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The

Telecommunication Journal of Australia

VOL. 10, No. 5 OCTOBER, 1956

MR. R. V. McKAY A.M.I.E.Aust.

Our former Engineer-in-Chief, Mr. R. V. McKay, A.M.I.E.Aust., retired this month after 45 years in the Post Office. He is returning to London to resume his position as Australian Member on the Commonwealth Telecommunications Board.

Mr. McKay has had a very interesting career in the Post Office, details of his early activities being given in the issue of June, 1940, at which time he was first appointed Engineer-in-Chief. Between 1940 and 1950 Mr. McKay was responsible for directing the activities of the Engineering Division in the Commonwealth, including the busy and exacting times in the war and immediate post-war periods. His energy and drive during this period have been largely responsible for the immense strides made in the very great expansion of the telecommunication system of the Australian Post Office.

In 1950 Mr. McKay took up duty in London as official Australian Post Office Representative in England, as well as being the Australian representative on the Commonwealth Telecommunications Board, which organisation controls the communication system between the various countries in the British Commonwealth. In the course of his duties in London, Mr. McKay represented Australia at many conferences in various overseas countries. His travels for this purpose took him to such places as Atlantic City, Mexico City, Paris, Florence, Geneva, Stockholm and Munich, and his contributions to telecommunication engineering progress generally have been outstanding. During all this period he did not lose touch with Telecommunication Journal activities and was always ready to assist the Society in its endeavours to improve techniques by the dissemination of worthwhile information relevant to A.P.O. telecommunication problems.

Our good wishes go to him in his retirement and also in his activities in London.

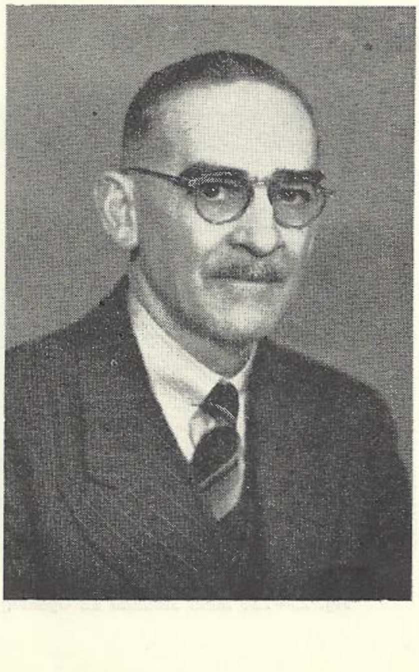
MR. R. E. PAGE A.M.I.E.Aust.

Congratulations are extended to Mr. R. E. Page, A.M.I.E.Aust., on his appointment as Engineer-in-Chief, Australian Post Office, on 14/2/57. His ability, boundless energy and wide experience in the field of telecommunication engineering have been recognised for some time as he has occupied the position as Acting Engineer-in-Chief for the past seven years.

Mr. Page commenced his Post Office career in Melbourne as a junior assistant engineer in 1910. Since that time his activities have been characterised by a rapid series of promotions through the various engineering grades, combined with a variety of assignments. He was promoted to New South Wales as Divisional Engineer in 1923 after having served a period of some six years at Headquarters. In New South Wales he was one of the pioneers in the field of carrier equipment and was promoted as the leader of the newly created Transmission Section in 1929. Further promotions followed up to Assistant Superintending Engineer, and in 1939 he was promoted as Superintending Engineer, Queensland.

His period of service in that State only lasted a short time and in 1940 he returned to Headquarters, where he occupied in turn the positions of Supervising Engineer, Lines and Supervising Engineer, Transmission, during the war years.

Throughout this period he had, amongst other tasks, the overall responsibility of ensuring that the communication channels necessary for the efficient working of the Australian and American army establishments were provided throughout the country as necessary. Upon the conclusion of the war he was promoted as Superintending Engineer, New South Wales in 1946, and directed the engineering effort in that State for three years, including the heavy task of rehabilitating the telecommunication system. In 1949 he returned to Headquarters and for a time directed the activities of the post-war organisation which was set up by the Government with a view to meeting the immense demands for telecommunication service built up during the war years. He was appointed as Deputy Engineer-in-Chief in 1950 and from that time forward has been acting as Engineer-in-Chief.



Mr. Page has always supported the activities of the Postal Electrical Society and has contributed several articles to the Telecommunication Journal. He has always been ready to assist anyone who appealed to him for help to solve engineering problems and has retained throughout his career the quality of being readily approachable by all his staff.

STAGING THE 1956 OLYMPIC GAMES — THE TELECOMMUNICATIONS ROLE

I. M. GUNN, M.B.E., B.Sc.[*]

Fig. 1.—The Olympic Flame, Melbourne, 1956.

Ancient Olympic Games: History does not record accurately just how the ancient Olympics started, but legend has it that they began as a religious festival in honour of the Greek God of Gods, Zeus, at Olympia in the valley of Elis, Greece, about 776 B.C. From this time the Olympiads were introduced on the Greek calendar, each four year period being known as an Olympiad, Olympic Games being held in celebration of each Olympiad. The ancient Olympic Games were last held in A.D. 394. Theodosius, Emperor of Rome, abolished the Games, and later ordered the destruction of all pagan temples, included in which was the Temple of Zeus. Subsequent floods and depradations of time completed the destruction of Olympia.

The absence of early reports of the first Olympic Games have led to contradictory statements concerning these Games, but it is believed that the stade foot race of about 200 yards (the length of the stadium) was the only contest at early Games. Coroebus, of Elis, was the first recorded victor, the four-year period to the next meeting being known as the Olympiad of Coroebus. Gradually other events were added, notably the pankration (a combination of boxing and wrestling); wrestling (as a symbol of the triumph of science over brute force); diskos (the winner of the discus throw was idolised, as this was a favourite sport); javelin throwing, jumping, chariot racing and foot racing between contestants clad in light and heavy armour. The pankration was said to be the most spectacular of the events, as, with only gouging and biting barred, these contests were a fight to the death or surrender. Contestants fought nude. The only prize for victory was a garland of wild olive with which the winner was crowned.

The Revival of the Olympic Games: Discovery of the ruins of ancient Olympia by Richard Chandler in 1776, and subsequent excavation work by the French Government (1820) and the German Government (1876) were events which rekindled the Olympic flame after a lapse of time of more than 1,500 years. The world-wide interest in the ancient Olympics followed and, soon after, the seed for the revival of the Games was sown by the French visionary, Baron Pierre de Coubertin.

De Coubertin saw in an intensified athletic endeavour a hope for a stronger more virile French race, following the ill-effects of the Franco-Prussian War, and visualised a mammoth international sports festival which, he thought, would be a means of achieving universal peace. After contacting athletic bodies throughout the world in 1893, the Baron saw his dream come true with the first modern staging of the Olympic Games at Athens in 1896. Only track and field athletics, the 100 metres swim and weightlifting were contested in the inaugural meeting. An Australian won two events.

Such has been the triumphal progress of the Games since 1896 that the record number of 68 nations participated in the 1952 Olympic Games at Helsinki, Finland, and this record was equalled at the Melbourne Games, 1956.

The Role of Telecommunications in the Olympic Games: Throughout the history of the Games, telecommunications have played a part of ever increasing importance. In the Ancient Games, we have examples of some of the oldest known communication methods (still in use in some parts of the world today)—the runner with the message stick and smoke signals. Nations were summoned to compete at Olympia by a runner sent out sometimes two years before the event and who in the course of his advertising campaign traversed many lands.

At the conclusion of each Olympiad the news of victory was signalled across the then known world by beacons lit on hilltops and bringing the glad tidings weeks and months before the victorious athletes arrived home. This was most important in order that the local heroes could be met with due pomp and ceremony and so that public holidays with feastings and pageantry could be organised.

In the modern Games, as the science of communications advances, the world is not prepared to wait on such methods for the news, and elaborate systems of telegraphic, telephonic and radio communications are essential. In addition, the Games have grown to such a mass concentration of numerous types of sports, with so many competitors, that officials must have the assistance of the best telecommunication methods in order to control the staging of events with split-second timing.

Telecommunications in the Melbourne Games: These aspects were of peculiar importance to the Melbourne Games because of two particular features. Firstly, because of its physical isolation from the rest of the world, Australia depends wholly on telecommunications for dissemination of news. When the Games

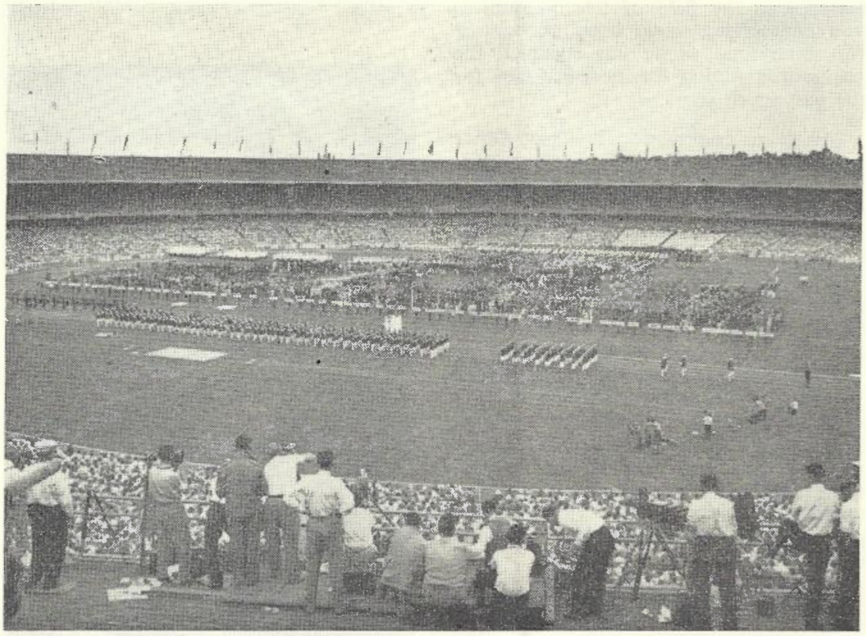


Fig. 2.—The Main Stadium on Opening Day—The Australian Team Marches Past.

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[*] Mr. Gunn is Superintending Engineer, Services, in the Victorian Administration.

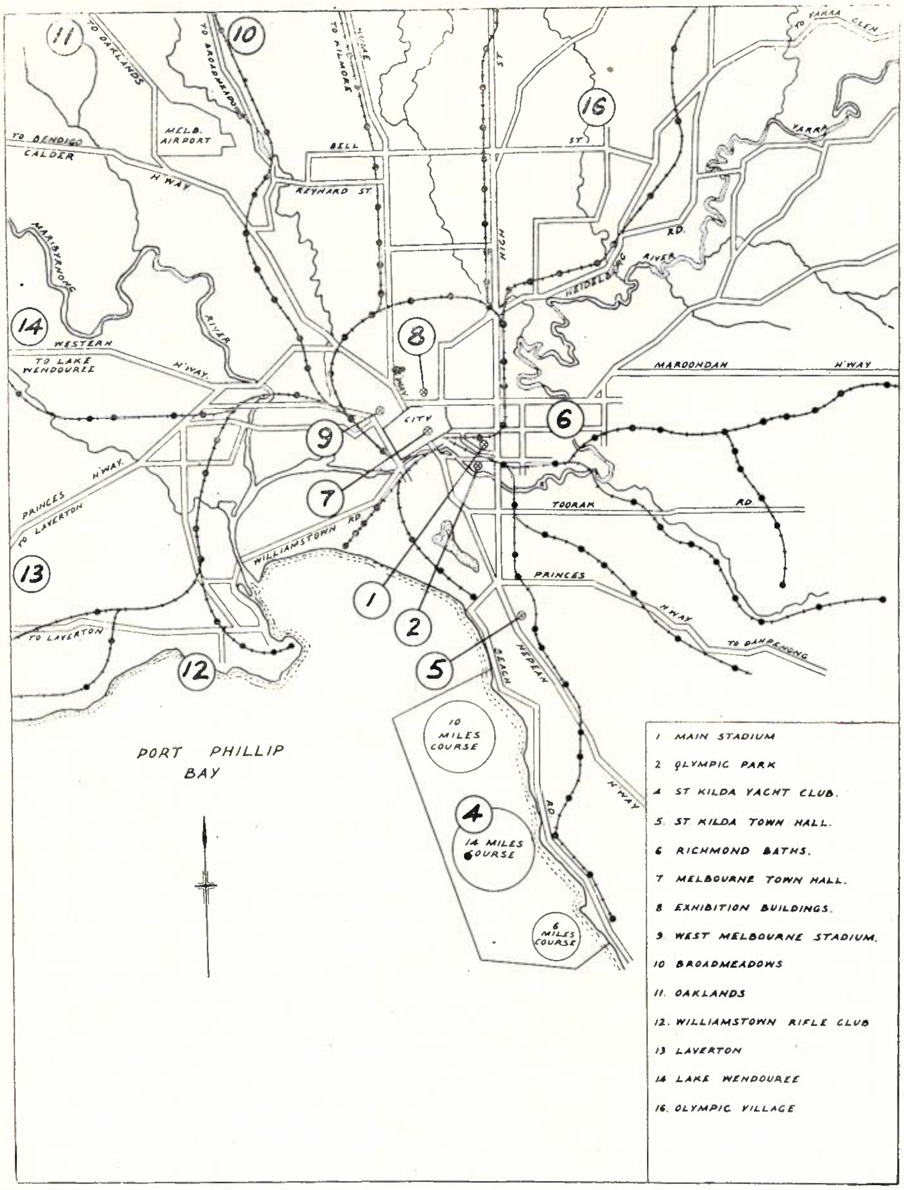


Fig. 3.—Map showing Location of Venues in Melbourne.

are held in Europe and North America reporters from foreign adjacent lands can attend particular events and be back in their own offices the same night to prepare copy, very much in the same way that a Sydney reporter can visit Melbourne for the Melbourne Cup, fly home and have the full story in the next editions of his paper. This, of course, was impossible for overseas correspondents visiting Australia. Secondly, because of problems of buildings and suitable arenas in Melbourne, the venues for the various sports were scattered over a wide area, as can be seen from Fig. 3, and telecommunications played a large part in providing and maintaining the necessary co-ordinated control.

The clearing of overseas press and radio traffic was a joint problem for the Overseas Telecommunications Commission, the Postmaster-General's Department and the Australian Broadcasting Commission. Facilities available were submarine telegraph cables, radio telephone and telegraph channels and short wave radio coverage from Radio Australia (Shepparton) and Lyndhurst short wave stations. Apart from direct transmission to some nearer countries such as New Zealand, Japan and South Africa, main routing of traffic is via London for distribution throughout Europe and San Francisco for relay to North and South America. Consequently, for the Games and subsequent use, reinforcement of circuits was to these two distributing centres. In support of this a number of radio telegraph channels suitable for high speed machine telegraphy was made available by the three Armed Services.

The Main Stadium at the Melbourne Cricket Ground, some 1½ miles from the heart of the city, was to become the focal point from which the majority of all services associated with the Games were to operate. It accordingly had to be built up as the nerve centre of the communication network with quite large temporary radio, telegraph and telephone installations and associated operating facilities. Fig. 4 gives an indication of the extent and layout of the underground cabling required at this centre. Actually, more than half of the total room space at the M.C.G. was devoted to telecommunication facilities and an army of up to 200 engineers and technicians was engaged for four months on the various installations. Associated with these installations was the provision of junction cables to gain access to the normal civil networks and beyond these to overseas terminals. For security of communications these were planned and provided via several alternative routes. Fig 5 shows the circuits required on the various junction and trunk routes.

The several component sports covered by the Games were conducted at 15 separate venues, of which 14 were in the Melbourne Metropolitan area (within a 15 mile radius) and the other at Ballarat (Lake Wendouree) some 70 miles from Melbourne. The particular sport at each venue was controlled by a local Arena Manager with an overall co-ordinating control from the Technical Director located at the Main Stadium. Residentially all competing athletes were concentrated at Olympic Village, Heidelberg, and the Olympic Hostel, Ballarat.

The telecommunication services for control purposes consisted firstly of a local network at each venue, the nature of which depended on the particular requirements of each type of sport. As well as the standard speech circuits these included timing and signalling devices and, in some cases, local public address systems. Secondly, there was the intercommunication network of telephone and telegraph lines, in some cases supported by radio, connecting the venues and the accommodation centres with the main control centre at the Main Stadium. Apart from these special services there were the standard services provided for administrative purposes and those to meet the requirements of the general public.

The administrative organisation for the Games grew from a small central planning committee and, as the requirements arose, sub-committees or directorates were set up to handle particular aspects. By early 1956, eleven of these directorates were established with offices throughout the city and suburbs of Melbourne. A number of these directorate controls moved into the Main Stadium on the eve of the Games. There was a corresponding growth and movement of telecommunication facilities, most of which had to be planned and built in advance of the establishment or movement of offices.

This administrative network included the two residential villages. These corresponded to the establishment of telephone networks to serve towns of 6,500 and 600 people respectively with the exception that the build-up of population took place over a period of a mere four weeks. Consequently, about 95% of the construction had to be provided in advance and streamlined procedures devised for dealing with the customer requirements and the remaining 5% of the work without the normal administrative delay. Public facilities, mostly of the normal type (public telephones, post offices, etc.) were provided at all places where a demand was anticipated, but in a number of cases special designs to give utmost flexibility were adopted.

Organisation for Directing the Games: The Olympic Organising Committee was formed in 1949 with the small planning group mentioned. In due course, the following directorates under the overall control and guidance of the Olympic Organising Committee were established:

Finance and General Purpose.
Construction.
Technical.
Housing and Catering.
Communications and Broadcasting.
Press and Publicity.
Transport.
Reception.
Fine Arts.
Medical.
Legal.

In each case a prominent citizen associated with the particular business or profession was selected as chairman and sub-committee members were drawn from a representative group of the interests concerned.

Communications and Broadcasting Sub-Committee: This directorate was chaired by Mr. M. R. C. Stradwick, Assistant Director-General (Telecommunications) of the Postmaster-General's Department. Committee members represented the Technical Directorate of the Olympic Organising Committee, the Postmaster-General's Department, the Overseas Telecommunications Commission, the Australian Broadcasting Commission and the Federation of Commercial Broadcasting Stations, Australia. This Committee was responsible for the policy planning relating to telecommunications and broadcasting and for the overall co-ordination and direction of the provision and operation of services. Each authority represented therein set up its separate local organisation responsible for the construction, maintenance and operation of the several services. These local organisations worked directly in close liaison with each other and with the "customers" who, in particular, were the Technical, Housing and Catering, Press and Transport Directorates, with the Finance and General Purposes Directorate in the role of the authorising body.

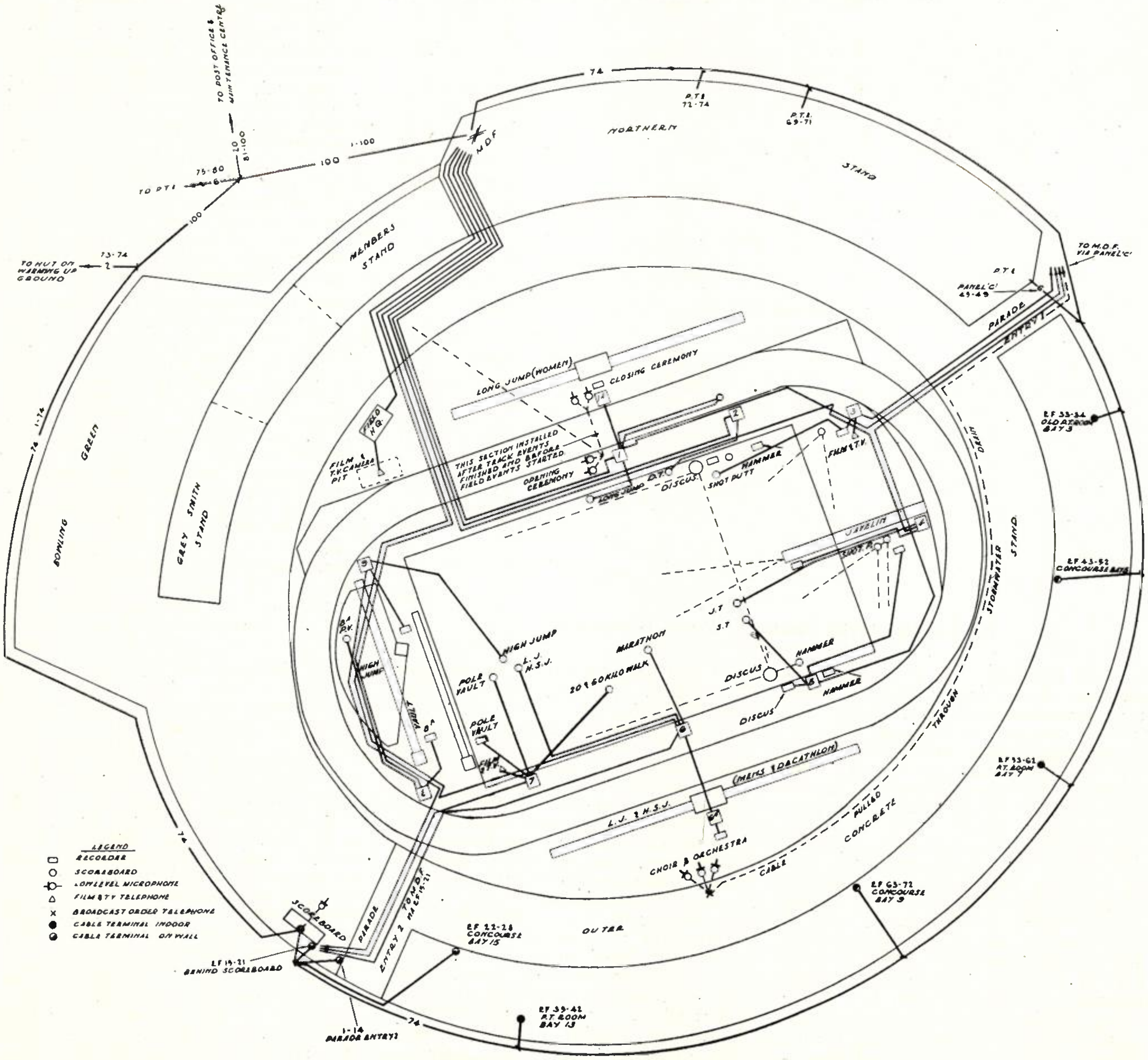


Fig. 4.—Plan of Melbourne Cricket Ground showing Underground Cabling.

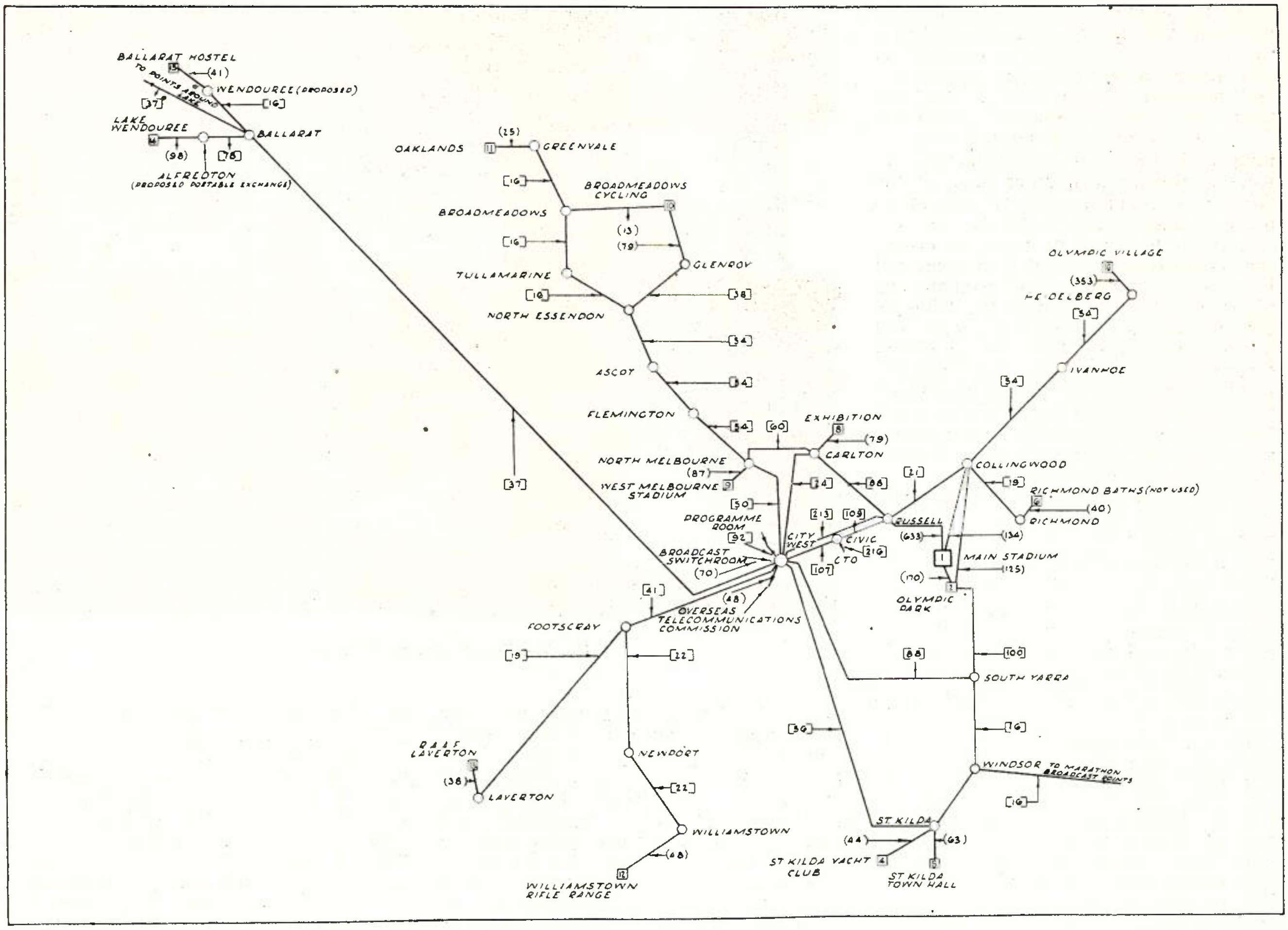


Fig. 5.—Circuits provided in Trunk and Junction Cables.

Venue	Lines to:—									Key to Fig. 5	Activity
	Public Exchange	Main Stadium	Other Venues	Central Telegraph Office	A.B.C. Switch-room	Melbourne Programme Room	Ballarat	Olympic Switch-board	Other Points		
Main Stadium	296		415	100	50	40		4	30	1	Athletics
Olympic Park	142	160	1	8		20		4	50	2	Swimming, Hockey, Water Polo, Soccer, Track Cycling
St. Kilda Yacht Club	20	13		3				1	7	4	Yachting
St. Kilda Town Hall	23	23		3	2	4		2	6	5	Fencing
Richmond Baths	21	15	1	2				1		6	Water Polo (not used)
Exhibition Buildings	27	26		4	2	8		2	10	8	Wrestling, Weightlifting, Pentathlon Fencing, Basketball
West Melbourne Stadium	31	28		4	2	8		2	12	9	Boxing and Gymnastics
Broadmeadows	41	17		3	2	8		2	6	10	Road Cycling
Oaklands	11	13		2				1		11	Pentathlon Riding and Running
Williamstown Rifle Range	26	15		3	2			2		12	Rifle and Pistol Shooting
Laverton	19	15		3				1		13	Clay Pigeon Shooting
Lake Wendouree	20	11	4	6	4	10		1	36	14	Rowing and Canoeing
Ballarat Hostel	25	1	4	4			6	1		15	Living Quarters
Olympic Village	317	19		6	2	2	6	2	5	16	Athletes' Living Quarters
Athletics Road Events	13	16								—	Marathon Run and 50 Km. Walk

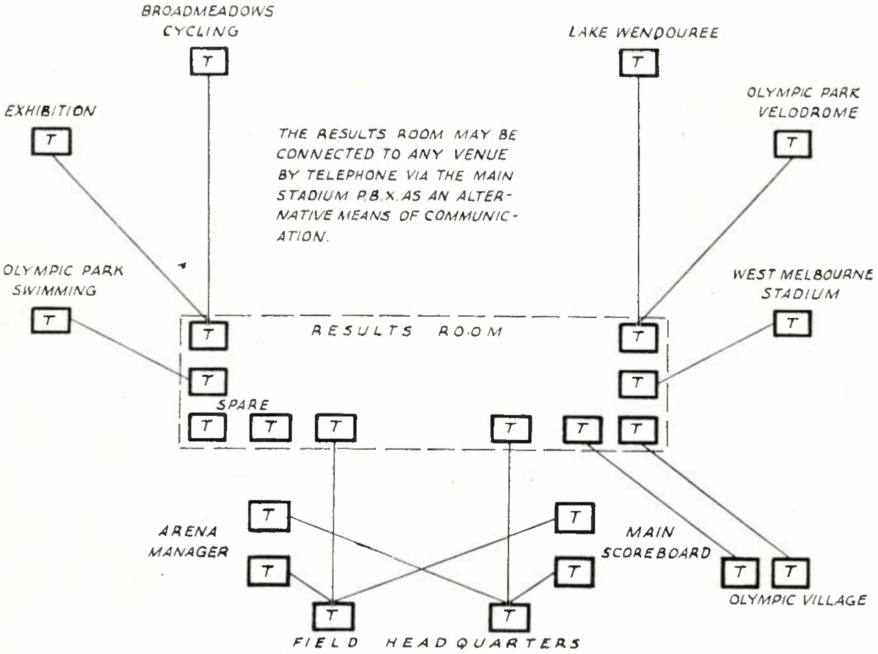
Fig. 7.—Results Room—Main Stadium.

In the Postmaster-General's Department, the Olympic Section consisted of a small group of engineers, commercial and traffic officers, clerks, technicians and representatives of the Postal Services and other Branches concerned. The section carried out the detailed planning and design of requirements and worked directly with other units of the Organising Committee. Provision, maintenance and operation of the services (except in the case of overseas broadcasting) were carried out by the normal Departmental organisation, strengthened where necessary, and with the Olympic Section acting as co-ordinators and directors of activity. For overseas broadcasting the staff and equipment requirement was as great as that which existed throughout Australia for normal national broadcasting purposes and it was necessary to set up and train a special group to handle this particular complex task. This group operated in close partnership with the Australian Broadcasting Commission team who attended to the programe and accommodation needs of the visiting radio commentators.

The Task: As the plan developed the communications task sorted itself into five fairly well defined categories:

The administrative network.
The venue control and results network..
Press requirements.
Broadcasting requirements.
Public facilities.

The Administrative Network: This was at first a slow build up as the Organising Committee came into being and developed its various subsidiaries, but it gathered momentum about six weeks before the Games opened when Olympic Village was occupied and Directorate office staffs, sometimes doubled overnight, started to overflow from city headquarters into wherever space could be made available. Apart from the Village occupation most of this growth was quite unheralded and accordingly there could be no pre-planning. Fortunately equipment and material had been stock piled and exchanges made ready to cater for an influx of telephone services, and with a large labour task force, provision was in all cases met, usually in advance of occupation. The administrative telephone network grew from four P.B.X. switchboards and 100 or so telephone services to 30 switchboards and close on 3000 services in this short period, but this does not fully represent the true picture as many of those services were removed up to eight times before the position stabilised. Furthermore, the work had to be done concurrently with the activities of building contractors, painters, electricians, plumbers and furniture removers.



THE RESULTS ROOM MAY BE CONNECTED TO ANY VENUE BY TELEPHONE VIA THE MAIN STADIUM P.B.X. AS AN ALTERNATIVE MEANS OF COMMUNICATION.

Fig. 6.—Results Teleprinter Network.

As Olympic Village, Heidelberg, the new town built to house competitors and officials, was later to be converted to normal housing, telephone facilities were planned on a permanent basis. The difference, however, to a normal distribution system was that the location or density of services was quite unknown until the teams actually arrived; service then was required on demand. The system installed, then, had to be entirely flexible to meet whatever situation ensued, the only fixed factor being that teams were limited to telephone services in accordance with their numerical size. This entailed a cabling system far more elaborate than is normally necessary, but one which is not entirely wasted in that it will meet all possible future development of the area up to 100% saturation. In addition, at Olympic Village and the Ballarat Hostel, temporary post offices were installed with full mail, telegraphic, money order and all other standard facilities. These operated on a seven day week, 8 a.m. to 10 p.m. basis, in keeping with the continental pattern. Special facilities were installed to overcome the language problem and staff with multi-lingual knowledge were concentrated in the appropriate locations.

The administrative network covered airport and seaport terminals to cater for the arrival (and later the departure) of visiting teams and overseas visitors. Facilities were also expanded at some 45 city hotels which provided the accommodation for visiting officials and pressmen.

Fig. 8.—Field Headquarters—Main Stadium.

The Venue Control and Results Network: The general control and results reporting system consisted of mutually supporting teleprinter, telephone and radio networks radiating from the Main Stadium. All were controlled and co-ordinated by a communications co-ordinating officer on the staff of the Technical Director. Fig. 6 shows the results teleprinter network in diagrammatic form. The teleprinters were provided on point to point working between the Results Room at the Main Stadium (shown in Fig. 7) and all venues required to report any volume of results. This actually covered seven venues outside the Melbourne Cricket Ground, but included some locations such as the Exhibition Buildings, where one installation was used to report several sports, in this case wrestling, weight lifting, basketball and pentathlon fencing. All results reported, progressive and final, were received on stencil sheets on machines at the Main Stadium. Approximately 1,200 copies of each results sheet were run off and distributed by messengers to Organising Committee officials, team officials, pressmen and radio commentators. Selected results were also relayed by teleprinter to the main scoreboard at the Main Stadium and to Olympic Village.

A telephone network radiating from the Main Stadium switchboard supported the teleprinter network and also covered those venues not served by teleprinter, for example, the Soccer and Hockey Stadia, where only limited results were required at the end of matches. U.H.F. Radio also provided emergency circuits to some venues in case of line breakdown, but in general these were limited to road events such as the Marathon and the 20 and 50 km. walks. Radio was also used as an intercommunication system for these road events and for athletic events at the Main Stadium.

The local intercommunication and control system at each venue was designed to cater for the particular requirements of the sport conducted there. For example, the arena at the Main Stadium was cabled to provide a number of reporting points fitted with field telephones with light weight headsets. Progressive results were phoned back to the "Field Headquarters" which consisted of a dugout on the boundary of the arena. Fig. 8 is a view of "Field Headquarters" showing the telecommunication equipment. The radio network mentioned in the preceding paragraph also fed back results and information to this same centre. Results were assembled and checked by officials, and when authorised were transmitted back to the Main Results Room by teleprinter. Reporting points, Field Headquarters and the Results Room were manned by Olympic Officials and Army Servicemen from the Corps of Signals. For some events, for example, road events and rowing, the starters signal was transmitted to check points and the time-keepers at the finish line by electrical means over either line or radio.

The particular design at each venue required a detailed study of the method of conducting each sport and what information was required at the central control. As very few officials had any previous experience of conducting international sporting events, little information was available as the basis of these designs. Accordingly, rehearsals at each venue were arranged for the dual purpose of training officials and testing the effectiveness of communications. These rehearsals were invaluable and resulted in many important last minute alterations to systems and procedures. In some instances problems arose due to the lack of knowledge of the English language by competitors and visiting officials who reinforced local officials on some sports not commonly conducted in Australia.

Press Facilities: Some 700 pressmen were in Melbourne to cover the Games. Some of these represented large news combines and agencies like Reuters, American Associated Press, Agencie France, etc., others, periodical sporting magazines and others again were free-

Fig. 9.—Reuters Press Agency—Main Stadium.

lance journalists who sold their copy independently. The Press and Publicity Directorate for some months prior to the Games had endeavoured to assess requirements of accommodation, press seating and other facilities but met with little success except from the large agencies and combines. They accordingly concentrated on preparing full facilities for this group and skeleton facilities for an unknown number of others, commonly referred to as "unaffiliated press".

The Main Stadium was the hub of the press services. A number of rooms were fitted up as agency headquarters and copy rooms, and telecommunications facilities to collect and clear copy overseas were concentrated in these rooms. Most agencies leased telegraph channels either to their home cities and/or to London and San Francisco. These channels were extended from overseas terminals in Sydney, Canberra (Navy), Diggers Rest (Army), and Frognall (Air Force), to the Main Stadium Pressrooms and fitted with the appropriate equipment. Fig. 9 shows a typical press room at the Main Stadium. For local collection of copy, telephone services were installed in press seats and in the case of agencies these were extended on private lines to private branch exchanges

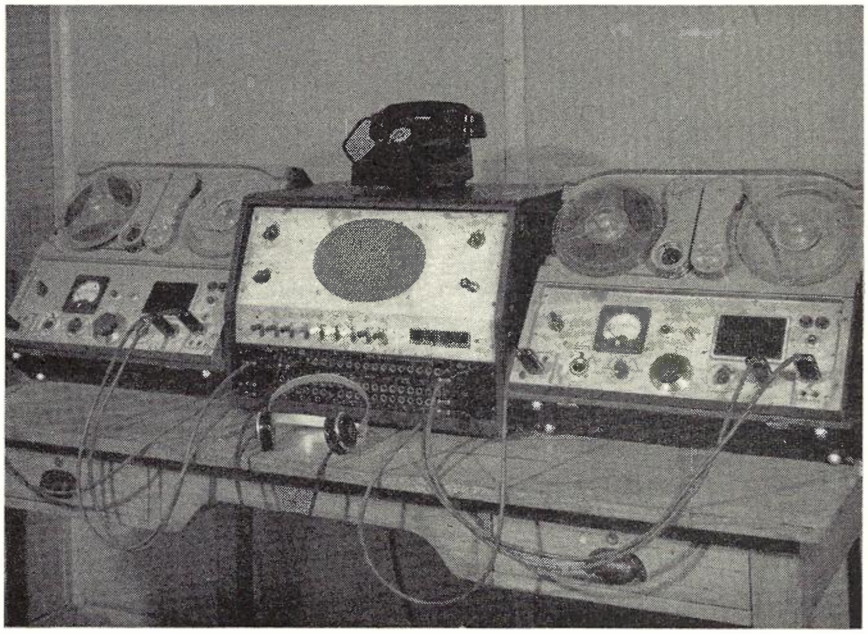


Fig. 10.—Studioette Equipment.

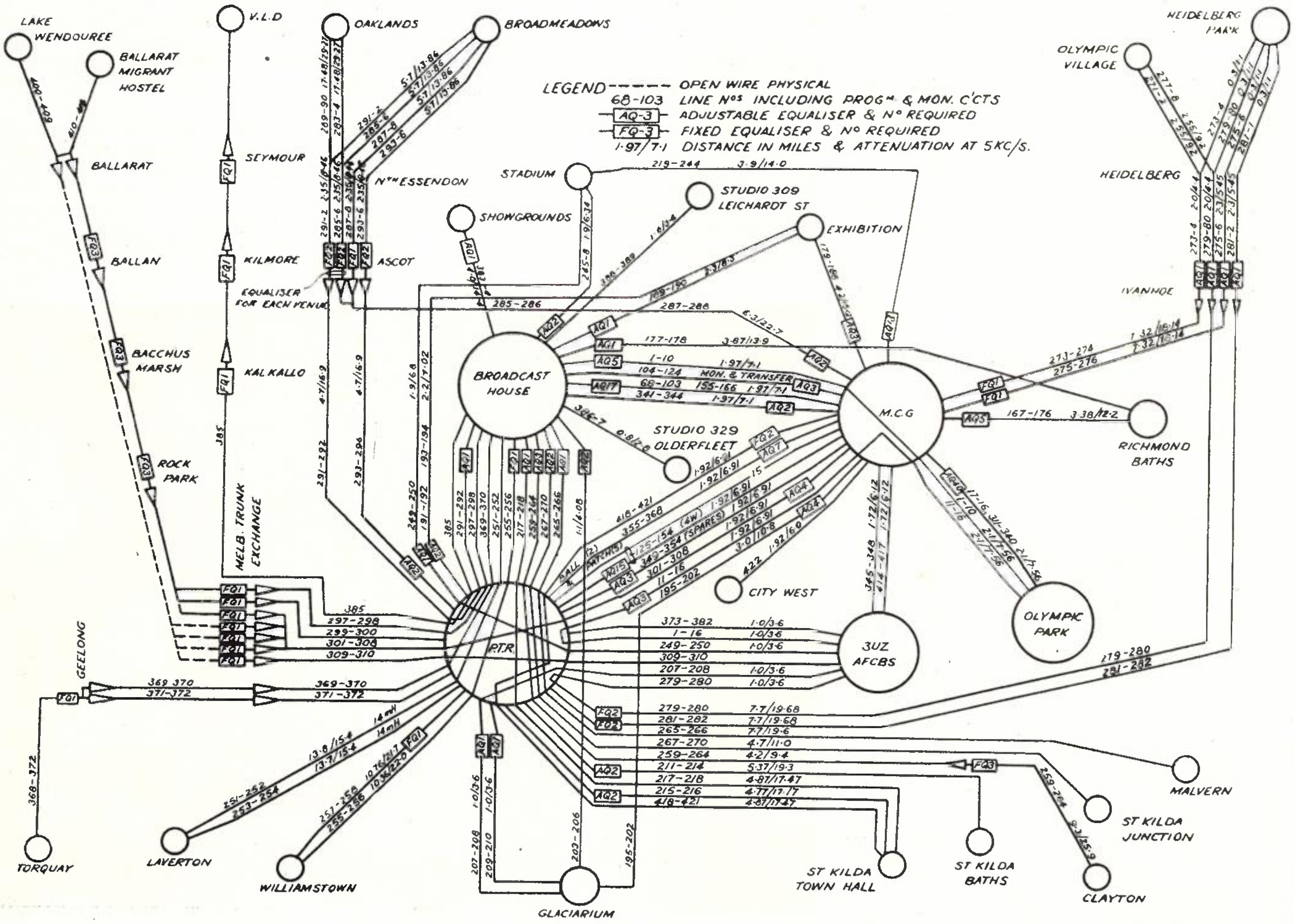


Fig. 11.—Programme Lines Provided for Olympic Games.

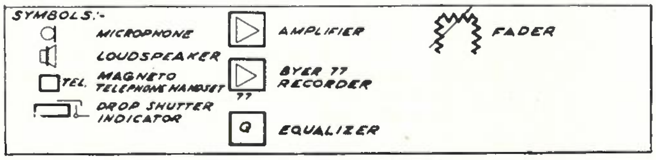
in the Main Stadium pressrooms. Other pressmen at times used leased telephone services on the public network for clearing copy to Overseas Telecommunications Commission and public telegraph offices. For the unaffiliated press, public telephones were available, either at pay stations or call boxes.

The Overseas Telecommunication Commission set up a large terminal office at the Main Stadium with a subsidiary at Olympic Park. The Post Office also set up public telegraph offices in the press reserve at all venues and also at Olympic Village, Heidelberg, Olympic Hostel, Ballarat, and the Airways Terminal, Essendon. Most of the visiting pressmen were quartered in city hotels and, when required, telephone and teleprinter services were installed in bedrooms or in lounges reserved for the press visitors. A night press telegram collection service was also operated with collection boxes located at the reception desks of a number of hotels. As equipment available in Australia only catered for telegraphic transmission of English letters and numerals, all messages handed in for transmission over the public system or using leased Australian equipment had to be converted to the Roman alphabet. It was not generally appreciated how many of the competing nations use other characters in their alphabet and, at first, there was some little delay until all became accustomed to the requirements.

Broadcasting Facilities: The problem of radio coverage of the Games for overseas nations was rendered complex by virtue of the difference in times between Australia, Europe and the Americas and also because of the rather limited channels available for passing programmes. There are no interconnecting land line circuits suitable for programmes whatever and the other two methods, short wave broadcast transmission via Radio Australia and radio telephone, are suitable only when ionospheric conditions permit. Transmission of programmes is usually satisfactory only during our night hours which, however, fortunately correspond with daylight hours in Europe and America. As 45 of the competing nations were represented by radio commentators, transmission time had to be rationed and bookings of time organised on a fairly tight schedule. All these limitations meant that the only satisfactory method of obtaining and transmitting sufficient and suitable radio coverage was to tape record commentaries at the various venues, assemble and edit these after the events and transmit what was virtually a condensed story of the day's events during the night.

This was the basic plan behind the broadcasting organisation, and, apart from the Australian Home Service and some daytime direct broadcasts to adjacent countries such as New Zealand and Japan, all material was put on tape from commentators' seats and assembled at the Main Stadium at night where the final editions were prepared and transmitted. This entailed a vast installation at the Melbourne Cricket Ground capable of handling all the technical requirements normally found in permanent studios and programme transmission centres.

A complete floor of the new Northern Stand was taken over for these facilities. Forty-eight studioettes were constructed and specially treated for acoustical characteristics and installed with equipment to originate or edit tape recordings, and with facilities for transmission by land line via a central switching centre to Radio Australia or a radio telephone terminal or to both simultaneously. The equipment provided in each studioette is shown in Fig. 10. Other rooms were devoted to booking and staff offices, repair workshops, equipment storerooms, etc. The switching centre was connected by land line to all venues so that, if necessary, tape recordings made at remote venues like Ballarat or late at night such as for night events like wrestling, could be transmitted direct to the studioette used by a particular nation. Fig. 11 shows the network of programme lines set up for broadcasting the Games, and a block schematic of the equipment and switching arrangements is shown in Fig. 12.



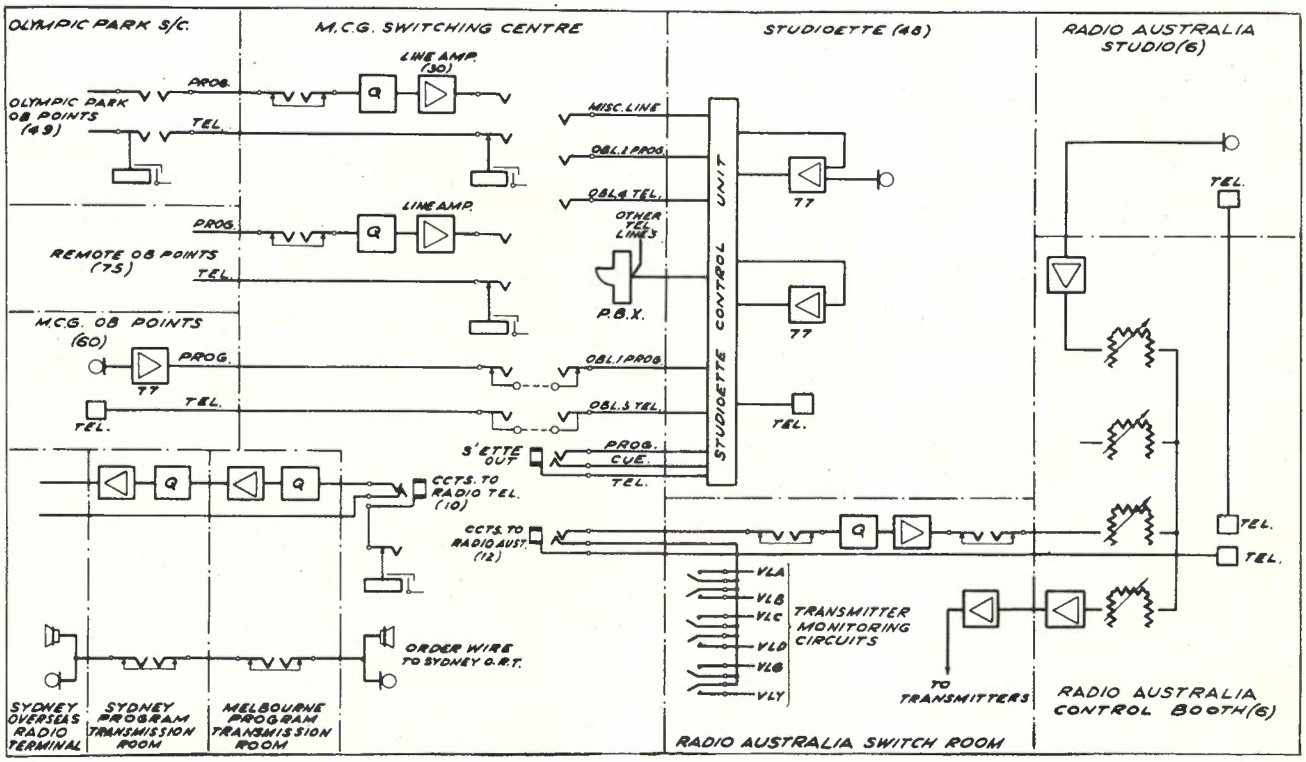


Fig. 12.—Schematic of Broadcasting Facilities.

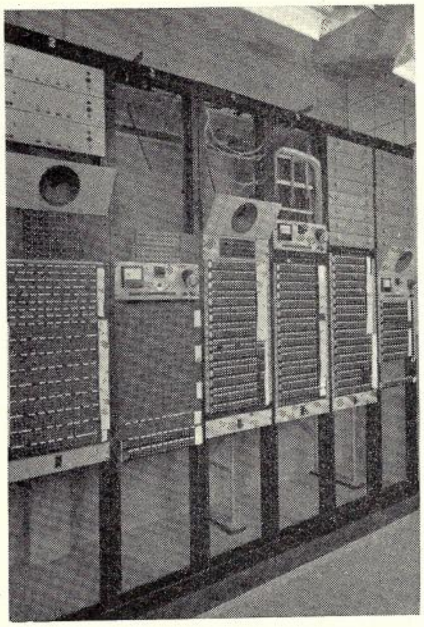


Fig. 13.—Radio Switching Centre—Line Terminations.

The Switching Centre shown in Figs. 13 and 14 was the technical focal point of the whole Olympic broadcasting system. Its main function was to establish the necessary cross-connections between microphone points, the studioettes, and Radio Australia or radio-telephone channels. All programme and associated control lines were terminated on special switching panels and the cross connections were made manually by means of patch-cords. Apart from the main function of switching, much of the equipment required for the other technical facilities for Olympic broadcasts was located in the Switching Centre. Line amplifiers and equalisers, distributing amplifiers for public address and "atmosphere", special programme splitting amplifiers, monitoring facilities, a teleprinter connected to the studios and transmitters of Radio Australia and general power supply distribution boards were the other main items of equipment. To minimise installation time at the Main Stadium, the major portion of the Switching Centre equipment was prefabricated and tested in the Australian Post Office Workshops to the exact layout used in the final location. It was then transported in sections to the Radio Centre and reassembled there. Many of the amplifiers used were of a design new to the National Broadcasting Service and were constructed on a plug-in principle so that they could be readily replaced in the event of faults occurring. This arrangement also enabled a substantial saving in space.

A dial monitoring system employing automatic telephone exchange switching equipment enabled the monitoring of all the important programme lines of the broadcasting network. 270 lines were connected to the monitoring equipment and considerable use was made of the system, particularly in checking that the correct connections were established between the studioettes and Radio Australia. A telephone switchboard, separate from the broadcast switching panels, provided intercommunication between the Switching Centre, the Studioettes and the Venue Supervisors. Lines from this switchboard also connected to Radio Australia and the Melbourne Trunk Exchange. The telephone switchboard operator also controlled the system of coloured lights along the studio corridor which indicated that a technician in a studioette required advice or assistance.

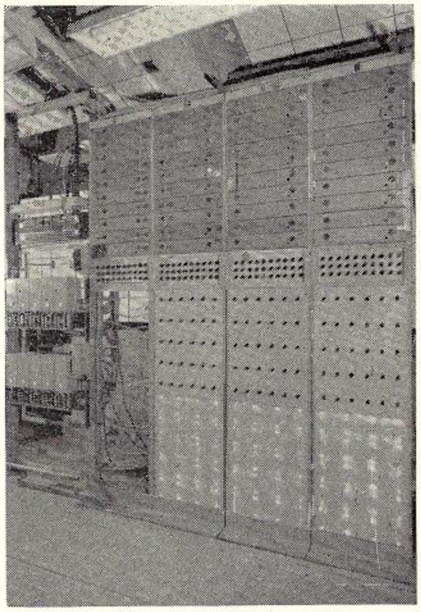


Fig. 14.—Radio Switching Centre—Programme Amplifiers.

Some 250 tape recorders of a type designed and developed in Australia were concentrated in Melbourne. These were distributed amongst the venues in proportion to the bookings received. Each commentator's seat was wired with a control unit to give facilities for tape recording, transmission to his studioette at the Main Stadium or to broadcasting stations, sound effects such as crowd noise or music that could be dubbed on tape as a background and telephone lines back to studioettes and the radio switching centre. A technician was allocated to each commentator and was responsible for all the technical operations and the equipment. Figs. 15 and 16 show radio commentators at the Main Stadium and Exhibition Building.

As the force of technicians required for this task exceeded the normal broadcasting staff in the Commonwealth and as this latter staff was, in any case, required for the Home Broadcasting Service and the many other special broadcasts made concurrently with the Games and with the Duke of Edinburgh's visit, it was necessary to select and train other technical staff in the P.M.G. Department for the purpose. From some 1,200 volunteers, technicians were selected and trained to an ever increasing pitch of efficiency over a period of nine months. 283 were finally put through an exhaustive rehearsal on the eve of the Games to establish firstly, the individual's ability to handle his task under pressure, and secondly, the volume of bookings that could, as a maximum, be accepted and handled efficiently. Although bookings were heavy during the Games, they never reached the limit imposed at these rehearsals.

Public Facilities: The provision of facilities to serve the public, both visiting and local, was strictly a Post Office matter and whilst it was handled by the

Fig. 15.—Press and Broadcasters' Seats during Opening Ceremony.

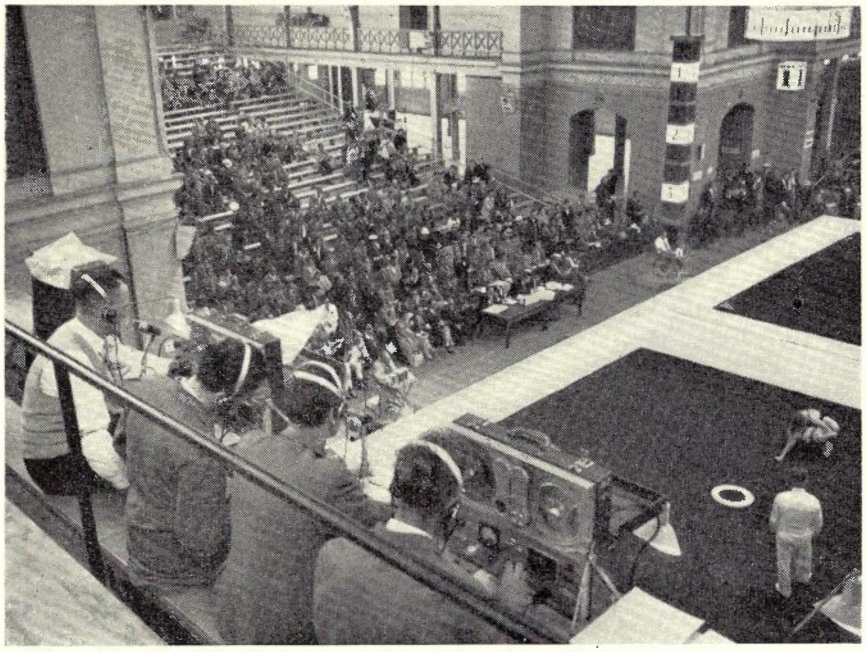


Fig. 16.—Broadcasters' Seats at Exhibition Building.

Olympic Games unit in the P.M.G. Department, it was not related to any requirements requested by the Olympic Organising Committee.

A telephone information bureau with the call sign MOLY-16 (Melbourne Olympic Games of the 16th Olympiad) was set up in part of the old Central C.B. Manual Exchange, and is shown in Fig. 17. Whilst originally intended to handle only enquiries relating to postal and telecommunication matters, it became the established policy to answer all questions within reason. In the process a card index dossier of questions and appropriate answers was built up and made available on a rotary container to each of the 15 telephonists staffing the bureau. Some of these telephonists were linguists and in addition a panel of linguists employed by the Department was made available for contact by telephone when queries could not be understood.

Three post offices of modern design were erected in the parklands surrounding the Main Stadium and Olympic Park and provided the public with full postal facilities including sales and Olympic postmarking of the special stamps designed to commemorate the Games. As will be seen from Fig. 18, these present a very attractive appearance. Two mobile trailer Post Offices were built to serve smaller venues where no other accommodation was available and also to support the park post offices on busy days. These mobile offices were equipped with postal, public telephone and telegraph services, and one of the units is shown in Fig. 19.

Other special facilities provided for the public were:—

(i) A number of public telephone cabinets installed in busy locations, in particular in the two villages and adjacent to the Main Stadium.

(ii) Special philatelic bureaux for the sale and postmarking of Olympic stamps.

(iii) Compartmented letter receivers at the village and several of the main venues. Each compartment was designated by a distinctive postmark so that customers could pre-select a particular stamping for their letters.

Information booklets on postal and telecommunication matters and a special Olympic telephone directory were printed and distributed to visitors and the local public.

Summary of Facilities Provided: Some of the interesting statistics of P.M.G. Department facilities provided, and traffic handled are:

Telephone facilities installed—	
Exchange lines	1,500
Private lines	560
Switchboards	36
Extension services	750
Telephone information bureau: positions	15
Public Telephones	190
Total line provision (including telegraph, broadcasting and television)	4,000
Olympic telephone directories	6,000
Telephone traffic handled—	
Overseas daily average connections (100% increase on normal)	135
Interstate connections (25% above normal)	5,345
Intrastate connections (10% above normal)	15,571
P.T. Calls from venues (daily average)	5,500
Telegraph facilities provided—	
Teleprinters	300
Telegraph offices (including 2 in mobile post offices)	12
Mobile picturegram transmitting units	4
Leased channels (local and overseas)	45
Telegraph traffic—	
Messages originating—Press (305,179 words)	1,698
Others	2,319
Messages terminating	11,365
TOTAL	15,382

Fig. 17.—Telephone Information Bureau "MOLY 16".

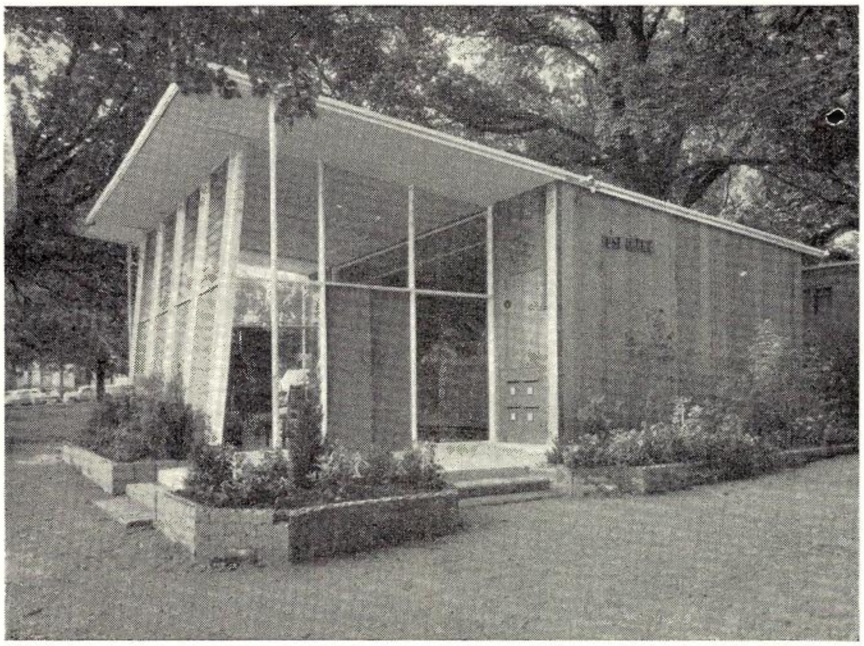


Fig. 18.—Temporary Post Office near Main Stadium.

Total traffic transmitted over public channels: words	2,897,357
Picturegrams:	
Commonwealth	1,029
Overseas	2,110
TOTAL	3,139
Picturegrams: Private line bookings: hours	166

Broadcasting facilities—

Studioettes	48
Tape recorders	300
Special lip microphones	175
Broadcast microphone points	200
Broadcasting lines	400

Switch and repair centre, Main Stadium.

Broadcasting business—

Overseas transmissions:	
Radio Australia occupying 537 hours.	857
Radio telephone occupying 200 hours.	285
TOTAL occupying 737 hours.	1142
Bookings lodged at radio centre for various facilities	4,116

Postal facilities—

Temporary post offices	10
Mobile post offices	2
Special Olympic stamps (From 4d. to 2/-)	140,500,000
Special Olympic postmarkers	52
Postal information centres	2
Philatelic bureaux	2
Olympic postal guide booklets	10,000

Postal business—

Mail handled at venues: articles	750,000
Stamp sales at venues	£36,766
First day cover sales	330,000

Conclusion: The striking feature of the work was that, as the Games ran for a mere 15 days, the operating period for the majority of the services provided was confined to this short term. There was consequently no time once the "balloon went up" to make any major variations. Everything was accordingly planned with the primary object of adequate provision, without being lavish, and utmost flexibility. The success of the telecommunication services proved that these principles were correct.

Fig. 19.—Mobile Post Office.

RYDE NEW AUTOMATIC EXCHANGE

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

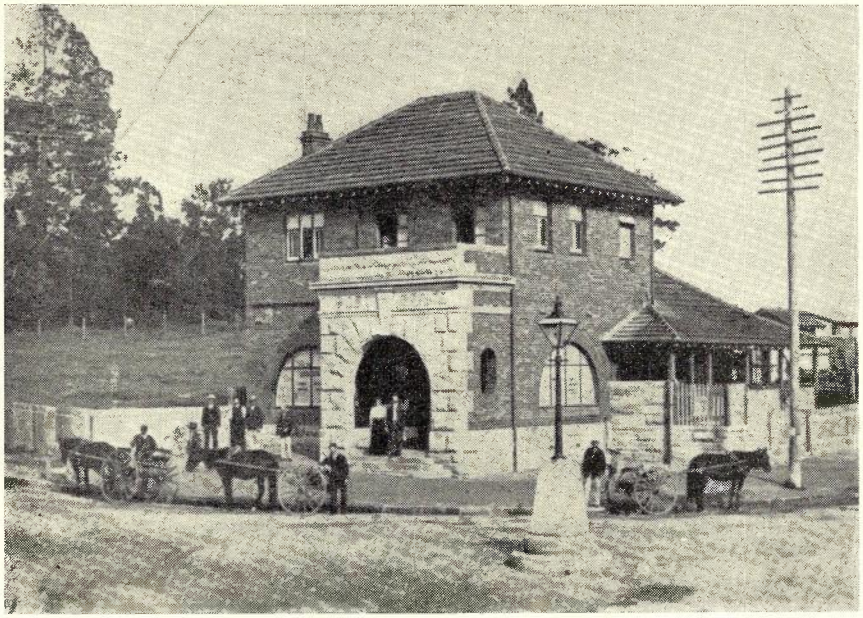


Fig. 1.—Original Ryde Post Office and Exchange.

On Saturday, September 15, 1956, a new 3000 number automatic exchange was brought into service in the Sydney Metropolitan network in Ryde, New South Wales. This exchange replaced a temporary 2000 type automatic exchange of 800 numbers and also provided sufficient numbers to replace the associated 1600 number magneto exchange. The cutover of the manual numbers to automatic commenced on Monday, Septemmer 17, 1956. Replacement of the 1600 manual services marked the completion of the work commenced many years ago of converting the whole of the Sydney Metropolitan Unit Fee Area to automatic operation. As Ryde was the last of Sydney's Unit Fee manual exchanges, it is interesting to record a little of the history of telephony as associated with the Ryde district.

In 1899, the year before the Commonwealth Government became responsible for Posts and Telegraphs, Ryde Exchange was established. It was part of the magneto network when telephony was in its infancy. The calling charges were high at sixpence for three minutes in the local exchange area, and one shilling for the first three minutes and sixpence each three minutes thereafter, when the call extended to adjacent and City exchange areas. The average weekly wages were £2 in those days and comparative prices for everyday commodities were £3 for a man's suit, ten shillings per week for house rent, twopence for a loaf of bread, and milk was one penny per pint; half a sheep could be purchased for 2/6.

On 19/5/99 the Ryde Magneto Exchange came into being when a 50 number switchboard was brought into service behind the counter in the Ryde Post Office, the same office which provides postal facilities today. Fig. 1 indicates the conditions at the Post Office about this time. There were 28 subscribers connected with continuous service initially.

The number of subscribers grew gradually during the early 1900's reaching 100 in 1910 and 222 in 1914, and by 1915 it was found necessary to again extend the magneto switchboard. About this time the neighbouring exchanges of Newtown, Glebe and Balmain had been converted to automatic working and a new building was ready at Ryde to convert the area to automatic. The old magneto switchboard was still behind the Post Office counter and this location was becoming too congested to allow for an extension. As an interim measure it was decided to install a P.M.G. Workshops switchboard, to provide temporary service, in a back room of the new automatic exchange building. This would not impede the installation of the new automatic equipment which was expected to arrive before the close of the year. Alas for Ryde! The fortunes of war caused the ship carrying the automatic equipment from England to be sunk. This ill fortune characterised many reviews of the Ryde conversion to automatic working plan. There always appeared to be works of a more urgent nature on which to spent the limited funds available.

The Workshops board installed in the back room was extended from time to time until further extension was impossible and by 1920 a new location had to be found. The number of subscribers at that date was 340. It was deemed expedient in view of a possible early change to automatic operation to leave the automatic equipment switchroom unencumbered and the Ryde manual exchange was moved to the battery room, its final location. It grew until 1941 when nearly 1600 numbers were connected. There have been many Ryde magneto subscribers transferred in the past to the three new automatic exchanges which were brought into service around the periphery of the Ryde area. The exchanges concerned were

Fig. 2.—New Exchange Building.

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* Mr. Power is a Divisional Engineer in the Metropolitan Installation Section, Sydney.

Eastwood, Epping and Hunters Hill, and in all the tranfers totalled nearly 2000 subscribers. Despite the relief afforded to the magneto exchange by these surrounding exchanges, the point was finally reached in 1950 where the demand for telephones exceeded its capacity to accommodate them. At this point the switchroom of the 1915 exchange building in part fulfilled its destiny and was used to house an 800 number automatic exchange of a modern type. Thenceforward, the automatic exchange supplemented the magneto exchange.

Ryde was operated by male telephonists in the beginning, but by 1918 there were female telephonists in the day time with male operators at night. Transport to the area in the early days was quite hazardous, particularly for the night telephonists, as the tram terminated at Drummoyne, some miles closer to the city. By 1926 the double tram line was extended to Gladesville with a single line to Ryde. If connections were missed then at least 30 minutes' delay was incurred.

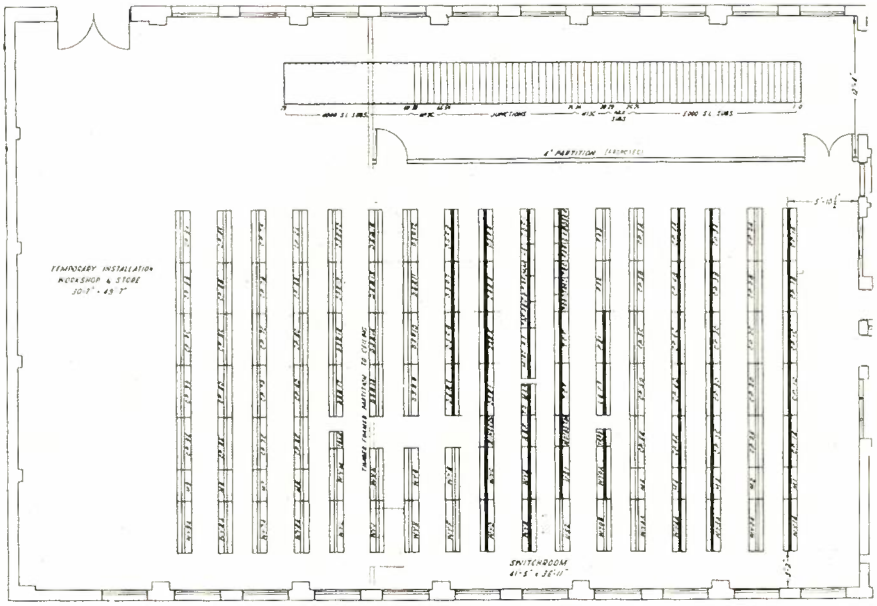

Fig. 4.—Switchroom Layout Plan.

The new exchange was installed in a completely new building erected adjacent to the Post Office (see Figs. 2 and 3). The floor layout (Fig. 4) adopted at Ryde is conventional for a modern 2000 and S.E.50 automatic exchange of this type, and involves the segration of equipment in the "O" thousand to serve P.B.X. subscribers exclusively as shown on the trunking diagram (Fig. 5). The use of the 200 number composite uniselector — final selector rack generally precludes the use of anything but straight-line services on these racks, there being space for only 20 final selector banks on the rack. Thus, P.B.X. services were withdrawn from the regular equipment suites which then become uniformly of 100 number capacity for straight line services. (See Fig. 6). Composite racks were made up at Ryde from standard uniselector and final selector racks. It was realised that this involved a certain amount of additional pre-installation effort but this was counterbalanced by the saving in actual installation time once the composite racks were manufactured. One interesting layout feature shown in Fig. 7 is the relative positions of the M.D.F. and desk suite, the latter being installed in an acoustically treated room close to the M.D.F. to facilitate testing.

To reduce the dust hazard to a minimum during the course of installation work at Ryde, a partition was placed across the equipment room at the rear, all possible work being done there in preference to the equipment room. Ultimately the partition will be removed to allow for equipment extension. As a development of the same idea, a movable partition was used in a more recent new exchange installation at Balgowlah. This partition is made up in rack-sized units and can be dismantled and moved from job to job.

In bringing the new exchange into service, the manual conversion was done on a line-by-line basis extending over a period of about two months. This practice makes multiple visits to the subscribers premises and temporary work unnecessary. As each line was cutover, the appropriate multiple jacks in the manual exchange were fitted with re-direction plugs marked with the new number (see Fig. 8). Special organisation is necessary in cases such as this to avoid congestion on the test desks and arrangements were made to ensure that functions other than testing were carried out by subsidiary staff. Fig. 9 shows a view of the old manual exchange replaced, with its associated combinations of older and newer ideas, for example, the lighting fixtures of kerosene and fluorescent types make an odd contrast. Fig. 10 is of interest in that it illustrates the wiring conditions in this old switchboard, together with the tools used in clearing jack and multiple faults.

Fig. 3.—Ryde Post Office and Exchange Buildings Today.

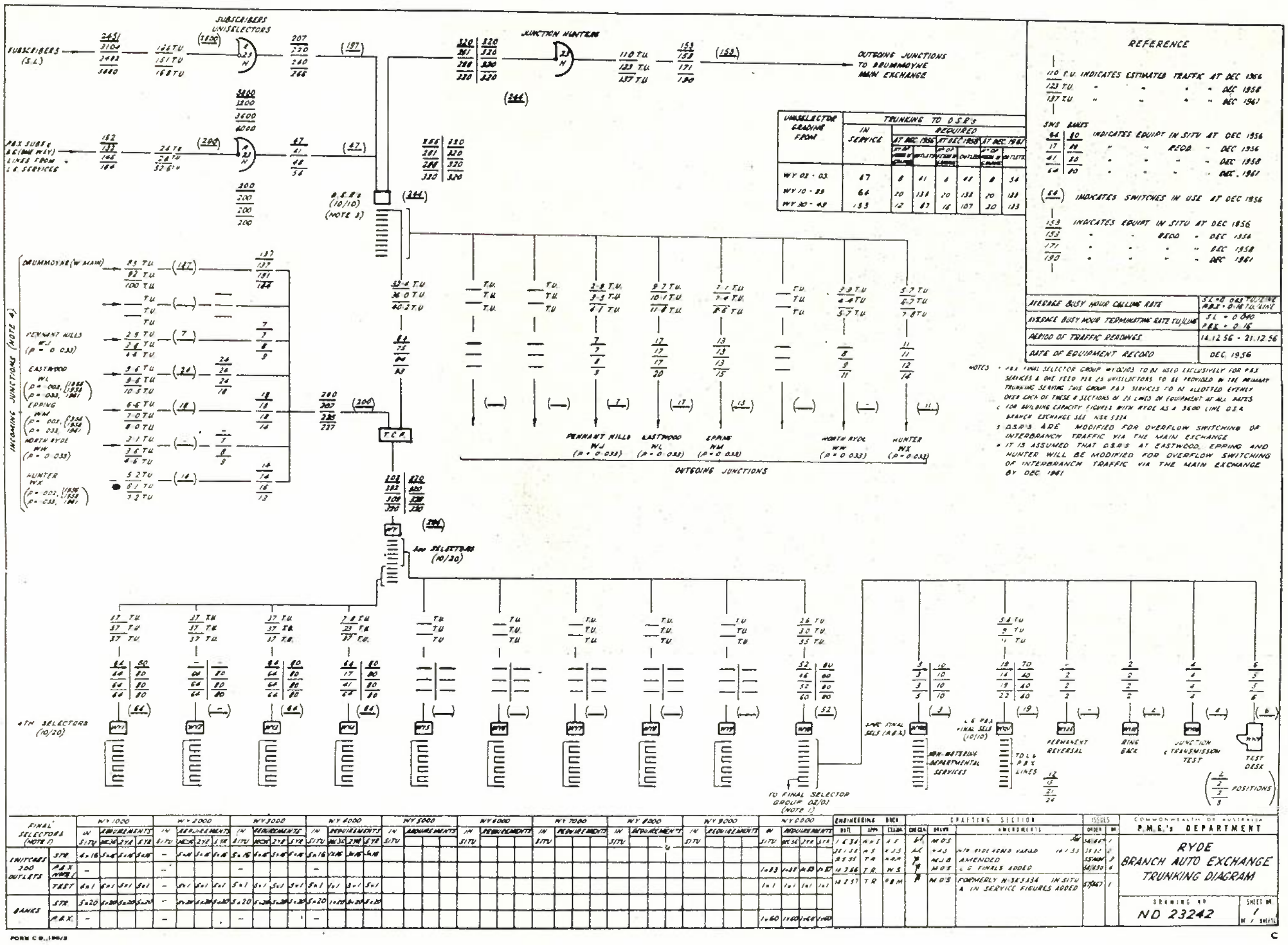

Fig. 5.—Trunking Diagram.

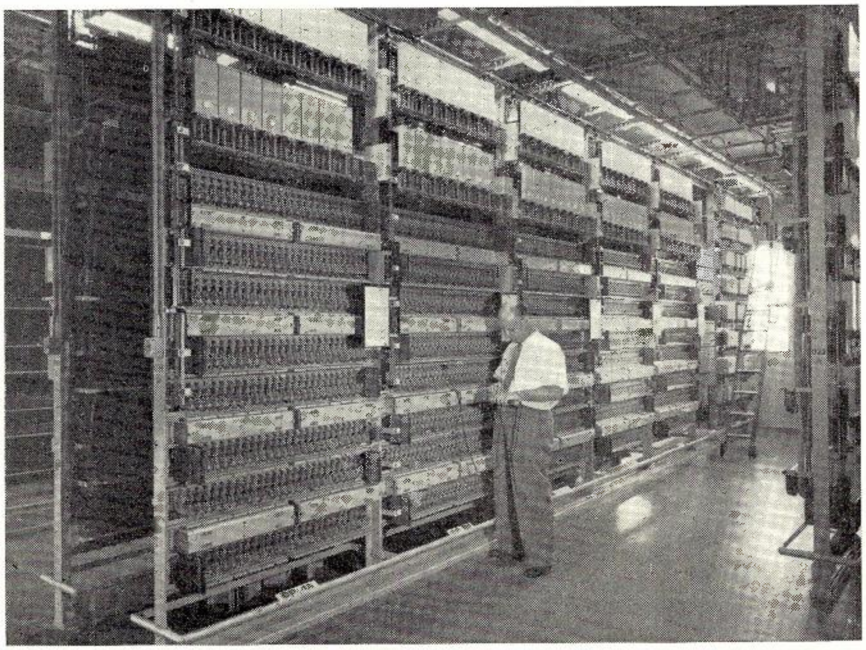

Fig. 6.—1000 Number Composite Suite.

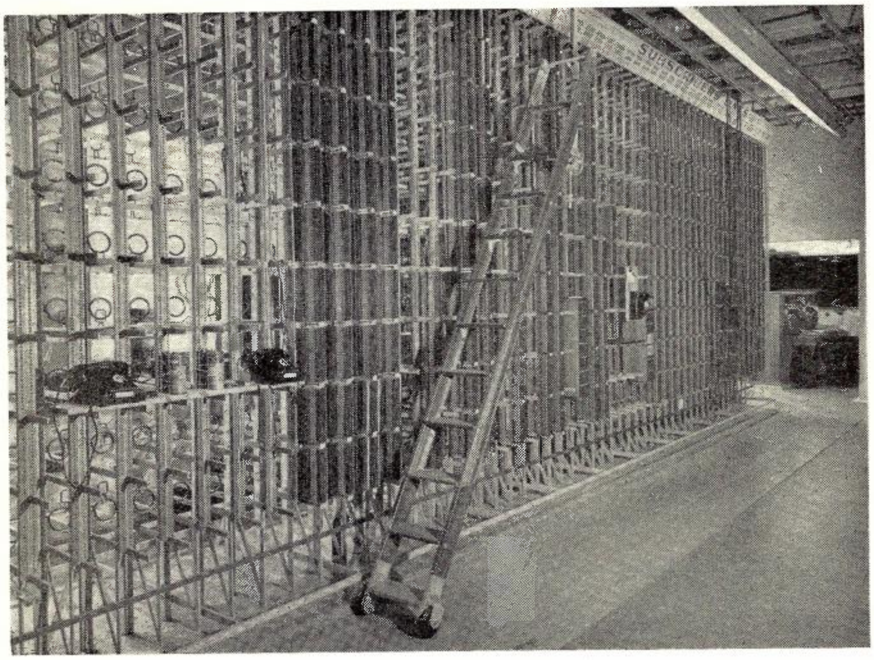

Fig. 7.—View of New Exchange M.D.F. and Test Desk.

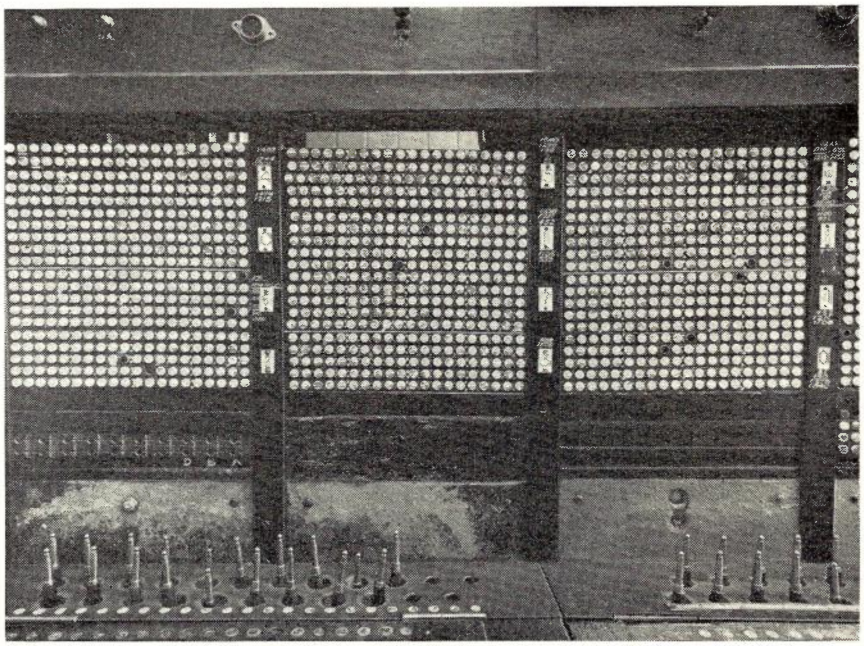

Fig. 8.—View of Manual Exchange Multiple with Interception Plugs after Cutover.

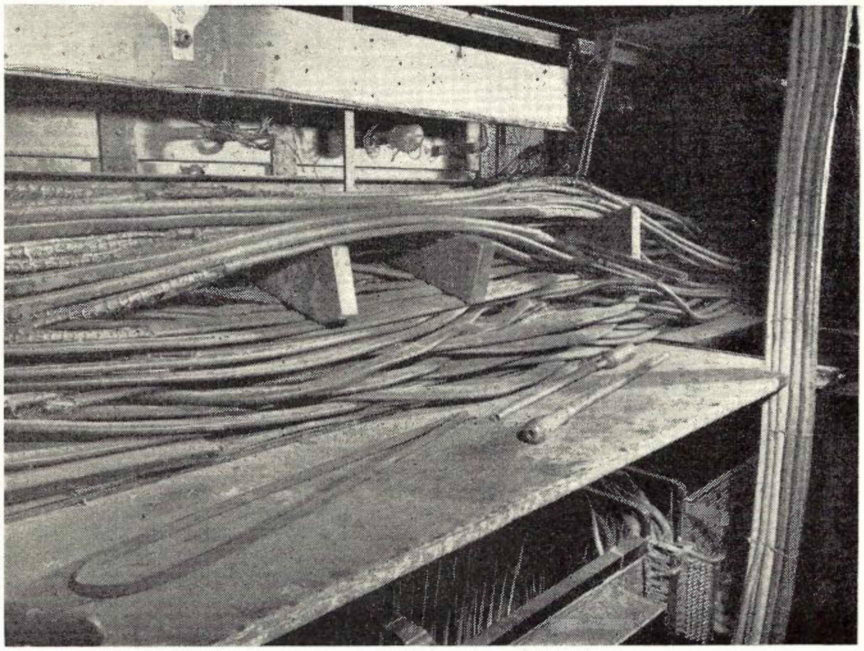

Fig. 10.—Manual Exchange Multiple with Tools.

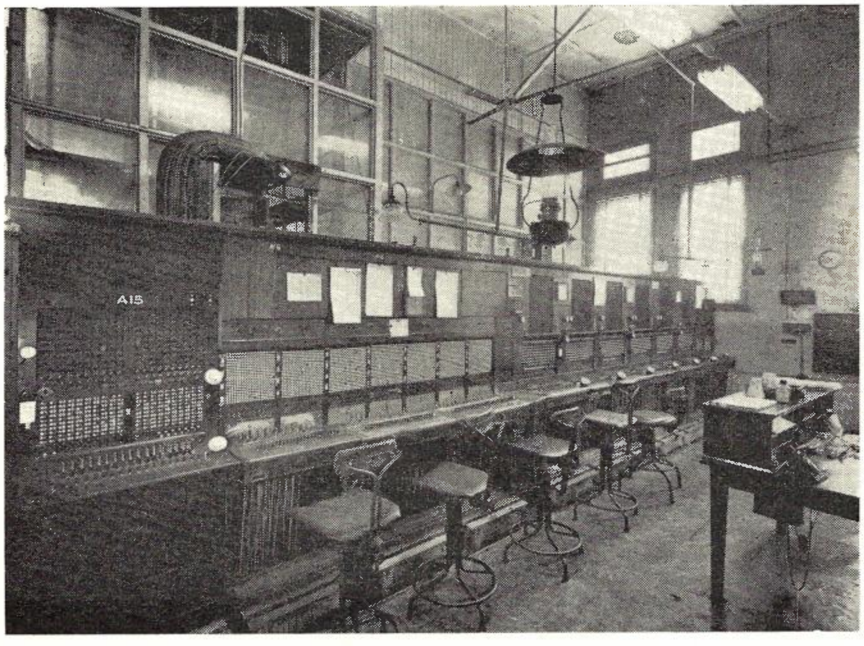

Fig. 9.—View of Old Magneto Exchange after Cutover.

THE BASS STRAIT SUBMARINE CABLE — 9-CHANNEL EXTENSION CARRIER SYSTEM

D. A. GRAY, B.E.E., A.M.I.E.Aust,*
E. RUMPELT, Dr.-Ing.*

INTRODUCTION

Commercial telephone communication between the Australian mainland and Tasmania, across Bass Strait, was established for the first time in 1935 following the laying of a submarine cable between Apollo Bay (Vic.) and Stanley (Tas.) with an intermediate repeater station at Naracoopa on the east coast of King Island, situated centrally in the Strait (Refs. 1-5) (See Fig. 1).

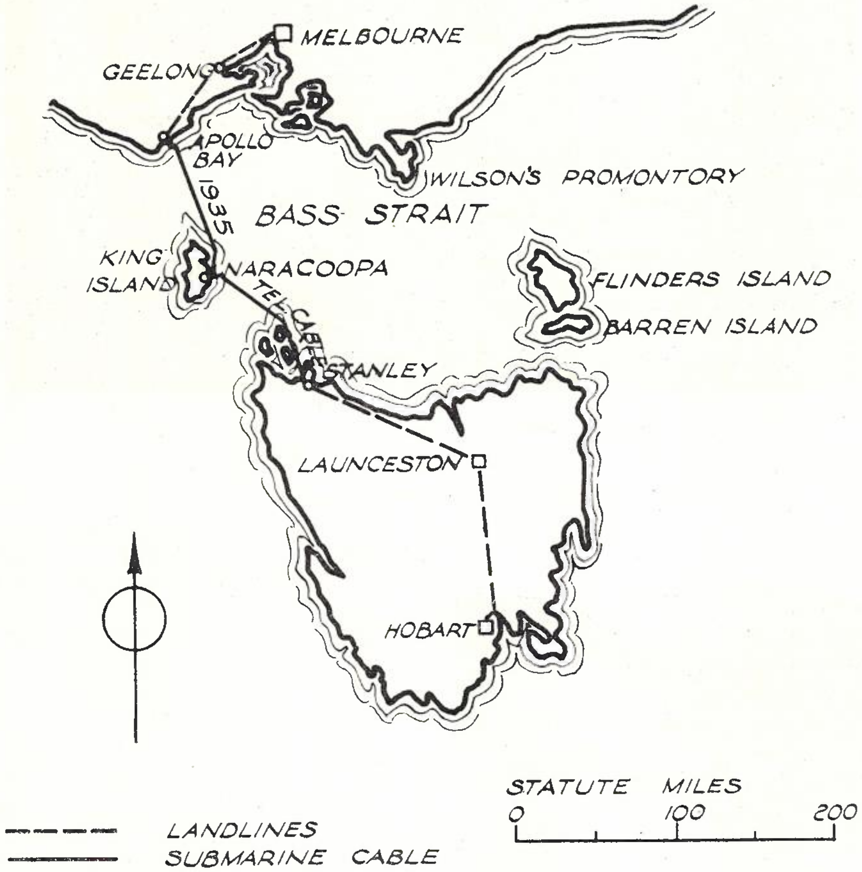

Fig. 1.—Location of Bass Strait (1935) Telephone Cable.

The first telegraph cable across Bass Strait had been laid in 1859 (Ref. 4), but was short lived. The Eastern Extension Company laid the first successful telegraph cable in 1869, and this was duplicated in 1886. These two cables continued in service until 1909, when they were supplanted by two cables laid by the Australian Post Office. These cables have now been lifted, and the 1935 telephone cable provides the only existing wire communication across Bass Strait.

A radio telephone link was brought into regular service (after some years of intermittent use) in January, 1945, for use during the busy traffic periods (Ref. 6). This service operates over a propagation path 168 miles long between Tanybryn, near Apollo Bay (Victoria) and Stanley (Tasmania) on a carrier frequency of approximately 40 Mc/s using amplitude modulation. The path length is approximately twice the optical limit and the signal to noise ratio was originally sufficient for commercial telephone traffic during on the average, 94% of the operating time. At the present time a total of 12 channels on two separate transmitters is provided. These are operated during the daylight hours. Provision of a further 6 telephone channels by V.H.F. frequency modulated radio over a different route (Wilson's Promontory-Flinders Island-Mount Arthur) (Ref. 9) was completed during 1955. Further extensions have recently been made to this service.

The various means by which short-term extensions might be made to the numbers of channels on the hard-pressed main trunk routes between Australian capital cities were being considered in 1951 by the A.P.O. Engineer-in-Chief (Mr. R. V. McKay), then in London, and Mr. R. E. Page who at the time was acting Engineer-in-Chief. Consideration was given to various means of bandwidth reduction as a means of obtaining extra channels on existing systems, and in regard to the Bass Strait Route enquiries were made in London concerning the economics of laying a new submarine cable and of installing submerged repeaters on the existing (1935) submarine cable.

It was decided to investigate the practicability of obtaining short term relief for the Bass Strait route by making extensions to the submarine cable terminal equipment, so as to provide additional carrier telephone channels with 3 kc/s carrier spacing. These channels would provide the same quality of transmission as that obtained from 3-channel open wire systems, large numbers of which are installed on Australian trunk routes.

Enquiries were made from equipment manufacturers and it was found that the L.M. Ericsson Telephone Company, of Sweden, were able to supply carrier telephone channelling equipment of modern design, with 3 kc/s carrier spacing, at short notice. It was decided to design and manufacture locally the necessary high-performance line and directional filters, and amplifier equipment, making use of engineering information published by the British Post Office (Ref. 8). After preliminary investigations it was found that a 9-channel 3 kc/s spaced system would be practicable provided an existing 2-channel extension system were first removed. The design of the new equipment was put in hand in 1951 and all channels were in service by November, 1954.

CABLE FACILITIES EXISTING PREVIOUSLY

Descriptions of the original cable facilities provided have already been published (Refs. 3 and 5), but in addition, a further two telephone channels were provided in 1946, giving a total of 8 telephone channels (used for multi-channel V.F. telegraphy as required). One reversible broadcast programme channel is also provided. The frequency spectrum of these channels is shown in Fig. 2, together with the frequency spectrum existing at the conclusion of the project. A highly simplified block schematic circuit of the King Island repeater as it now exists, is shown in Fig. 3, attached; the equipment existing previously is shown with dotted lines.

Cable channels Nos. 1, 2 and 3 (see Fig. 2) use balanced 2-wire transmission making use of hybrid transformers, and all remaining channels in use before 1954 and also transmitted via these transformers (see Fig. 3). The new channels (Nos. 7-15) are not transmitted through the hybrid transformer, but make use of system-separating ("line") filters between the hybrid transformers and the cable. The transformer loss and non-linearity has thus been by-passed, but additional balance networks have had to be provided to stimulate the character-

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* Mr. D. Gray and Dr. E. Rumpelt are Divisional Engineers in the Research Section, Central Administration.

istics of the line filters and maintain the hybrid transformer balance in the frequency spectrum of the balanced channels (300 c/s-10 kc/s).

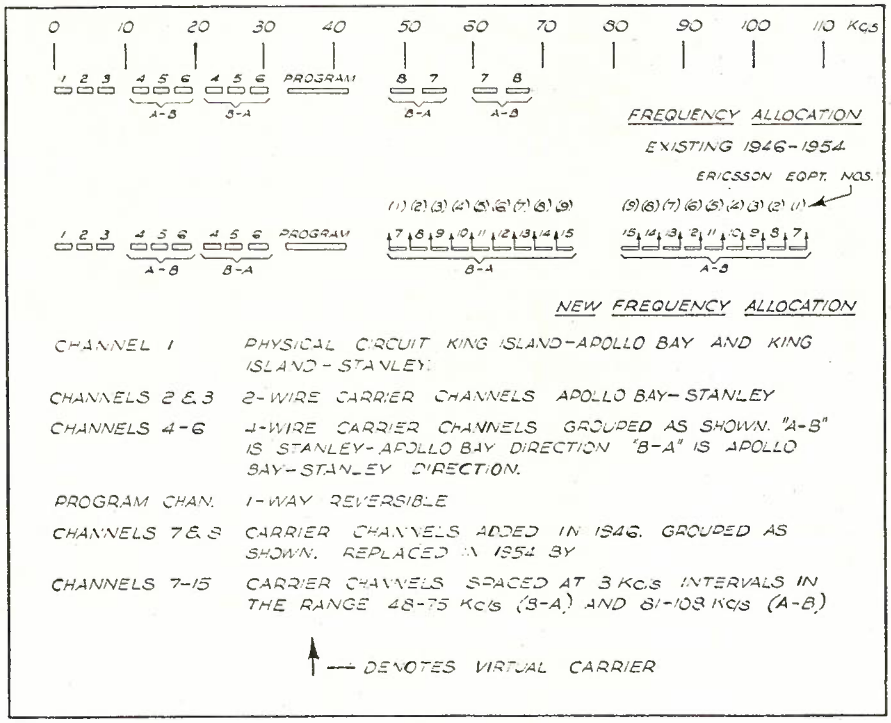


Fig. 2.—Channel Frequency Allocation.

The two-channel extension equipment installed in 1946 (not shown in Fig. 3) used 4 kc/s channel spacing as compared with the 3 kc/s spacing used for the first six channels. Furthermore, this equipment was mounted on a completely separate rack which could easily be removed. These factors gave rise to the decision to abandon this equipment and provide a new 9-channel system using 3 kc/s spacing.

CABLE TRANSMISSION PARAMETERS

The submarine cable is a transmission line of coaxial construction having a characteristic impedance of about 52 ohms. The coaxial line is of the type known as 508/690/852 paragutta, the three numbers representing the weights in pounds per nautical mile of the inner conductor, paragutta insulant, and outer conductor respectively. It is fully described in Reference 2. The attenuation is shown in Fig. 4. In the frequency range 40-150 kc/s the cable impedance is substantially resistive, and varies between 48 and 54 ohms.

Near-end crosstalk measurements between the North and South cables were made at Naracoopa where the crosstalk attenuation was beyond the limit of a measurement, which was as follows:—

Frequency	Crosstalk Measurement Limit
50 kc/s	163 db
110 kc/s	157 db
180 kc/s	153 db

Cable noise measurements were also made at Naracoopa on both cables at frequencies between 50 and 180 kc/s. The method of measurement was to use an amplifying system of low noise factor and to compare the cable noise with that of thermal agitation in a 52 ohm resistor. There was no observable difference between the cable noise and resistance noise. However, later observations and careful listening tests during system trials in October 1954 disclosed the presence of occasional bursts of noise reminiscent of atmospheric effects, which occasionally increased the amplified thermal agitation noise measured at the channel terminations by a few decibels. There appear to be no other sources of noise affecting the submarine cable.

NOISE LIMITS FOR THE 9-CHANNEL SYSTEM

Objectives: The system design was carried out on the assumption that the prevailing cable noise is due to thermal agitation. The channel noise target for a Melbourne-Hobart telephone channel was set at –50 dbm, measured at a point of zero relative level on a noise meter to the 1934 specification of the C.C.I.F. psophometer. (A point of zero relative level is a point in the circuit at which signals have their same absolute level as at the transmitting trunk switchboard; in the following text the abbreviation dbmo is used for the level in decibels relative to one milliwatt, referred to a point of zero relative level.) The choice of the noise level limit was an arbitrary one. No recommendations are made by the C.C.I.T.T. — "Comite Consultatif International Telephonique et Telegraphique", which replaced the C.C.I.F. in 1956—for submarine cable systems, it being recognized that each case needs separate consideration.

For design purposes the noise limit was apportioned as follows:—

Overall noise . .	–50 dbmo	(10,000 pW)
Land line noise	–53 dbmo	(5,000 pW)
Cable noise . . .	–56 dbmo	(2,500 pW)
(thermal agitation only)		
Cable equipment noise	–56 dbmo	(2,500 pW)
(mainly intermodulation effects)		

Note: 1 pW = 10^{-12} watt

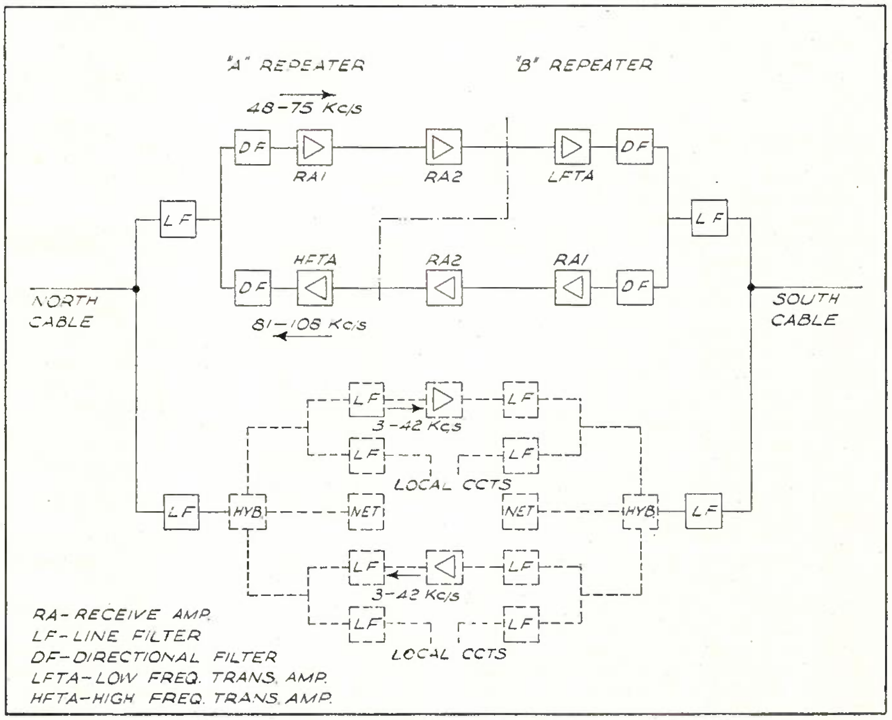


Fig. 3.—Naracoopa Repeater Station—Simplified Block Schematic.

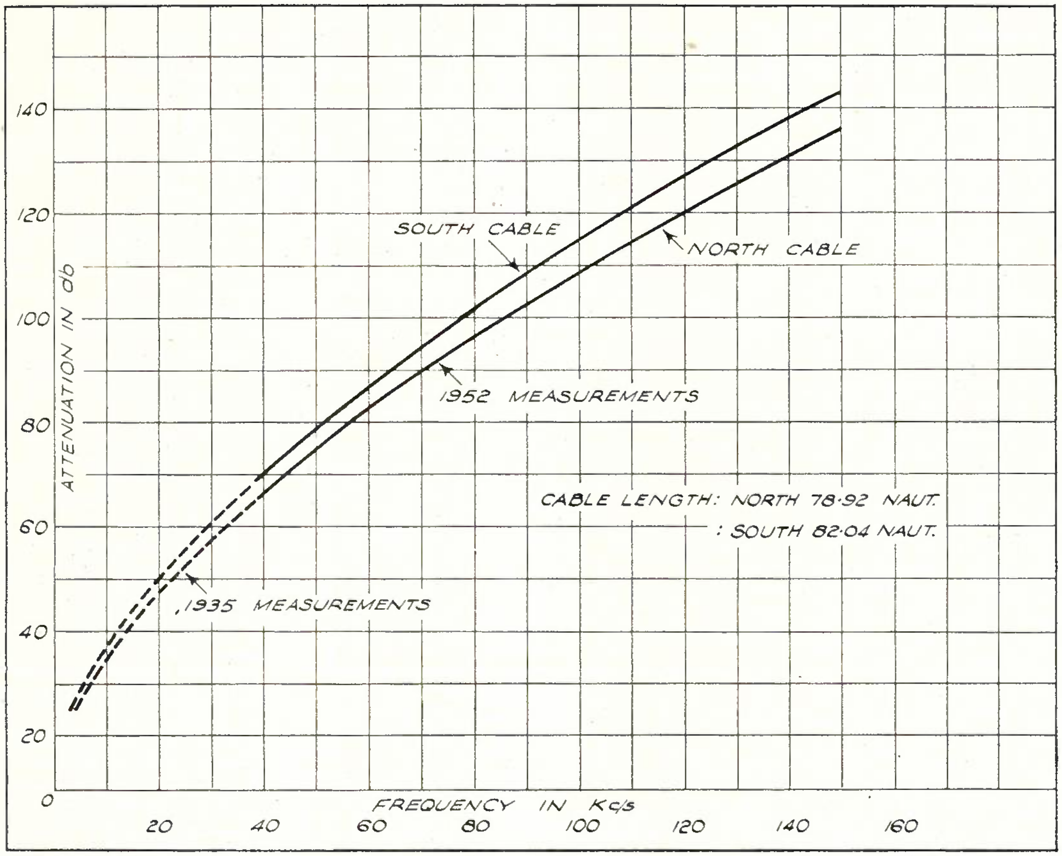


Fig. 4.—Cable Attenuation.

The data given above shows that the objective for the cable plus cable equipment was 5000 pW (–53 dbmo). As shown in the following paragraphs, it was expected that this performance could just be provided (without any margin for error) by the use of the best known equipment designs and without the use of compandors. Compandors were ordered to provide this margin, and in the event it was found necessary to bring them into use on certain channels.

Resistance Noise: The level of thermal agitation noise at the cable termination is obtained from the well-known relation (due to H.Nyquist)

$$\bar{e}^2 = 4KTBR$$

where $\bar{e}^2$ is the mean square noise voltage

K = Boltzman's constant = 1.374 x 10^{-23} joule per °K

T = absolute temperature, °K.

R = resistance component of impedance across which the thermal agitation noise voltage is developed

and B = frequency bandwidth of measuring device in cycles/sec.

In the present case the cable impedance is substantially resistive and approximately 52 ohms. The cable equipment provides a matching impedance, so that at the input terminals of the receiving amplifier the noise voltage due to thermal agitation is that generated by a 26 ohm resistor. The bandwidth B involved in the present calculation is the equivalent noise bandwidth of the 1934 C.C.I.F. psophometer; this may be calculated from the published weighting curve to be 1412 c/s. (Apart from a 5.5 db difference in sensitivity, the 1934 C.C.I.F. weighting curve is very similar to the "144 line" weighting used in the Western Electric 2B noise set). Thus at 17°C

$$\bar{e}^2 = 4 \times 1.374 \times 10^{-23} \times 290 \times 1412 \times 26$$
$$= 5.85 \times 10^{-16}$$

therefore $\bar{e} = 2.42 \times 10^{-8}$ volt.

In the 52 ohm amplifier input circuit this corresponds to a power level of –139.5 dbm.

This noise level will determine the signal to noise ratio at the points in the circuit where the signal level is lowest, that is at the input to the receiving amplifiers. The lowest level points in this system are at the end of each cable. The cable attenuations at the highest working frequency (108 kc/s) are

North cable . . .	113.4 db.
South cable . . .	119.6 db
Difference . . .	6.2 db

The combined noise from these two sources is 0.95 db greater than the larger, so that the minimum signal level for an overall noise level of –56 dbmo is:

$$-139.5 + 0.95 + 56 = -82.5 \text{ dbm}$$

To achieve this a sending level of 119.6 – 82.5 = + 37.1 dbm must be used. This involves (see Holbrook and Dixon's Figure 7, Ref. 7) a transmitting amplifier with an overload level of +37.1 + 15.5 = +52.6 dbm when channel limiting is used. Plus 52.6 dbm is equivalent to an output power of 182 watts. The most suitable amplifier design available to provide this output was one developed in the British Post Office Research Station and known as a "100 watt" Amplifier. Despite its name, its overload level is about 60 watts, or + 48 dbm. With such an amplifier the line up level in a conventional 9-channel carrier system would be + 48 – 15.5 = + 32.5 dbm, subject to corrections for valve ageing, level of signalling tones, etc. Because of the volume compression effect of the compandors, which are used on four of the nine channels, a lower line up level, namely + 30 dbm, is used in this system. Using the above method of calculation it is seen that the use of this sending level in lieu of + 37.1 dbm will give psophometric noise level of –48.9 dbmo. When an allowance of 1.9 db is made for the measured noise contribution of the receiving amplifiers an expected psophometric noise level of –47.0 dbmo for the cable equipment (highest frequency channel) is obtained; intermodulation noise causes a further degradation. Actual measurements after installation showed the measured channel noise on the relevant channel (Channel 1, A – B) to be –45dbmo. With compandors in circuit, noise in this channel is lower than –70 dbmo. The difference between the expected channel noise of –47 dbmo and the measured figure of

-45 dbmo is due to contributions from several minor noise sources.

To achieve the best possible figure for quiescent noise (resistance noise as distinct from intermodulation noise) the equipment connected between the cable termination and the input of the receiving amplifier must have negligible attenuation, and for this reason no equalisers are inserted in the circuit between these two points. The cable equaliser has been divided into two equal parts, one part being the pre-equaliser at the input to the transmitting amplifier and the other being connected between the first and second receiving amplifiers together with supplementary filters and filter equalisers. The use of pre-equalisation has the additional advantage of reducing the speech power loading on the transmitting amplifiers and line directional filters by signals from the 9 channels passing through them. This reduces the amount of non-linear distortion generated in this equipment, the effects of which are discussed in the following paragraphs.

Intermodulation: In directional filter systems of this type, with repeater sections of high attenuation, intermodulation effects can set a fundamental limit on the maximum repeater section attenuation which can be worked.

Amplitude non-linearity in the components of the transmission path gives rise to intermodulation which takes the form of non-linear crosstalk between channels. Such non-linear crosstalk is usually unintelligible and may give rise to far-end or near-end interference effects.

In this system far-end non-linear crosstalk is caused by non-linear inductors in the equalisers and transformers and by non-linear effects (harmonic distortion) in the amplifiers, the latter source being the more important one. Control was exercised over the harmonic distortion of all amplifiers and transmission levels were set so that the harmonic distortion products of a single tone of 0 dbmo (corresponding to a 1 mW signal at a point of zero relative level) were at least 80 db below the fundamental. This ensured that far-end non-linear crosstalk would be negligible in comparison with resistance noise.

Since the frequency band employed in each direction of transmission (48 to 75 kc/s and 81 to 108 kc/s, see Fig. 1) is less than one octave, only odd order intermodulation products give rise to crosstalk within each transmission band and actually only third order products (of the form $2f_1 \pm f_2$ and $f_1 \pm f_2 \pm f_3$, where f_1, f_2 and f_3 are the frequencies of the component signals) are of practical importance.

The level of far-end non-linear crosstalk is of the same order in this system as in a conventional land-line carrier system and the methods employed to control it are just the same as in a land-line system; however, near-end non-linear crosstalk is of great importance in any high gain two-wire system, because of the difficulty of obtaining the necessary linearity of the components in the path common to both directions of transmission.

The greatest level differences in the common paths of this system occur in the cable terminal equipment connected to the longer (that is, south) cable, the actual figures being 109 db at Naracoopa and 111 db at Stanley, so that to achieve a signal to noise ratio objective of 56 db the intermodulation products must be at least 167 db below a signal at line-up level giving rise to them. This is difficult to achieve, even in purely passive circuits, at the powers used in this system. The components which must have this performance are the line filters, the end sections of the directional filters, the coaxial chokes used for longitudinal current suppression and a few miles of the submarine cable itself.

The line and directional filters, particularly the latter, together with their susceptance compensating networks give rise to the greatest part of the near-end intermodulation crosstalk, because the resonant circuits in the filters and compensating networks are subject to greater electrical and magnetic stresses than the non-resonant parts of the circuits.

Harmonic distortion measurements made on a set of directional filters showed that a signal level of + 35 dbm at a frequency of 45 kc/s gives rise to a third harmonic 162.5 db below the fundamental. This approaches the minimum separation necessary for satisfactory intermodulation performance, but unfortunately worse intermodulation occurs for signal frequencies near 48 kc/s, 75 kc/s and 81 kc/s adjacent to the resonant frequencies of the filters and compensating networks. The overall effects of near-end intermodulation are sufficiently great to require the use of compandors on the channels having frequency allocations near to the directional filter transition band (75 – 81 kc/s).

The frequency band of importance in the consideration of near-end crosstalk being greater than one octave in span (48 – 108 kc/s), second order intermodulation products (of the form $f_1 \pm f_2$) and second harmonics could give rise to interference. However, the nature of the non-linearities occurring is such that second order products are small in comparison with third order products. The variation of the latter with level of the applied signal corresponds approximately to a square law dependence of the harmonic power on the fundamental power, and this suggests that the non-linearities are due to dielectric and magnetic hysteresis effects.

Amplifier distortion at very low levels not due to hysteresis distortion generally follows a characteristic law of the following type:

$$P_n = K\,P_f^{\,n}$$

where P_n = nth. harmonic power

P_f = fundamental power

and K = a constant.

The same relationships apply to intermodulation products and harmonic products of the same order.

Effect of Compandors. The noise improvement to be obtained by the use of compandors has been discussed by various authors (Ref. 10 for example). The idealised compandor characteristics are shown in Fig. 5 where input and output levels are shown in dbmo (that is dbm referred to the point of zero relative level). In all commercial compandors manufactured to date, the exponent n of the expander characteristic in the expansion range R is approximately 2.0. The compressor characteristic is complementary to the expander characteristic so that when a compandor is added to a telephone system there is no change in the overall loss of the system. In general, the compressor and expander do not individually have zero gain at line-up level (zero dbmo), and for maximum compandor advantage it has been shown that the zero gain point should be above line-up level. In the Bass Strait cable system the compressor and expander zero gain points are adjusted to occur at lineup level so that the compandor can be cut into or out of the circuit without effect on the lineup levels at the associated "mod. in" and "demod. out" circuits.

If C_i and C_o represent, in logarithmic units, the compressor input and output levels respectively, and E_i and E_o represent the expander input and output levels, then the idealised compandor characteristics shown in Fig. 5 can be represented by the following simple equations, where Z is the zero gain level and R is the non-linear level range:—

In the "companding" (non-linear) range

$$E_o = C_i$$

$$\left.\begin{aligned} C_o &= \frac{1}{n} C_i + \frac{Z}{n}(n-1) \\ E_o &= nE_i - Z(n-1) \end{aligned}\right\}$$

For $Z > C_i > (Z - R)$

and $Z > E_i > (Z - \frac{R}{n})$

Above the non-linear range

$$E_o = C_i$$

$$\left.\begin{aligned} C_o &= C_i \\ E_o &= C_i \end{aligned}\right\} \begin{aligned} &\text{For } C_i > Z \\ &\text{and } E_i > Z \end{aligned}$$

Below the non-linear range

$$E_o = C_i$$

$$\left.\begin{aligned} C_o &= C_i + \frac{R}{n}(n-1) \\ E_o &= E_i - \frac{R}{n}(n-1) \end{aligned}\right\}$$

For $C_i < (Z - R)$

and $E_i < (Z - \frac{R}{n})$

It is to be noted that E_o is equal to C_i in all three regions of the compandor characteristic, that is, the compandor introduces no change in overall gain, as has already been stated. This statement applies only to the idealised characteristic and in practice the compandor introduces a small gain or loss, the magnitude of which usually varies with level.

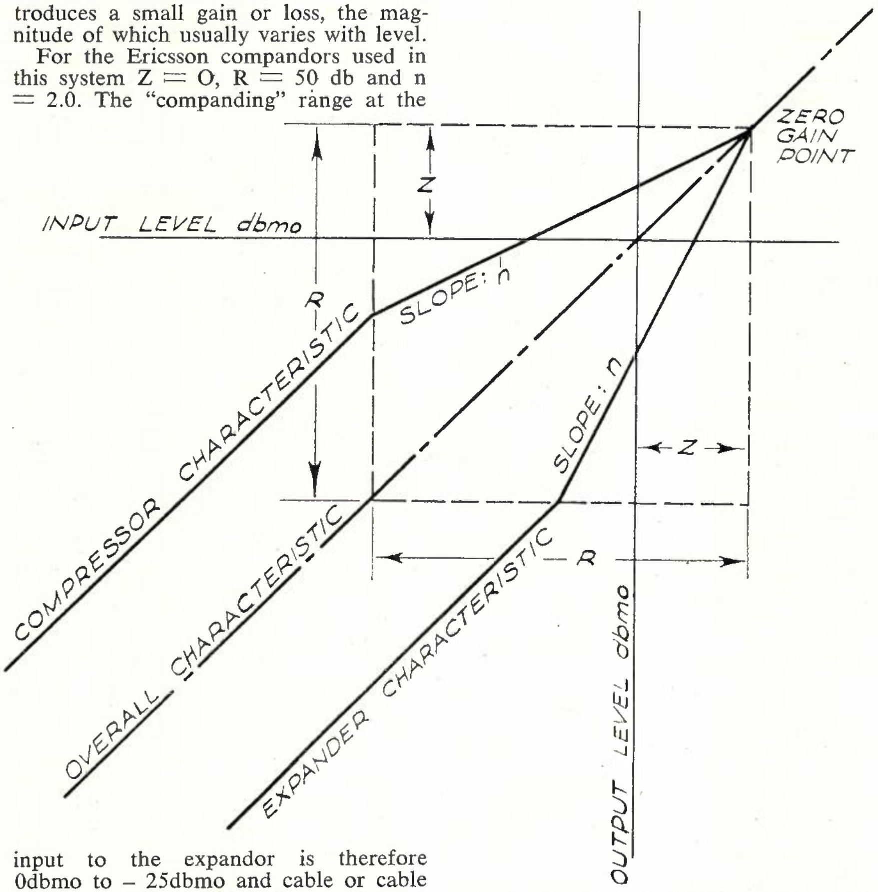


Fig. 5.—Idealized Compandor Characteristics.

For the Ericsson compandors used in this system Z = O, R = 50 db and n = 2.0. The "companding" range at the input to the expandor is therefore 0dbmo to – 25dbmo and cable or cable equipment noise, which passes through the expander, and not through the compressor, mostly falls below the expansion range. The noise level at the expander output is therefore

$$E_o = E_i - \frac{R}{n}(n - 1)$$

$$= E_i - \frac{50}{2}(2 - 1)$$

$$= E_i - 25 \text{ db}$$

Thus the effect of the compandor on cable and cable equipment noise is to produce a reduction in level of 25 db; e.g., cable noise of –50 dbmo is read as -75dbmo at the expander output. This 25 db improvement in noise level applies only between speech pauses and when signals are not passing through the channel (see Ref. 10).

CROSSTALK CONSIDERATIONS

In a carrier system of the present kind where level differences between various parts of the circuit reach 120 db, special consideration has been given to crosstalk. The greatest level differences appear in the equipment mounted on the filter amplifier rack so that the most important linear crosstalk problems are concerned with unwanted couplings between the various circuits on that rack. It is to be noted that the only effect of linear crosstalk in this system is to cause unwanted feedback.

Crosstalk Couplings in Rack Wiring: The submarine cable consists of an armoured coaxial pair. Its characteristic impedance being approximately 52 ohms unbalanced, the line and directional filters are designed to match this impedance, since matching transformers would be impracticable because of intermodulation requirements. For reasons of convenience, all of the amplifiers and equalisers in the A.P.O. designed equipment have also been made with 52 ohm nominal input and output impedances.

For rack wiring a 45 ohm flexible coaxial cable ("Telcon" PT81M) has been chosen. This particular cable has low attenuation and a closely woven tinned copper braiding for the outer conductor which is capable of giving good screening. It is, however, rather large (0.40 inch diameter over the P.V.C. sheath) and hence difficult to terminate.

The crosstalk between coaxial cables can be calculated by well known methods. For two short coaxial pairs with the sheaths in perfect electrical contact throughout the whole of their length, the crosstalk voltage ratio is given by

$$F = \frac{Z_{12}}{2Z_0} . L$$

where F is the crosstalk voltage ratio.

Z_{12} is the mutual impedance between the coaxial pairs, per unit length

Z_0 is the circuit (characteristic) impedance

L is the length of each coaxial pair.

Near-end and far-end crosstalk are identical for short lengths. Z_{12} in this case is one-half of the surface transfer impedance inside-to-outside, of the outer conductor of the coaxial pair. This transfer impedance can be obtained from the cable constants. The calculated value for frequencies up to 108 kc/s does not deviate by more than 20% from the D.C. resistance of the sheath.

The crosstalk between spaced PT81M coaxial cables has been measured on 10 ft lengths (that is, the approximate lengths involved in a standard 10 ft. 6 in. rack). When the sheaths of the cables are strapped together at the terminations, as is effectively the case when all terminations are earthed on one side, the attenuation figures given in Fig. 6 were obtained, both measured and calculated figures being shown. The calculated crosstalk attenuations were obtained from surface transfer impedance data and the simplified equivalent circuit given in Fig. 7.

It will be noted that even for 3 inch spacing the crosstalk figures given in Fig. 6 are insufficient for the present system, being of the same order as the working gains. If, however, the cables have their sheaths strapped together at one end only, it will be seen from the simple equivalent circuit of Fig. 7 that the crosstalk attenuation should rise to infinity. With two 10 ft. cables close together, the actual value obtained in tests was approximately 150 db at all frequencies between 50 and 200 kc/s when the cable spacing D (see Fig. 6) was very nearly zero and much greater than this when the cable spacing D was increased to three inches.

Crosstalk Couplings Between Panels: Panel-mounted group equipment in the system is designed as a "coaxial structure" whereby filters, amplifiers and similar equipment are mounted inside a screening tube or box (insulated from the mounting panel and dust cover) which is used to carry the return current of the unbalanced circuit. The external field surrounding the assembly is very small and crosstalk between panels occurs mainly as a result of multiple earthing of the screening structure (conditions corresponding to the coaxial cable crosstalk already considered), or in the case of amplifiers, due to coupling through the common impedance of the battery power supply system. The latter case will be discussed first.

Coupling Through the Battery Supply System: Coupling from amplifier to amplifier through the common 130 volt or the common 24 volt battery supply systems has been controlled by means of low-pass filters in the receive amplifier supply circuits. These decoupling filters also serve to reduce to negligible proportions the effect of any H.F. battery noise on the noise performance of the present system. In the absence of definite control over the H.F. noise appearing on the battery busbars, a H.F. noise level of 10 millivolts and H.F. busbar impedance of 1 ohm were assumed for design purposes.

Coupling Through Multiple Earthing of the Screening Structure: Multiple

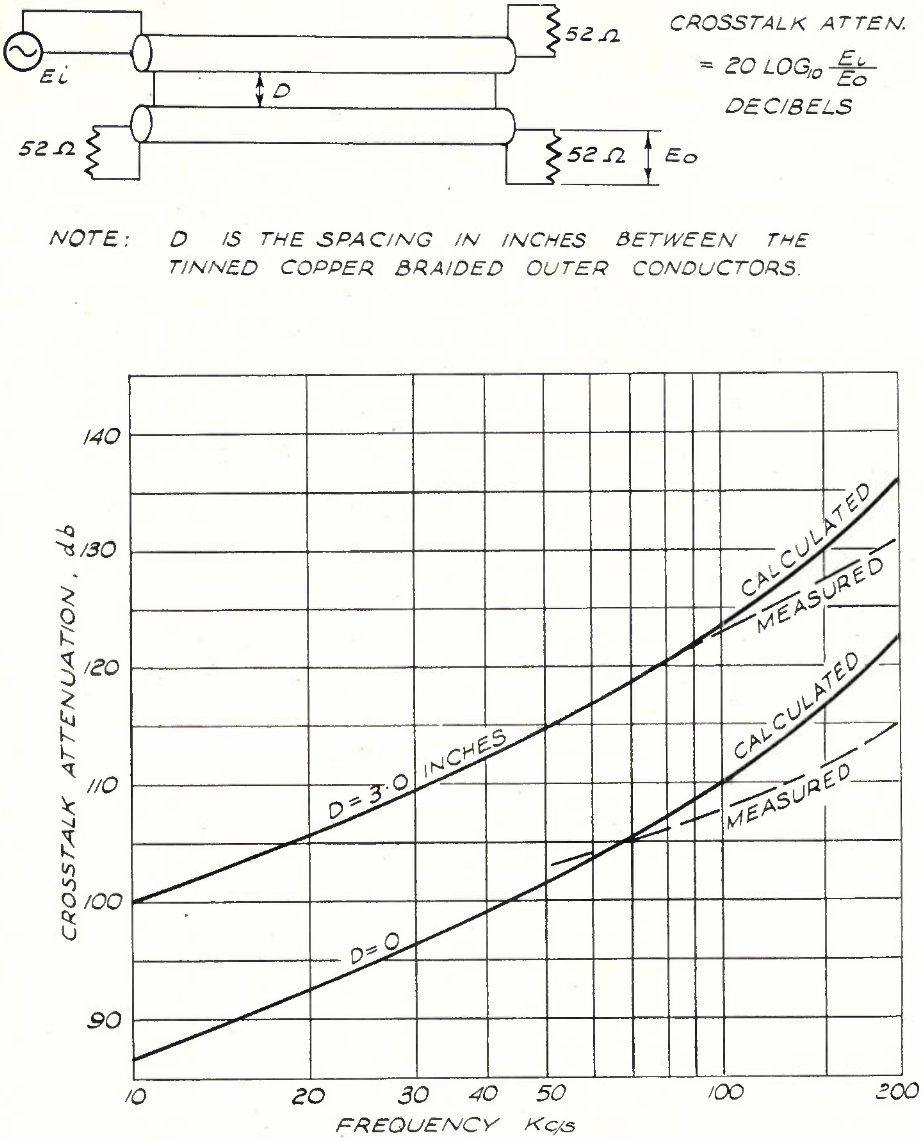


Fig. 6.—Crosstalk Between PT.81 Coaxial Cables (10 Foot Length).

earthing of the present system occurs as the result of the operation of a number of amplifiers in the one system from common batteries, earthed on one side. Its effects can be obviated by the use of inductors in the battery supply circuits or by means of transformers or coaxial chokes (having high impedance to longitudinal currents) in the transmission circuits between earthing points (namely at amplifiers). The latter alternative has been adopted in the present case, both transformers and coaxial chokes having been used.

Transformers have been used where the longitudinal impedance must be maintained down to zero frequency and coaxial chokes have been used at points where the intermodulation performance must be of a high order.

The prime requirement from these two devices is high longitudinal impedance. This is obtained in the transformers by separating the primary and secondary windings as much as possible consistent with the leakage inductance requirement for frequency response. The coaxial chokes have been constructed from coaxial cable wound on a "mumetal" magnetic core and the high longitudinal impedance is obtained by using the maximum number of turns possible, consistent with the requirements of transmission loss and overall size. Transverse (that is signal) currents passing through the coaxial chokes produce no magnetic flux in the core and hence intermodulation effects can be kept to very small values. For this reason coaxial chokes are provided in the submarine cable path where both high and low level signals are simultaneously present and the intermodulation requirements are therefore most stringent. In addition, the coaxial chokes provide a zero frequency path for insulation and conductor resistance tests on the submarine cable.

In both devices it is important that the coupling between the longitudinal circuit and the transverse circuit must be small, since coaxial cable crosstalk mostly arises through coupling via the longitudinal circuit. This requirement is easily met in coaxial choke construction, but the design of double screened transformers is much more critical. This is discussed further in Appendix I.

LINE AND DIRECTIONAL FILTER REQUIREMENTS

Line filters are used to separate the nine channels of the extension system from the older system at the cable ends to make separate amplification of the new channels possible. For the new channels the frequency range from 48 kc/s to 75 kc/s is used for transmission from Apollo Bay to Stanley, and the range from 81 kc/s to 108 kc/s for transmission from Stanley to Apollo Bay. In order to transmit and amplify signals in these two frequency ranges in opposite directions they are separated by directional filters. A set of line or directional filters is a combination of a low pass filter and a high pass filter connected together at one end. The corresponding common terminal pair is usually called the "line" terminals. The other two terminal pairs are independent and called the "drop" terminals.

Pass Band Requirements

The pass band specifications of filters of this sort are usually given in terms of a minimum return loss against a specified impedance at their line terminals, as a rule between 20 and 30 db. No particular requirements of this kind have to be met in the present case and the minimum return loss was arbitrarily chosen to be 30 db for the line filters and 26 db for the directional filters. These values ensure small insertion loss

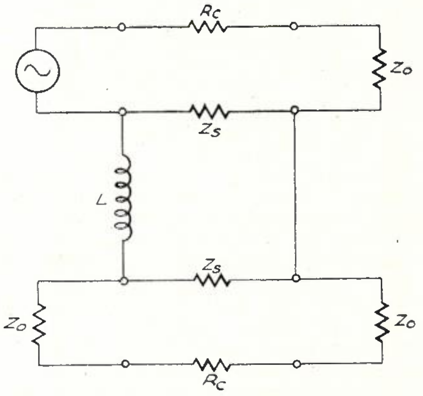


Fig. 7.—Equivalent Circuit for Calculation of Coaxial Cable Crosstalk.

Zo = Terminating impedance on Cable.
Zs = Surface transfer impedance of cable sheath.
L = Self inductance of loop formed by the parallel cable sheaths and their end connections.
Rc = Resistance of centre conductor.

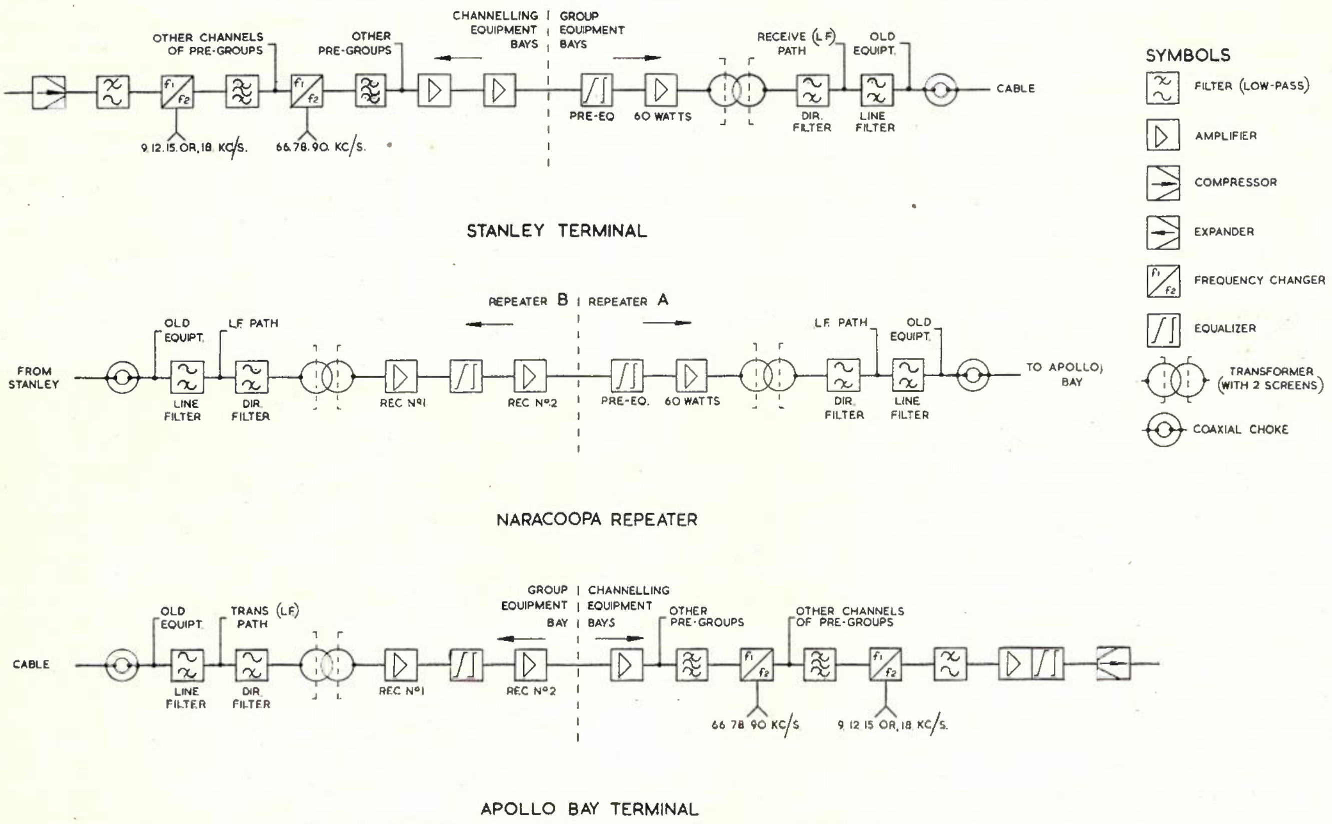


Fig. 8.—Simplified Block Schematic—Stanley to Apollo Bay Transmission.

variations due to mismatch in the pass bands of the filters.

Stop Band Requirements

Requirements at the Repeater Station: The attenuation requirements in the stop bands (including the transition bands) of the line and directional filters are mainly determined by the transmission conditions around closed loops in the repeater station on King Island. The simplified block schematic in Fig. 3 shows that there are four branches of the repeater circuit providing through amplification; the two lower branches are in the original repeater and the two upper branches are made up by the 9-channel extension equipment. These branches form four feedback loops, one involving the 9-channel system only, which is controlled by the directional filters; one involving the old system only and which does not require consideration here; and two loops involving part of the old and new systems and which are controlled by the line filters. To ensure the absence of self oscillations the voltage transfer factor around each one of these loops must be smaller than unity at all frequencies from zero to infinity. In the frequency ranges which are not used for signal transmission, only a safety margin against self oscillations is needed. The loop gain without filters reaches up to 230 db in these bands and a safety margin of 20 db was considered necessary.

In the frequency ranges which are covered by the transmitted signals more stringent requirements must be met, since signal voltages fed back over a loop are superimposed on the original signal with a relative phase angle which, owing to the transmission properties of the filters, varies rapidly with frequency. This causes amplitude variations which can be kept sufficiently small only by keeping the feed back voltages small in relation to the original signal voltages. A singing margin (loop loss) of 40 db was considered desirable restricting the amplitude variations due to feedback to ± 1%.

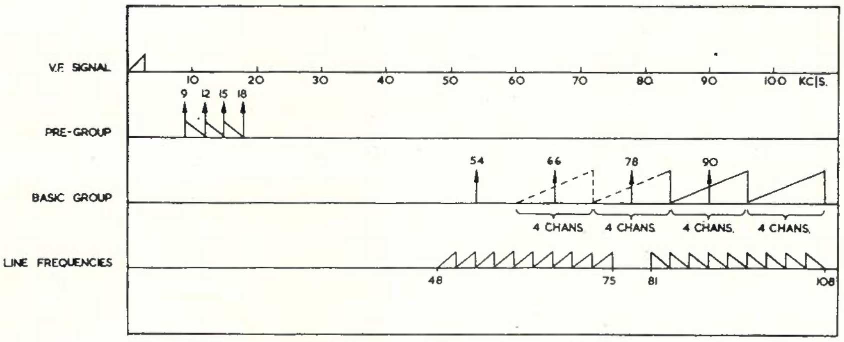
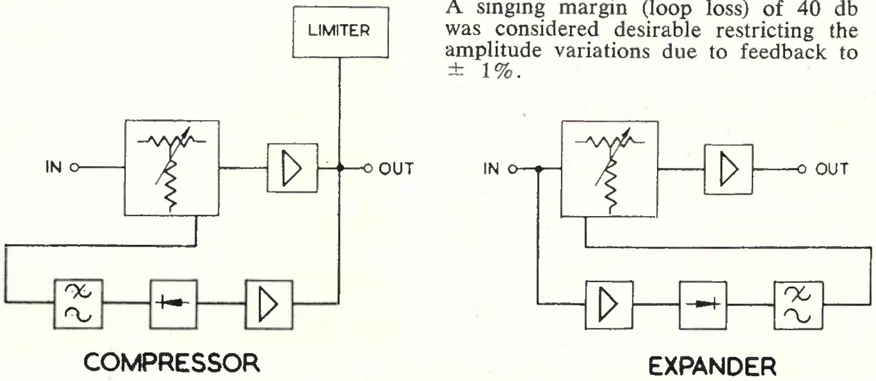


Fig. 9.—Modulation Plan for 9-Channel System.



COMPRESSOR

EXPANDER

Fig. 10.—Compandor Block Schematic.

It is the main purpose of the directional filters and of the line filters to cancel the total gain in the respective feedback loop and to produce on top of that the mentioned attenuation margins. The specified minimum attenuation as a function of frequency between the two drop terminal pairs of one set of these filters is therefore given by one half of the sum of the net gain in the two branches of the respective loop (without these filters) and the specified margin.

At the line terminals of the line and directional filter sets there appear together high level signals transmitted into the cable and, in other frequency ranges, low level signals received from the cable, the average level-differences being up to 100 db. Transmitted signals following the same path as the received signals reach the amplifiers provided for the latter. To prevent overloading of those amplifiers by the transmitted signals they should be attenuated to such an extent that they do not exceed the amplitudes of the received signals. The required attenuation must be produced in the corresponding part of the line or directional filter set. A specification scheme for the minimum attenuation of the individual filters of each set is thus obtained which, combined with the previous scheme for the whole sets gives the final attenuation specifications for the filters.

Requirements at the Terminal Stations: So far only the filter requirements at the repeater station on King Island have been considered. Line and directional filters are also used in the terminal stations at Apollo Bay and Stanley. No closed feedback loops exist there as signals transmitted from the receiving leg into the land line equipment are there modulated several times and return to the transmitting leg in a different frequency range.

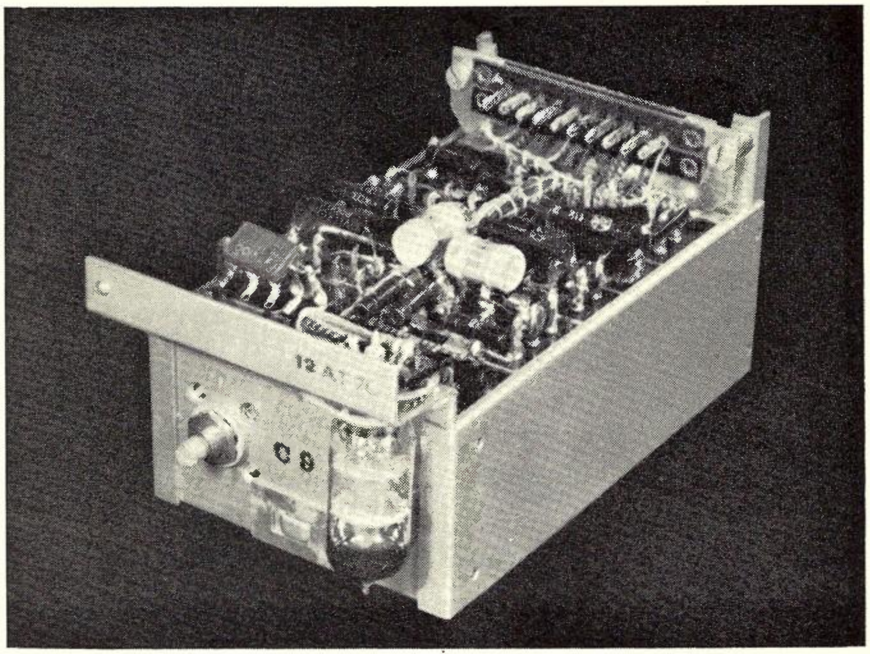
The conditions for avoiding overload of the amplifiers are substantially the same as in the repeater station and therefore the same filter designs are used.

DESCRIPTION OF EQUIPMENT

The equipment may be divided into two categories, namely, channelling equipment and group equipment. The former category includes all the voice frequency and the modulation equipment and carrier supply arrangements for it; it is of fairly conventional design and was supplied by the L.M. Ericsson Telephone Company and is of Swedish manufacture. The group equipment was designed and mainly manufactured in the Department and comprises the line and directional filters, the cable equalizers, and the special transmitting and receiving amplifiers.

Fig. 8 shows the circuit traversed by one channel in the course of transmission from Stanley to Apollo Bay. Voice frequency input signals are applied first to the compressor unit of the compandor and then pass via a low-pass filter to the channel modulator. The channels are assembled in pre-groups of four as shown in Fig. 9. The output from the channel modulators are applied to the channel bandpass filters, which are inductor-capacitor types. The four-channel pre-groups are then applied to group modulators as shown in Fig. 8 and the upper sideband selected by the following band-pass filter. In a fully equipped system this would produce 16 channels, 3 kc/s spaced, in the C.C.I.T.T. basic group band 60 to 108 kc/s. In the present case only nine channels are required and these occupy the band 81 to 108 kc/s. This is the band of line frequencies used for Stanley to Apollo Bay transmission. For the reverse direction of transmission, not shown in the block schematic diagram, this band of frequencies is group-modulated on a carrier wave of 156 kc/s, to produce a 9-channel group in the range 48 to 75 kc/s. The spectrum of line frequencies produced by the 9-channel system is shown in the last line of Fig. 9.

As shown in Fig. 8 the output from the group modulator (Stanley terminal) is then amplified and passed to the Group Equipment bay, where it is applied to a pre-equaliser which pro-



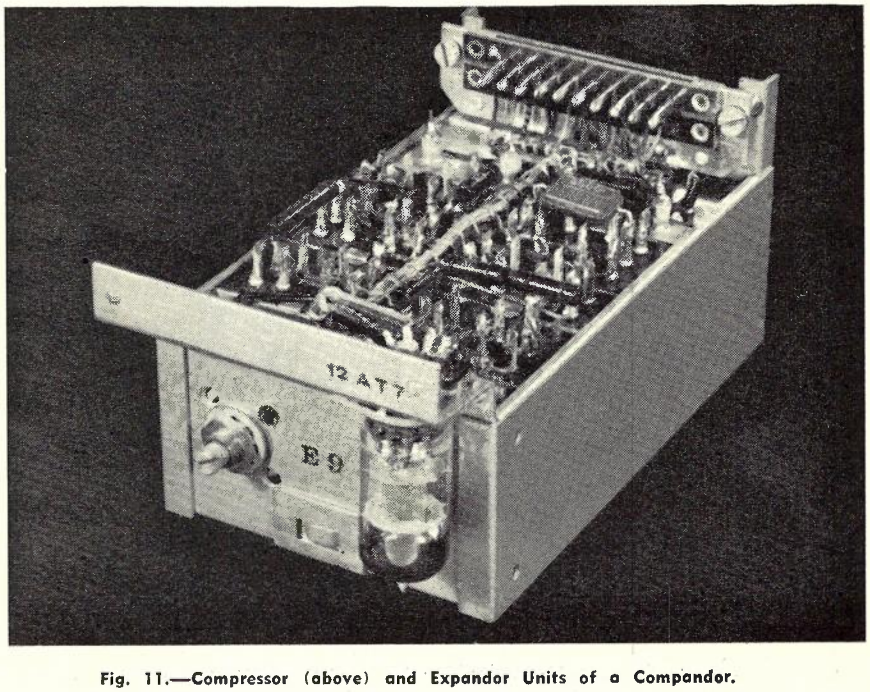


Fig. 11.—Compressor (above) and Expandor Units of a Compandor.

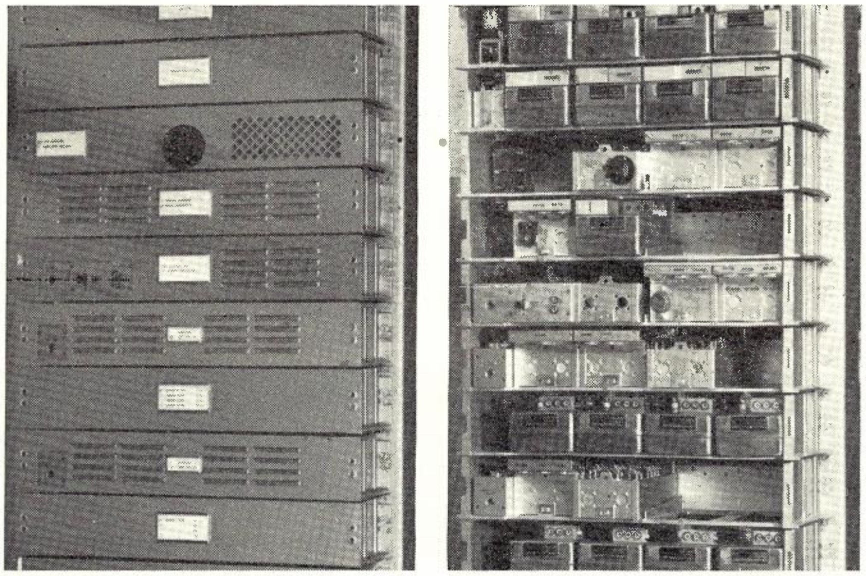


Fig. 12.—Construction of Channelling Equipment showing Die-cast Shelves Attached to the Rack and Plug-in Filters and Amplifiers in Position. The view at the Right is with Dust-covers Removed.

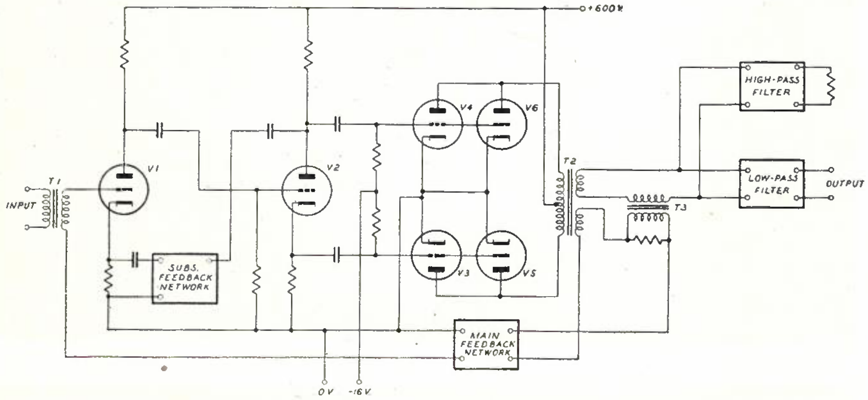


Fig. 13.—Schematic Circuit Diagram of the "100 Watt" Amplifier.

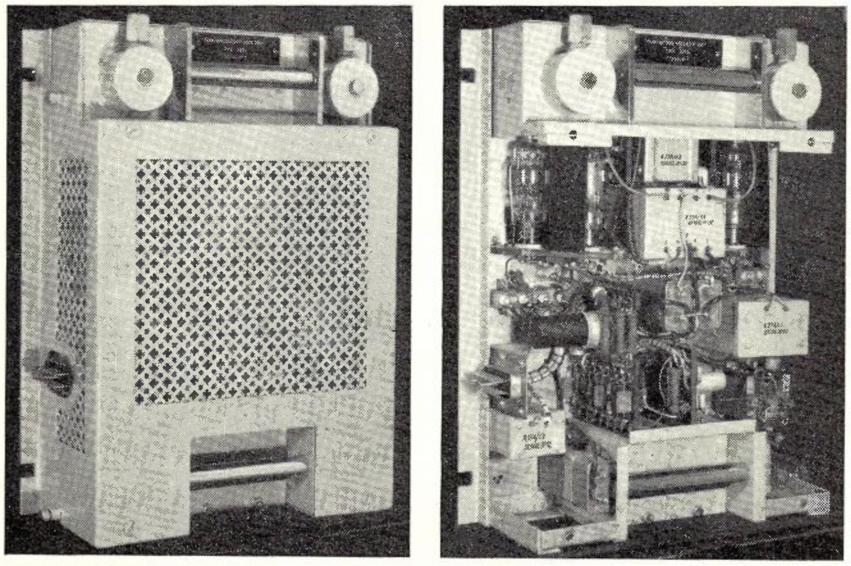


Fig. 14.—Two views of a "100-Watt" Amplifier, at Left with Screening Cover in Position, and at Right with Cover Removed. This Unit Slides into a 10 ft. 6 in. Cubicle.

duces approximately 8 db more loss for the lowest frequency channel than for the highest frequency channels. The 9-channel group is then amplified in the "100 watt" amplifier (actual peak power output is 60 watts) and applied through a double-screened transformer to the submarine cable via the directional and line filters. Referring again to Fig. 8 the channels transmitted from Stanley are received at the Naracoopa repeater station and after passing through the line and directional filters in the "B" repeater are applied through double-screened transformers (for suppression of longitudinal currents) to the two tandem-connected receiving amplifiers. A cable equalizer is connected between the two receiving amplifiers and equalizes that portion of the cable attenuation not already dealt with by the pre-equaliser at Stanley.

The 9-channel group is then passed to the "A" repeater which is identical to the group equipment in the Stanley ("A"') terminal. At Apollo Bay, the "B" terminal, the receiving group equipment is identical with that in the "B" repeater. The output from the second receiving amplifier is passed to the channelling equipment, where it is first of all broken down into the 6-18 kc/s 4-channel pre-groups, and then demodulated to voice frequencies. Following the channel demodulator is a low-pass filter and combined demodulator amplifier and adjustable channel equalizer. The adjustable equalizer has both "slope" adjustments and also "corner" adjustments to equalize frequency response distortion produced by the channel filters. The demodulated channels then pass through the expander unit before connection to the land-line carrier systems.

Also shown in the simplified block schematics of Fig. 8, are the coaxial chokes which are connected between the submarine cable and the cable equipment to produce isolation of cable and equipment earth connections, and to attenuate longitudinal currents.

The operation of the compressor and expander units forming the compandors will be explained by reference to the block schematic diagram in Fig. 10. In the compressor the incoming voice frequency signals are applied to the variolosser, or current-controlled variable attenuator. The signals are then amplified by an amplifier across the output of which is connected a volume limiter and control circuit amplifier (lower path). The output of the control amplifier is rectified and filtered to obtain the control current which is then applied to the variolosser.

The operation of the expander is similar to that of the compressor, except for the variolosser control characteristics and the fact that the control current is obtained from the input of the device instead of the output. The characteristics of the compressor variolosser are such that an increase of control current causes an increase in attenuation, whereas for the expander the reverse is true. These effects are obtained by means of rectifier elements which are connected across the transmission path in the compressor and in series with the transmission path in the expander.

It is essential that the time constants of the control circuits of the compressor and of the expander are matched and in these units the time constant of control current build-up in 3 milliseconds, whilst the decay time constant is 30 to 50 milliseconds. The compandors in this system use a single double triode valve in each of the compressor and expander units, one triode operating as the signal amplifier and the other as the control amplifier. The construction is illustrated in Fig. 11. Four compressor or four expander units fit on to a shelf which requires only 3½ inches mounting space on a standard rack.

Carrier supplies for the chanelling equipment are obtained from a 6 kc/s quartz crystal master oscillator at each terminal. The carrier frequencies required for the channel modulators are harmonics of 3 kc/s, which is obtained from a 3 kc/s oscillator frequency-locked to the master oscillator. The remaining carrier frequencies are harmonics of 6 kc/s and are obtained from a harmonic generator of the saturating inductor type driven by the master oscillator.

The channelling equipment is mounted on racks 9 feet high. Individual units slide into die-cast metal shelves, the circuit connections being made by means of plug-and-socket connectors; see Fig. 12. Circuit operating currents are measured on a monitoring panel adjacent to the jackpanel. Plug-in alarm-type fuses are also mounted on this panel, under a hinged protecting cover.

The group equipment, which is Departmentally designed, is assembled on 10ft. 6in. racks. The filters, equalizers and receiving amplifiers at each terminal station are mounted one rack and a separate 10ft. 6in. rack is required for the "100-watt" amplifier equipment. The latter comprises working and standby amplifier units, power control equipment, and alarm and changeover circuits. These amplifiers require 24V direct current for the valve heaters and for relay operation, and 600V for the anode circuits.

A simplified schematic circuit of a "100-watt" amplifier unit is shown in Fig. 13. The first valve is a pentode voltage amplifier (for the sake of simplicity, shown as a triode in the circuit diagram). The second valve is operated as a phase-splitting stage to drive four 25-watt (anode dissipation) pentodes in push-pull parallel in the output stage. The output circuit includes a high-pass low-pass filter group with a cut-off frequency of 175 kc/s. Above this frequency, the amplifier output termination is virtually that provided by the resistor terminating the high-pass filter. This arrangement is necessary to ensure control of the amplifier terminating impedance characteristics at frequencies in the region of 450 kc/s, where due to the characteristics of the feedback circuit, the stability margin is smallest.

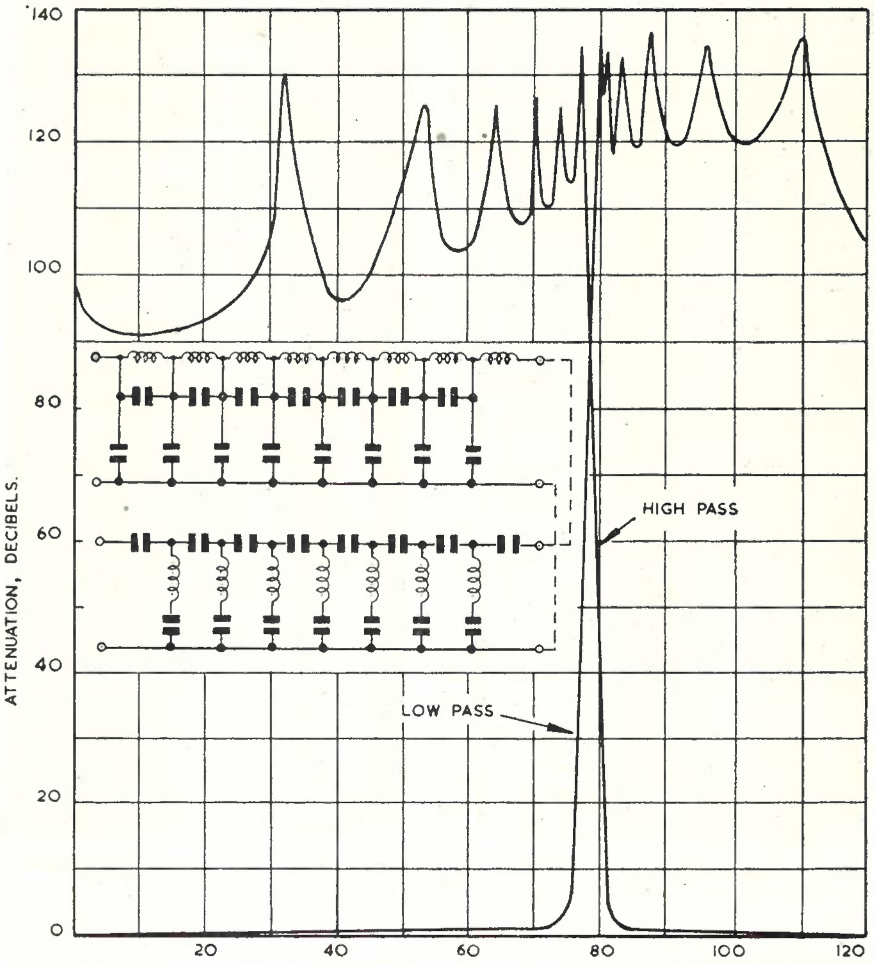


Fig. 15.—Attenuation of Directional Filters.

Voltage feedback is obtained from a tertiary winding on the output transformer T_2 and current feedback from the current transformer T_3. The combined feedback voltage is applied to the grid circuit of the input valve through the main feedback network. Effectively in series with this feedback voltage is the output from the subsidiary feedback network connected between the anode of the phase splitter valve and the cathode of the input valve. The output voltage from the subsidiary feedback network is negligible at frequencies within and below the designed operating frequency band of the amplifier (300 c/s to 108 kc/s). Above the operating frequency band the feedback voltage supplied by the subsidiary feedback path increases until at a frequency of approximately 500 kc/s, it is equal to the feedback voltage supplied by the main feedback path. At frequencies higher than this the feedback voltage from the subsidiary path exceeds that supplied by the main path, effectively in series with it as far as feedback voltage is concerned. The effect of this arrangement is to reduce the stability problems associated with the phase shifts in the output circuits at high frequencies. The mechanical construction is illustrated in Fig. 14.

The 600 volt power supply for these amplifiers is obtained from rectifier power converters when A.C. power is available, and at other times from dynamotors run from the 24 volt station battery. The high tension supplies are automatically disconnected from the amplifier when certain fault conditions arise or when the covers are removed from the rack.

The transmitting amplifiers used in the low frequency direction of transmission are of the same design, apart from 52 ohm output impedance, as the transmitting amplifiers used in standard open-wire 12-channel carrier systems. In their normal application these amplifiers are operated at a normal output level of + 17 dbm but in this system they are operated at a level of + 20 dbm in the highest frequency channel and at + 11 dbm in the lowest frequency channel of the 9-channel group. This level difference is the result of pre-equalization. The receiving amplifiers, of which there are two in each receiving path, each have a gain of 55 db. They are 3-valve amplifiers with cathode feedback from the first to the third valve and the construction is based upon a British Post Office design. These amplifiers have a design operating bandwidth of 10 to 500 kc/s and have a noise figure exceeding

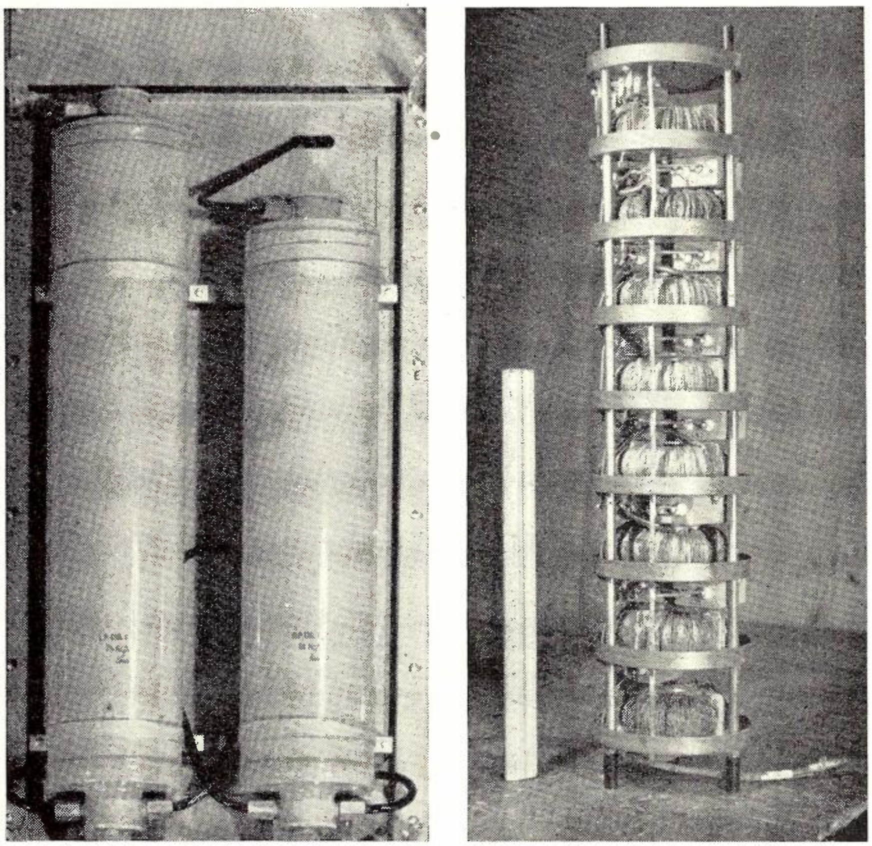


Fig. 16.—Directional Filter Construction. The Left-hand Photograph Shows a Low-and High-Pass Filter Group Mounted on a Panel, while at the Right the Internal Construction of the Low-Pass Filter is Shown.

the theoretical minimum by only 1.9 db. They are operated from 24 to 130 volt battery supplies which are carefully filtered and decoupled.

The directional filters, together with the line filters and the balance filters necessary to preserve the balance of the cable hybrid transformers, comprise a large proportion of the total volume and cost of the group equipment. One side of a 10ft. 6in. rack is required at each cable end to accommodate this filter equipment.

The attenuation of the directional filters is shown in Fig. 15, together with a schematic circuit diagram. The line filters are of a similar configuration and have the same order of attenuation. The directional filters do not provide the whole of the directional attenuation, and are backed up by supplementary filters operated at low level parts of the circuit where magnetic-cored inductors can be used. The supplementary filters are required to provide approximately 15 db of extra attenuation.

The inductors in the line, directional, and balance filters are air-cored toroids which are wound on moulded polystyrene formers, the overall diameter of a fully wound coil being approximately 4½ inches. To ensure adequate screening, these coils were mounted on a long framework, together with the filter capacitors, and enclosed in copper tubes 6 inches in diameter. After adjustment, these filter assemblies were pressure-tested to check for air leaks and were then filled with dry air and hermetically sealed. The constructional principles will be apparent from a study of Fig. 16.

During the course of the assembly operations, the inductors were all heat treated to stabilize their inductance values. Fine tuning of the resonant circuits was accomplished by adding small capacitors to the circuit, in parallel with the main resonating capacitors.

Difficulties were experienced in keeping the non-linear distortion in the filters sufficiently low at the powers transmitted by the "100-watt" amplifiers, as already mentioned. It was known, when the filter designs were prepared, that silvered-mica capacitors, although preferable in respect of stability to mica-and-foil capacitors, were particularly prone to non-linear distortion. In the construction of the filters mica-and-foil capacitors using non-magnetic construction were used. Despite these precautions, capacitor distortion remained an important factor. Later investigations have shown that efficient clamping of the mica-and-foil stack is most essential and this can be satisfactorily effected by steel clamping components. The magnetic properties of the clamping structure do not appear to introduce any significant non-linear distortion.

It was found, however, that magnetic materials in the conducting path produced very serious intermodulation and some unexpected distortion was traced to the inadvertent use of tinned mild steel solder tags. Glass-to-metal hermetic terminal seals had to be replaced with silvered ceramic types because the nickel-iron alloy conductors used are magnetic and caused excessive intermodulation.

The filters and all group equipment were double screened, the steel dust covers forming the outer screen. The inner screen was so connected as to form an extension of the outer conductor of the coaxial cable used for wiring the group equipment and was insulated from the steel mounting panels.

Similarly the rack frameworks were insulated from the adjacent racks and earthed by means of a single connection to the 130V negative battery busbar. The filament circuit earth return (24 V positive) and anode circuit earth return (130V negative) were insulated from each other and where possible were connected to separate supply busbars. All high frequency pairs on the group equipment were provided with individually screened termination cells for soldered connections. Non-magnetic solder tags were essential for all connections on the submarine cable side of the directional filters.

FUTURE DEVELOPMENTS

Studies of the performance achieved in this system have been made with the object of determining whether further increases in the number of channels carried by this cable could be made by further use of the same methods. It was found that only small increases in capacity (a few channels) were practicable. The possibilities of extension by the use of submerged repeaters are much more favourable. The successful completion of the trans-atlantic submarine telephone cable, carrying 36 carrier channels on two cables, each including 51 submerged repeaters, shows that any doubts about the submerged repeater scheme for a comparatively short link across Bass Strait need be entertained no longer. In addition, as pointed out in the introduction, radio bearer circuits can be expected to provide increasing numbers of channels on this route.

REFERENCES

1. G. N. Smith—"Laying the Victorian-Tasmanian Submarine Telephone Cable"; The Telecommunication Journal of Australia, Vol. 1, p. 25, December 1935.

2. A. Rosen—"Submarine Telephone Cables"; The Telecommunication Journal of Australia, Vol. 1, p. 70, June 1936.

3. N. W. V. Hayes and C. Anquetil—"Mainland-Tasmania Cable, Description of Equipment"; The Telecommunication Journal of Australia, Vol. 1, p. 81, June 1936.

4. J. M. Crawford—"Notes on the Victorian-Tasmanian Telephone Cable"; J.I.E. Aust., Vol. 8, p. 236, June 1936.

5. F. Ralph and R. L. Hughes—"The Carrier Telephone and Telegraph Equipment of the New Bass Strait Submarine Cable System"; Electrical Communication, Vol. 15, p. 284, April, 1937.

6. D. McDonald—"Ultra High Frequency Experiments between Victoria and Tasmania"; The Telecommunication Journal of Australia, Vol. 2, p. 5, June, 1938.

7. B. D. Holbrook and J. T. Dixon—"Load Rating Theory for Multichannel Amplifiers"; B.S.T.J., Vol. 18, p. 624. October, 1939.

8. R. J. Halsey—"Modern Submarine Cable Telephony and the use of Submerged Repeaters"; J.I.E.E., Vol. 91, p. 218, December, 1944.

9. O. M. Moriarty—"Projected New Radio Telephone Link from the Mainland to Tasmania—Propagation Measurements"; The Telecommunication Journal of Australia, Vol. 7, p. 281, October, 1949.

10. J. Lawton—"Compandors for Reducing Noise and Crosstalk"; A.T.E. Journal, Vol. 9, p. 109, April, 1953.

APPENDIX I

Longitudinal to Transverse Transmission in Coaxial Circuits Containing a Transformer

Fig. 17A illustrates a two-winding transformer coupling in a coaxial circuit; the interwinding capacitances can be lumped as shown. Figs. 17B and 17C, which can be considered as special cases of Fig. 17A, show the capacitances which are relevant in the case of transformers with inter-winding electro-static screens.

Referring again to Fig. 17A, the transformer considered is of 1 : 1 turns ratio. In the working frequency range the winding resistance and leakage reactance can be taken as of negligible magnitude in comparison with the reactance of the interwinding capacitance. It is desired to calculate the voltage across R_2 in the transverse circuit due to an e.m.f. V arising in the longitudinal circuit.

C4, being in parallel with the generator, does not affect the coupling. The component of the voltage across R2 due to capacitance C1 is:

$$= \frac{V.\ R_2}{2j\ X_{C1}}, \text{ if the fluxes in the core}$$

add and jX_{C1} is much greater than R1 and R2.

$= O$, if the fluxes in the core cancel.

The component due to C2

$$= \frac{V.\ R_2}{2\ jX_{C2}}$$

The component due to C3

$$= \frac{V.\ R_2}{2\ jX_{C3}}$$

The total voltage across R2 (equal to that across R1)

$$= O + \frac{VR_2}{2jX_{C2}} - \frac{VR_2}{2jX_{C3}}$$

$$= \frac{VR_2\omega}{2} (C_2 - C_3)$$

if the fluxes in the core cancel; if the fluxes add the total voltage is

$$\frac{V\ R_2}{2\ jX_{C1}} + \frac{V\ R_2}{2\ jX_{C2}} + \frac{V\ R_2}{2\ jX_{C3}}$$

$$= \frac{VR_2\omega}{2} (C_1 + C_2 + C3)$$

Discussion: The above analysis shows that if the transformer windings are suitably poled, there is no coupling between the longitudinal and transverse circuits provided $C_2 = C_3$. If a high degree of decoupling is required it is best to reduce C2 and C3 to a small value by means of two inter-winding screens, as shown in Fig. 17C. Here the winding-to-screen capacitances C5 and C8 act merely as shunt capacitors across R1 and R2 and do not affect longitudinal to transverse transmission. The inter-screen capacitance C9 merely acts as a shunt across the source of longitudinal voltage. Care has to be taken in the construction of the screens to ensure that the inter-screen current flowing via capacitance C9 does not induce an e.m.f. into the main windings.

A single electrostatic screen between windings, as shown in Fig. 17B is of little use in the present case, that is, when both terminating circuits are earthed on one side. The voltage across the transformer termination in this case is that due to C6, that is $\frac{V\ R_2}{2\ jX_{C6}}$.

The double-screened transformers used in this system were required to have a longitudinal to transverse voltage ratio of 100,000 (100 db).

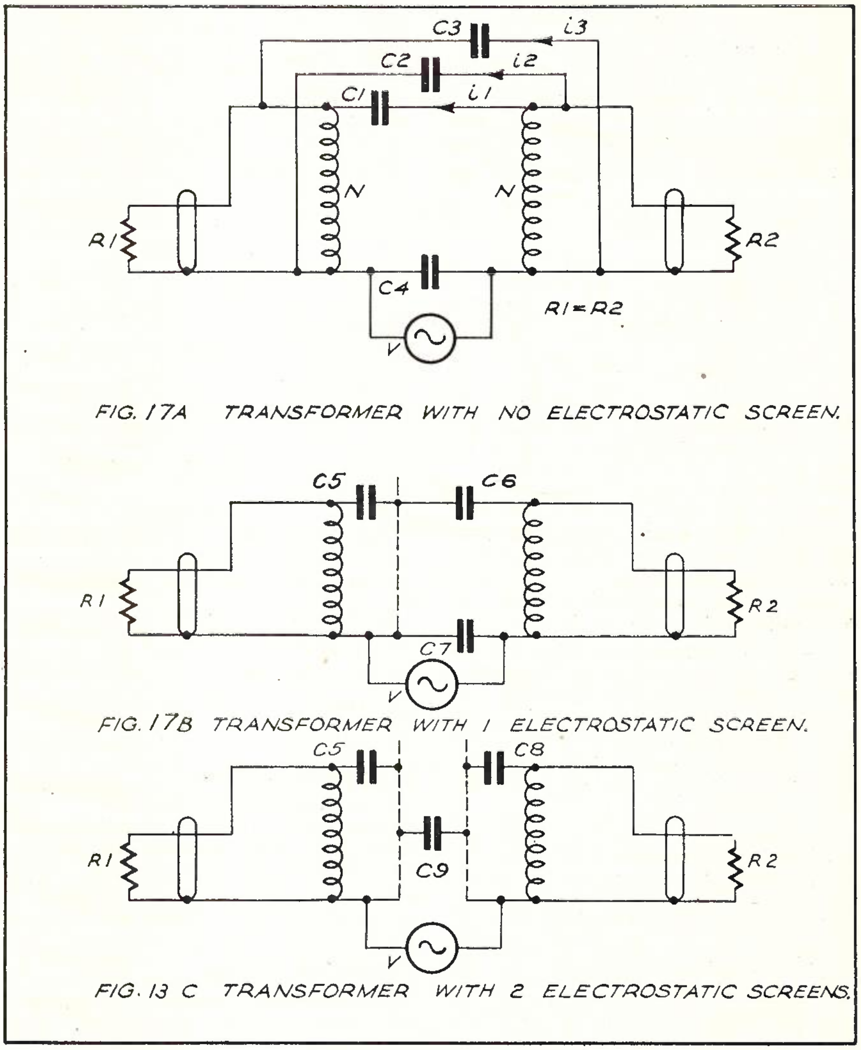


FIG. 17A TRANSFORMER WITH NO ELECTROSTATIC SCREEN.

FIG. 17B TRANSFORMER WITH 1 ELECTROSTATIC SCREEN.

FIG. 13 C TRANSFORMER WITH 2 ELECTROSTATIC SCREENS.

Fig. 17.—Longitudinal-to-Transverse Transmission in Coaxial Circuits Containing a Transformer.

ANSWERS TO EXAMINATION PAPERS

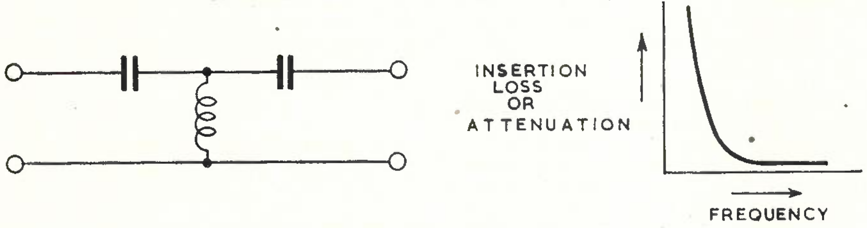
EXAMINATION No. 3942 SENIOR TECHNICIAN. ELECTRICAL THEORY AND PRACTICE

K. A. Neilson.

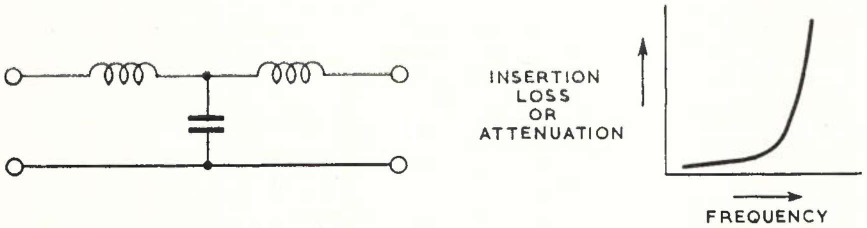
Q.5. (a) Draw a diagram of the arrangements of capacitances and inductances for:—

(i) a high pass filter
(ii) a low pass filter
(iii) a band pass filter.

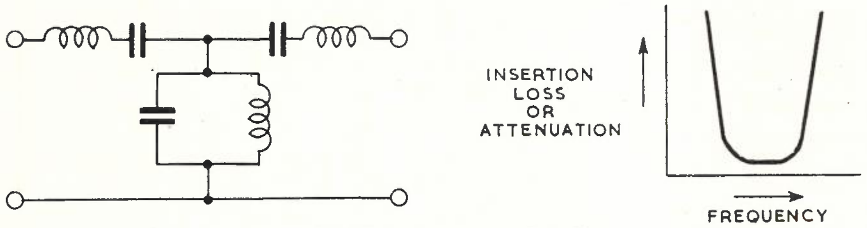
A.—(a) Take in Q.5 Fig. 1



(a) HIGH PASS FILTER



(b) LOW PASS FILTER



(c) BAND PASS FILTER

Q.5. (b) What points would you consider important in the choice of capacitances and inductances for an audio frequency band pass filter if a sharp cut off is required.

A.—(b) A filter may be defined as a network of inductors and capacitors selected and arranged so as to permit currents of certain selected frequencies to pass freely and at the same time offer high impedance to all other frequency components which do not lie within the selected band.

Sections shown in Fig. 1 are the basic or prototype filter sections from which are developed the sections used in practical filters. The sharpness with which a properly designed band pass filter "cuts off" and the attenuation offered in the band pass range, depends on the following features.

(a) **Inductors**

(i) A high ratio of inductive reactance to resistance, since the reactance of a coil of given inductance increases directly with increase in frequency, while the resistance remains substantially constant in the lower frequency range.

(ii) Close tolerance to specified values.

((b) **Capacitors**

(i) Low Leakance

(ii) Close tolerance to specified values

(iii) As far as possible non resistive.

Q.6. Define the following terms in relation to a telephone condenser—

(a) Dielectric Constant
(b) Dielectric Strength
(c) Capacitance
(d) Power Factor
(e) Insulation Resistance

A.—(6)

(a) **Dielectric Constant**

The dielectric constant, or specific inductive capacity of a material, is the ratio of the capacitance of a condenser with the material as a dielectric, to the capacitance of the same condenser with air as a dielectric. The dielectric constant of air is taken as unity.

(b) **Dielectric Strength**

The dielectric strength of a material is measured by the voltage at which break-down occurs in a sample of the material 1 m.m. in thickness.

(c) **Capacitance**

The capacitance of a condenser is estimated by the potential difference which exists between its plates when it carries a given charge.

$C = Q/E$

where C = capacity in farads
Q = charge in coulombs
E = voltage in volts

The practical unit of capacity is the Farad and a condenser is said to have a capacity of one Farad, when a charge of one Coulomb, creates one volt potential difference between its plates. Capacity varies directly as the area of the plates and dielectric constant, and inversely as the distance between them.

(d) **Power Factor**

Power factor is the ratio of true power to apparent power dissipated in a condenser and is expressed by the formula.

Power Factor = True power/Apparent power
$= EI\cos\theta/EI$

Where E = R.M.S. value of voltage.
I = R.M.S. value of current in amps.
$\cos\theta$ = cosine of the angle by which the current leads the voltage.

(e) **Insulation Resistance:**

The insulation resistance of a condenser is the value in ohms given by the ratio E/I where

E = D.C. potential between the plates
I = leakage current flowing between the plates after the condenser has been fully charged to voltage E.

Q.7. A telephone receiver has an impedance of 400 ohms with an angle of lag of 70° when an A.C. at a frequency of 500 C.P.S. is passing through it. Calculate its effective resistance and inductance at this frequency.

Tan 70° = 2.75

A.—

$Z = \sqrt{R^2 + (\omega L)^2}$

Where Z = impedance in ohms
R = resistance in ohms
L = inductance in henries
$\omega = 2\pi f$ where f is frequency in c/s.

substituting:
$400^2 = R^2 + (\omega L)^2$
since $\omega L/R = \tan 70° = 11/4$
$(\omega L)^2 = (11/4R)^2$ 1
$\therefore\ 400^2 = R^2 + (11/4R)^2$
$= R^2 + (121/16)R^2$
$= (137/16)R^2$
and $400 = \sqrt{(137/16)}R$
$\therefore\ R = 1600/11.7 = 136.7$ ohms.
From 1 since
$(\omega L)^2 = (11/4R)^2$
$\omega L = (11/4)\ 136.7$
and since $\omega = 2\pi f = 5029$
$L = (11 \times 136.7)/(4 \times 5029)$
$= 0.0747$H or **74.7 mH**

Answer (i) $R = 136.7$ ohms
$L = 74.7$ milli henries

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