering, thence a tin foil shield in close contact with an 0.6 millimetre copper wire running throughout its length. Then follows a clear plastic covering followed by the wires themselves. The copper wire running throughout the length of the cable is earthed on the 25th row of pins on the 6 x 25 terminal blocks used on the IDF.

The carrier frequency cable (Fig. 7a) is for use on those bays using frequencies up to and including 612 Kc/s with the exception of the basic supergroup outputs from the group modem bay. It is also used to carry the programme from the IDF to the programme bays, and the interbay multiples within the installation. Physically it consists of a grey plastic outer covering ((7) of Fig. 7a), followed by an alloy foil screen (6). In close contact with this screen is a narrow flat ribbon of tinned copper wire (5) used as an earth connection for the cable and this strip is separated from the symmetrical pair by a clear plastic covering (4). The two wires are held symmetric throughout their length by clear plastic extrusion (3) and the individual wires (1) are identified one from the other by the "A" leg having a clear covering (2) and the "B" leg being covered orange (2). In practice, the cable is used as a three-wire cable, A, B and screen, with the tin foil cut back and the ribbon used as the screen termination.

The jumper wire has the same physical make-up as the CF cable excepting that it is much smaller in size. It is used for the various cross connections required at the Group Distribution Bays and is terminated in the same manner as the CF cable.

The high frequency cable (Fig. 7b) is used on all unbalanced terminations within the installation, that is, supergroup input and output including carrier frequencies used within the supergroup bays and inter-bay multiples found within the supergroup suites. There are two types of cable used:

1. Common type, used up to and including the input to the line amplifiers at attended stations.
2. High-voltage type which is used between the line amplifier and the power-feeding bays at attended stations.

The high voltage type can be recognised from the standard type by the difference in colour, black instead of grey, and it is also larger in diameter than the standard. Physically they both have the same elements, outer cover (8), outer shield (7), foil (5), inner shield (3), dielectric (2) and inner conductor (1). (4) and (6) are plastic covering separators. Variations are a larger inner conductor and dielectric in the case of the high-voltage type and also the screens are woven instead of lap wound as is the case with the standard type. Though having different physical specifications, the two cables have similar electrical characteristics with the exception that the larger cable has a much higher voltage rating.

There are also two types of terminations for these cables. One, as used on the group modem, supergroup modem, supergroup carrier supply and distribution bays, is a screened terminal block using a three-wire system, and the other, a solid coaxial connector as used on the line amplifier and power feed bays. The other wires and cables mentioned in category 4 are standard single and multi-core power and earth cables and do not require elaboration further than to say they all have a fire-proof thermoplastic covering and are of sufficient gauge to carry the currents involved.

Table II is a table of category 1-3 cables showing a few of the physical dimensions of these cables.

Installation

The steps in erecting the group frame are, firstly, the four extreme end pieces of the installation are stood up and checked for correct alignment. Next is the erection of the first and last suite angle irons, checking the diagonals to obtain correct frame length at both duct height and plinth level. The remaining end pieces are then erected and all the end pieces connected with the channel iron, and after checking all dimensions the end pieces are screwed down tight. Whilst each bay has individual height adjustment screws on its four corners, the end pieces do not, and therefore it is still necessary to have a reasonably level surface along the major axis of the group frame. The end pieces are coach screwed to the floor or plinthing and then the bays adjusted (approximately ¾ in. maximum travel) to any variation in level along the length of the frame. After the

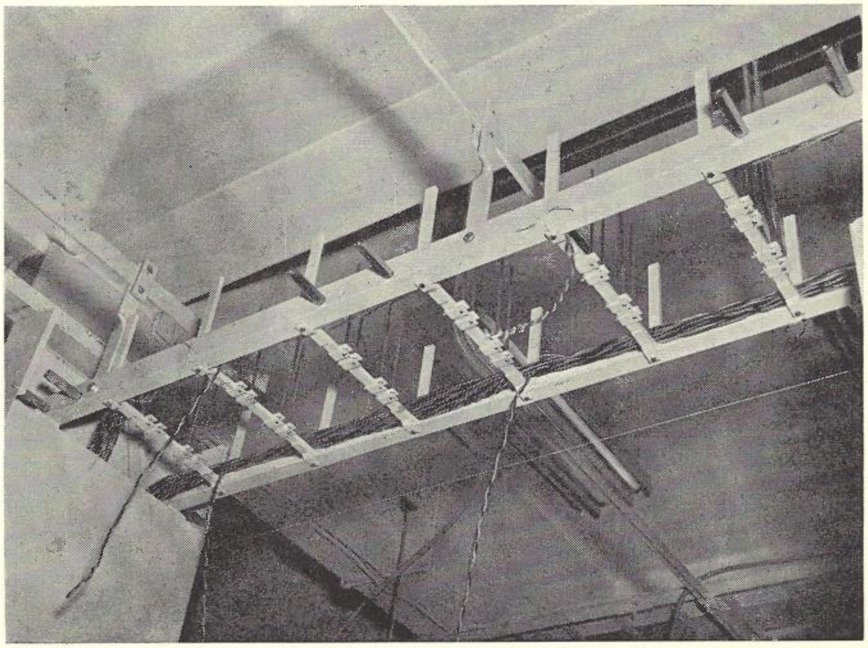

Fig. 4.—View of the Group Frame Angle Iron Positioning and Accessories.

TABLE II

Catalogue No.	Use	Weight, Grams per Metre	Outside Diameter, Millimetres	Nominal Impedance
SXY(ST) 48 x 0.6	VF	260	15	
SXY(ST) 12 x 0.6	VF	115	9	
2Y(ST)Y 2 x 0.5/1.5	CF	40	6.2	150 ohm ± 5%/250 Kc/s
2Y(ST)Y 2 x 0.5/2.2	CF	50	6.5	150 ohm ± 5%/250 Kc/s
2YC(MS)CY 0.5/3.0	HF	90	6.0	72 ohm ± 2%/30 Mc/s
LUD(MS)DY 0.6/4.0	High Voltage HF	95	7.5	72 ohm ± 2%/30 Mc/s

end pieces have been secured to their final position the cable ducts are installed, firstly the suite ducting and then the station ducting, at this stage, naturally, without covers. The bays themselves may then be installed and require only to be bolted at the bay head to the angle iron of the group frame after first being adjusted for the desired level and alignment.

Except for the suites containing a number of channel modem bays, there is sufficient width and depth in the suite ducting to accommodate all the cabling required, so that detailed planning of the positions of the various cable runs is not required. Generally speaking the alarms, multiples, power and earth runs are laced to the uprights of the cable slats thus leaving the centre of the ducting clear for the F1, F2 and carrier cabling (see Fig. 8). The terms F1 and F2 will be clear from the figures in Mr. Walklate's article in this issue.

The carrier cables are formed on the extreme outside of the ducts with the F1 and F2 cabling straight up and down the centre of the ducting, fanning off to each side of the row. No effort is taken to space the send and receive direction of cabling up to the F2 side of the supergroup modem bay, as the variation in levels is only in the order of 4 to 6 db. The line side (F1) of the supergroup and line amplifier bays do, however, have a 2 inch or more spacing between send and receive directions as the level difference is of the order of 20 to 40 db. This spacing is not difficult to obtain as the suites containing supergroup equipment do not carry a great amount of cabling. In the case of those suites containing channel modem bays, space is at a premium and therefore careful planning of the cable runs is necessary.

In the majority of stations, the group frames have not been filled to capacity initially and, since the utility cabling is easier to install before bays are stood up, all bay positions within the group frame have been wired for power, earths, alarms and multiples. To retain continuity of alarms and multiples, these cables have been looped in and out of the bay positions as can be seen in Fig. 3, and later when bays are installed, the loops merely have to be cut and terminated. Similarly all bays, whether initially equipped to full capacity or not, are cabled for full facilities and access.

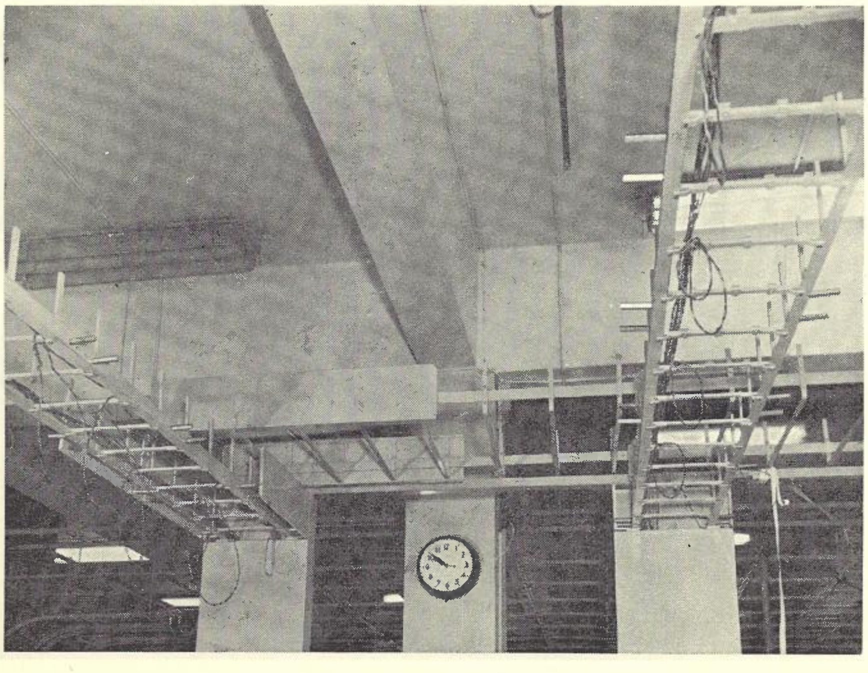

Fig. 5.—Station Ducting Construction.

The earthing system used within terminal and intermediate stations makes use of the fact that the coaxial cable itself will give the best earth within the station. Fig. 9 is a schematic of the earth and power distribution system with equivalent local wire sizes indicated for comparison. A large diameter cable (90 mm.) ties the equipment earths to the cable via the cable-distribution bay and gives an earth approximately one and one half inches wide by six hundred miles long. To provide an earth when the cable sheath requires to be opened close to the station, a second smaller cable (25 mm.) is tied to the station earth. The rows of equipment are wired with a 25 mm. loop and each bay picks up a 6 mm. earth from this loop, all joins being made with pressure clamps as can be seen in Figs. 3, 8 and 10.

The 25 mm. loops are connected to the main earth which is run in the station ducting, also by pressure clamps and, as has already been indicated, the system tied to the cable at the cable distribution bay. Modern techniques require also that the power earth be connected to the equipment earth system, and this is accomplished within the side pieces.

The power runs from the side pieces to the bays are run in a special hard thermoplastic fire-proof cable, bunched and laced to the bottom of the cable slat uprights and guarded by the earths above them, multiples behind them, and duct covers in front of them. This method can be seen in Figs. 8 and 10 after bunching and lacing, and in Figs. 4 and 5 before lacing.

TESTING

General

Testing of the terminal equipment of a broadband carrier system varies from that for the normal cable or open-wire system in that, due to the number of modulation stages and the large number of amplifiers in tandem, more care has to be taken to ensure that each item of equipment is compatible with all others in the system, and that where large numbers of identical units are used each is interchangeable with the others. This permits circuits to be transferred from one place to another as desired with only minor adjustments and reduces the number of spares to be held.

The general method of approach to the testing of the equipment is what might be called the "step by step" method. Each individual bay is pre-tested and lined up as a separate entity, checks are then made by looping back within the terminal itself, leaving only minor adjustments to compensate for the addition of tolerance errors when two terminals are connected by the high-frequency bearer.

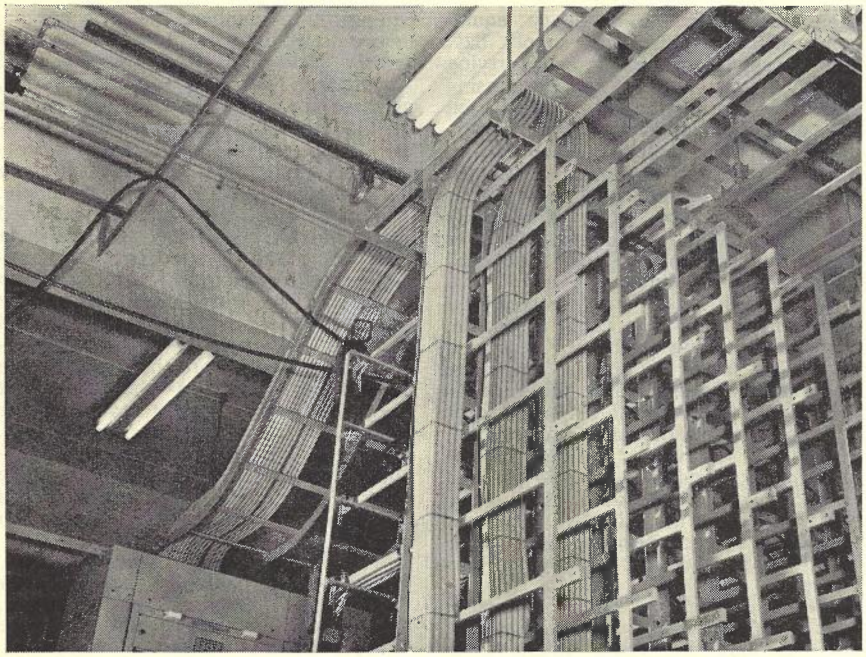

Fig. 6.—Method Used to Adjust Height Variations between Departmental and Contractors' Equipment.

A Note on Test Instruments and Their Use

In order to carry out the testing of a carrier installation, it is necessary to have suitable instruments available, to be able to rely on their measurements, and to be well aware of their limitations, with respect to both frequency and level. The majority of instruments used on the Sydney-Melbourne project have a specified level accuracy of ± 0.2 db. However, this does depend upon calibration and can be greatly exceeded if an instrument is subjected to severe vibration or shock, as is the case during transportation. Where really accurate measurements are to be made, great care must be taken to observe the basic measuring precautions. Instruments should have ample time to warm up, their calibrations should be checked frequently and it is a wise precaution to see that they are well earthed, particularly in the case of the psophometer.

There are very few cases where an absolute measurement has to be made, so that where at all possible, both transmitting and receiving levels should be read on the same instrument. If absolute levels must be read accurately, as in the case with pilot generators, it is necessary to calibrate the level meter against some form of standard immediately before carrying out the measurement, and the adjustment of the zero deflection of the meter should not be overlooked.

Selective measurements at low levels should always be made with great care and steps taken to ensure that the frequency measured is in fact that which is sought. Sometimes it is merely a matter of listening at the earphone output of the level meter where speech and other interferences can be recognised easily, and in other cases, such as when measuring signal frequency leak at the channel modem bay, it is simply a matter of increasing the level to prove that the measuring instrument follows this increase. In the case of signalling leak (which is only 175 c/s away from carrier leak), this can be done by earthing the signalling lead.

Purpose of Testing

The field testing engineer has three main functions, namely, fault finding, lining up and acceptance testing.

Factory tests carried out by the equipment manufacturer are very thorough, each component, sub-assembly and shelf being tested after each progressive manufacturing stage, and where practicable, a "soak test" is carried out on the complete bay of equipment, that is, a complete bay is left standing in the operating condition for some weeks before carrying out final tests. Unfortunately, no matter how much effort is concentrated on factory testing, faults do occasionally slip through. In addition, equipment is subjected to vibration and shock, and often to wide variations of temperature and humidity during transportation to the site. All of these factors can cause occasional faults and changes to factory adjustments. Errors can also be made during installation. The testing engineer must arrange tests so that all of these faults are detected prior to the equipment going into service.

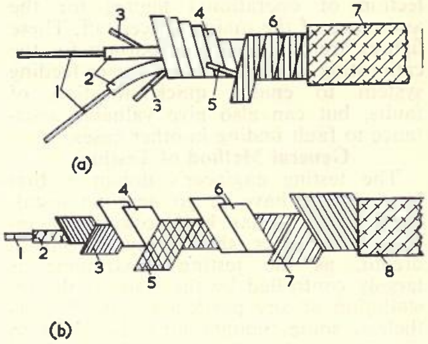

Fig. 7.—Sketch of Component Parts of the CF and HF cables Used on the Installation of Equipment.

Just as a car has to be tuned by adjustment of tappets, spark gaps, etc., so the levels, gains, etc., on a carrier system must be adjusted. This "lining

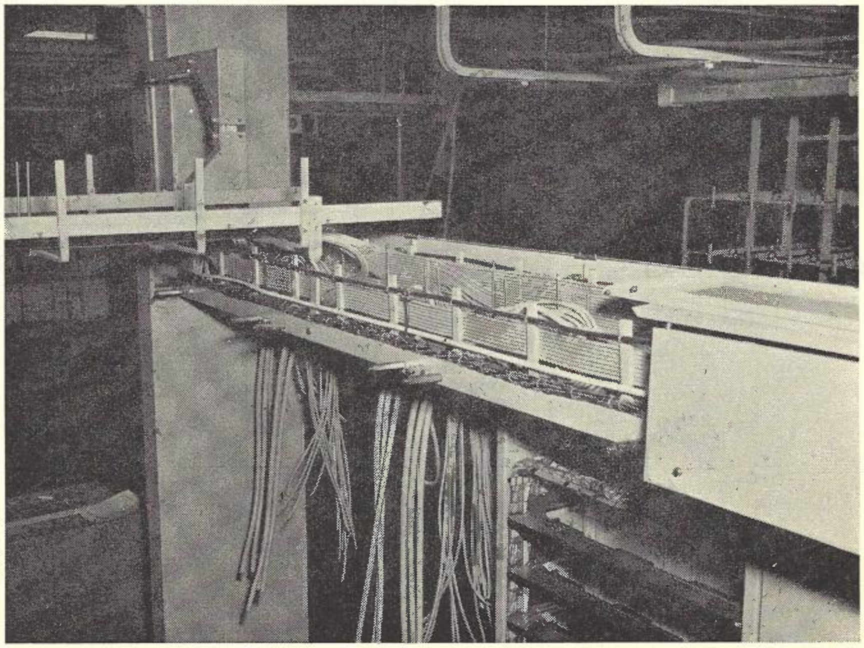

Fig. 8.—Showing Earth, Power, Multiple, F1 and F2 cabling in Position within a Frame Duct.

up" is best carried out by the testing engineer in conjunction with his fault-finding tests. In fact, it is very often the lining-up procedure which indicates the presence of a fault. As indicated in Mr. Macdonald's article in this issue, acceptance tests must also be carried out to ensure that the standards laid down by the Australian Post Office are met.

There is one additional type of information which is not strictly within the realm of the testing engineer, but which nevertheless must be kept in mind when making out test records. This is the collection of operational figures for the assistance of the maintenance staff. These figures are particularly important for the calibrating of the remote power-feeding system to enable quick location of faults, but can also give valuable assistance to fault finding in other cases.

General Method of Testing

The testing engineer's dream is that he does not have to go near an installation until it has been completely installed. However, this is usually only a dream, as the testing programme is largely controlled by the state of the installation at any particular time. Nevertheless, some thought must be given to planning, and as far as possible, a logical approach made. It is necessary to commence with the carrier supply bay, for example, before attempting any work on equipment involved with modulation stages. Care must also be taken to ensure that all important alarms, circuit breakers, etc., affecting the safety of personnel and equipment are thoroughly tested before leaving any equipment switched on.

The logical method of approach is to commence with the auxiliary equipment such as the carrier supply bay, then to begin from the V.F. end, carrying out individual bay tests and progressing along the transmission path, testing each type of equipment in turn until the terminal output is reached. Each bay is completely tested, any faults corrected and all lining-up adjustments made. If possible, acceptance testing of the bays can be carried out at the same time, or where not convenient, may be carried out separately at some later time.

When individual bays have been lined up, station "loop tests" are made, again commencing at the V.F. end and proceeding from bay to bay along the transmission path, looping the send to the receive directions after each stage until the terminal output is reached, that is, looping the whole station. By this means the inter-bay wiring is checked and confirmation obtained that crosstalk is well down, and that adjustment tolerances do not accumulate to have any detrimental effect on system performance.

Having proved that the equipment in each terminal is working satisfactorily, and assuming the bearer circuit is in order, the next tests are the overall or end to end tests. These are, of course, the most important of all as they are the nearest approach to actual working conditions.

Once the overall tests have been completed, the system is ready for traffic.

Bay Tests

The individual bay tests form the major part of the testing. It is obvious that actual tests vary from one type of equipment to another, and it is not intended to go into details of methods of testing such things as "return loss," "crosstalk," "harmonic distortion," etc., as these are well known to most people in the telecommunications field. However, some of the more unusual tests will be outlined later. The first check in the case of all bays is the power supply. The input must be within the required specifications and all bay voltages must be checked and adjusted to their nominal value. The alarms are the next on the check list. Alarm conditions can be simulated by removing fuses, links and valves and by operation of circuit breakers. Valve currents are then read (where applicable), and then the equipment lined up to give correct levels and/or frequencies at the various test points. The measurement of "return loss," "frequency response," "noise," "harmonic distortion," etc., as required for each particular type of equipment, can then proceed.

Unusual Bay Tests

Although no details of the commonly known tests are given in this article, brief descriptions of two of the more unusual tests are included below.

Testing for Dry Joints: One of the big difficulties during the manufacture of electronic equipment is the prevention of "dry joints." Sometimes the wire is wrapped on the terminal and soldering completely overlooked, and at other times, due to dirt and/or bad soldering, there is no fusion of the solder to the wire. The result is a joint which may behave perfectly at first, but which will probably break down and cause a fault

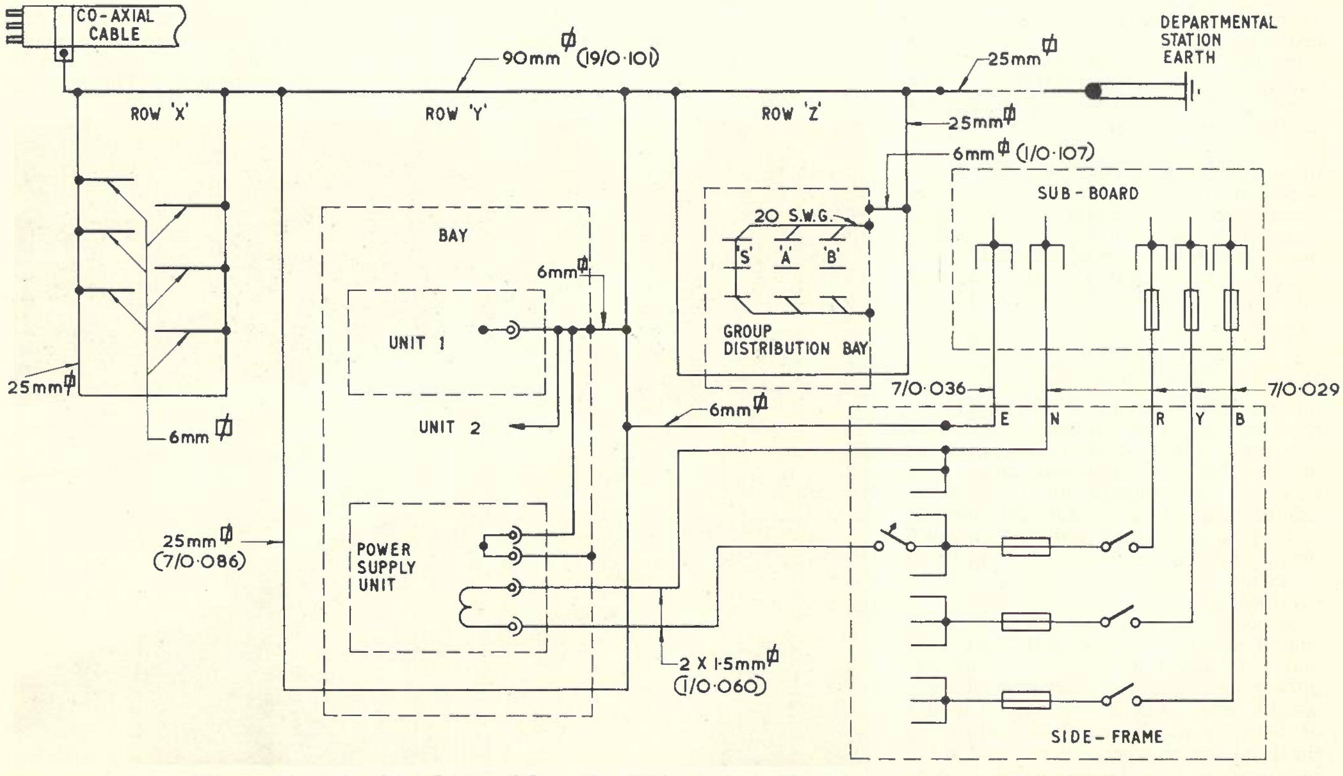

Fig. 9.—Schematic of the Earth and Power Distribution System with Equivalent Local Wire Sizes Indicated for Comparison.

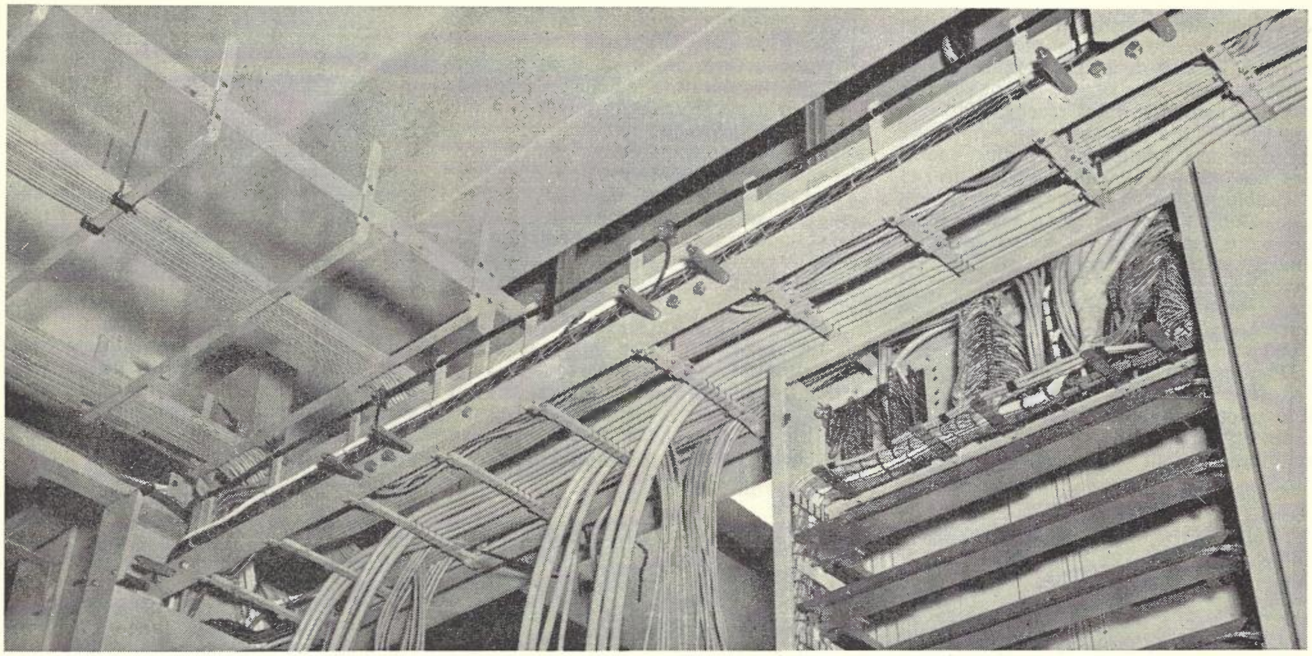

Fig. 10.—Illustrates Row Earth and Bay Earth and Method of 240V AC Distribution to Bays.

some time during the life of the equipment. Tests and inspections are carried out in the factory to detect these faults as far as possible, but it can take some time for the surfaces to oxidise and for the fault to become apparent. The vibration in transportation helps to speed this process so that by the time the equipment has been installed, many of the faults, if present, could be in an ideal state for detection, and it is well worth the effort to carry out tests which will locate these. For this purpose a "contact fault locator" is used, and the general method of testing will be covered by an article in the next issue of this Journal. This is a test which is carried out on all equipment, and can be fitted into the test programme at any convenient time after the apparatus is functioning.

Frequency Measurements: Four basic oscillators are used in the carrier system. These are 4kc/s as a derivative for the channel, pregroup, and group as well as first supergroup carriers, 124kc/s for the remaining supergroup and line pilots, 84.08kc/s for the group pilot and 3.825kc/s for the channel signalling frequency. The latter has an accuracy requirement of the order of one in four hundred, and can be checked readily on a "Berkley" frequency counter, but the others must be set to an accuracy of better than 1×10^{-6} for the 4 kc/s and 84.08kc/s supplies, and better than 2×10^{-7} for the 124kc/s oscillator. These limits are beyond the accuracy of most counters which are readily available. There are several ways of setting these frequencies, but the following methods have been found to be the most convenient.

It is necessary to have a standard frequency of 1kc/s available which has an accuracy better than the desired accuracy, and it is usually a simple matter to arrange this in a carrier station. The only other items required are a phase-splitting network and a C.R.O. with access to both X and Y amplifiers and which also incorporates Z or beam modulation.

The frequencies of the 4 and 124kc/s oscillators are set in an identical manner, and the method of setting these will be discussed first. The 1000 c/s reference frequency is split into two components approximately 90 deg. out of phase, and each fed to either the vertical or horizontal plates of the C.R.O. respectively as shown in Fig. 11 (a). This will produce the circular pattern as indicated in Fig. 11 (b).

Now if one of the multiples of the basic frequency derived in the carrier supply bay (for example, 516kc/s) is taken and used to modulate the beam, the resultant pattern will be as shown in Fig. 11 (c), that is, a circle broken up into a number of dots. In the case of the example quoted, there would be 516 dots. If the 516kc/s frequency is not exactly correct in frequency, that is, if it is not an exact multiple of the 1kc/s reference frequency, these dots will appear to move around the circle at a rate dependent on the difference in frequency between the carrier supply and the exact multiple of the reference frequency. In fact, the number of dots passing a given point per second is the difference in cycles per second between the 516kc/s produced from the carrier supply bay and the 516th multiple of the reference frequency. The assumption is made that the frequency being measured is somewhere near the correct value, a fact which can be checked on a frequency counter. By adjustment of the X and Y amplifiers, the pattern can be expanded to make the movement of the dots easily seen, and the basic frequency can be adjusted to make one dot take a minute or more to pass a given point.

The 84.08kc/s supply is not an exact multiple of 1kc/s and cannot be measured in this manner. Here the reference frequency of 1kc/s is applied directly to the Y amplifier in the C.R.O., adjusting the internal time base to give exactly 25 cycles, including retrace, on the screen. This gives a complete sweep period of exactly 25ms.

One cycle of 84.08kc/s has a period of 1/84.08 ms., hence during a time of 25 ms. there are 25 x 84.08 = 2102 cycles of the frequency 84.08kc/s, that is, an exact whole number. Therefore, if the beam is modulated with the 84.08 kc/s supply, 2102 dots will be obtained around the 25 sine waves and displayed on the screen, and provided the frequency is exact with respect to the reference frequency, the dots will be stationary.

The Coaxial High-Frequency Bearer

Some detail has been given of the testing procedures adopted for the terminal station equipment and a great deal

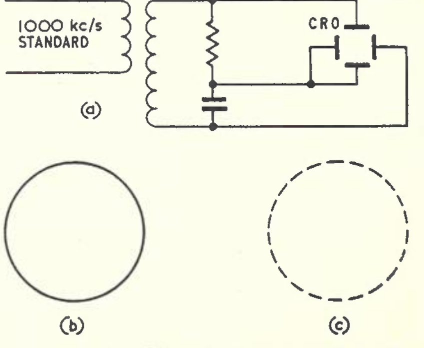

Fig. 11.—(a) Phase Splitting Circuit for Frequency Comparison; (b) and (c) Frequency Comparison Patterns on CRO.

of this applies equally to the line equipment. However, there is one basic difference in that it is not convenient to carry out full tests of equipment such as the line amplifier, pilot receiver, etc., on the actual site, as there is very little room in the unattended stations, mains are not always available, and it is not desirable to carry large pieces of test gear along the route. As a result, these units are thoroughly pre-tested in an attended station, as shown in Fig. 12, taken to their working position, and there only functional tests are carried out. All voltages and valve currents are checked as in the terminal stations.

The normal method of carrying out the functional tests is to transmit the line pilot at correct level and use this as a reference, starting from the transmitting terminal and progressing from station to station to the distant end. The artificial lines are adjusted in accordance with the actual length of each section, and the temperature equalisers are adjusted to a position corresponding to the cable temperature at the time of lining up. Remote power feeding and the remote supervision present their own particular problems, but the tests carried out are mostly functional in nature. Great care must be taken with the remote power-feeding equipment to ensure that all alarm and safety apparatus functions as designed.

Generally, the testing and adjustment of the high-frequency line equipment for optimum performance over a long period of time is most complex, and an article in a later issue of this Journal covering the system test results will give more details of the procedures involved.

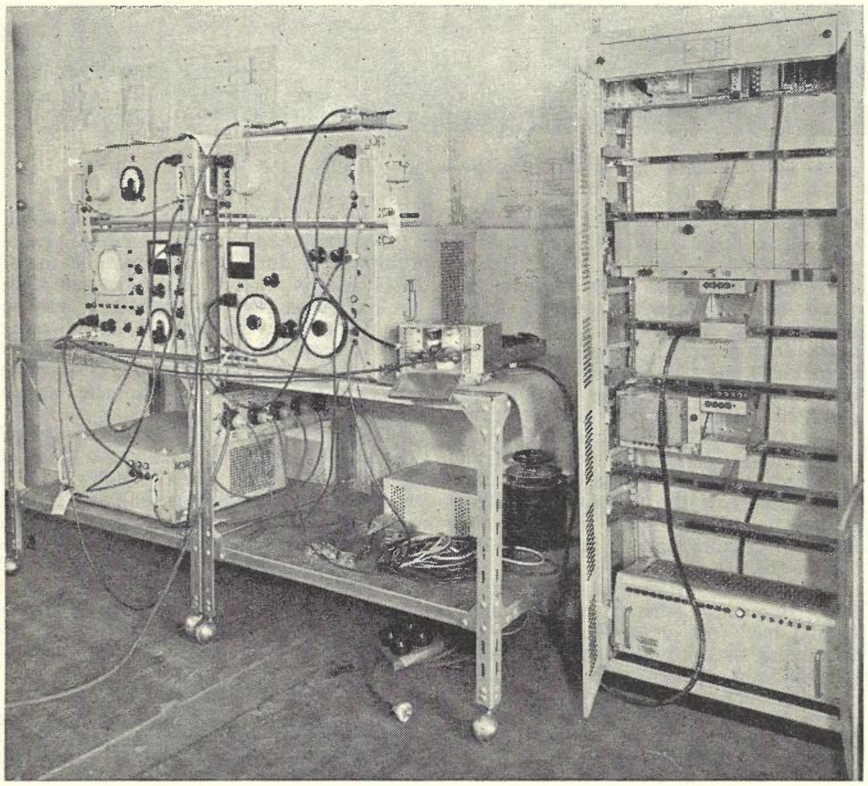

Fig. 12.—Unattended Station Line Amplifier Bay and Test Equipment Set Up in Attended Station for Check of Amplifiers.

End to End Tests

Once the complete system has been established and all individual bays and the high-frequency bearer have been tested, the final alignment and overall performance tests can be carried out. The first step is to ensure that the group pilot control amplifiers in both terminals are adjusted to give correct incoming pilot level, and then to transmit nominal level at each channel input and adjust the corresponding receive direction gain at the other terminal, thus compensating for the errors introduced by the allowable tolerances in the individual bay tests. It is interesting to note that in the system used over the Sydney-Melbourne route, this is the only overall adjustment required between four wire voice-frequency points. The channels are then ready for the overall performance tests referred to in Mr. Macdonald's article, the most important of which are noise, harmonic distortion, V.F. return loss, frequency response and signalling, after which they can be handed over for traffic.

PROGRESS TO DATE

On Saturday, 24th June, 1961, the telephone channels between Sydney and Canberra were made available for traffic and, at the time this article was written (January, 1962), all transmission equipment for Stage II, Sydney-Canberra-Melbourne had been installed and alignment and testing was in the advanced stage. The installation at that time had consumed a total of approximately 150,000 feet of VF, CF and HF cable and 10,000 feet of power cable. About 320 bays had been stood up and over 3,600 plug-in units installed in the 118 stations along the 600 mile route, whilst the fleet of vehicles had been doing a total mileage of the order of 15,000 per month.

Although modifications to the overall planning were necessary to cater for some changes in factory delivery order and shipping delays, the general form has proved to be most effective. Caravan accommodation has been most satisfactory for the personnel on the job and very convenient for the organisation of the work. The installation of the transmission equipment over the 600 mile route between Sydney and Melbourne has been a most difficult but interesting operation, which would never have been possible except for the splendid co-operation received from Departmental officers and other persons concerned.

POWER PLANT

*A. HANNAH**

INTRODUCTION

The measure of success in the operation of any telecommuncation system is the degree to which the uninterrupted transmission of intelligible signals over the system is achieved. There are many obstacles to be surmounted and hazards to be guarded against in the achievement of completely uninterrupted signal transmission, and one of these is that of ensuring continuity of power supplies for the operation of the various electronic and electromagnetic devices forming part of the system. In this article the reasons for the use of "No Break" A.C. power plant in coaxial cable systems will be discussed and the particular type of plant chosen for the Sydney-Melbourne coaxial system will be described.

REASONS FOR THE USE OF NO BREAK A.C. POWER PLANT

In coaxial cable transmission systems a wide band of frequencies is transmitted . . . . from 60 Kc/s to 6,000 Kc/s in modern systems such as that provided between Sydney and Melbourne, with ultimate extension of the frequency band to 12 Mc/s. In terms of telephone speech channels 1,260 separate channels can be accommodated within the 60-6,000 Kc/s bandwidth on each pair of coaxial tubes and more than twice this number of channels in the 12 megacycles bandwidth. Alternatively, each coaxial tube may be used for a single television transmission, or in a 12 Mc/s system, be used to provide both television and telephone facilities. There are six tubes in the Sydney-Melbourne cable so that it could be used ultimately to provide, for example, for the simultaneous transmission of several thousand telephone channels and two television transmissions, and still leave two tubes "spare" for standby use. This large block of telephone channels transmitted over a single medium, the coaxial cable, demands the utmost reliability in the design, quality of material and workmanship in the cable itself, the transmission equipment and the power plant, since failure of any one of the component parts entails interruption of transmission on all channels.

The attenuation of the cable at high frequencies is such that it is necessary to insert line amplifiers at intervals of about 5.7 miles, that is to say a power-consuming device . . . an electronic amplifier . . . must be provided every 5.7 miles to attain the objective of the transmission of signals with sensibly zero loss or distortion. The cable route distance between Sydney and Melbourne is 590 miles and over this distance there are 118 "repeater stations" or points at which amplifiers are provided; it would be uneconomic to install this large number of power plants which would be required if one plant per repeater station were provided.

Fortunately, by using 50 c/s A.C. power supplies it is possible to transmit power over the coaxial cable in addition to the high frequency telephone and television signals, and by this means the number of separate power plants on the Sydney-Melbourne route has been reduced to fifteen. The reasons for the

TABLE I

Station	Power Feeding	N.B. Set		N.S. Set	
		K.V.A.	P.F.	K.V.A.	P.F.
Melbourne	— — ↑	47	0.8	2 x 281 (Existing Sets).	0.8
Seymour	11 ↑	15	0.8	60	0.8 to 1.0
Euroa	6 ↑ 5 ↓	15	0.8	30	0.8 to 1.0
Benalla	— ↓ 4 ↓	15	0.8	30	0.8 to 1.0
Wangaratta	— — ↑	30	0.8	60	0.8 to 1.0
Albury	8 ↑ 5 ↓	40	0.8	100	0.8 to 1.0
Culcairn	— — ↑	10	0.8	30	0.8 to 1.0
Wagga	8 ↑ 9 ↓	40	0.8	100	0.8 to 1.0
Gundagai	— ↓ 11 ↓	30	0.8	60	0.8 to 1.0
Yass	— — ↑	10	0.8	30	0.8 to 1.0
Canberra	6 ↑ 5 ↓	50	0.8	100	0.8 to 1.0
Goulburn	5 ↑ 8 ↓	30	0.8	100	0.8 to 1.0
Bowral	— — ↑	10	0.8	60	0.8 to 1.0
Campbelltown	7 ↑ — ↑	15	0.8	60	0.8 to 1.0
Sydney	5	2 x 40	0.8	330	0.85

Notes: "N.B. Set" refers to the "3-machine all electric" plant. "N.S. Set" refers to the "Normally Stationary" diesel/alternator. The "Power Feeding" column shows the stations from which power is fed along the coaxial cable, the direction of power feeding (vertical arrows) and the number of "dependent" stations fed.

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* See page 271.

use of No Break A.C. power plant can thus be summarised briefly as being:—

(i) No break, or continuous, power supply is essential for uninterrupted signal transmission.

(ii) A.C. power supply is most convenient for transmission over the coaxial cable, because by using well-established voltage transformation techniques, the necessary power can be transmitted at comparatively low current values.

In passing it might be mentioned that the provision of continuous power supplies for telecommunication purposes has been an accepted feature of the art since the days of primary cells; continuity of service is a traditional and jealously guarded feature of telecommunication work.

POWER CONSUMPTION AND SIZES OF PLANT

The power consumption of each pair of line amplifiers, one "GO" and one "RETURN", is about 200 Watts with the present design of electron tubes, so that the power drain at each repeater station when all six coaxial tubes are equipped is about 600 Watts. The stations at which power plant is provided are those at which not only line amplifiers but, in addition, terminal equipment from which the telephone channels are derived, is installed. These stations also accommodate the transmission equipment for other cable and open-wire telephone systems and in all cases are also either, or both, trunk and subscriber telephone exchanges. The power plant is suitably dimensioned to serve, not only the ultimate drain of the transmission equipment for the Sydney-Melbourne coaxial system, but also the drain of all other equipment to be installed at each station throughout the next twenty years.

The locations at which power plant is installed and the rating of the plant at each station are shown in Table 1.

DESCRIPTION OF PLANT

Before the No Break A.C. power supply plant is described it will be helpful to readers to consider the established means of providing power supplies for telecommunication equipment in the Australian Post Office. In the main the power supplies required are:—

48 Volt D.C.	for telephone exchanges
24 Volt D.C.	for "D.C.-operated" long line equipment using electron tubes
130 Volt D.C.	

The method used to provide these power supplies is by the well-known means of secondary cell, lead-acid batteries which are operated on a "constant potential float" system, that is, comparatively small-capacity batteries are floated across the output of dry element (selenium) rectifiers, the input to which is normally obtained from public supply mains. Fairly well regulated mains supplies are required in order that the necessary very closely regulated D.C. output may be obtained from the rectifiers to maintain the batteries in optimum condition. The most ecnomical means of ensuring these D.C. power supplies is to provide a "normally stationary" diesel/alternator (N.S.) set arranged to start automatically if public mains supply voltage fluctuates outside limits and use the output of the diesel/alternator to supply the rectifiers, the diesel/alternator being arranged to continue running until public supply mains is restored to its nominal value. The elements of this D.C. power plant are shown schematically in Fig. 1 and are:—

(i) Mains Supply switchboard.

(ii) Rectifiers, 48 Volt, 24 Volt and 130 Volt.

(iii) Secondary cell batteries 24-cell, 12-cell and 63-cell.

(iv) Automatically controlled diesel/alternator set.

The additional No Break A.C. power plant required to supply continuous A.C. power for coaxial cable systems is also shown in Fig. 1 and comprises:—

(v) the 3-machine all electric N.B. plant.

(vi) the motor battery.

(vii) the motor battery rectifier.

An ancillary element not shown in Fig. 1 but referred to later, is the "Synchronsing Cubicle" which is provided to facilitate synchronising and paralleling of the N.B. and N.S. outputs.

There has been, and still is proceeding, continuous development in the design of No Break A.C. power supply plants and the several variants have particular application in specified fields of use. All modern types of plant use public supply mains as the prime source of energy but employ a regenerative process to isolate the load from surges or impulses present in mains reticulation systems. Although public supply mains are reliable to a great degree, the reliability is not sufficiently great to permit unsupported use of mains for telecommunication purposes so that an alternative (standby) source of power must be provided. The prime mover for this alternative power is a diesel engine which may be integrated into the system in several ways.

Bearing in mind the established power supply plant shown in Fig. 1, it was decided by the Australian Post Office to use a system for No Break A.C. supply which employed techniques familiar to the operating personnel and provided the maximum standby facilities. The plant used is known as "3-machine all-electric" and its operation is briefly described thus:—

(i) with mains "healthy", that is within the specified limits of voltage and frequency, the A.C. motor is driven by public supply mains.

(ii) mounted on the same bed-plate and connected to the double-ended A.C. motor shaft by flexible couplings are an alternator and a D.C. motor. The alternator, driven by the A.C. motor, supplies the load.

(iii) if mains fails, that is voltage or frequency fluctuates outside the prescribed limits, the mains input is disconnected, the 136 Volt battery is connected to the D.C. motor and drive of the set is continued, power being supplied by the battery.

(iv) upon restoration of power at correct mains voltage and frequency the set reverts to drive by the A.C. motor. The change-over of drive between A.C. motor and D.C. motor takes place within 250 milliseconds, and during the change-over the voltage output of the alternator is main-

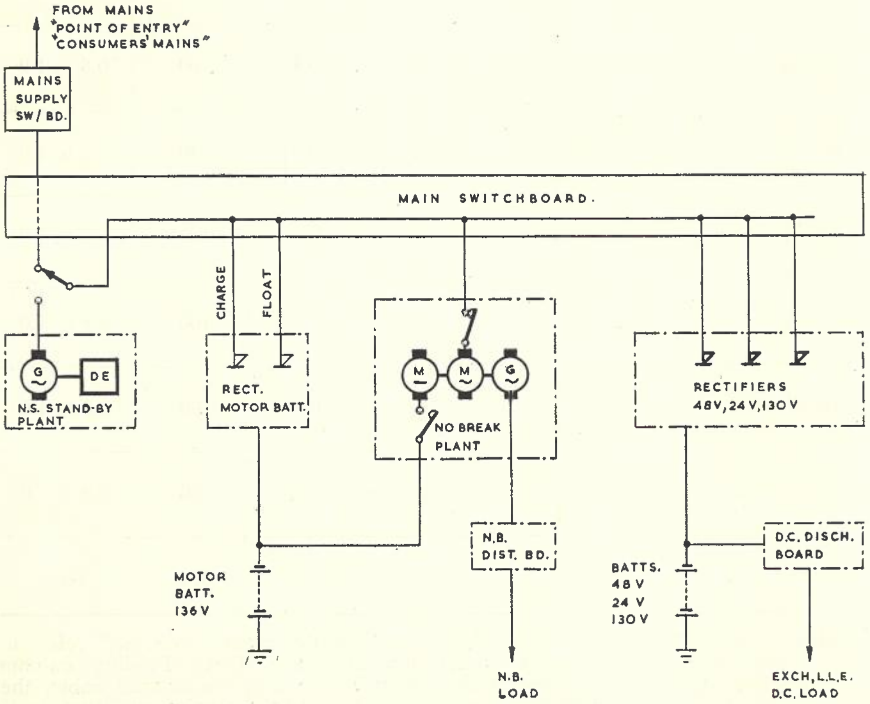


Fig. 1.—Elements of Standard Power Plant for Telecommunications.

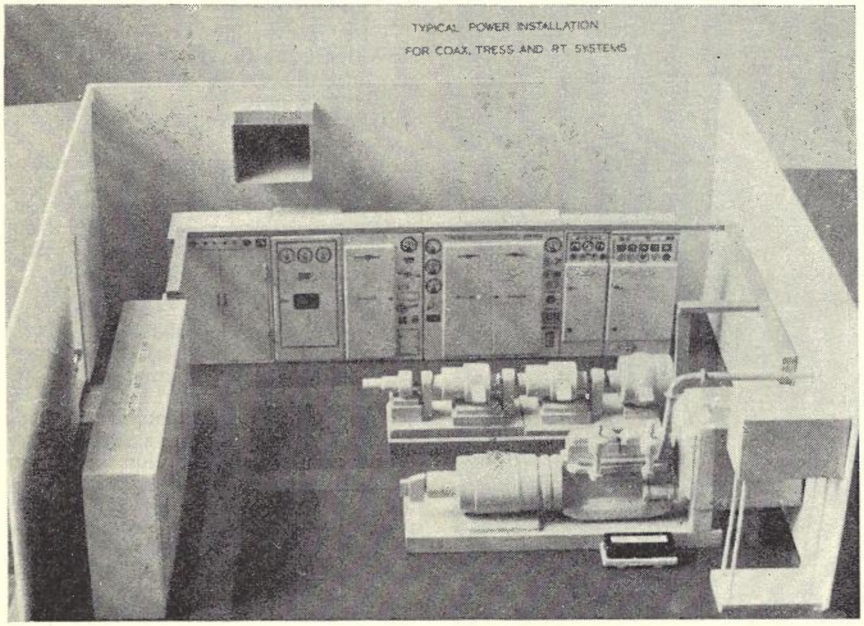


Fig. 2.—Photograph of a Scale Model of a Complete No Break Installation. Battery Cabinets in Left Foreground, Control Cubicles in Background.

tained within ± 5% of nominal and the frequency of the output does not fall below 45 c/s.

This system has several advantages which can be enumerated as follows:—

(i) The alternative source of driving power at mains voltage, that is the diesel/alternator set, is a separate unit and its rating can be such as to serve not only the N.B. set but all other "emergency" load at the station.

(ii) Both the electro-magnetic clutch and the flywheel present on other types of N.B. plant are eliminated. These components are maintenance hazards particularly if the clutch is a friction type, also the flywheel imposes stringent requirements upon the rigidity of the bedplate and the consequences of its failure are usually sudden and catastrophic.

(iii) During periods of stoppage of the N.B. set for maintenance attention the N.S. set can be run continuously to serve the load.

(iv) If the output of the N.B. set fails for some reason other than mains failure, a signal is transmitted to start up the N.S. set and the N.B. load is automatically switched to the output of the N.S. set instead of to "Mains Direct" which is unregulated.

(v) At most locations, the A.C. load can be divided into two parts:
  (a) A true No break portion that must be served with uninterrupted A.C. power.
  (b) A portion that can tolerate a short break, for example, the interruption corresponding to the interval between mains failure and start of an auto start diesel/alternator.

The No Break set can be rated to serve the true No Break load only and can thus be smaller than would be the case, if for example, a diesel engine/clutch/flywheel/motor/alternator set rated to serve both loads (a) and (b) were used.

(vi) A "first-line" of reserve power in the form of the capacity of the secondary-cell battery is obtained. This reserve can be made as great as is desired by suitably dimensioning the battery but, generally speaking, battery capacity sufficient to run the set for 1 hour is the smallest size that should be contemplated. Batteries provided in the Australian Post Office network are of sufficient capacity to run the set for 3 hours.

(vii) The N.S. diesel/alternator, although the main source of standby power, need not meet extremely stringent requirements for reliability of starting. If, for example, the diesel fails to start, there is time for the intervention of an attendant to rectify a fault before the output of the N.B. set fails because of complete discharge of the battery.

It is difficult to take a photograph which in a single print embraces all the components of an integrated No Break power plant, but Fig. 2 is a photograph of a model to a scale of 1" to 1 foot which does show a complete installation.

The several component items are identified in Figs. 3, 4 and 5 which are photographs of the installation at Bowral Repeater Station and typical of all installations on the Sydney-Melbourne route.

A satisfactory floor plan for a medium sized installation is shown in Fig. 6, but variations of this particular layout are permissible and indeed are often necessary to accommodate the plant in existing buildings. It is most desirable however to retain the en suite arrangement of the "N.S.", "Synchronising", "N.B.A.C." and "N.B.D.C." control cubicles. The "Mains Supply and Mains Switchboard" need not necessarily be en suite with, or even in the same room as the control cubicles. The motor battery can be accommodated in an adjacent room and its charge/float rectifier can be detached from the control suite with only slight inconvenience for operators of the plant.

FACILITIES PROVIDED BY THE PLANT

The main requirements specified for the performance of the plant were:—"To deliver to the load without interruption, power at 230 Volt or 240 Volt

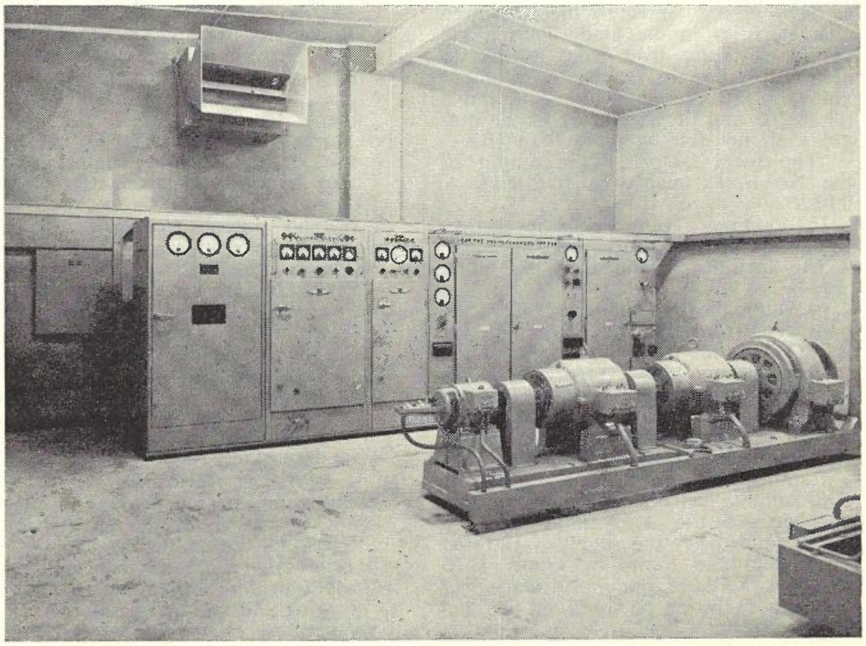


Fig. 3.—View Showing Control Cubicles and 3-machine N.B. Set at Bowral.

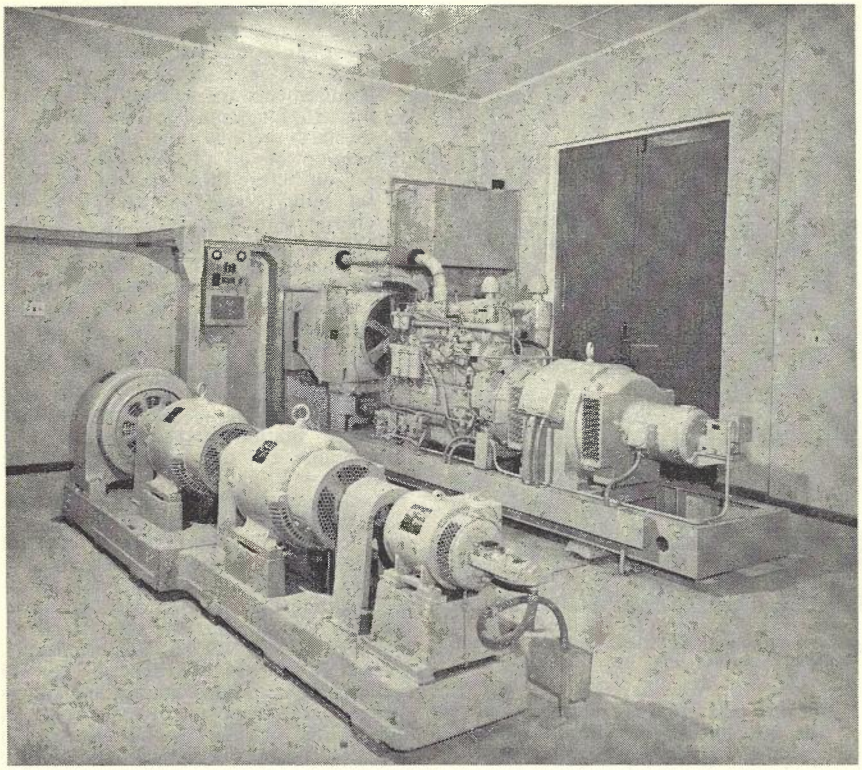


Fig. 4.—View Showing 3-Machine N.B. Set and 60 KVA N.S. Set at Bowral.

phase to neutral, 400 Volt or 415 Volt phase to phase, regulated to be within ± 1% in voltage and at a frequency of 50 c/s +1% —5%.

"When public supply mains fails change-over to the source of power alternative to public supply mains shall take place within 250 milliseconds and the No Break plant shall continue to supply power having the required characteristics to the load. During the period of change-over from normal to alternative power supply, the output voltage shall remain within the limits of ± 2% and the frequency of the output shall not fall by more than 10%.

"The form factor of the output of the No Break plant shall be 1.11 ± 0.03."

In addition a number of protective, signal and alarm features were specified.

The facilities provided by the plant are:—

(i) Automatically changing over the drive from the A.C. motor to the D.C. motor when the supply voltage on any one phase varies outside the limits minus 17% or plus 10% of the nominal value, if any one phase of the supply fails, or if the supply frequency varies outside the limits minus 2% or plus 1%.

(ii) Automatically changing the drive back to the A.C. motor 5 to 8 seconds after the supply is restored within the limits of minus 10% plus 7.5% of nominal voltage and minus 2% or plus 1% of nominal frequency.

(iii) Manually reducing the alternator output voltage to allow the alternator to be initially connected to the load at a reduced voltage to minimise surge currents caused by inductive elements which go to make up the load.

(iv) Operating the station alarm if the output voltage is outside the limits ± 5% of the nominal value or if the output frequency is less than 45 c/s.

(v) Preventing transfer from D.C. to A.C. drive if the output frequency is greater than 49 c/s to prevent generation of power into the A.C. mains.

(vi) Stopping the set, transferring the load to the standby engine-alternator and operating the station alarm if:—

  (a) The output frequency or the voltage is outside limits for more than 5 seconds.

  (b) The output voltage of any phase of the N.B. alternator fails completely.

  (c) The overload of either A.C. or D.C. motor operates.

  (d) Fuse feeding A.C. motor rotor blows or contactor coil feeding the rotor fails.

  (e) The "Stop Set, Transfer Load" button is pressed.

(vii) Preventing transfer to D.C. drive and operating the station alarm if the D.C. motor field fails.

(viii) Operating the station alarm and shutting down the N.B. set if a bearing thermostat operates.

(ix) Operating the station alarm if an alarm type fuse fails.

(x) Routine testing the change-over circuits and the output voltage and frequency relays.

(xi) Measuring the phase voltage of the incoming supply and of the alternator output.

(xii) Sensing the frequency of the alternator output.

(xiii) Measuring the phase currents of the alternator.

(xiv) Measuring the D.C. motor current.

(xv) Isolating the control cubicle from the A.C. supplies and the D.C. motor from the Motor Battery.

OPERATION OF THE PLANT

The operation of the N.S. diesel/alternator has been described in a previous issue of this Journal (1). Later developments in design have been in the direction of refinements in automatic control circuitry with the aim of increasing reliability of operation. To integrate this standard automatic start/stop diesel/alternator set with the No Break plant, it was necessary to modify the control circuitry only slightly to provide for a "no-delay" start on the receipt of

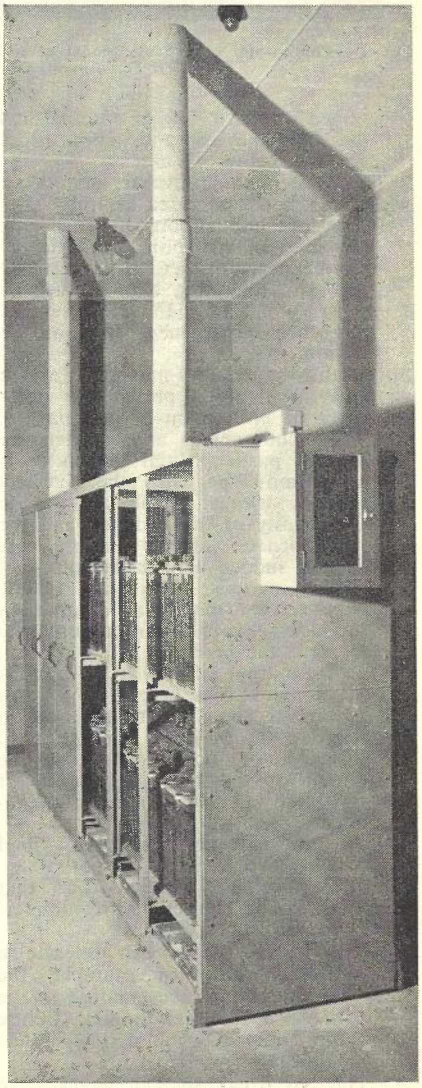


Fig. 5.—View Showing 500 A.Hr., 68-Cell Motor Battery in Cabinets at Bowral.

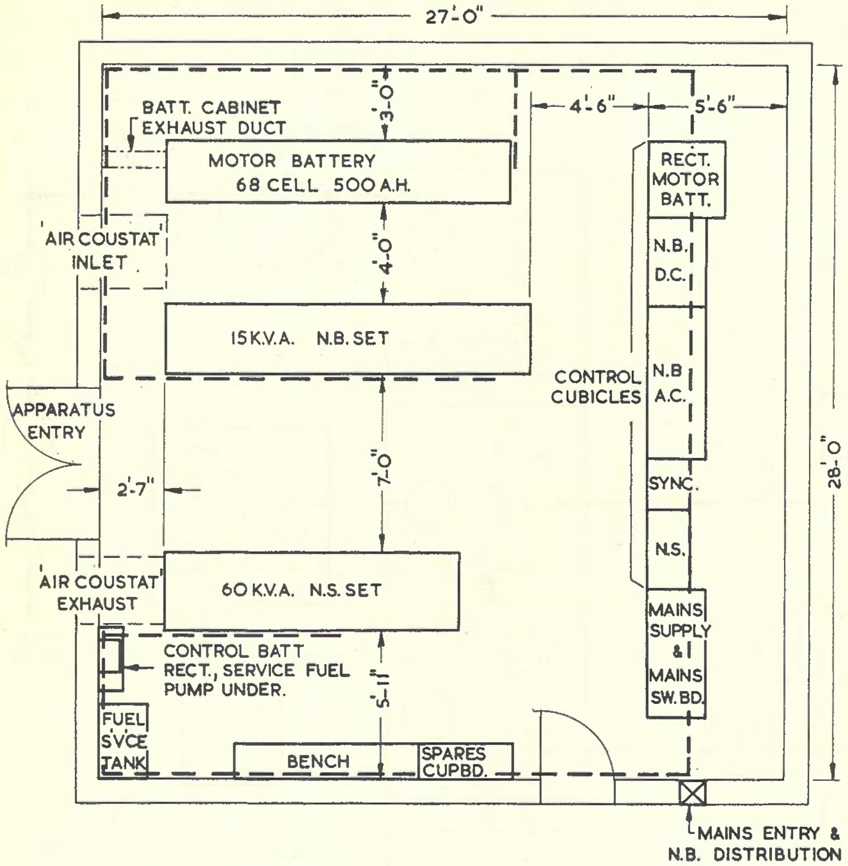


Fig. 6.—No Break Installation — Typical Layout.

Notes:
1. **Clear Height 12'-0".**
2. **"Aircoustat" inlet — top of hole in the wall to be 11" Minimum From Ceiling.**
3. **Cable Ducting Runs Shown Thus — — —.**

a signal from the No Break set in the event of failure of the latter set.

For the purpose of this article the operation of the plant will therefore be confined to a description of the functional schematic circuit of the 3-machine N.B. set shown in Fig. 7. It will be appreciated that the A.C. input to the set, designated "from Essential Bus Bar" is normally public supply mains and, in the event of failure of public supply mains, is the output of the automatically-started diesel/alternator (N.S.) set. The "136 Volt" battery supply is derived from a 68-cell lead acid secondary cell "motor battery" normally floated across the "Float" output of a rectifier which is also provided with a large-capacity "Charge" output to restore the battery to a fully-charged condition after each occasion when the drive of the set has transferred to the D.C. motor. The rectifier itself is automatically controlled, switching from the "Float" to the "Charge" output in response to signals from "Sunvic" hot wire vacuum switches monitoring the battery voltage.

Normal Operation

(i) The set is started from rest on no load by applying the motor battery output via a ratchet-type starter switch which in the full "on" position, short circuits all resistance in the D.C. motor armature circuit.

(ii) Mains voltage, mains frequency and the output voltage and frequency of the set are being monitored by the sensing units (contact voltmeters) shown in Fig. 7 and if within limits, transfer to A.C. drive takes place, the resistance in series with the rotor of the A.C. motor being cut out in 5 successive steps at intervals of approximately two seconds under the automatic control of a synchronous timer KM until the A.C. motor is running with the rotor windings short-circuited. At this stage the armature of the D.C. motor is disconnected at contacts E and F but the field is kept excited in readiness for transfer to D.C. drive.

(iii) The set is put on load by push button operation which de-energises contactor G and energises contactor H and will continue to run, driven by the A.C. motor, while "mains" and "output" are within limits.

Failure of Mains Supply

(iv) If public mains supply fluctuates outside limits of —17% +10% in voltage or +1% —2% in frequency relay MF operates to disconnect the circuit of relay TD and mains contactor M. At the same time change-over to D.C.-drive is effected by the release of contact F.1 followed by the operation of contact E in parallel with F.1. Contact F.1 is mechanically light in construction to give very fast operation, so connecting D.C. power to the armature of the D.C. motor with minimum delay.

(v) One contact of relay MF (MF2) in operating completes the circuit of a pneumatic time delay relay D, the operate time of which is chosen to suit each location and can be adjusted throughout a range of from several seconds to 30 minutes. If the mains fluctation persists for the preset time of relay D, the operation of this timing relay causes a signal to be sent to automatically start the N.S. diesel/alternator standby set. When the N.S. set has started and reached correct speed and voltage, in from 6 to 10 seconds, its output is switched to the Essential bus bar. If the output of the N.S. set is within limits of voltage and frequency, the N.B. set after a delay of five seconds transfers back to A.C. drive and removes the D.C. drive by the release of contact E and operation of contact F.1.

Failure of No-Break Set Output

(vi) The output voltage and frequency of the N.B. set alternator are monitored by the contact voltmeters shown in Fig. 7. Each phase of the output is also monitored by a "No Volt" relay connected via a bridge rectifier between each phase and neutral. The contact voltmeters are set to signal excursions of voltage and frequency outside the limits of ± 5% and 45 c/s respectively (Note:— The sensing of the upper frequency of 49 cycles per second is necessary to prevent the set reverting to A.C. drive, and thus generating back into the mains network, as would happen if its output frequency were greater than mains frequency).

(vii) If the output voltage or frequency exceeds these limits relay OV operates and completes the circuit of a thermal time delay relay DCD which, after an interval of 5 seconds, operates the "Close Down" relay C.D. The operation of relay C.D. closes down the set by releasing contactors M (mains) and A (D.C. drive) and by-passes it by operating contactor G and releasing contactor H. The operation of contactor G causes a signal to be sent to start the NS diesel/alternator set which on reaching correct speed and voltage now supplies the No Break load via contactor G.

(viii) Complete failure of the output of the N.B. set is sensed by one or all of the "No Volt" relays of which one only, RNV, is shown. Release of one of these relays operates the

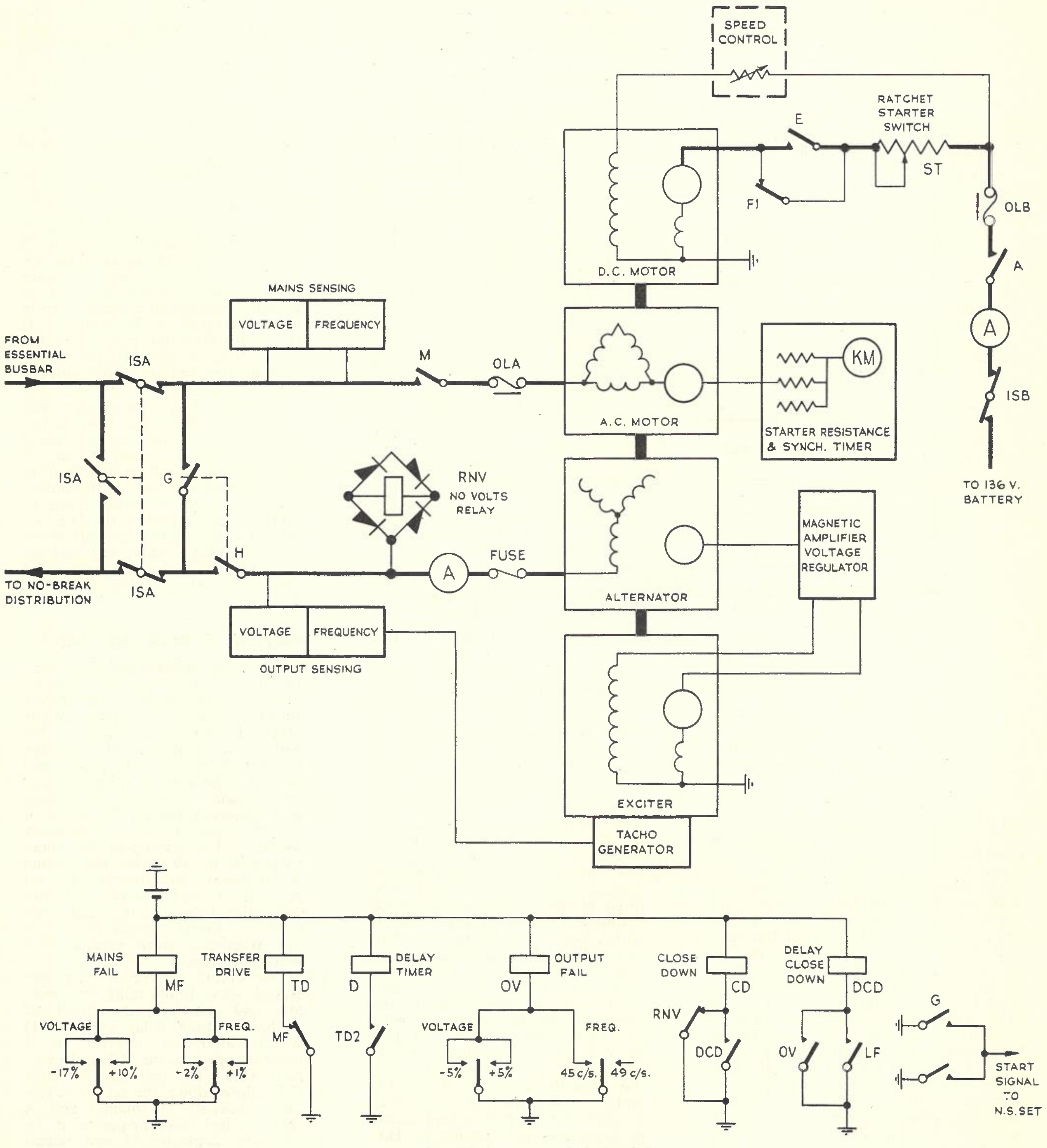


Fig. 7.—Simplified Diagram of No Break Plant.

"Close Down" relay C.D. without delay, the N.B. set closes down and the N.S. set is started as described in (vii).

Synchronisation

(ix) It is necessary to shut down the continuously-running No Break set at intervals for inspection, cleaning and preventive maintenance attention to brush gear, contactors and relays. It is also necessary to check the calibration of meters and timers from time to time. Transfer to an alternative source of A.C. power can be effected by manual (push button) operation but to avoid the brief switching break, of the order of 150 to 200 milliseconds, entailed in this operation, means of synchronising and paralleling the output of the N.B. set with either mains or the N.S. set have been provided. The equipment required, comprising a synchroscope, two voltmeters, push-button-controlled contactors and potentiometers, is mounted in a small cubicle installed between the N.S. and N.B. A.C. control cubicles. In general the N.S. set rather than the (unregulated) public supply mains will be used and all that has to be done is to start the N.S. set under manual control, switch its output together with that of the N.B. set, to the synchroscope and voltmeters on the synchronising cubicle, and with the controls provided adjust the voltage and speed of the N.S. set until it is in synchronism with the N.B. set. At synchronism a push button is operated to parallel the two sets to the load and the N.B. set is then closed down manually for servicing. The process is carried out in reverse to restore the N.B. set to the load.

CONSTRUCTION OF PLANT

Machines

The design and manufacture of the rotating machines used has been well established in many years of practice and no novel techniques are introduced in factory production. A close-up view of a 10 kVA, 3-machine set is shown in Fig. 8, the 136 Volt D.C. motor being in the foreground, followed in that order by the slip-ring 3-phase A.C. motor, the 240/415 Volt alternator, the alternator exciter and, directly coupled to the exciter, the tacho-generator.

The bed-plate is cast in two sections, the mating faces of the two halves being machined and dowelled for accurate assembly at site. To secure silence in operation and long-life, sleeve bearings with oil ring lubrication were specified and generously proportioned phosphor-bronze bearings are fitted in the end shields of all machines except for the 40 and 50 kVA sizes in which two pedestal-type bearings are provided for the D.C. motor shaft. A bearing temperature monitor in the form of a toggle-action thermostat is accommodated in a pocket in each bearing housing and, in the event of any bearing overheating, operates to give an alarm and shut down the set.

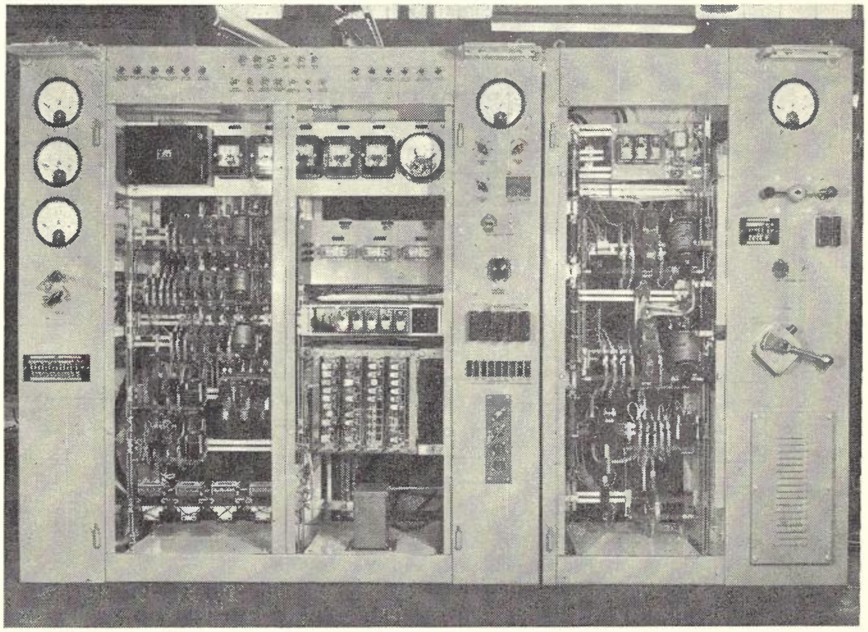


Fig. 9.—A.C. and D.C. Control Cubicles, Doors Open. The A.C. Cubicle is on the Left of the Photograph.

Control Gear

All control gear including monitoring, metering, switching, protective, signalling and alarm components is accommodated in folded sheet metal (16 Gauge) cubicles six feet in height. Two cubicles, one "D.C." and one "A.C." are used either 2′3″ or 2′6″ in depth and from 9′6″ to 11′0″ in total width depending upon the size of the plant. The cubicles are arranged for top or bottom entry of cables and for front and rear access for maintenance purposes. Front access is gained by full-length hinged doors fitted with a "Castell" lock mechanically interlocked with isolating switches so arranged that the cubicle doors cannot normally be opened until the isolate switch is operated to remove hazardous voltages from the equipment. Rear access is normally necessary only for assembly and installation purposes and is gained by the removal of full length panels bolted to the rear flanges of the cubicles. All components are bolted to a sub-frame or frames of square section aluminium bar which are in turn bolted via anti-vibration mountings to the cubicles. Care has been taken to assemble components in functional groups and to provide for example, hinged sub-frames for 3,000-type control relays to facilitate maintenance inspection and adjustment. Fig. 9 shows an A.C. and a D.C. cubicle with doors open to show the layout of equipment.

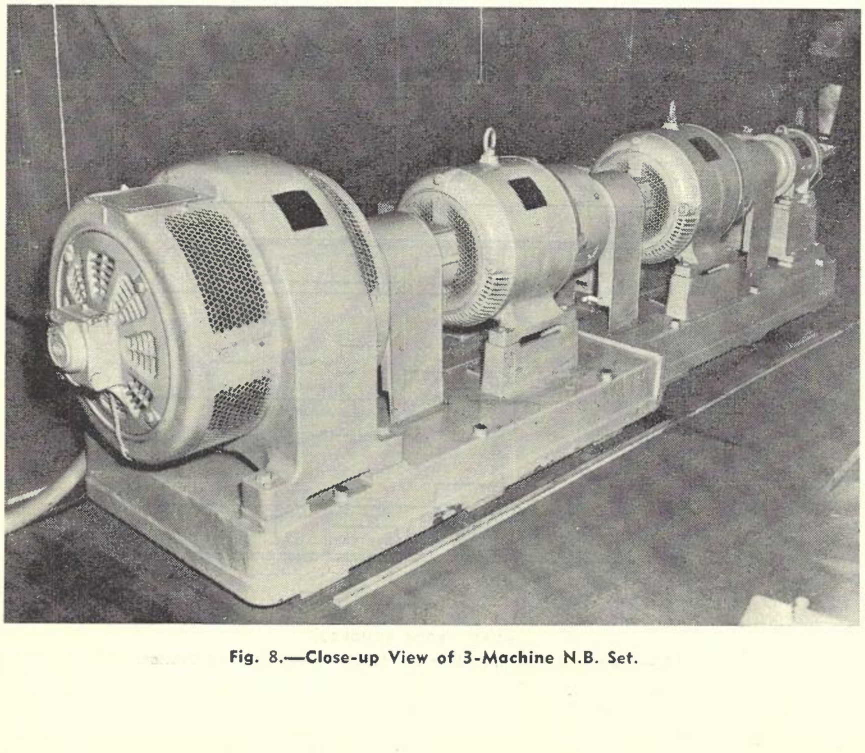
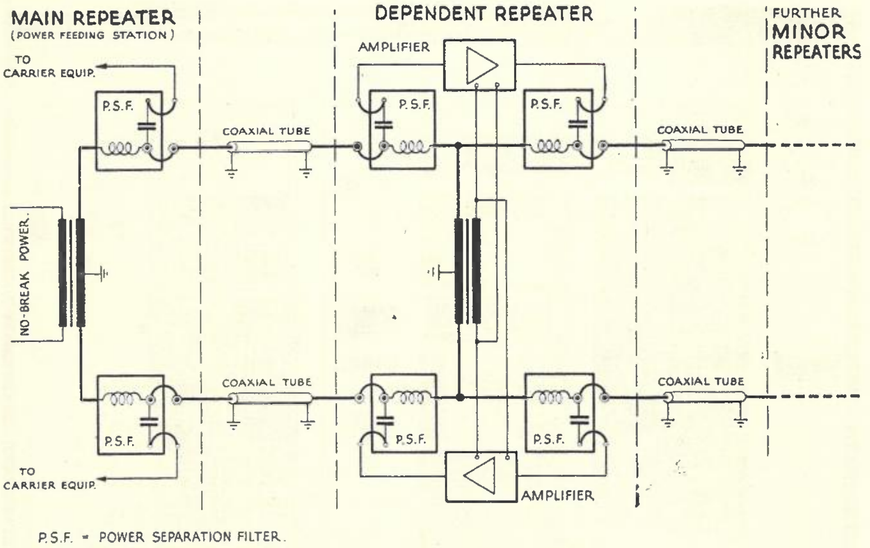


Fig. 8.—Close-up View of 3-Machine N.B. Set.

MOBILE POWER PLANT

As described elsewhere in this Journal and referred to earlier in this article, a feature of coaxial cable operation is the feeding of power supply to dependent repeaters over the central conductors of the coaxial tubes. The voltage at which this A.C. power is injected via power separation filters is a maximum of 1,500 Volts (750 Volts between each conductor and earth) and in the event of it becoming necessary to work on the underground cable because of damage to the cable, it is necessary to remove this hazardous voltage from that section of the cable affected. Bearing in mind that there are six tubes in the cable two of which are normally



P.S.F. = POWER SEPARATION FILTER.

Fig. 10.—Principle of Power Feeding.

reserved for standby purposes, it is possible to carry out extensive repair work, while still maintaining high frequency transmission over the tubes not actually being worked on by cable jointers. To remove the power feeding voltage from the section affected it is necessary to terminate the section preceding the fault in a dummy load simulating the load of the remainder of the normal power feeding section and to inject power at the correct voltage at the repeater beyond the fault. The principle of power feeding and the removal of power from a section of cable between two dependent repeaters is shown in Figs. 10 and 11.

The dummy load comprises a highly stable resistor, variable in steps corresponding to the loads of repeater sections up to ten, thus covering the maximum possible dummy load of the longest power feeding section on the cable. Three such loads will ultimately be accommodated in a small, 2-wheel weather-protected trailer thus providing for terminating all three pairs of tubes at any dependent repeater station. The mobile generator is an 8 kVA, 240 Volt single phase 50 c/s alternator driven by a Lister air cooled 16 BHP diesel engine and is accommodated together with its control gear and the substitute power feed racks in a tandem axle trailer of minimum practical size as shown in Fig. 12.

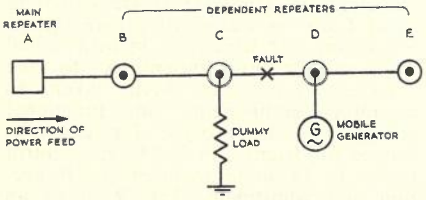
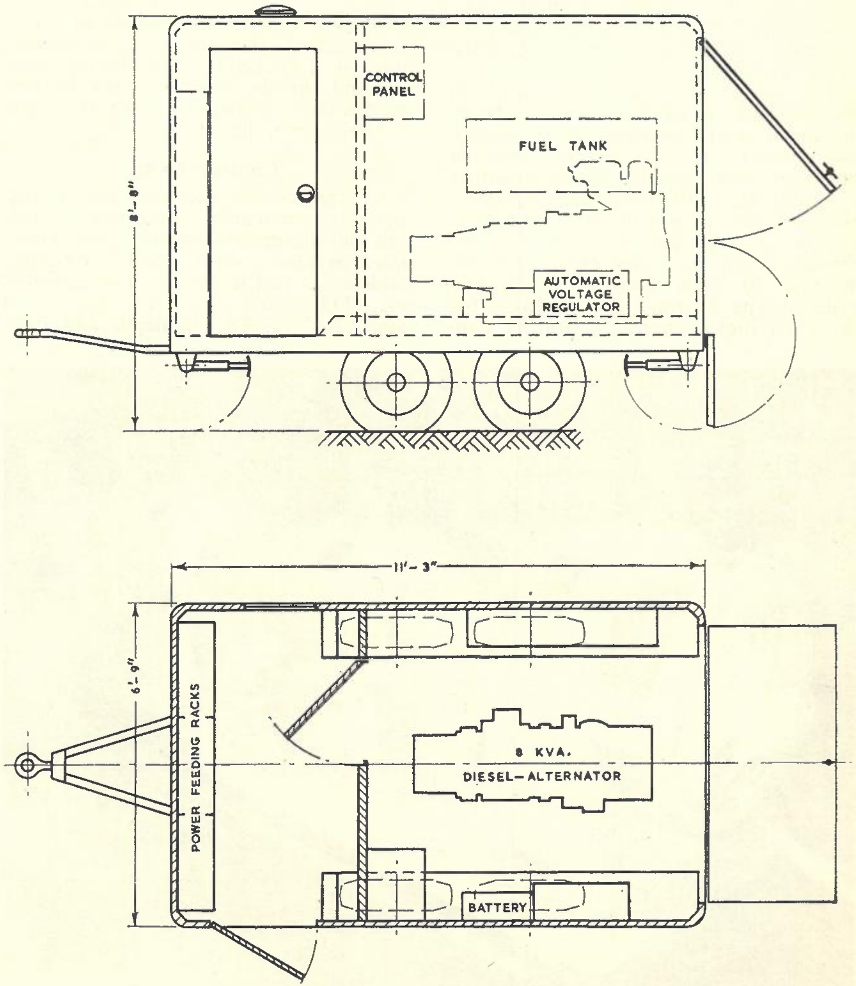


Fig. 11.—Removal of Power From Section C-D in which a Cable Fault has Developed.

At the time of writing the mobile power feeding equipment has not been used in an actual cable fault and there is no means of accurately forecasting the incidence of cable faults requiring the use of this mobile equipment. There is no doubt, however, that cable faults will occur and must be cleared quickly. A system of patrolling of the cable route is in operation and it is considered that by the provision of three complete sets of mobile generators/dummy-loads, detection of a fault either by gas pressure failure or report by the patrolling personnel will be followed by arrival of a mobile set on the scene with reasonable minimum delay. It should be appreciated also that the mobile power feeding equipment is required only while permanent repairs to the cable are being effected; if for example only one tube in the cable is faulty, the working channels can be patched quickly to spare tubes and service restored temporarily, while if the whole cable is interrupted, the power feeding can be disconnected immediately while temporary repairs are made. The permanent repairs involving the mobile sets are then carried out at the earliest possible opportunity but time is not critical. The sets will be located at Benalla, Wagga and Goulburn thus being evenly spaced along the length of the route.

OPERATION IN SERVICE

At the time of writing this article, the installation of all fifteen plants was com-



PLAN (ROOF REMOVED)

Fig. 12.—Plan and Side Elevation of Mobile Power Feeding Trailer.

pleted at the stations shown in Table 1 and the plant at the five stations from Sydney southward to Canberra had been in operational service for six months. Remarkably few failures have been experienced and the total "out of service" time of the coaxial system attributable to power plant faults was 35 minutes. A serious potential cause of failure is the presence of dust and dirt in the power rooms and special precautions are most desirable to ensure scrupulous cleanliness during the installation and subsequently. Although care was taken to protect the equipment against the ingress of dust, some trouble was detected in the commissioning stages of the installations and in almost every case the final cause was found to be dust which, once present, is difficult to completely eradicate.

CONCLUSION

The performance in service of the relatively complex plant comprising an integrated "No Break" installation described in this article justifies the choice made by the Administration and it is confidently expected that up to 25 years service will be given with minimum maintenance attention. It is recognised however, that continuously-running plant of this kind, performing the vital fuction it does, demands skilled and conscientious inspection on a daily basis and arrangements to this end have been made.

ACKNOWLEDGMENTS

With the exception of the "Rectifiers Motor Battery" and the batteries themselves, the plant was supplied and installed by McColl Electric Works Ltd., Springvale, Victoria, as sub-contractor to Telecommunication Company of Australia Pty. Ltd., who were responsible for the provision and installation of all equipment for the Sydney-Melbourne project. Table II shows the sources of supply and manufacture of the major items.

TABLE II

Item	Manufacturer
Normally Stationary Diesel/alternator	Electric Construction Company, England
Control cubicle for N.S. set	McColl Electric Works, Springvale, Victoria
3-machine N.B. set and control cubicles	Electric Construction Company, England
Synchronising cubicle	McColl Electric Works, Springvale, Victoria
Rectifier, Motor Battery	McKenzie & Holland, Newport, Victoria
Batteries	Drawn from normal Departmental stocks

REFERENCE

E. J. Bulte and K. A. G. McKibbin, "Telecommunication Power Plant in Telephone Exchanges"; Telecommunication Journal of Australia, Vol. 9, No. 2, page 65.

BACK COPIES

The Society has available in quantity, back copies of most issues of the Journal from Volume 5 onwards. Volume 12, Number 1 is out of print, but reprints of the two articles on coaxial cables may be obtained for a total cost of 3/-.

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OUR CONTRIBUTORS

A. H. KAYE

I. S. McDUFFIE

J. F. SINNATT

G. I. B. VERMONT

A. H. KAYE, author of the article "Main Features of the Project", entered the Postmaster-General's Department, Victoria, as a Cadet Engineer in 1929. He graduated as Bachelor of Science during his cadetship, shortly after which he was transferred as Engineer to the Transmission Section, Central Administration. There he was engaged on the provision of equipment for programme transmission channels and broadcasting studios and on the organisation of arrangements for relaying broadcasting programmes for national and commercial broadcasting stations. He then had a period in Papua and New Guinea installing radio stations, after which he returned during the Second World War, to the Central Administration of the Postmaster-General's Department to organise the supply of equipment and materials and the installation of radio stations handled by the Department on behalf of the Armed Services.

After the war he continued with the Central Administration of the Department dealing with the supply of equipment and the installation of radio stations for the National Broadcasting Service and for radio telephone systems operating at high, very high and ultra high frequencies, and then he later took charge of the Department's Radio Section in Victoria. In 1957 he returned to the Central Administration of the Department to assume overall responsibility for the Sydney-Melbourne coaxial cable system and for the co-ordination of the many parts of this project.

Mr. Kaye is an Associate Member of the Institution of Engineers, Australia, and a Senior Member of the Institution of Radio Engineers, Australia.

I. S. McDUFFIE, author of the article "The Telecommunication Aspects", is a Traffic Officer in the Development Branch of the Telecommunications Division at Headquarters. Born in Melbourne in 1933, he commenced with the Postmaster-General's Department, Central Administration, as a Clerk in 1951. Initially, Mr. McDuffie worked in the Public Relations Section. He transferred to the Telecommunications Division in 1953 and had experience in that Division as a Clerk and acting Traffic Officer. He completed the Traffic Officers' Training course in 1959, and since qualifying has worked mainly in the Development Branch, in both the Trunk Line and the Equipment Sections. He has also worked for periods in the Telephone and Telegraph Service Branches. Mr. McDuffie is also very active in Postal Institute affairs, and for some time was Secretary of the Central Office Branch.

J. F. SINNATT, author of the article "Design of Cable Plant", is Divisional Engineer, Trunk Cable Planning, in the Lines Section at Central Office. After graduating B.Sc. at Melbourne University, he joined the Department in 1948 as a Physicist at the Research Laboraties; later the same year he went to Sydney as an Engineer and worked in the Long Line Installation and Transmission Planning Sections. In 1951 to gain country experience he moved to Narrandera as a Group Engineer and remained there until 1955 when he transferred to the Lines Section at Central Office. He has occupied his present position since February 1958.

His main outside interest is in railways: he is a member of the Australian Railway Historical Society and is currently President of the Victorian Model Railway Society.

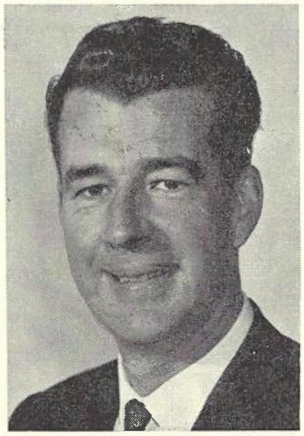
D. BARRY

G. I. B. VERMONT, author of the article "Manufacture of Cable" was born in Hungary. He graduated from the Hungarian Royal Military Technical Academy with Honors as Dux of the Academy, and received the Regent's Sword. He saw active service as Commanding Officer of Headquarters Signal Group and was decorated with the Hungarian Knight Cross (Military). The end of the war found him in Germany where he became Area Supervisor of Administration with the U.N.R.R.A., and later with the Control Commission of Germany, caring for over 15,000 Refugees. In 1948 he immigrated to England, and won a Scholarship to the University of London to complete a course of study for the B.Sc. (Eng.) Degree. He also obtained the Higher Diploma in Engineering of the Institute of Electrical Engineers. After completing his studies, he joined Standard Telephones & Cables Ltd. in London as Design Engineer in their Coaxial Cable Division. He joined the Australian Post Office in 1956, and worked as Group Engineer in the Long Line Equipment Section at Headquarters. With the start of the Sydney-Melbourne Coaxial Cable production, he became the Technical Head of the Telecommunications Division of Olympic Cables Pty. Ltd.

D. BARRY, co-author of the article "Installation of the Cable", joined the Postmaster-General's Department as a Cadet Engineer in 1950 during the third year of the Engineering Degree Course at Sydney University which he had started under the Commonwealth Reconstruction Training Scheme. He gradu-

A. L. FISHER

R. J. CLARK



R. A. COLLINS

F. J. HARDING

ated Bachelor of Engineering in 1951 and until 1957 worked as an Engineer Grade 1 and Group Engineer in Metropolitan District Works. From 1957 to 1959 he was attached to Trunk Line Planning Division and carried out the route selection and survey in New South Wales of the Sydney-Melbourne cable route. Since 1959 he has been Divisional Engineer in charge of the project Division responsible for the installation of the Coaxial Cable in New South Wales.

A. L. FISHER, co-author of the article "Transport of Cable and Other Materials", graduated in Engineering at the University of Tasmania in 1948. After two years with the Electrolytic Zinc Company, Hobart, he joined the Vacuum Oil Company. In 1956 Mr. Fisher entered the Postmaster-General's Department as a Group Engineer, Automotive Plant Section, in Victoria. In 1957 he was promoted to Assistant Controller, Transport Branch, Central Administration, the position he now occupies.

R. J. CLARK, co-author of the article "Transport of Cable and Other Materials" joined the Post Office in 1936 and spent a total of 14 years in Post Offices Branch. This period was broken by five years' service with the A.I.F. He was promoted to the Transport Branch in 1955 as Senior Clerk, in which position he was responsible for contract mail services throughout New South Wales. In 1957 Mr. Clark was appointed Superintendent, Transport Branch, New South Wales, the position he now occupies.

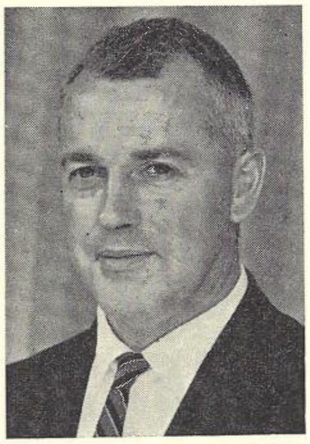
R. A. COLLINS, co-author of the article "Transport of Cable and Other Materials", joined the Post Office as a Telegraph Messenger in Victoria in 1938 and was with the Telegraph Branch for three years. After four years A.I.F. service, he was transferred to the Personnel Branch, and in 1956 became Assistant Superintendent, Transport Branch, Victoria. In 1961 he was promoted to Superintendent, Transport Branch, and is responsible for the transportation of mails and stores throughout Victoria.

J. R. WALKLATE, author of the article "Design of Transmission Equipment", graduated Bachelor of Science from the Melbourne University in 1950. He then joined the Department of Civil Aviation where he was engaged on material specification work in the Engineering Branch, Division of Airways, until May, 1953, when he transferred to the Postmaster-General's Department, taking up duty in the Long Line Equipment Section, Central Staff, as Engineer Grade 1. He was promoted to Group Engineer in 1954. During this initial period in the Post Office, Mr. Walklate was responsible for the prototype design and manufacture by the Department of sixteen 3-channel open wire carrier systems using surplus Departmental spare component stocks, and was for a time in charge of the Long Line Equipment Laboratory. Early in 1955 he transferred to the Cable Carrier Division, and since October, 1957, has been Divisional Engineer responsible for the design, specification and procurement of cable carrier equipment and the general oversight of cable carrier works programmes. This latter period saw a tremendous expansion of the work of this Division into the broadband carrier field, and Mr. Walklate has been intimately connected with the planning and execution of all broadband projects to date, including Sydney-Melbourne, Melbourne-Morwell and Sydney-Brisbane. An official overseas visit to Europe was made in this connection in late 1959. Mr. Walklate will be leaving the Department shortly to take up an appointment with Philips Electrical Industries Pty. Ltd. as Product Manager, Line Telephony Division of Telecommunication Company of Australia Pty. Ltd.

J. R. WALKLATE

F. J. HARDING, author of the article on "The Gas Pressure Alarm System", joined the British Post Office in 1940 as a Youth-in-Training, leaving at the end of 1953 to join as Assistant Controller, the Telecommunications Department, Federation of Malaya and Singapore. He joined the Australian Post Office in January 1959. His service with the B.P.O. included several years connection with the Air Defence of Great Britain Network and ended with over five years in the Transmission and Main Lines Branch of the Engineer-in-Chief's Office. In Malaya he was primarily concerned with the economics of system operations (including tariff reforms), carried out a complete reorganisation and mechanisation of the pan-Malayan Telegraph Network and was largely responsible for the creation of a Renewals Trust Fund.

Mr. Harding is now Divisional Engineer, Coaxial Cable Installations, Lines Section, Central Office and is currently engaged in Major Project Work Study applied to coaxial cable installations having been intimately connected with all major coaxial cable projects so far undertaken in Australia. He is an Associate Member of the I.E.E. (1953).



J. V. DUNN

M. FIZELLE

C. R. AUSTEN

A. W. SISSON

J. V. DUNN, co-author of the article "Buildings", joined the Postmaster-General's Department as a Draftsman in 1952, and later the Buildings Branch as a Buildings Officer. He is at present an acting Senior Buildings Officer at Central Office. He is a registered architect, having qualified with a Diploma of Architecture at the Royal Melbourne Technical College and in Architectural Design at the Melbourne University Architectural Atelier.

His work with the Buildings Branch has been mainly connected with the provision of Communication buildings of various types. He was the Central Office buildings project officer for the flood relief radio telephone network in Northern New South Wales and was closely connected with the Brisbane, Adelaide, Perth and Hobart television transmitter buildings projects. He has been, for the last two and a half years, the Central Office project officer for all building work required to house the Sydney-Melbourne cable equipment.

M. FIZELLE, co-author of the article "Buildings", is a Superintending Architect with the Head Office of the Department of Works, Melbourne, and in that capacity is at present responsible, in addition to other duties, for the programme of work for the Postmaster-General's Department.

From 1939 to 1944, he was in charge of the Defence Liaison Section of the Department of Works at Victoria Barracks, Melbourne, and upon the cessation of war, was seconded to the Commonwealth Disposals Commission and held the important post of property Sales Manager until 1947 when he was appointed to the position of Principal Architect, Department of Works, Adelaide. In 1950 he was appointed to the position of Designing Architect at Head Office. In that capacity he made a visit overseas to Great Britain and Europe, to study the latest trends in hospital design in connection with the Tuberculosis campaign. In 1954 he travelled again overseas, both in a private and official capacity and on his return, was appointed Assistant Director of Works (Planning and Design), at Canberra. In 1958 he returned to Head Office to the position of Superintending Architect. Mr. Fizelle is a Fellow of the Royal Australian Institute of Architects.

C. R. AUSTEN, co-author of the article "The Testing of the Cable" started his career as a Cadet Engineer with Amalgamated Wireless (A'sia) Ltd., in 1943. He became an Engineer associated with that company on graduating at the Sydney Technical College in Electrical Engineering in 1949. He joined the Postmaster-General's Department in New South Wales as an Engineer Grade 1 in 1950, and worked in Transmission Planning Section on filter and equaliser design and power co-ordination problems. In 1955 he became a Group Engineer and in 1957 was transferred to duties associated with the installation and testing of carrier frequency lines and the balancing and loading of carrier and voice frequency cables. Since 1960 he has been responsible for the testing of the New South Wales section of the Sydney-Melbourne Coaxial Cable and associated minor trunk cables. Mr. Austen is an Associate Member of the Institution of Engineers, Australia.

J. M. WALKER

A. W. SISSON, co-author of the article "The Testing of the Cable", joined the Department as a Cadet Engineer in Sydney in 1947. After qualification in 1951 he spent four years in Lines Planning and Metropolitan District Works Divisions in Sydney before transferring to Country District Works at Narrandera, New South Wales, in 1955. He came to Central Office, Lines Section to take up the position of Acting Divisional Engineer, Cable Design in 1960, in which capacity he is responsible for underground cable designs and specifications, instruments for installation and acceptance testing of cables, and investigations into experimental cables. He is a Graduate Member of the Institution of Engineers, Australia.

J. M. WALKER, co-author of the article "The Testing of the Cable", joined the Postmaster-General's Department in Victoria as a Technician-in-Training in 1935. He worked as a Technician and Senior Technician in the Victorian Transmission Laboratory and qualified as Engineer in 1944. After experience in the Victorian Transmission Lines Planning and the Bendigo Country Divisions, Mr. Walker was transferred to the Central Office Long Line Equipment Section in 1950 as Divisional Engineer, Transmission Design & Standards. He is at present Sectional Engineer in charge of design, planning and transmission standards in that Section. Mr. Walker is an Associate Member of the Institution of Engineers, Australia.

R. A. PEACOCK

W. G. BEARD

A. HANNAH

J. S. BROGAN

R. A. PEACOCK, co-author of the article "Installation of Transmission Equipment" joined the Post Office, Melbourne, as a Technician-in-Training in 1939. During the following ten years he gained experience with various installation groups and spent several years on transmission measurements. In 1949 he joined Standard Telephones and Cables Pty. Limited as a Project Engineer engaged on the manufacture of telephone equipment, and in 1957 was appointed Installation Engineer handling PABX, PAX, Remote Supervision, Public Address and similar systems. In 1958 he resigned to become Manager of Telecomponents Pty. Limited, a unit of Ferris Industries, Sydney. In 1959 he joined the Staff of the Telecommunication Company of Australia Pty. Limited as Project Manager for the Sydney-Melbourne Coaxial Cable Project.

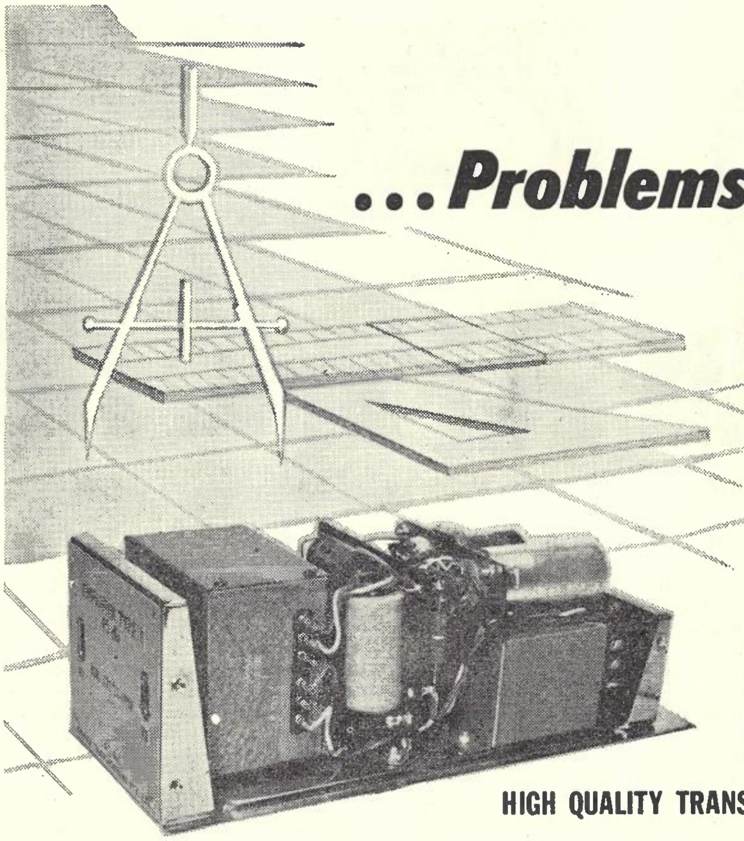
A. M. BOYD, co-author of the article "Installation of Transmission Equipment" is employed by the Telecommunication Company of Australia Pty. Limited as Installation Engineer, Coaxial Cable Project. He joined the Company in June, 1959 from Army Signals where he was employed as Foreman of Signals. Before proceeding overseas in September, 1959 he was engaged in pre-planning for the project. He spent nine months in Germany and Holland undertaking study of the associated Companies' equipment to be used on the project. Since his return he has been engaged in supervising the delivery and installation of equipment at the various attended and unattended stations. He is as Associate of the Institution of Radio Engineers, Australia.

W. G. BEARD, co-author of the article "Installation of Transmission Equipment", joined the Post Office, Sydney, as a Cadet Engineer in 1950. He graduated as Bachelor of Engineering at the University of Sydney. After completion of his cadetship, he worked at the Postal Workshops, Sydney, and then in Metropolitan Service as a Group Engineer. In 1959 he joined the Staff of the Telecommunication Company of Australia Pty. Limited and almost immediately went overseas for nine months to study carrier telephony practices with the associated companies in Germany and Holland. Since his return to Australia he has been engaged on testing of the equipment for the Sydney-Melbourne Coaxial Cable Project. Mr. Beard is an Associate Member of the Institution of Engineers, Australia.

A. M. BOYD

J. S. BROGAN, author of the article "Contract and Supply Arrangements", commenced as a Telegraph Messenger in 1935. He was appointed as a Clerk in the Stores & Contracts Branch at Headquarters in 1937, where he has served since. Mr. Brogan has had considerable experience of contract work, and has been associated with supply arrangements for several major Post Office undertakings.

A. HANNAH, author of the article "Power Plant", started his career in the British Post Office as a Youth-in-Training in 1927. In 1937 he was promoted to Inspector, and later to Assistant Engineer, in the Engineer-in-Chief's office, London, and was employed in both the Equipment and Main Line Transmission Sections of that office on the specification, procurement, installation and operation of equipment for multi-channel balanced pair, coaxial land and submarine cable systems. He was a member of the group concerned with the assembly of communication systems designed for use in operation "Overlord" and was attached to War Office Signals in 1944/45, serving in France with 13 Line of Communications Signals unit throughout the restoration of the London-Dover-Calais-Paris multi-channel cable system. In October, 1949 he was appointed Engineer in the Australian Post Office and commenced duty in the Long Line Equipment Section of the Engineer-in-Chief's office in December, 1949. He is at present an acting Sectional Engineer in that Section. Mr. Hannah studied telecommunication engineering at Northampton and Regent Polytechnics, London and holds City & Guilds of London Institute certificates in Telecommunication Principles and Line Transmission (Final).



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1st February, 1st June, 1st October.
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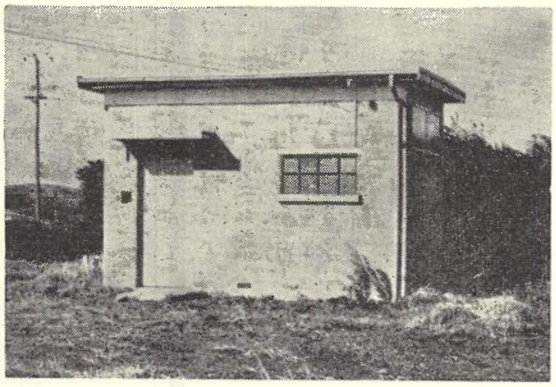

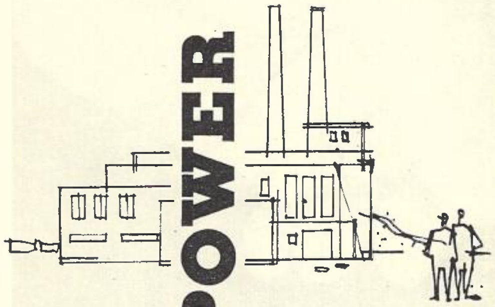

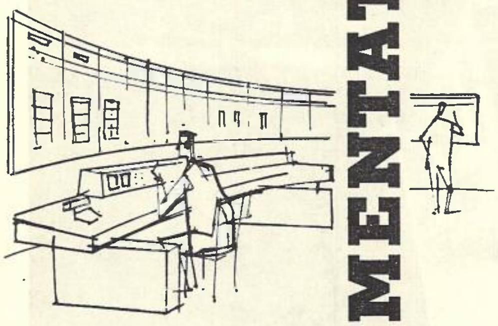

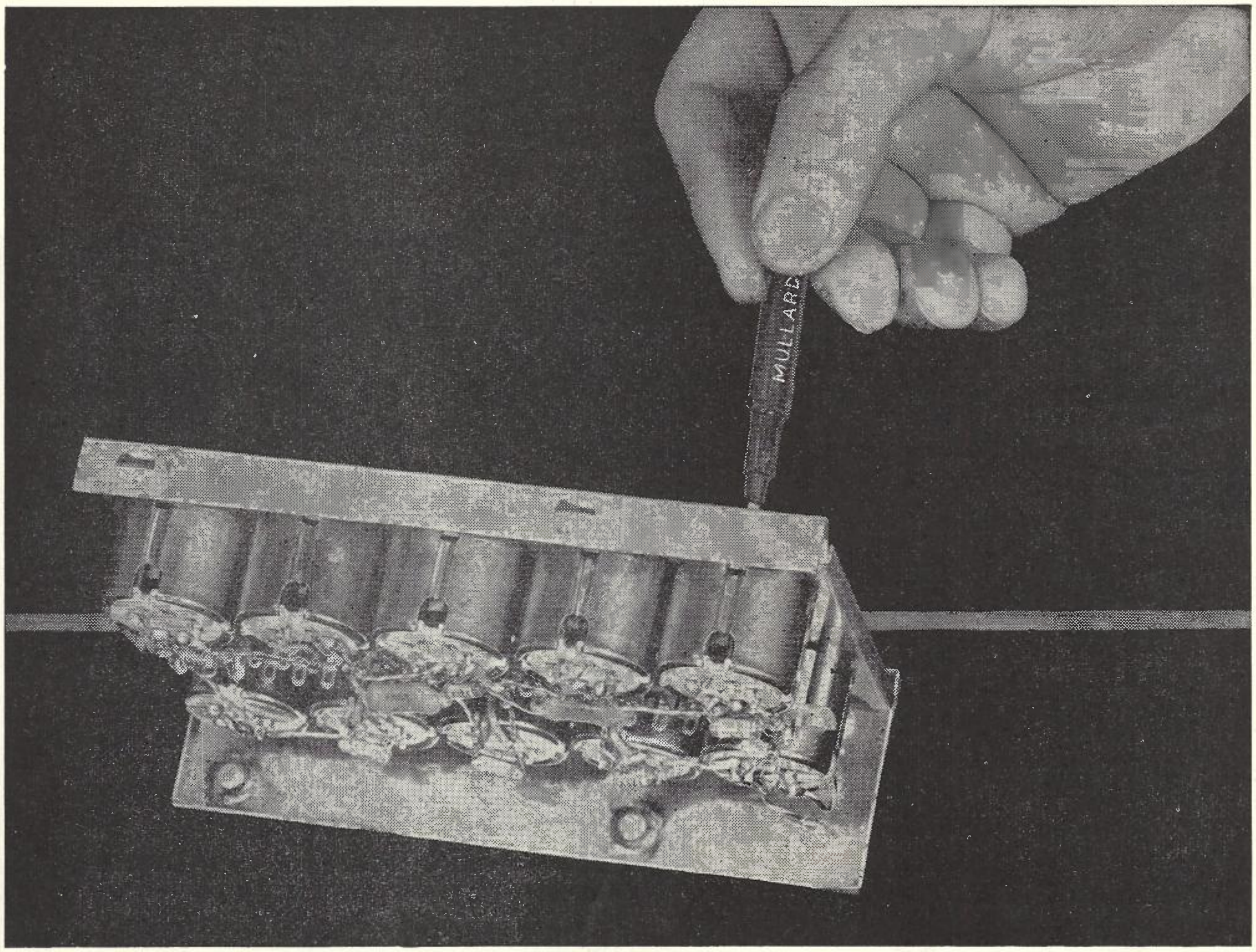
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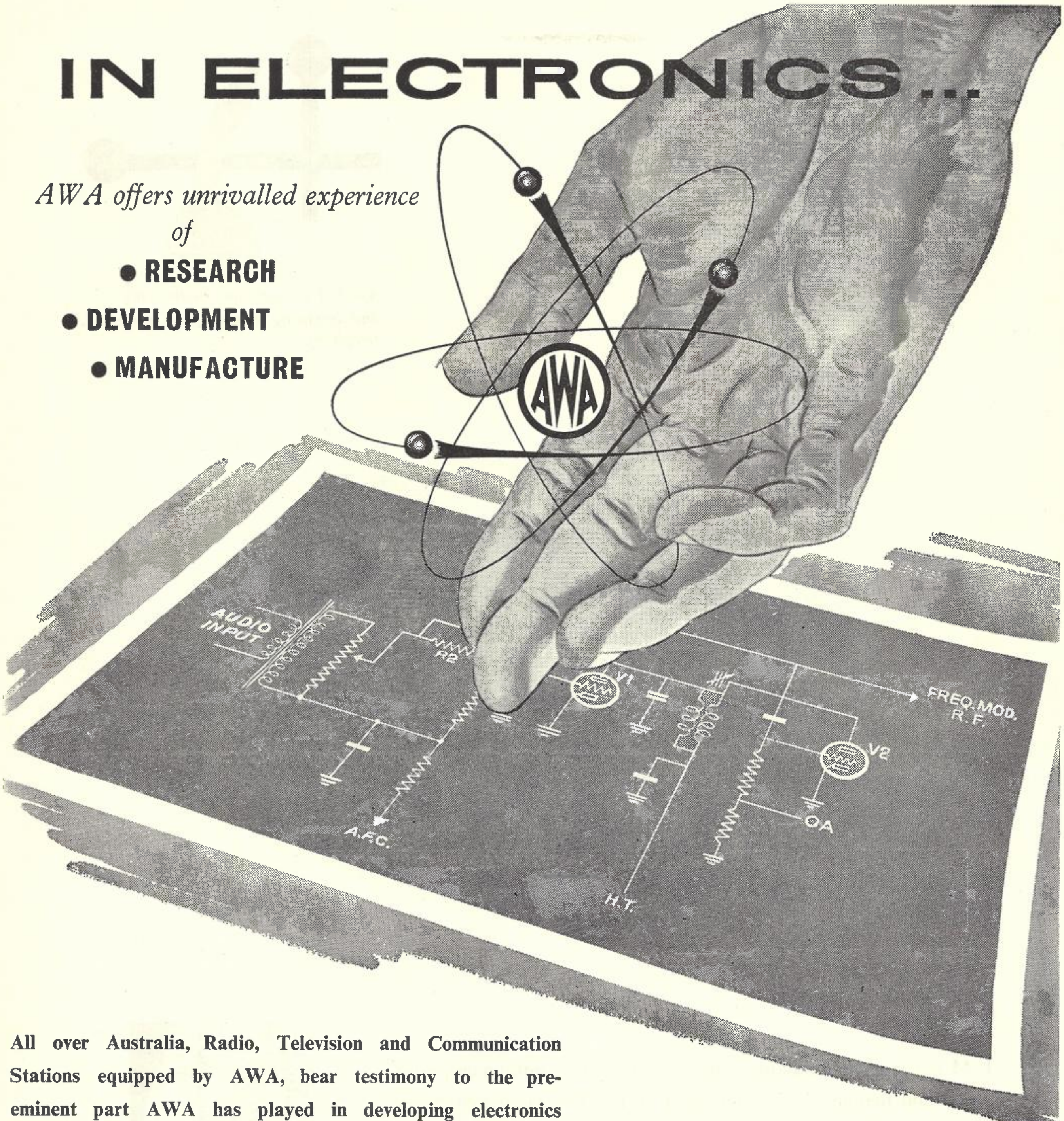
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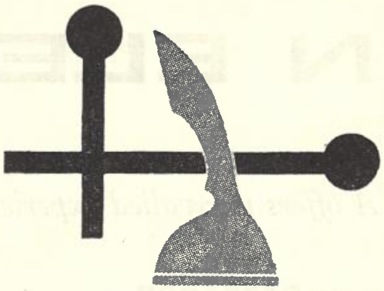

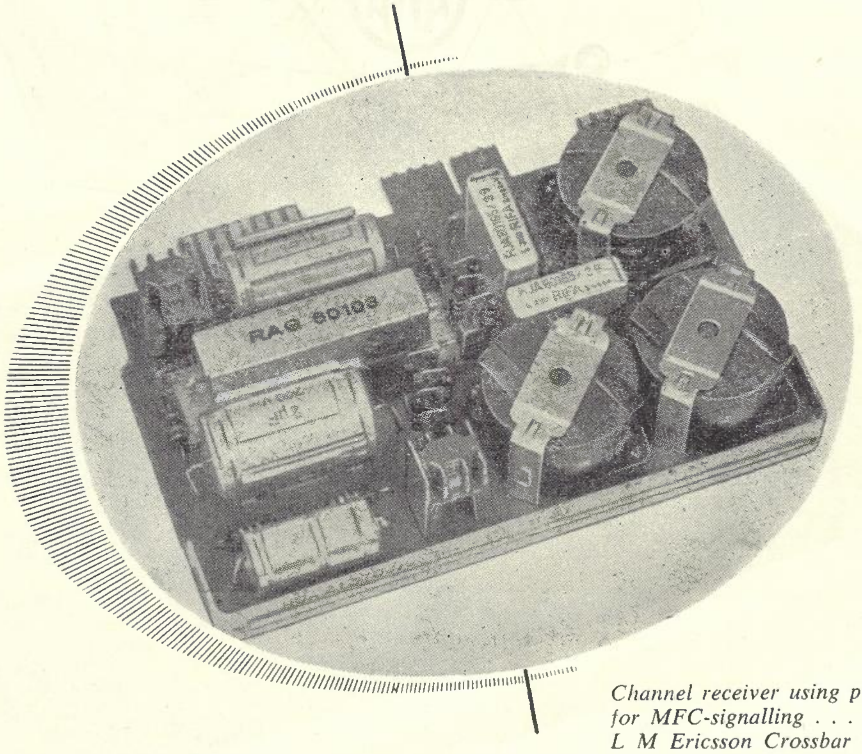

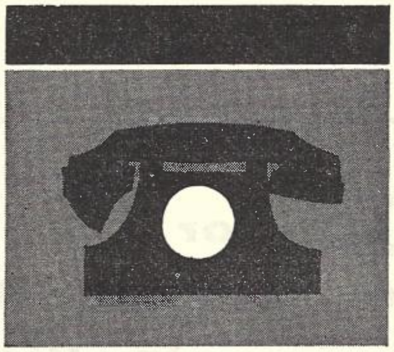


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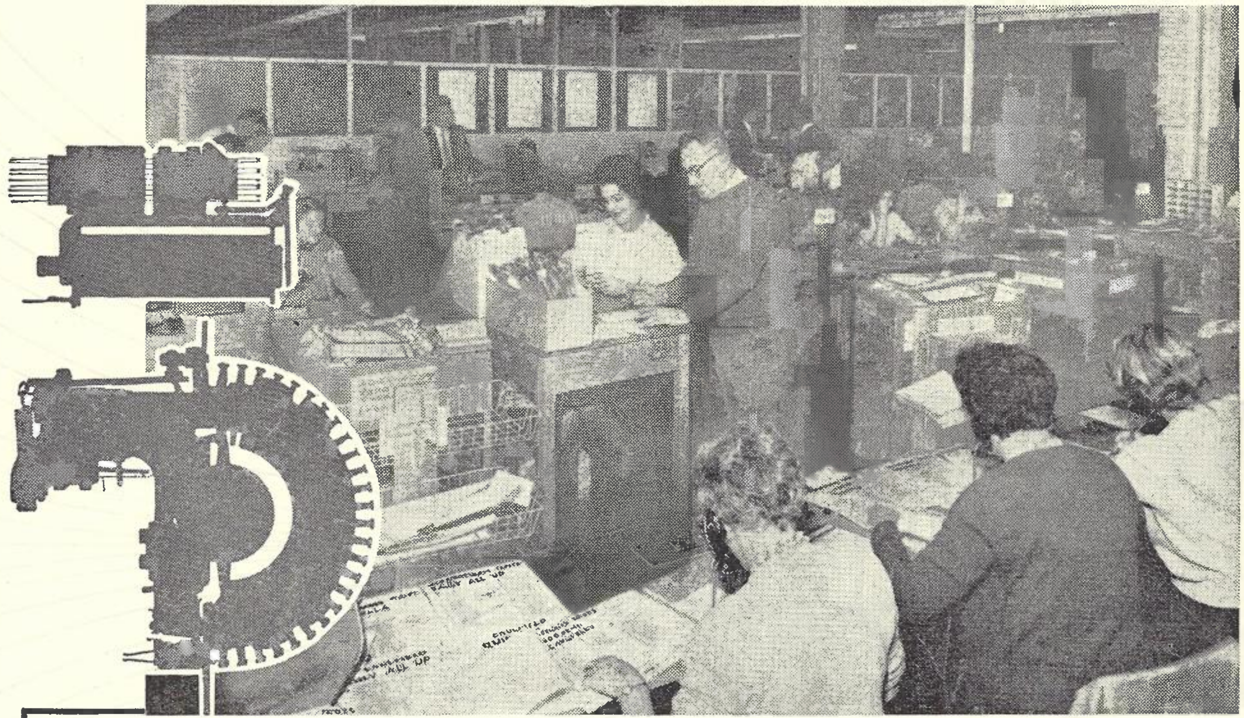
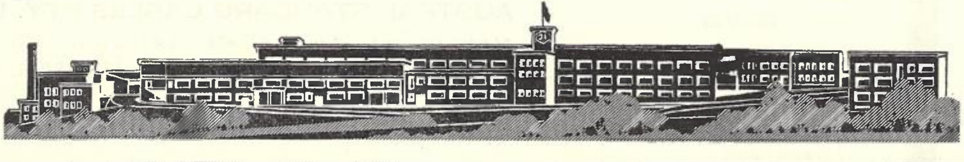


Legislation was passed in Victoria recently legalising off-course betting on races held at all Victorian courses with Totalizator facilities.
All off-course investments are co-related by the Totalizator Agency Board's Head Office in Melbourne and passed on to the Totalizator at the course or courses in operation for the particular day.
Provision is made for cash betting through Branch Offices of the Totalizator Agency Board which will eventually be distributed throughout the State.
In addition, registered clients may place their investments by telephone direct to the Totalizator Agency Board by calling a given telephone number over which calls are received via a call queueing system to twenty answering positions in a group.
The illustration above shows an operator accepting a client's investments on the day's races at Caulfield.

Standard 2000 TYPE RACK COMPONENTS AND 3000 TYPE RELAYS are used to provide these facilities. T.E.I. were able to assist at the circuit-design stage and have manufactured the call queueing equipment, answering circuits and supervisors' consoles.



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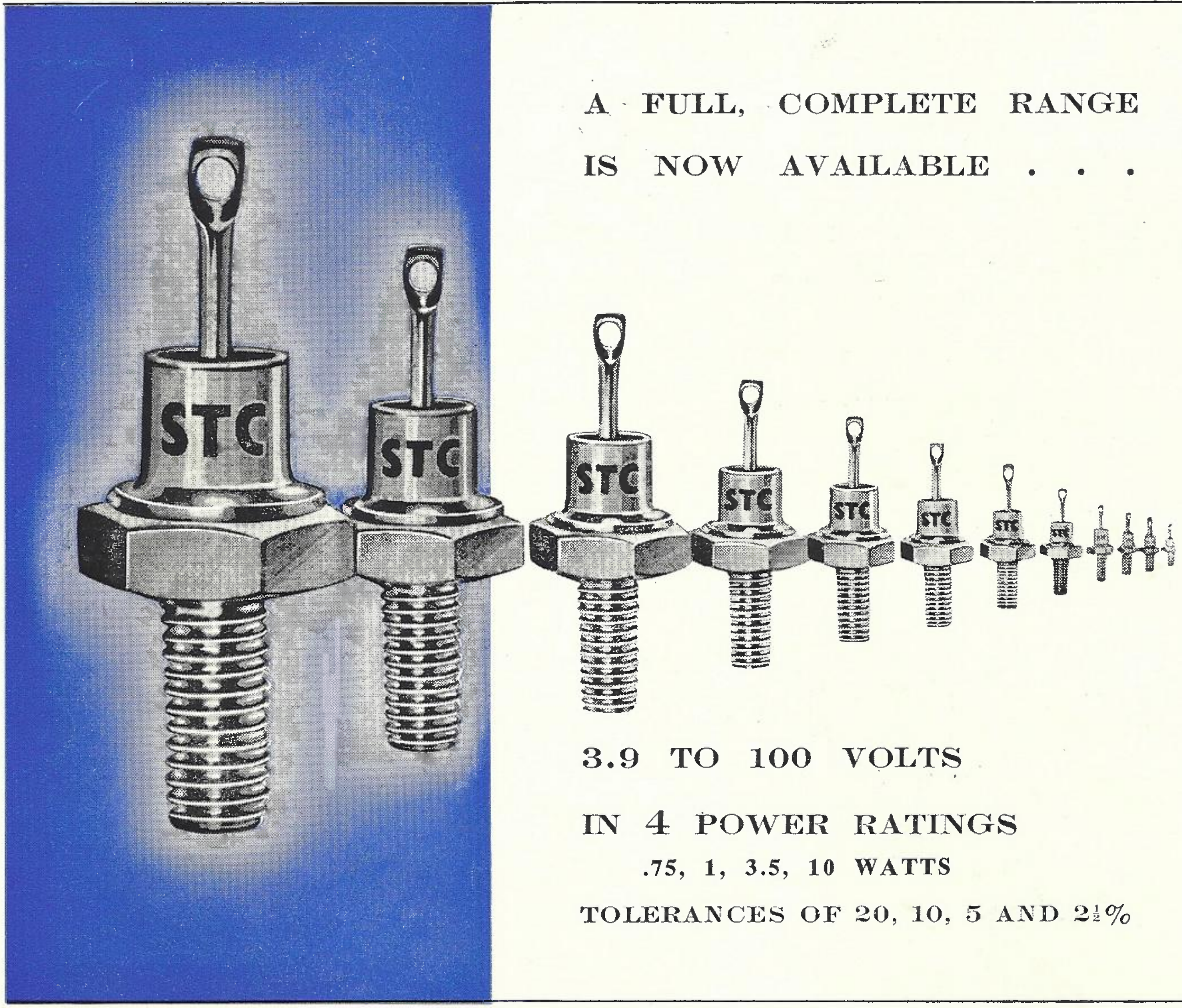

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Printed by the Ruskin Press Pty. Ltd., 39 Leveson Street, North Melbourne.