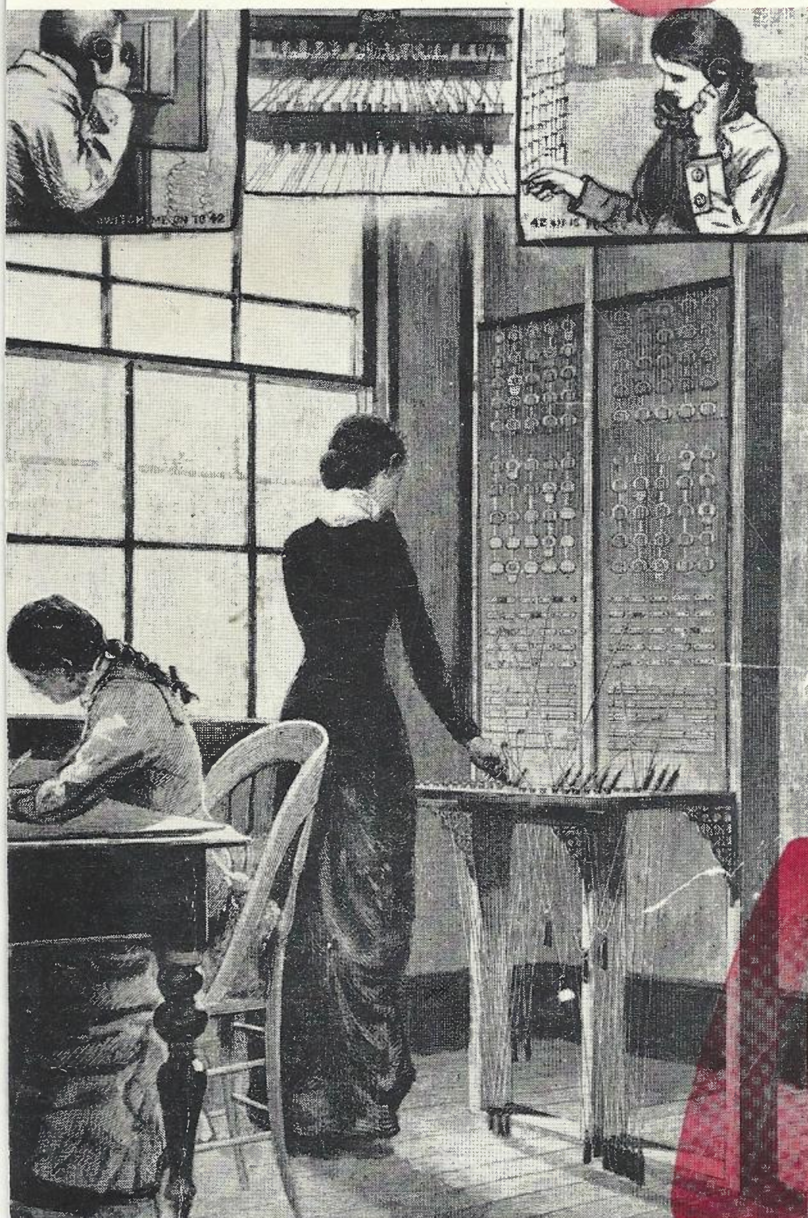
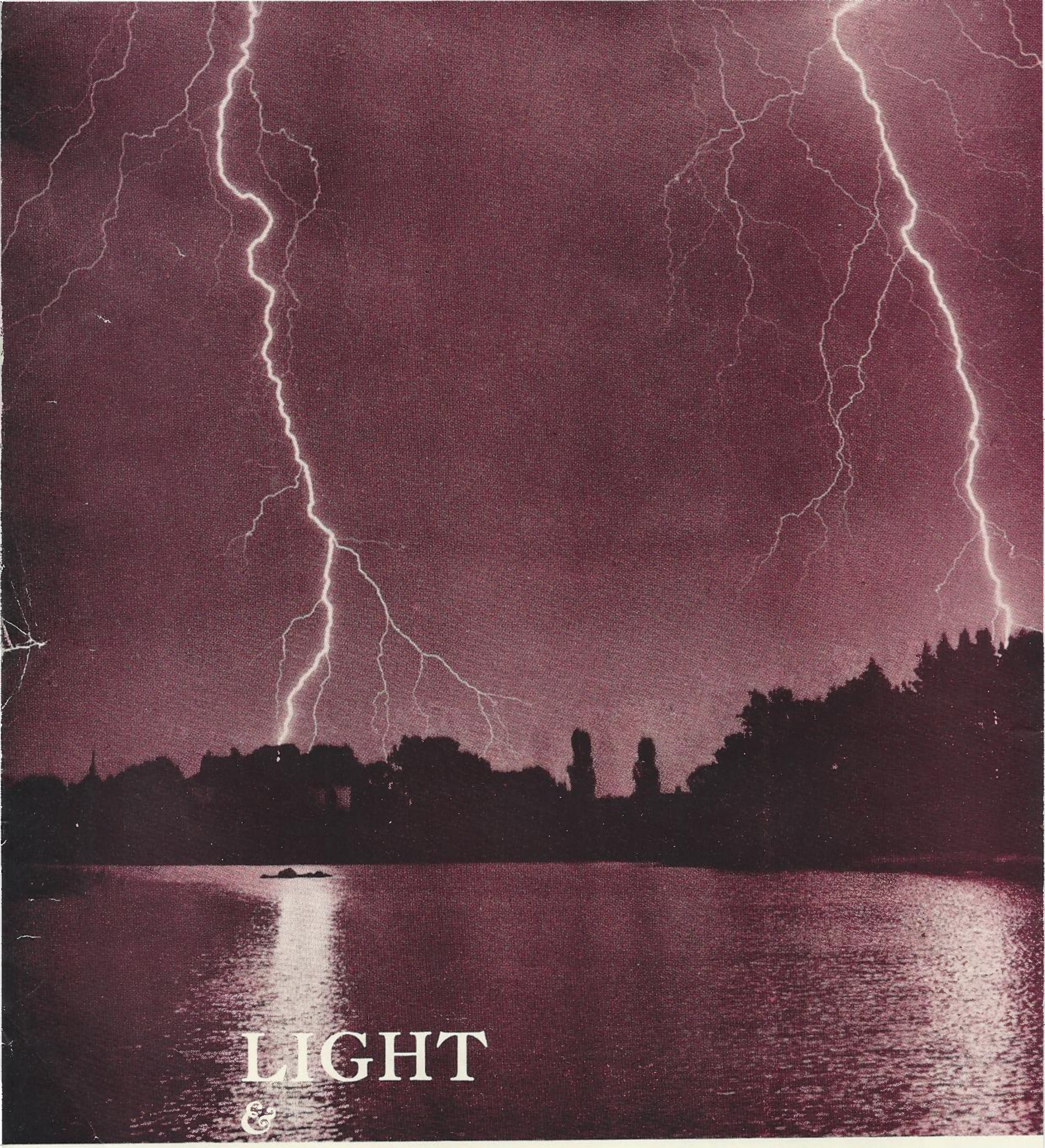
THE Telecommunication Journal OF AUSTRALIA



IN THIS ISSUE

VOL. 13, No. 5 Registered at the General Post Office Melbourne, for transmission by post as a periodical. OCTOBER, 1962



LIGHT & SOUND

Electrical energy and sound were associated in a familiar, elemental way long before Edison and Bell began to reorganise them.
Now less elemental, but increasingly familiar, the association has been turned to man's ends. President talks to Prime Minister; Jack talks to Jill. In the coming day when anyone can talk to anyone, anywhere, at any time, we shall be there, still helping.

Standard Telephones and Cables Pty. Ltd.

STC

AN ITT ASSOCIATE

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The
TELECOMMUNICATION JOURNAL
of Australia

VOL. 13, No. 5 — *Registered at the General Post Office, Melbourne, for transmission by post as a periodical.* — OCTOBER, 1962

CONTENTS

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

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

*For addresses see inside back cover.

THE EARLY HISTORY OF THE TELEPHONE IN VICTORIA

*R. M. J. KERR**

INTRODUCTION

The year 1962 has been a notable one in Australian telephone history. On Monday, 9th July, the Prime Minister officially opened the Australia-New Zealand section of the Commonwealth Pacific Cable to provide the first trans-Tasman telephone cable link. A few days earlier, the 6th July saw the 50th anniversary of the opening of Australia's and the Southern Hemisphere's first automatic exchange at Geelong, Victoria. With automatic telephony now having been established for half a century, with ELSA and subscriber trunk dialling now an established fact, and last of all the opening of "COMPAC" which has made international dialling between Australia and New Zealand a commonplace routine, one tends to concentrate on these present-day developments as being the most important events on the Australian telephone scene.

Readers of this Journal could well take time off to spare a thought for those more leisurely days towards the close of the last century when a few far-sighted pioneers laid down the foundations of the telephone system in this country. Without their vision and efforts, Australia could not hold the position in the communication world which it does today.

THE EARLY DAYS

Dr. Alexander Graham Bell invented his telephone in 1876 and the possibilities of having a network of subscribers instead of mere point-to-point communication were quickly realised. Within two years the world's first exchange was opened in New Haven, Connecticut in January 1878. Australia was well to the fore even in those days, and also in January 1878, long distance speech was transmitted between Port Augusta and Semaphore in South Australia. The following month a similar transmission took place between Melbourne and Ballaarat.

In 1880, Messrs. W. H. Masters and T. T. Draper (see Fig. 1) formed The Melbourne Telephone Exchange Company Limited, and on 12th May opened Australia's first telephone exchange in the old Stock Exchange building at 367 Collins St., a site now occupied by the Commonwealth Bank. The manager of the company was Mr. H. Byron Moore who was later known throughout Australia as Secretary of the Victorian Racing Club. Fig. 2 gives an artist's impression of the first exchange equipment, and Fig. 3 shows a copy of the first telephone directory issued by the company. Another early directory is shown in Fig. 4 and many of the names of these subscribers will be recognized as being still in business.

A letter from the manager of the company to one of his principals is reproduced in Fig. 5 and gives an outline of the development of the company after two years' trading. The number of subscribers had risen to 300 and the company was paying a dividend of 100%. This letter refers to the exchanges which had been opened at Ballaarat and Sandhurst (now Bendigo), and as a result of this venture the name of the firm was later changed to "The Victorian Telephone Exchange Company".

Late in 1884 the operations of the company were transferred to a new location in Wills St., a site originally occupied by the Government Lands Office. The new switchboard installed there is illustrated in Fig. 6. It is interesting to compare this illustration with Fig. 2, and to note that the earlier model bears a closer resemblance to present-day equipment than did the later installation. In the original switchboard the cords and plugs were arranged the same as today and the operator was equipped with a handset, whereas the later model used a wall type telephone and the connecting cords were suspended from an overhead rack.

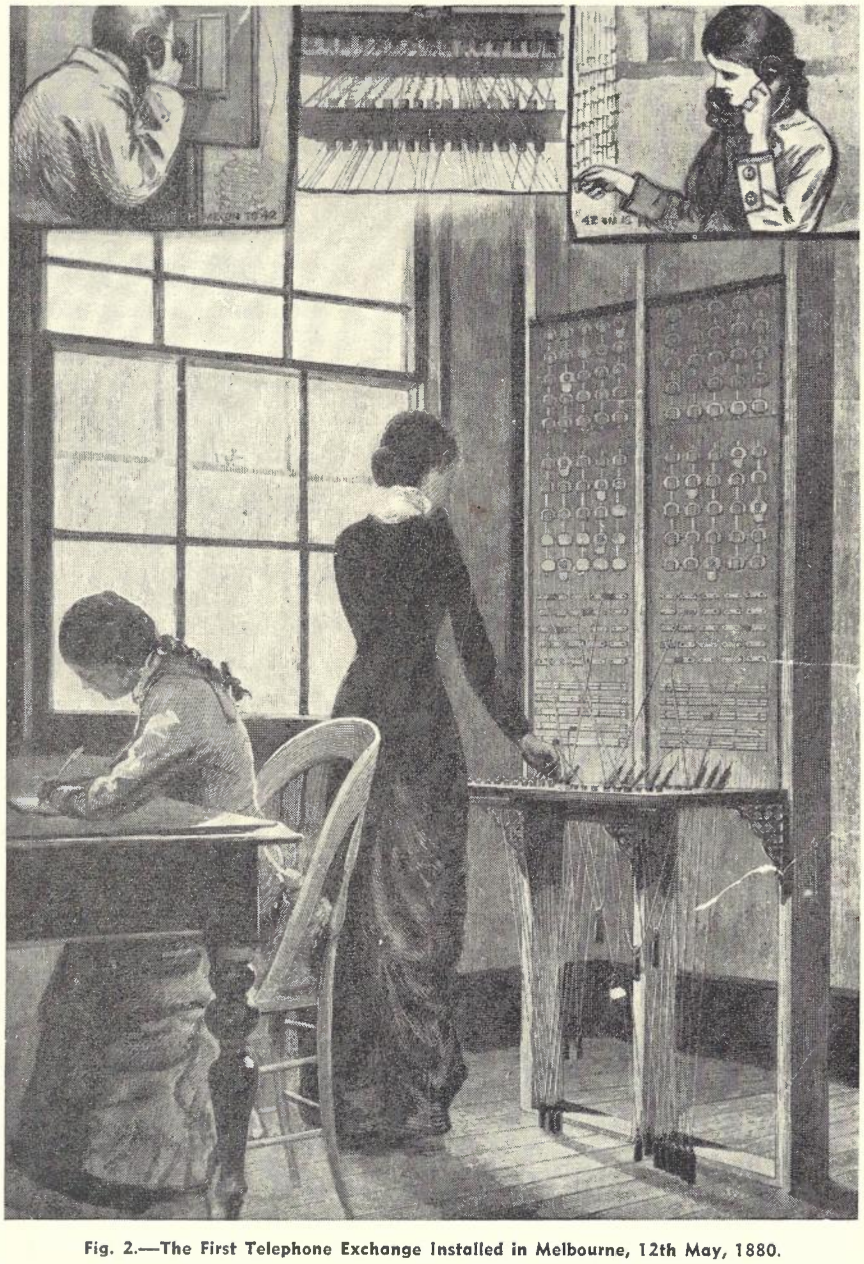

Fig. 2.—The First Telephone Exchange Installed in Melbourne, 12th May, 1880.

* See page 432.

Mr. T. T. Draper, Superintendent

Mr. W. H. Masters, Chairman

Fig. 1.—Founders of the Victorian Telephone Exchange Company Limited.

Mr. Thomas Theophilus Draper, Superintendent of the company, was born in London of Scottish parents in 1839 and landed with his family in Australia in 1854. Upon his arrival in this country he adopted the trade of builder and contractor and served a thorough apprenticeship in all its branches.

From an early age he took a deep interest in the science of electricity and his leisure hours were spent experimenting in that direction. He was responsible for lighting up the first building (the Public Library), and also successfully carried out the lighting of the Melbourne Cricket Ground on the occasion of a night football match. In association with Mr. W. H. Masters he introduced the diamond drill, the telephone in practical form, and the process of nickel plating. In 1884, he visited Europe, partly on account of his health and partly for pleasure. During his absence from the colony he inspected every telephone exchange of note from Colombo to San Francisco, and collected much valuable information, with a view to the extension of the telephone system.

Mr. William Henry Masters, Chairman of the company, was born in Canada in 1843. He was first employed as a message boy in a telegraph office, and later joined a firm of wholesale stationers in Buffalo, U.S.A., where he remained until the beginning of the civil war, in which he served from start to finish. After the war he joined a party which crossed the Rocky Mountains and was then employed in assisting to build a telegraph line to Port Saunders. In 1867 he returned to Guelph, Canada, where he was engaged in the manufacture of sewing machines. Two years later he was sent to Australia to introduce a special make of machine. He sailed from Liverpool in February in the iron ship Explorer (Captain Trimble). In the course of the voyage a collision occurred between the Explorer and a French barque from Buenos Aires, bound for Bordeaux. The French vessel sank in 15 minutes, the captain and four others being drowned. After a rough passage the Explorer reached Australia in June.

In 1873 Mr. Masters visited Europe and America and in 1880 in association with Mr. T. T. Draper instituted the first telephone exchange in the Southern Hemisphere.

—Illustrations and text from "Town and Country Journal", September 10, 1887.

The "Town and Country Journal" of September 10, 1887, described the exchange in the following terms:

"The premises occupy an area of 47 ft. by 124 ft., the site having been extremely well utilized by Mr. Lloyd Tayler, the architect. The exchange is a substantial brick building with cement dressings and cornices, and bluestone base. On the entablature is inscribed the title 'Melbourne Telephone Exchange', and above is indicated the fact that the institution was established in 1881. One of the features of the front of the building is the wide and high balcony through which the overhead wires are brought into the operating room. The triangle can now be dispensed with as the cables which hold respectively 25, 30, 50, and 100 wires can be carried underground.

Upon the ground floor of the telephone premises, opening on Wills St., are comfortable offices for the clerks, superintendents, etc. From behind the superintendent's office stairs lead up to the first floor of which

The Operating Room

occupies the greater portion, its dimensions being 71 ft. by 32 ft. and 14 ft. high. The operating room is not only a spacious apartment, it is splendidly ventilated and well lighted; and a capacious stove is provided for the cold weather. Leading out of the room at the far end are a neat refreshment room and a cloak-room, and adjoining the balcony are ante-rooms and lavatories. The operators stand up when attending to subscribers' calls, chairs being, however, provided for the leisure moments of the fair and nimble-fingered battalion of operators. There are in all twenty-four lady operators employed in the Exchange, the time-table being so arranged as to provide eleven always in attendance at the switchboard.

The hours of duty average six and a half a day. Three young ladies begin duty at 8.30 a.m., working till 2 p.m. Four are on duty from 9 a.m. to 5 p.m., others from 10 a.m. to 6 p.m., others again from 1 p.m. to 6 p.m. From 10 to 12 and 2 to 4 are the busiest portions of the day; attendants being on duty through the night, on Sundays and holidays.

Place yourself in the middle of the room and gaze upon the delicate hands in magic confusion playing as it were upon metal switches, plugs and switching cords. There is no shouting or even excitement — no apoplectic strain into the machine's mouth. The young ladies rarely turn their heads. There is a soft sighing murmur in the room; and one could easily imagine the spare forms to be automatic figures; and yet that little pouting delicate mouth is wrestling with the pangs, groans and tempers of 100 subscribers, that number being attended to by one lady operator, 'sectionised' all over the city and the suburbs. A telephone tells a person's character as surely as a sea voyage. A woman is quick to wrath when crossed in her

THE

EDISON-BELL TELEPHONES

ARE NOW IN CONSTANT USE BY THE FOLLOWING PARTIES IN MELBOURNE.

Messrs. Sands & McDougall; warehouse to factory.
" James McEwan & Co.; warehouse to yard.
" Robison Bros. & Co.; warehouse to foundry, Moray street.
The *Daily Telegraph*; office to Parliament House.
The *Argus*; office to Parliament House.
The *Age*; office to Parliament House.
Department of Public Works; Secretary's office to Water Accountant's office.
Messrs. W. Howard Smith & Sons; office to Australian Wharf.
Victoria Racing Club; office to race-course and Mr. Bagot's house, (Ascot Vale).
Victoria Sugar Company; office to refinery, (Yarraville.)
Messrs. Swallow & Ariell; warehouse to works (Sandridge).
John Danks, Esq.; warehouse to works, (Moray-street.)
Messrs. James Miller & Co.; warehouse to rope-walk.
" R. Goldsbrough & Co.; office to warehouse.
" Wm. Peterson & Co.; office to mill.
" J. Kitchen & Sons; office to works, (Sandridge.)
" David Alston & Co.; office to store.
" Felton, Grimwade & Co.; warehouse to factory.
" Fitzgerald & Perrins; store to brewery.
" Wm. Dean & Co.; warehouse to factory.
" Jas. Henty & Co.; counting house to residence of Hon. James Henty, (Richmond.)
H. Byron Moore, Esq., Melbourne; Exchange to Law Courts.
Messrs. L. Kitz & Son; shop to cellars.

Melbourne Telephone Exchange Company,
(LIMITED.)

THE EXCHANGE,

ALSO,
60 LITTLE COLLINS STREET EAST,
MELBOURNE.

Fig. 3.—The First Telephone Directory Issued in Melbourne. Date: June, 1880.

Melbourne Telephone Exchange Company
LIMITED.

H. BYRON MOORE, Manager.

LIST OF SUBSCRIBERS.

1. Robison Bros. and Co.
2. Exhibition.
3. James Henty and Co.
4. E. C. Waddington and Co.
5. Fanning, Nankivell and Co.
6. W. F. Dixon and Co.
7. Blake and Riggall.
8. W. W. Couche and Co.
9. Connell, Hogarth and Co.
10. Beath, Shiess and Co.
11. Wm. M'Culloch and Co.
12. H. Wertheim.
13. Dr. James.
14. James Service and Co.
15. E. Andrews.
16. Henry Francis.
17. Apollo Candle Company.
18. Jas. M'Ewan and Co.
19. W. H. Rocke and Co.
20. M'Lean Bros. and Rigg.
21. Swallow and Ariell.
22. W. B. Jones.
23. Alliance Insurance Co.
24. Newell and Co.
25. Liverpool and London and Globe Insurance Co.
26. Henry Moss.
27. Lyell and Gowan.
28. W. F. Walker.
29. Commercial Union Ins. Co.
30. Thos. Walker.
31. Commercial Bank.
32. Bank of Australasia.
33. John Zevenboom.
34. New Zealand Loan and Mercantile Agency Co.
35. Briscoe and Co.
36. Kitchen and Sons.
37. Wm. Sloane and Co.
38. F. W. Needham.
39. W. H. Masters and Co.
40. Mack and Ellis.
41. Superintendent's Office (Telephone Co.) 60 Little Collins-street East.
42. H. Byron Moore (Office).
43. H. Byron Moore, private residence, Ascot Vale.
44. Exchange.
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Fig. 4.—Melbourne's First 44 Telephone Subscribers.

enquiries, snaps bitterly, but has it all over in a moment; while a man in a passion switches off as if crazy.

What is

The Switch Board?

It looks like a pianoforte disembowelled and the marvellous manner in which its mysteries are utilised by the fair operators seems a poser to the onlooker. The switchboard is an intricate apparatus arranged in a most ingenious plan, by which the work of the operators is facilitated to the utmost possible degree. It is the famous 'multiple' board, manufactured by the Great Western Electric Company, of the United States, which has supplied similar apparatus to leading telephone exchanges in America and Britain. It embraces as many as seventy patents of which five are in the States in the name of Mr. J. C. Warner, constructing electrician to the Western Electric Company, under whose expert direction the Melbourne apparatus has been erected and set in good working order.

Exchange
21st March 1882

My dear Masters

As you will no doubt see our mutual friend Welles please kindly remember me to him and give him an a/c of our stewardship from our modest little list of seventeen subscribers in his day we have now nearly filled up to 300 and they are coming in so fast that it gives us all we can do to keep pace with the orders. In our second half year we divided 35% on our capital and at the last half yearly meeting we showed profits of over 100% not a bad beginning in a business which it is so difficult to oppose when one Exchange has got the start as we have. I believe we shall before long pay 200%. By the time the Government can buy us out (ten years) I think it will be quite good enough for us to sell. The capitalized value of such a business will run an actuary into big figures

I trust you will enjoy your holiday and pick up all the latest notions for us and you may depend upon Draper and myself running in subscribers by the dozen in fact if Ballarat and Sandhurst come up to the mark we will surprise

Wishing you a pleasant journey and a speedy return

I remain
Yours sincerely
H Byron Moore

W H Masters Esq

Fig. 5.—Letter from Mr. H. Byron Moore, Manager of the Melbourne Telephone Company Ltd. to Mr. W. H. Masters, Chairman of the Company, 21st March, 1882.

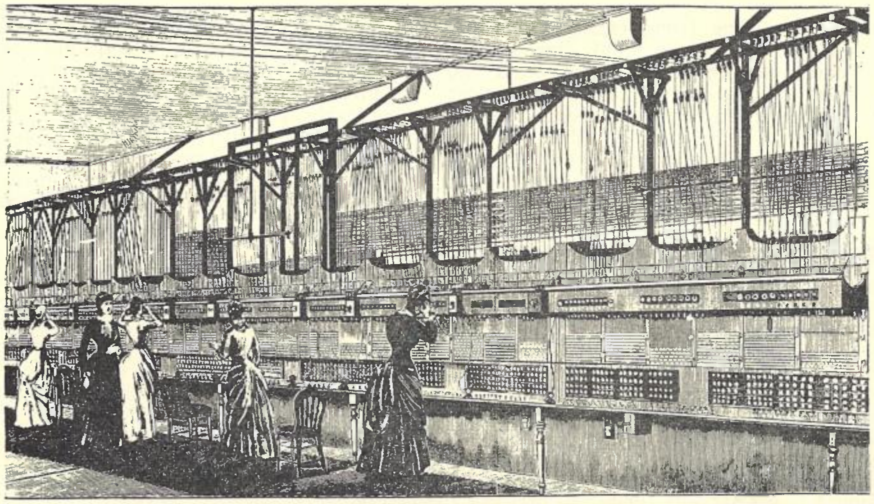


Fig. 6.—Switchroom of the Melbourne Telephone Exchange, 1886.

The frame is about 60 ft. long by 12 ft. in height, providing for 1,200 wires and adapted for 5,000 subscribers. Simplicity, speed and economy in work are the multiple attributes. The apparatus is fitted in an upright frame, in the lower part of which are placed small metal shutters. These are all numbered, and each subscriber has one attached to his wire. Above these are rows of metal switches resembling holes in the board, into which the plugs attached to the switching cords are inserted.

These switch holes are so arranged that each operator has all the subscribers at command, but only the calls of one section, 100 subscribers to attend to. The connections are made by means of covered wires, which look like thick cords. These are suspended from the top, and work up and down by means of small pulleys. A metal plug is attached to each end.

The operation is simply this: When a subscriber rings it causes the shutter to fall, and the number inside is exposed. Immediately, the operator puts the end of the switching cord into the corresponding switch. By pressing a small button on a sort of table in front, the subscriber's bell is rung. Then the number wanted is asked for, and as soon as it is given the other end of the cord is inserted in the switch of the required number. A second button is pressed to call that subscriber, and his ring in reply throws down a signal shutter (one of which is attached to every switching board); and they are then free to converse. When finished, a short ring from the subscriber who called first again throws the signal shutter, and the two are disconnected.

Negotiations have been carried on by the Government of Victoria and the company during the past two years, with a view to the

Sale of the Business

to the Government; and a satisfactory arrangement has at length been arrived at. The government recently agreed to pay £40,000 for the entire business and goodwill of the company, and it was arranged that the turnover should take place by September 1. The turnover included all the Company's patent rights (if any), all privileges and special discounts, or whatever other advantages it may enjoy; all subscriptions after September 1 to be the property of the Government. The Government also accepted the offer of the company to render all possible assistance to make the Telephone Exchange a success. For the present time the business of what is now the Government Telephone Exchange will be conducted in the company's premises, and in much the same way as hitherto. But the Postmaster-General will consult his officers as to what steps should be taken to connect the large centres of population in the colony, such as Geelong, Ballaarat, Sandhurst, and Maryborough, with the central exchange.

The Victorian Telephone Exchange was the first telephone exchange started in the southern hemisphere, and indeed, was brought into operation before any similar organisation in Great Britain. Mr. Draper (the present superintendent) has occupied that position since the creation of the exchange. Mr. W. H. Masters, the chairman of the company, shares with Mr. Draper the honour of having successfully carried out the enterprise."

At the time of the Victorian Government take-over in September 1887, the number of subscribers was 887 and the company had 21 employees. By the following year the number of subscribers had risen to 1,462.

Fig. 7.—Main Switchroom, First Floor, Central Telephone Exchange, Wills Street, 1908.

Before the Wills St. building was vacated, the growth of the system was such as to require the distribution of the equipment over three separate portions of the building. On the first floor was located the positions to which the Central subscribers' lines were connected. The second floor was occupied by the positions dealing with calls going to, or coming from, exchanges in the suburbs, whilst the trunk line switchboards, to which were connected the lines to the country exchanges, were installed in a separate room. Photographs of this new installation were taken in 1908 and are reproduced in Figs. 7 to 9.

By 1910, the development of the service at Wills St. necessitated additional accommodation which could not be provided in the existing building and arrangements were made to provide a new exchange in Lonsdale St. next to the Supreme Court buildings, and the change over to the new and up-to-date common battery equipment was made on 26th August, 1911. The original

Fig. 8.—Second Floor, Central Telephone Exchange, Wills Street, 1908.

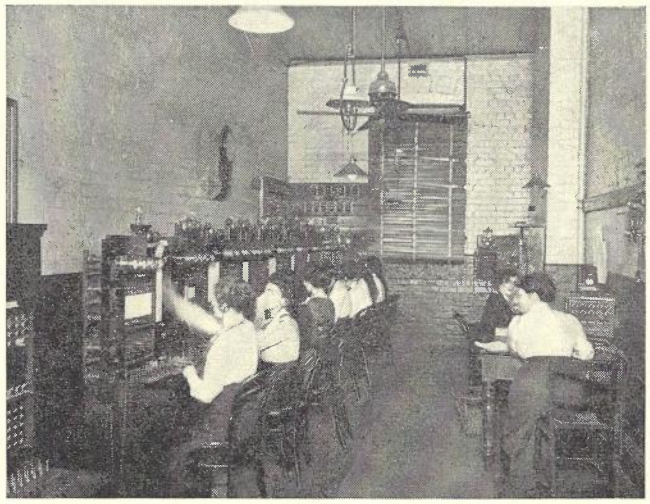


Fig. 9.—Melbourne Trunk Exchange, Wills Street, 1908.

Fig. 10.—A Recent Photograph of the Wills Street Telephone Exchange.

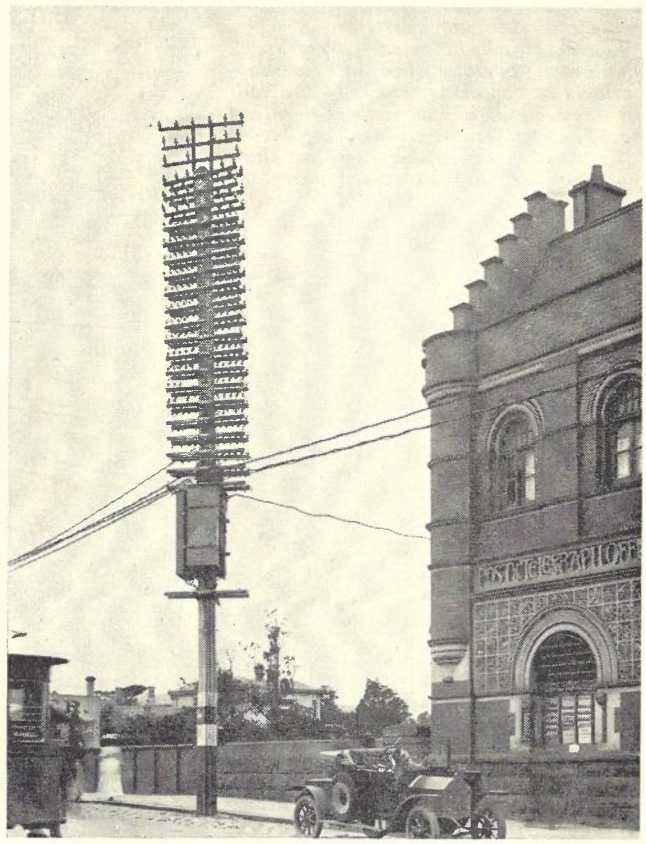


Fig. 11.—Aerial Construction Outside "Yarra" Exchange. Although this building is no longer used as an exchange, it still plays an important part in the Melbourne telephone story, as it houses the headquarters of the metropolitan traffic engineering division which is currently dealing with crossbar development in the Melbourne area.

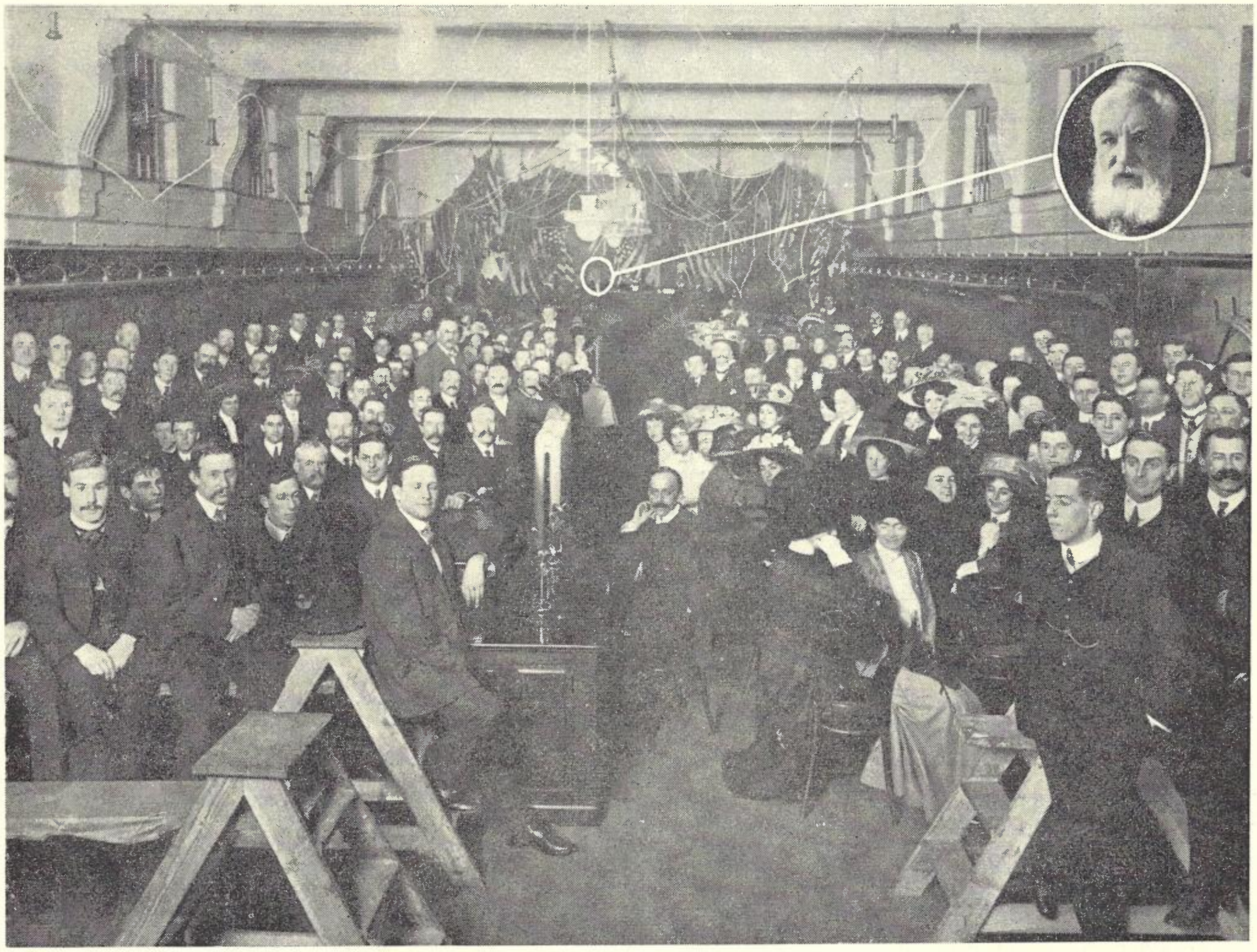


Fig. 12.—The New Central Exchange Lonsdale Street, on the Occasion of the Reception Given by the Postal Electrical Society, to Welcome Dr. Alexander Graham Bell, August 17, 1910.

exchange building in Wills St. is still owned by the Commonwealth and is occupied at present jointly by the Post-master-General's Department and the Commonwealth Lighthouse Service. A recent photograph is shown in Fig. 10.

The growth in telephone services which took place in the city around the turn of the century was matched by similar developments in the suburbs and by 1907 the following group of exchanges formed the metropolitan network:

Exchange	Subscribers
Central (Wills St.)	5,503
Ascot	246
Brighton	385
Brunswick	233
Canterbury	274
Cheltenham	83
Footscray	135
Hawthorn	980
Heidelberg	71
Malvern	880
Oakleigh	51
Williamstown	134
Windsor	1,268
Yarra	297
Total	10,540

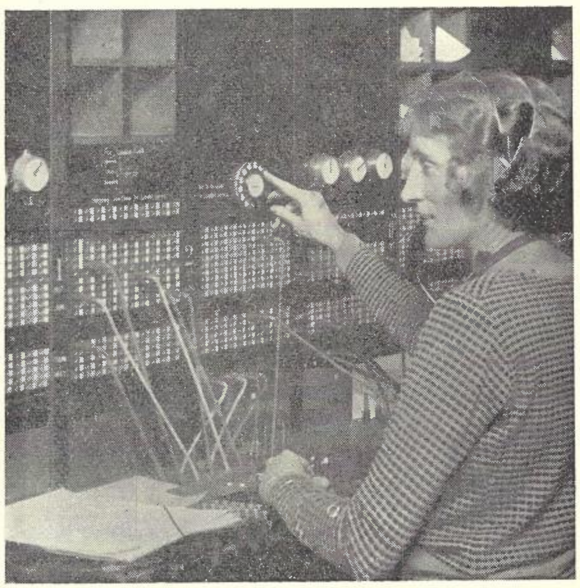


Fig. 13.—Overseas Trunk Position, Main Trunk Room, Melbourne, April 30, 1930, (Opening Day of Radio Telephone Service between Australia and Britain). The first commercial call was connected at 6 p.m. from London to Windsor 6872.

Fig. 14.—Geelong Automatic Telephone Exchange Installation Staff 1912.
Back Row: Messrs. S. French, W. Jarvine, J. Williams, T. Collins, A. Lee, H. Riley.
Second Row: Messrs. S. Lean, F. Hamilton, R. Gibson, B. Gibbons, A. Cook (Q'land), G. Middleton. C. Beissell.
Third Row: Messrs. G. Beard, W. Chrisfield, G. Green, W. Rickster (U.S.A.), Roberts (U.S.A.), Jones, T. Barton.
Front Row: Messrs. N. Green, F. Gowty.

The Yarra exchange (see Fig. 11) was short-lived, opening in 1907 but doomed to extinction in 1910 with the opening of the new C.B. exchange at Windsor. This installation heralded the advent of common battery systems which offered the great advantage of dispensing with the local batteries on the subscriber's premises. Following the opening of Windsor, new C.B. exchanges were also opened at Central and Hawthorn in 1911.

In 1910, Australia was honoured by a visit from Alexander Graham Bell, and a reception to welcome him was given by the Postal Electrical Society (now the Telecommunication Society of Australia) in the new Central Exchange which was being installed at the time. A photograph of this historic occasion is reproduced in Fig. 12.

TRUNK LINE PROGRESS

Early research into the problems of long distance communication led to the construction of the first commercial long distance telephone link between New York and Philadelphia in August 1885. Australia quickly seized on the possibilities of this new facility, and the first official trunk service in the colony opened in 1888 between Hobart and New Norfolk in Tasmania. The first intercapital services were established from Melbourne to Sydney in 1907, and from Melbourne to Adelaide in 1914. This inter-connection of three of Australia's largest cities compared favourably with progress in the United States, where a service between New York and San Francisco was not completed until 1915.

In 1926 the first international two-way radio telephone service was opened between New York and London, and the photograph reproduced in Fig. 13 shows the operator handling the Melbourne end of Australia's first international call from London to Windsor on 30th April, 1930.

THE AUTOMATIC ERA

Undoubtedly the most famous of all undertakers, Almon B. Strowger, patented his automatic telephone switch in Kansas City, Missouri, in 1891, and although some small automatic exchanges were operating in the U.S.A. by 1893, the automatic dial was not introduced until 1896.

In Australia the first automatic exchange was cut into service at Geelong at 11 p.m. on July 6, 1912. This was also the first automatic exchange in the Southern Hemisphere and the second in the British Empire; only the Epsom exchange in England preceded it. The new type of exchange, naturally enough, created a great deal of local interest. The "Geelong Advertiser", in a lengthy article describing the technical operation of the exchange, said: "Nothing could be nearer human; to see it work and grasp what it does, makes it look supernatural. It is so ingenious as to almost beggar complete description".

Figs. 14 and 15 show the staff employed on the installation of the Geelong exchange in 1912, and the laying of the first underground cable to the exchange.

The Geelong exchange had been in operation for almost two years before automatic telephony was extended to other States. The year 1914 also saw the opening of Melbourne's first automatic exchange at Brighton. Other installations followed and by 1930 automatic exchanges had been established at Sandringham, Malvern, Collingwood, Carlton, South Melbourne, Canterbury, Northcote, Elsternwick and Oakleigh. By now the network of metropolitan subscribers had reached a total of 68,000.

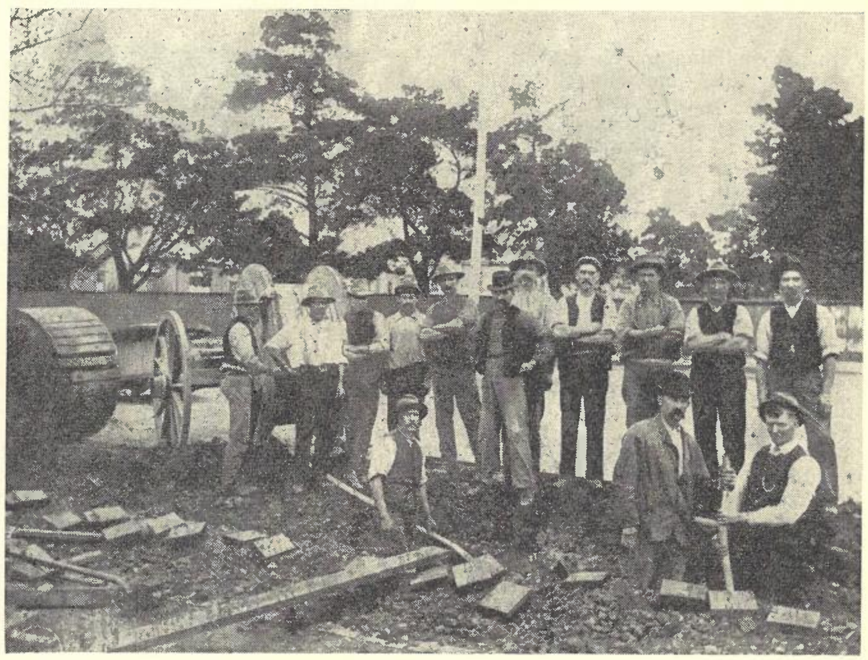


Fig. 15.—Laying the First Underground Cable Outside the Geelong Exchange, 1912.

During the twenties, attention was also being given to the problem of improving the service to subscribers in small rural areas, particularly where continuous service was not economical under manual operation. The Rural Automatic Exchange was the result, and the first of these units was installed at Vermont in 1926. The next year saw the installation of similar units at Springvale and Deer Park. These three exchanges have long since been absorbed into the Melbourne metropolitan network, but they were the forerunners of the hundreds of R.A.X.'s which have been established throughout Victoria and the other States.

FURTHER DEVELOPMENT DURING THE THIRTIES

Victoria took part in several other notable "firsts" during the decade leading up to the recent war. As mentioned previously the first overseas radio telephone call was successfully completed from London to Windsor in 1930. In 1935, Tasmania was connected to Victoria by submarine telephone cable. The cable was laid from Apollo Bay in Victoria via Naracoopa, King Island, to Perkins Bay near Stanley, Tasmania. Over a total distance of 161 nautical miles, it was the longest submarine telephone cable in existence. It was also the second carrier type submarine cable installed in the world.

Another achievement took place in November, 1937, with the cut-over of the Melbourne City West exchange which was the first installation of the new B.P.O. 2,000 type equipment. This represented a major development in automatic switching apparatus, and remained the Australian Post Office standard until the adoption of the S.E.50 switch in 1953, only to be replaced as the Australian standard five years later by the Ericsson crossbar system.

In 1938 two important events were the installation of Australia's first type J12-channel open wire carrier system to increase the trunk line channels between Melbourne and Sydney (this was the fifth 12-channel open wire system installed in the world and the first outside the U.S.A.); and the laying of a pair of underground trunk cables from Melbourne to Geelong. These cables were the longest underground cables of any sort in the Commonwealth.

1939 saw the introduction of Australia's first automatic trunk exchange using Siemens motor uniselectors. At the time of its installation this Melbourne automatic trunk exchange was the most up-to-date and largest of its type anywhere in the world.

CONCLUSION

From the very small beginning of almost 60 years before, the Melbourne metropolitan network had grown to 100,000 subscribers by the end of the thirties. The second 100,000 was achieved by 1952, and today's figures have doubled the total again. Numerous articles have appeared in this Journal, describing the rapid developments since 1945, and readers are referred to the index for the appropriate references which are too numerous to detail here. The developments in communications have been matched by developments in other fields. The comparisons shown in Figs. 16 to 18 are interesting as much from the view point of general progress as from that of communications, but Fig. 18 shows that some of the latest developments are perhaps not as novel as they now appear.

ACKNOWLEDGMENTS

The author would like to express apreciation of the assistance given by the Departmental photographic section for the reproduction of the various historical photographs presented; and also to Mr. D. Morrow of the Publicity section for his portraits of Messrs. Masters and Draper.

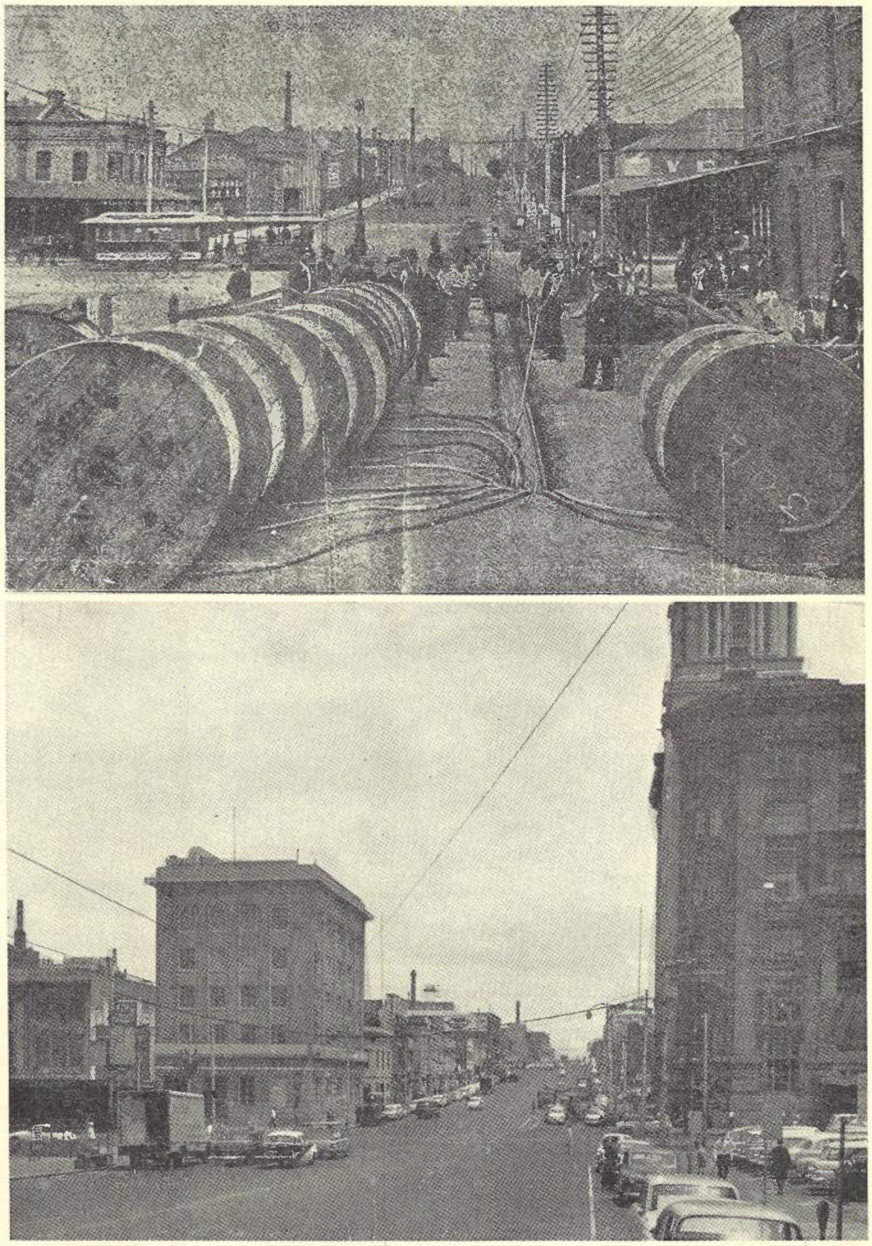


Fig. 16.—Upper—Laying of the first cable by the Department in La Trobe Street near the Elizabeth Street corner in 1898. Fourteen years earlier, Melbourne's first underground cable was laid in Queen Street by the Melbourne Telephone Co. Although difficult to see in the photograph the method of cable laying was to have the drum carried by a horse-drawn float which straddled the trench. Modern "mole plough" methods still use the same technique. Lower—The same corner today. The cable tram has given way to electricity, and the "Argus" office has replaced the old grocer's shop on the right. The skyline is still dominated by the chimney of the Royal Mint, but unfortunately the products of this establishment are less in evidence.

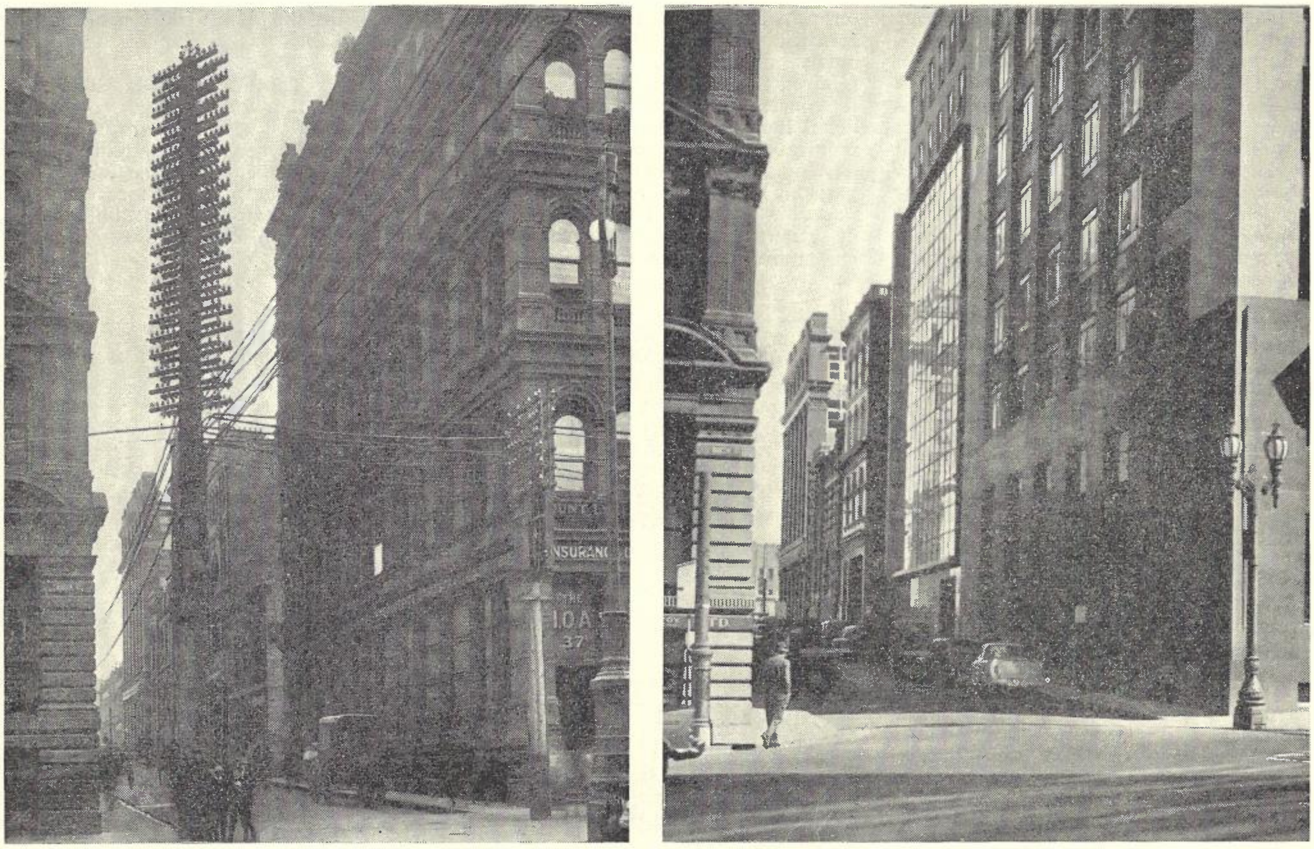


Fig. 17.—Left—A heavily laden pole on the corner of Flinders Lane and Queen Street. Right—The scene from the same viewpoint today. The glass fronted building on the right is the Batman Exchange.

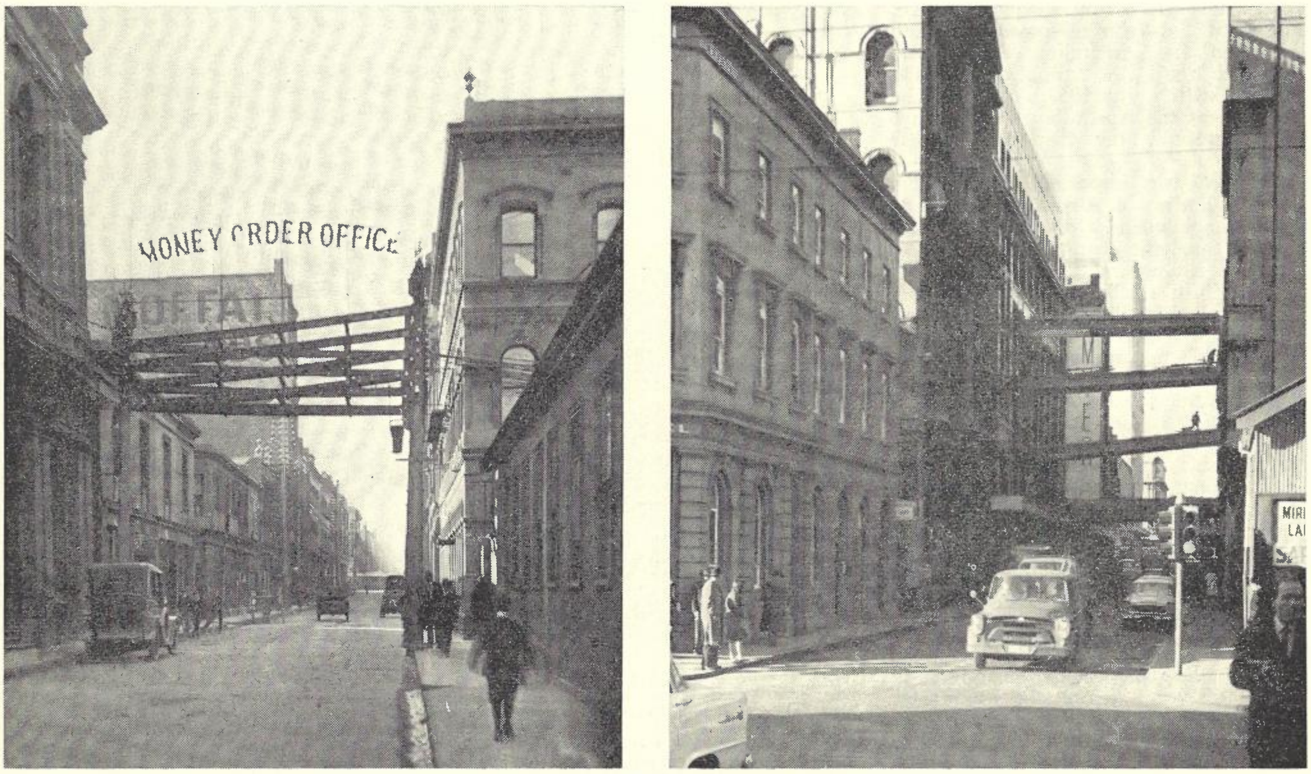


Fig. 18.—Left—Aerial telephone and telegraph lines in Post Office Place 40 years ago. Compare the "bridge" used for terminating the telegraph lines with that now being constructed over the same spot by the Myer Emporium (Right).

WORLD AUTOMATIC TELEPHONE NETWORK

*E. SAWKINS, B.Sc., A.M.I.E.Aust.**

INTRODUCTION

Remoteness has ceased to be the factor it was in influencing international affairs. When Australia was first settled 174 years ago, it took over 3,000 hours to travel from Great Britain. Today it can be done in approximately 30 hours and new airliners are being designed to do it in the order of 10 hours. Colonialism is rapidly becoming a thing of the past and continental countries and regional neighbours are drawing closer together. The European Common Market and the Malaysian movement are expressions of this. A recent meeting of the International Telecommunication Union (Plan Sub-Committee for Africa) held at Dakar in West Africa demonstrated the continental thinking of the nations of Africa as they face up to the need for international communications within Africa, in the past substantially provided only via European centres. In our part of the world too, Australia is drawing closer to its neighbours in South-East Asia, Asia generally, and in the Pacific.

Developments in telecommunications, whilst heightening the feeling of a shrinking world, also help to provide the means of coping with it. Technical advances in recent times have led to the emergence of a concept of vast significance, namely, the possibility of semi-automatic and automatic telecommunications on a global basis in accordance with an integrated world plan.

This concept has emerged from the successful laying and operation of the first long distance submerged repeater submarine telephone cable across the Atlantic in 1956—this is the TAT 1 cable. In the ensuing six years submerged repeater telephone cables have been laid in quick succession so that today there would be close to 20,000 miles in use, with firm proposals or work in hand to more than double this quantity. As would be expected, the main activity has been in the Atlantic Ocean and the North Sea, where at least seven cables are in service and a number in course of installation. Three cables are in service in the Pacific—U.S.A.-Hawaii, Australia-New Zealand (COMPAC) and U.S.A.-Alaska, and the following installations are in hand or in the late planning stage—New Zealand-Canada (COMPAC), Australia-South-East Asia (SEACOM) and U.S.A.-Hawaii-Japan-Philippines.

Before the successful introduction of the submerged repeater submarine telephone cable, long distance intercontinental communications were provided by means of radio; ring down double operator working was the normal procedure, and this allowed a country to develop its own individual telecommunications standards if desired. Semi-automatic or fully automatic working was impracticable because of the inherent instability of the radio circuits. With the advent of the new cable systems, compatibility for automatic inter-working between all national networks on an economical basis became the goal of the future.

Following the pioneering break through achieved by submarine cables—the oldest general form of long distance telecommunications—rapid advances in space vehicle design and space telecommunication techniques, culminating in the spectacularly successful 1962 Telstar experiment, have now shown that artificial earth satellites are also capable of linking continents and nations and cities with large numbers of high quality communication channels. The feasibility of world-wide automatic telephony is thus reaffirmed and intercontinental television relaying has become a new achievement.

It will be understood that from these developments the need arose for a plan setting out numbering, switching, signalling and transmission requirements for a world-wide automatic telecommunication network and also for a plan showing foreseen growth of international traffic and ways and means of best handling and routing this traffic. The International Telecommunication Union (I.T.U.) is the world forum for international discussions on such matters although international links are currently provided and operated by national and international bodies, either Government or privately owned. This article briefly describes the present organisation of the I.T.U. and summarises some of its activities in the development of the foregoing plans which, by resolution of the United Nations General Assembly, must now intimately be associated with the development and application of space communication systems.

THE INTERNATIONAL TELECOMMUNICATION UNION

Purpose

Consistent with its Convention, the International Telecommunication Union maintains and extends international co-operation for the improvement and rational use of telecommunications of all kinds. It also has a responsibility to promote the development of technical facilities with a view to increasing their usefulness and availability to the public, and to harmonise the actions of nations to this end. The responsibilities include the orderly utilisation of the radio frequency spectrum and the development of internationally accepted technical and operating standards associated with all means of telecommunications, both in relation to telecommunication system performance and national and international network performance. They include also assistance to new or developing countries in adapting their national telecommunication systems to those standards, and integrating them into the world-wide telecommunication network.

The Union had its origin with the founding in 1865 of the International Telegraph Union, which was expanded to include the new telephone service in 1885. The International Radio Telegraph Union was subsequently formed and the two Unions agreed to merge at conferences held concurrently in Madrid in 1932. Thus the International Telecommunication Union came into being. Generally speaking, all member countries of the United Nations are members of the Union. The Commonwealth of Australia has been a member since the earliest days of Federation (since 1903), and before this all the colonies held separate membership, South Australia joining first in 1878.

Organisation

Fig. 1 shows the organisation of the Union, of which the Plenipotentiary Conference is the supreme organ. It meets at intervals of about five years and its main task is to revise the International Telecommunication Convention if it considers this necessary, and to fix the Union budget for the interval between Plenipotentiary Conferences. The next meeting of the Plenipotentiary Conference is scheduled to take place in 1965—the year of the centenary of the Union.

In the intervals between meetings of the Plenipotentiary Conferences, the governing body is the Administrative Council, comprising 25 members of the Union. Australia is currently one of the Members of the Council as a representative of the Asiatic and Australasian Region (Region E). The other representatives from this Region are China, India, Iran, Japan and the Philippines. The Council meets annually and in addition to ensuring efficient co-ordination of the work of the Union, it is empowered to make policy decisions within the framework of the Convention and in conformity with the directives of the preceding Plenipotentiary Conference.

Members of the Union also meet at Administrative Radio Conferences which revise the Radio Regulations, taking into account the recommendations of the International Radio Consultative Committee (C.C.I.R.) and the recommendations of the International Frequency Registration Board (I.F.R.B.), and also at Administrative Telegraph and Telephone Conferences which revise the I.T.U. Telegraph Regulations and the Telephone Regulations, taking into account the recommendations of the International Telegraph and Telephone Consultative Committee (C.C.I.T.T.).

The Four Permanent Organs

The permanent organs of the Union consist of the General Secretariat, the International Frequency Registration Board (I.F.R.B.), the International Radio

* See page 433.

Consultative Committee (C.C.I.R.) and the International Telegraph and Telephone Consultative Committee (C.C.I.T.T.).

The General Secretariat: Apart from its responsibilities in the administrative area, under the direction of the Administrative Council, the General Secretariat administers the Union's technical co-operation programmes.

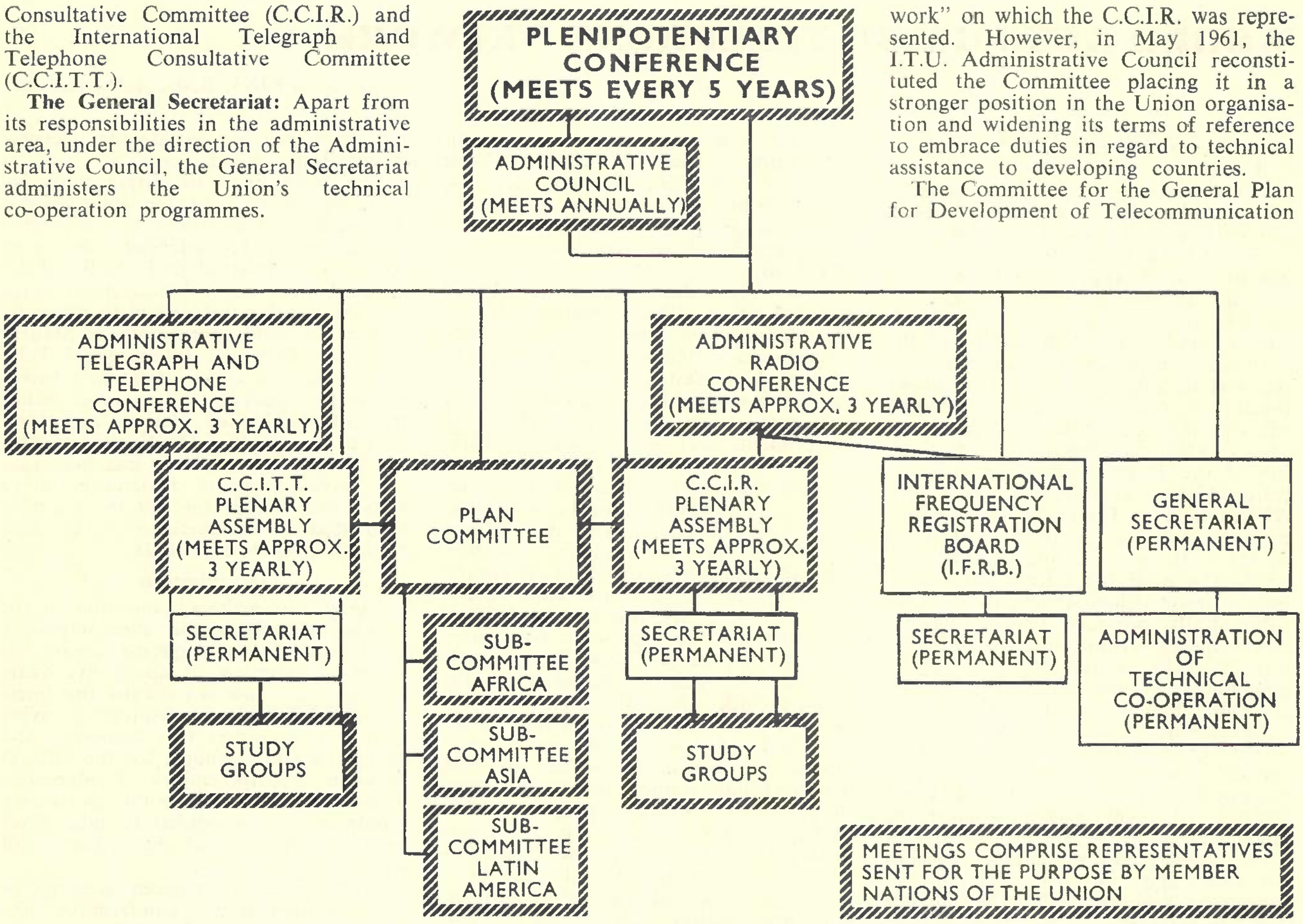


Fig. 1.—Organisation of I.T.U.

The International Frequency Registration Board: The I.F.R.B. consists of 11 independent radio experts, all nationals of different countries, elected by the preceding Administrative Radio Conference and working at the Union's Headquarters in Geneva. The Board is assisted by a specialised secretariat. It is responsible, among other matters, for the registration of frequencies, the study of the usage of the radio spectrum with the view to making recommendations for its more effective use, and the technical planning of radio conferences.

The Consultative Committees: The two C.C.I.'s are separate bodies. All Members of the Union can participate in their work and also certain manufacturers and private agencies operating telecommunication services. Each C.C.I. holds a Plenary Assembly at approximately three-yearly intervals. Usually a number of Study Groups meet first and draw up recommendations and new questions for study, which are submitted to the Plenary Assembly. Recommendations adopted by the C.C.I. Plenary Assemblies have an important influence with telecommunication scientists and engineers, administrations and operating agencies, manufacturers and designers of systems and equipment throughout the world.

All the Study Groups of the two C.C.I.'s consist of experts from Member countries of the Union so that their work and achievements are the results of the most advanced technical knowledge and experience in all fields of telecommunication. The work of the Study Groups continues between Plenary Assemblies by means of correspondence and through meetings, as necessary. Most Study Groups have established a number of Working Parties to investigate specially important questions and recommend solutions.

The **C.C.I.T.T.** studies technical and operational questions relating to telegraphy and telephony, and has 19 Study Groups.

The **C.C.I.R.** studies technical and operational questions relating specifically to radio communications, and provision is made within its 14 Study Groups for the study of questions of importance to the World Telephone Network, such as Propagation, Radio Relay Systems and Space Telecommunications.

There are two joint C.C.I.T.T./C.C.I.R. Study Groups, one dealing with noise and the other with television transmission.

The Plan Committee

Originally, this was a "C.C.I.T.T. Committee for the General Development Plan of the International Network" on which the C.C.I.R. was represented. However, in May 1961, the I.T.U. Administrative Council reconstituted the Committee placing it in a stronger position in the Union organisation and widening its terms of reference to embrace duties in regard to technical assistance to developing countries.

The Committee for the General Plan for Development of Telecommunication Networks (PLAN Committee) is now a joint C.C.I.T.T./C.C.I.R. Committee; it has associated with it three (also joint) regional sub-committees for Africa, Asia and Latin America. Europe is covered by the central Plan Committee. The Plenary Assembly of each C.C.I. determines representation, with the C.C.I.T.T. Plenary designating the Chairmen of the Committee and Sub-Committees, whilst the C.C.I.R. Plenary designates the Vice-Chairmen.

The Committee is responsible, either directly or through its regional sub-committees for:

(i) establishing a General Plan for development of the international network to help Administrations and recognised private operating agencies, when they conclude mutual agreements, to organise and improve the international services between their respective countries; and

(ii) examining the technical, operating and tariff questions raised either directly or indirectly in the various regions of the world by the application of the different stages of the Plan, to make an inventory of questions of interest to new or developing countries, and to set such questions for study by the competent C.C.I. or in co-operation with the two C.C.I.'s.

Close co-operation must exist between the two C.C.I.'s on the one hand and the Plan Committee and its regional sub-committees on the other hand. It might be said that the Plan Committee synthesises the specialised work of the two C.C.I.'s to assist member nations in their integrated planning. It will be noted from Fig. 1 that at the present moment there is no permanent secretariat associated with the Plan Committee and sub-committees.

Relation of the I.T.U. to the United Nations Organisation

On 15th November, 1947, the General Assembly of the United Nations acknowledged the I.T.U. as the specialised agency in the field of telecommunications. The Union operates with other specialised agencies, particularly with the International Civil Aviation Organisation (I.C.A.O.), the United Nations Educational, Scientific and Cultural Organisation (UNESCO), the World Meteorological Organisation (W.M.O.), and the International Maritime Consultative Organisation (I.M.C.O.).

WORLD-WIDE TELECOMMUNICATION SYSTEM PLANNING

World-wide Automatic Network

The 1959 Plenipotentiary Conference, recognising that many inhabited areas of the world do not enjoy the advantages of international telephony, instructed the Consultative Committees by Resolution No. 35, to continue joint studies with a view to recommending suitable means, having regard to technical and economic considerations, for linking to the world telephone network regions not yet connected thereto. In 1960, the C.C.I.T.T. recognised the need for a plan for world-wide automatic operation to facilitate effective and efficient application of new advances in communication technology. At the Plenary meeting in New Delhi that year, a special Study Group known as Special Committee B was set up to co-ordinate and oversight the preparation of recommendations which would lead to a plan for world-wide automatic telephony. Special Committee B was to use the resources of the existing Study Groups.

As mentioned earlier, these Study Groups comprise experts drawn from the Member Administrations, operating agencies and industrial organisations, and each is chaired by an Administration expert in the particular field of study concerned. The Study Groups of the C.C.I.T.T. cover all aspects of telephone planning, operation, standards, tariffs, and maintenance, and the majority of these Study Groups are involved to a greater or lesser degree in the planning for world-wide automatic telephony. These specialised Study Groups, together with Special Committee B, were requested at New Delhi to make as much progress as was practicable towards the formulation of a world-wide plan by the time the Third C.C.I.T.T. Plenary Assembly meets in March 1964 in Moscow. This will be a difficult time schedule to keep as a number of Study Group meetings are required and documentation involving questions, replies and distribution, takes about six months for each meeting.

It will be appreciated that the work on the world plan generally parallels on a global level the work that has been done in Australia in developing our national automatic network plan and which led to the adoption of particular switching and signalling standards in 1958/1959. Because of this and our understandable interest in securing reasonable compatibility between national and international standards, Australia has closely followed developments in this work.

All the C.C.I.T.T. Study Groups have a normal programme of work arising from the technical or operational subjects assigned to them but, in regard to the development of a plan for a global network, the Study Groups with the major responsibilities are as follow:

Study Group II (Telephone Operation and Tariffs) — Chairman, Mr. Terras, France. This Study Group is reviewing the operating procedures and suggesting modifications where necessary to allow for the introduction of semi-automatic working.

Study Group IV (Maintenance)—Chairman, Mr. Valloton, Switzerland. This Study Group is examining maintenance implications, both technical and operational.

Study Group XI (Signalling and Switching — Chairman, Mr. W. J. E. Tobin, U.K. This Study Group is preparing the technical specification of the signalling equipment and the boundary conditions required for the switching systems used on intercontinental circuits. In addition to the study of these intercontinental problems, Study Group XI has a function in the field of technical assistance. Following the Plenipotentiary Conference in 1959, at which the C.C.I.T.T. was given a responsibility for providing technical assistance of a documentary nature to new and developing countries, the New Delhi Plenary Assembly formed the Working Party on national automatic networks. This Working Party, which is dependent on Study Group XI, and is chaired by Mr. E. R. Banks, Supervising Engineer, Planning, of the Australian Post Office, has the task of preparing guiding principles on the planning and development of national automatic telephone networks and the selection of appropriate switching equipment.

Study Group XIII (Automatic Telephone Operation)—Chairman, Mr. M. Lambiotte, Belgium. This Study Group is working on the specification of the operating and signalling facilities required, the numbering plan, the routing plan, traffic engineering questions such as grade of service, and overall system service observation and maintenance standards.

Study Group XVI (Transmission)—Chairman, Mr. R. H. Franklin, U.K. This Study Group is developing the transmission plan.

Progress So Far

World-wide Numbering Plan: Study Group XIII (Semi-Automatic and Automatic Telephone Networks) has prepared a draft numbering plan, following discussions in Geneva in 1961 and Montreal in June of this year, which will now be circulated to Administrations for comment. In evolving this draft plan, the Study Group has made use of the main principles suggested in the numbering scheme contributed by Australia in 1960.

The general structure of the world-wide telephone numbering system as proposed is:

World Access Code*	+	Continental or Country Code	+	National Number
		1 digit	+	max. of 10 digits
		2 digits	+	max. of 9 digits
		3 digits	+	max. of 8 digits

* (This will not be standardised, being regarded as individual to each national system).

Normal world number length will be a maximum of 11 digits (12 will be permitted in some cases, notably European countries already using national numbers exceeding 9 digits and where a continental or country code of 3 digits is required).

Typical world numbers would be:

U.S.A.—

World Access Code	+	1 Continental Code	+	202 Washington Code	+	788 9527 Subscriber's number in the Washington area

United Kingdom—

World Access Code	+	44 Country Code	+	61 Manchester area code	+	349 5445 Manchester Directory number

Australia—

World Access Code	+	61 Country Code	+	2 Sydney area code	+	259 6363 Sydney Directory number

Each telephone subscriber would thus have an individual world telephone number. For example, in the final scheme, people in any other part of the world would dial the number shown above to get subscriber 259 6363 in the Sydney network.

World Switching Plan: Study Group XIII (Semi-Automatic and Automatic Telephone Networks) has also formulated a draft switching plan and at the recent Montreal meeting tentatively applied the plan to the world system to the extent which time and data available permitted. The main features of the proposed switching plan and details of the tentative application of it in Asia and Australasia as proposed by Study Group XIII are shown in Figs. 2 and 3.

The proposed switching plan uses principles currently accepted in national automatic switching practice. Three orders of switching centre—CT1, CT2 and CT3 (Centre de Transit), and automatic alternate routing are proposed. CT1 is the highest order centre—each CT1 would be directly connected to all other CT1's and would be the parent switching centre for a region of the world. It would switch final routes from CT2 and CT3 exchanges in that area. Similarly, the next order of centre, the CT2, would be a parent exchange switching the final routes of CT3 exchanges.

International exchanges would, therefore, be classified and interconnected by a network of final routes accordingly.

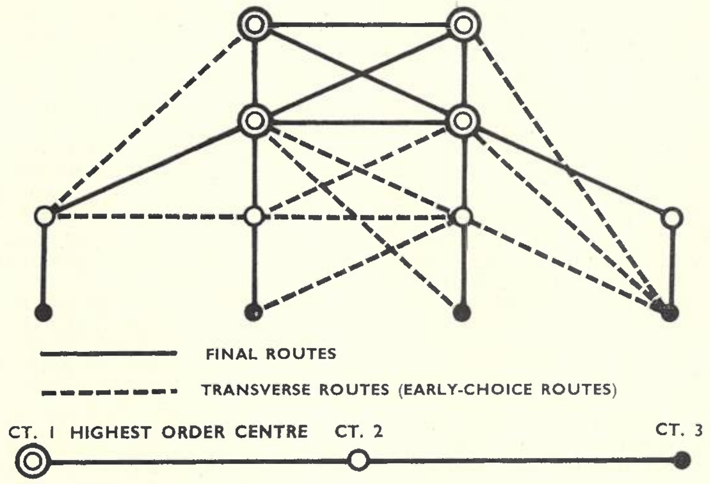


Fig. 2.—Typical Routing Pattern for World-wide Automatic Operation.

Superimposed on this final route system would be the network of early-choice (or transverse) routes shown by broken lines in Fig. 2. Early-choice routes would be provided between any two countries where warranted by traffic interest and economics. In traffic peaks their circuits would have a high traffic loading and excess traffic would be taken as overflow on the final route system.

Eight major telephone regions were selected by Study Group XIII for switching purposes. It was envisaged that each of these would have a CT1 and the following cities were tentatively selected:

Europe—London.
Far East—Tokyo.
Australasia—Sydney.
Africa — Not considered necessary to select the centre at this time.
Central and South Africa—Not considered necessary to select the centre at this time.
U.S.S.R.—As no Russian delegates were present it was not possible to make a decision.
India and West Asia—As no delegates representing the area were present it was not possible to make a selection.
North America—Agreement could not be reached at Montreal on whether there should be one CT1 or two for this region. The majority of delegates favoured one located at New York, but Canada also pressed the claims of Montreal.

Transmission Plan: Study Group XVI is reviewing the international transmission plan developed previously to meet the requirements for European working, and is preparing recommendations for intercontinental transmission standards. The greatly increased distances, the noise problem, the propagation time and the need for echo suppressors on intercontinental circuits are examples of the new problems being tackled.

Signalling Specification: Study Group XI has the responsibility to specify a signalling system, and to prescribe boundary performance standards for international exchanges. So far a study of the basic signalling problems has resulted in agreement that the line and information signals should be separate, that the line signalling should be link by link using a compelled sequence code of signals, and that the inter-register signalling system should use a multi-frequency code, each signal using two frequencies out of a possible six, thus providing 15 signals.

However, two important problems still require resolution:

(i) To what extent can the present "interim" signalling system in use on the TAT 1 cable and proposed for COMPAC and CANTAT, be adapted to meet the full facility requirements for intercontinental automatic working.
(ii) Should the standard specification require end to end or link by link inter-register signalling.

These questions are to be studied by a Working Party of Study Group XI in December 1962 and April 1963 and it is expected that decisions will be reached at the Melbourne meeting of the Study Group in October 1963.

C.C.I.T.T. Melbourne Meeting

It is necessary, prior to the Moscow Plenary in 1964, for the Study Groups to prepare and co-ordinate the results of their studies for the 1960/1964 period. At the invitation of Australia, Special Committee B and Study Groups XI and XII are to meet in Melbourne in October 1963 for this purpose and it will be the first time that a meeting of an I.T.U. Committee has convened in Australia. The meeting will last three weeks and it is expected that some 80 overseas delegates will attend from a total of 30 Administrations, agencies and industrial organisations.

WORLD-WIDE TELEX OPERATIONS

Parallel with the work proceeding on world-wide automatic telephony, progress is also being made with the preparation of plans for automatic telex operation, and passing reference is made here. A joint Working Party of C.C.I.T.T. Study Groups I (Telegraph Operating and Tariffs) and X (Telegraph Switching) has made recommendations on the form of the future system and the method of its development. The world-wide planning for telex is complicated by the present fairly high degree of development of international telegraph operation. The joint Working Party recommended that present direct inter-country operation continue and a separate world-wide transit scheme be developed using latest concepts.

SPACE COMMUNICATION SYSTEMS AND THE GLOBAL AUTOMATIC TELEPHONE NETWORK

Some survey of possible space communication systems now seems desirable before proceeding further to discuss their likely influence on world network

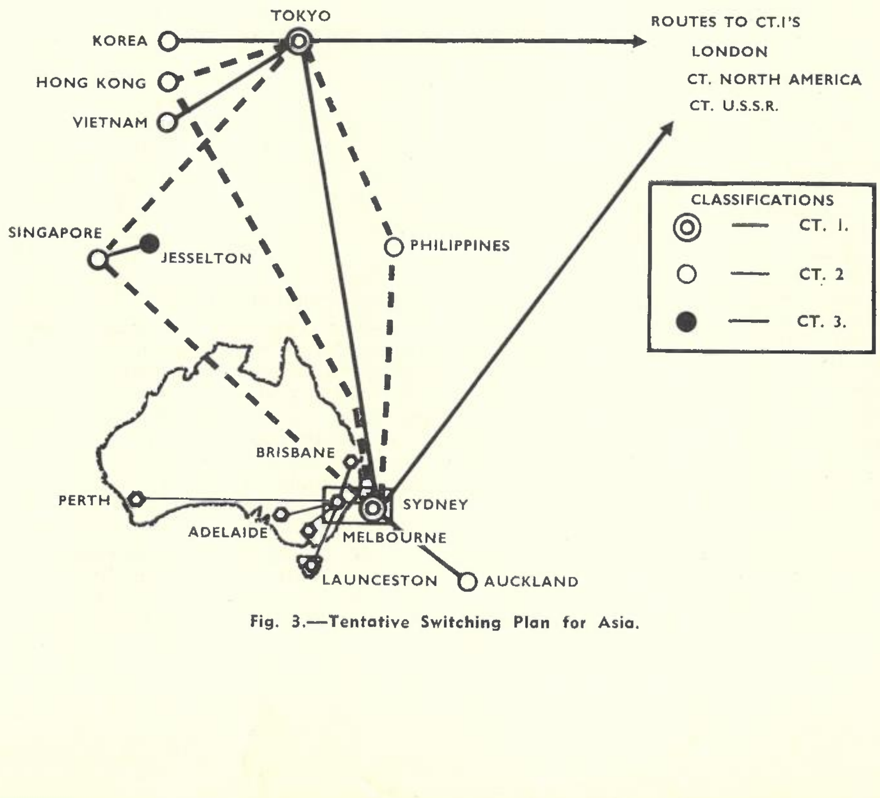


Fig. 3.—Tentative Switching Plan for Asia.

planning. As an introduction to this section, the activity of the I.T.U. in the space telecommunication field is first described briefly and special mention is made of the important United Nations Resolution referred to earlier.

The I.T.U. and Space Communications

Telecommunications is involved, and is essential, in practically all uses of outer space. It is of great importance in the operation of all types of space vehicles and in the exploration and study of celestial bodies. At the same time, space vehicles and systems will provide new telecommunication facilities for purely terrestrial requirements, new meteorological data to be used in improved weather forecasting and new navigational aid facilities for use by ships and aircraft.

The I.T.U. early recognised its responsibilities in this new field and its formal activities began shortly after the launchings of the first artificial satellites. In 1958, Study Groups of the C.C.I.R. formulated questions involving the protection of frequencies for the operation of artificial satellites. The Plenary Assembly of the C.C.I.R. meeting at Los Angeles in April 1959 established a new Study Group (Study Group IV) for space telecommunication problems with and between space vehicles. It also recommended the convening of an Extraordinary Administrative Radio Conference to allocate frequency bands for space radio-communication purposes, and the Administrative Council has now arranged for this to be held in October 1963. C.C.I.T.T. Study Groups are dealing with time delay and echo effects associated with very long transmission circuits and data transmission and these are of particular application in the study of communication via satellites.

The I.F.R.B. has special responsibilities in the technical preparation of the Extraordinary Administrative Radio Conference in 1963. It has requested the Administrations of the I.T.U. to furnish information on the frequencies used and the technical progress achieved in the use of telecommunications for space research purposes. Also, since the technical problem of frequency-sharing between new space telecommunication activities and the very great number of existing earth services (for example, microwave radio systems) is one which the Conference will have to consider most carefully, the Board has requested full particulars of the use which each Administration is making or expects to make of frequencies for all services in the band between 1 Gc/s and 10 Gc/s.

The work of the I.T.U. in space communications has been given added impetus and new status by a Resolution of the United Nations General Assembly—No. 1721 (XVI)—of December 1961, which, inter alia, included the following:

"The General Assembly

Believing that communication by means of satellites should be available to the nations of the world as soon as practicable on a global and non-discriminatory basis,

Convinced of the need to prepare the way for the establishment of effective operational satellite communication,

1. *Notes with satisfaction that the International Telecommunication Union plans to call a special conference in 1963 to make allocations of radio frequency bands for outer space activities;*
2. *Recommends that the International Telecommunication Union consider at this conference those aspects of space communication in which international co-operation will be required;*
3. *Notes the potential importance of communication satellites for use by the United Nations and its principal organs and specialized agencies for both operational and informational requirements;*
4. *Invites the Expanded Programme of Technical Assistance and the United Nations Special Fund in consultation with the International Telecommunication Union to give sympathetic consideration to requests from Member States for technical and other assistance for the survey of their communication needs and for the development of their domestic communication facilities so that they may make effective use of space communication;*
5. *Requests the International Telecommunication Union consulting as appropriate with Member States, the United Nations Educational, Scientific and Cultural Organisation, and other specialized agencies and governmental and non-governmental organisations, such as the Committee on Space Research of the International Council of Scientific Unions, to submit a report on the implementation of these proposals to the Economic and Social Council at its thirty-fourth session and to the General Assembly at its seventeenth session;*
6. *Requests the Committee on the Peaceful Uses of Outer Space, as it deems appropriate, to review this report and submit its comments and recommendations to the Economic and Social Council and the General Assembly."*

This Resolution was considered at the Administrative Council meeting of the Union early this year and Australia chaired the Drafting Committee which prepared the first report to the United Nations General Assembly and to the Economic and Social Council. This sets out the reaction of the Union to the Resolution, the work already being carried out within the Union in the field of space communications, and explains how the Union feels it can best satisfy the requirements of the Resolution.

The Resolution was concerned essentially with peaceful uses of outer space and in this context no mention is made of submerged repeater cables or the part they might play in achieving the United Nations' objectives in telecommunications. A careful study of the part of the Resolution quoted will reveal its far-reaching implications (as an expression of United Nations feeling) on any possible plans for a global automatic network. Not the least of the implications is the urgency which it conveys in the formulation of national telecommunication requirements and the development of national networks which will fit into a world plan. As a result, the work of Mr. Banks' Working Party on National Automatic Networks assumes increased urgency.

The Resolution carries the inference that the United Nations is specially interested in nations which are underdeveloped telephonically and for whom a space system requiring relatively inexpensive ground stations and capable of working economically with a small group of channels only, would seem to be required. The emphasis given to the development of national networks and new international links could, in the future, cause increases in world traffic which otherwise might not be foreseen and could produce a degree of decentralisation in international switching not necessarily justified by economic considerations.

The Resolution places new weight on the responsibilities of the Plan Committee and the regional sub-committees as these would appear to be the appropriate bodies to study the use of space systems in a world switching plan.

Australia has played a part in the work of the Plan Asian Sub-Committee and has had delegations at the Tokyo meeting in May 1959 and the New Delhi meeting in November/December 1960. At the present time, basic data is being assembled showing existing and predicted (1968) telephone and telex traffic and existing and proposed main telecommunication systems which could be used for international traffic in Australia and to connect Australia to other countries, in preparation for the next meeting of the Plan Asian Sub-Committee scheduled to take place in New Delhi in February 1963. Australia contributes financially to the technical co-operation programmes of the United Nations and makes experts (including telecommunication experts) available when possible to work in Member countries.

In the light of the United Nations Resolution No. 1721 (XVI), it is of special interest to note the passage on 31st August, 1962, of the "Communications Satellite Act of 1962" by the United States Congress. The stated aims of this Act, as quoted from the preamble to the Act, are:

"(a) *It is the policy of the U.S.A. to establish in conjunction and in co-operation with other countries, as expeditiously as practicable a commercial communications satellite system, as part of an improved global communications network, which will be responsive to public needs and national objectives, which will serve the communication needs of the United States and other countries, and which will contribute to world peace and understanding.*

(b) *The new and expanded telecommunication services are to be made available as promptly as possible and are to be extended to provide*

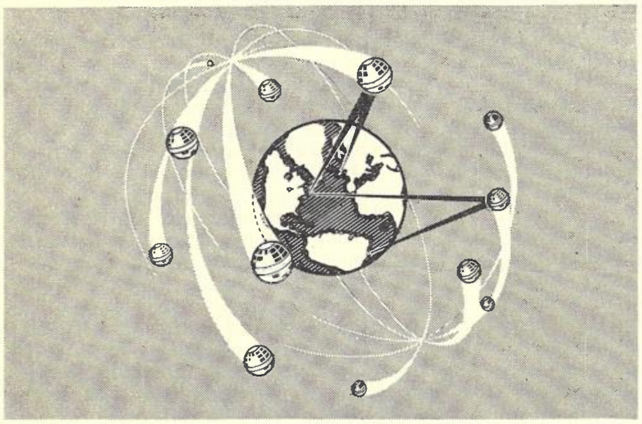


Fig. 4.—Random Polar Orbits.

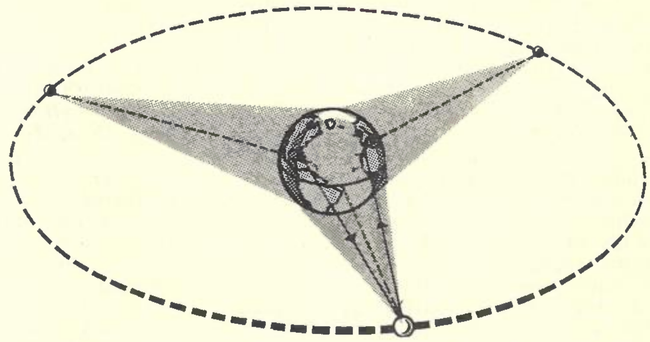


Fig. 5.—Synchronous Orbits.

global coverage at the earliest practicable date. In effectuating this programme, care and attention will be directed toward providing such services to economically less developed countries and areas as well as those more highly developed, toward efficient and economical use of the electro-magnetic spectrum and toward the reflection of the benefits of this new technology in both quality of services and charges for such services."

The United States participation in the global satellite system is to be in the form of a private corporation, subject to appropriate governmental regulation. It is intended that all authorized users shall have non-discriminatory access to the system.

Subsequent to the United Nations Resolution No. 1721 (XVI) the C.C.I.R. Study Group on Space Systems (Study Group IV) met in Washington in March 1962 and a number of important recommendations were drafted on technical questions concerning space telecommunications.

The principal subjects examined by the Study Group were:

(a) Telecommunication systems between fixed (and mobile) earth stations using earth satellites as relays. Direct broadcasting from earth satellites.
(b) Technical characteristics of earth-space and space-space telecommunication systems.
(c) Satellite systems for navigation and meteorology.
(d) Radio-astronomy.
(e) Propagation and noise.

Types of Space Communication Systems

Three types of system currently under consideration are demonstrated in Figs. 4, 5 and 6. Fig. 7 shows the application of one within the framework of the draft switching plan.

Fig. 4 shows a system using satellites in random polar orbits as envisaged by the A. T. & T. Company of America, of which the current Telstar satellite is the first experimental trial of a component of such a system. Consideration of the heavily loaded route across the North Atlantic between points of fairly high latitude, and a realisation of the difficulties of station-keeping in polar orbits, apparently influenced the A. T. & T. Company in 1960 to conceive this plan using 50 satellites in random polar orbits. The advantages and disadvantages of such a system are briefly as follow:

Advantages—
(a) It provides coverage to all points on the surface of the globe.
(b) Available accuracy of rocket guidance techniques is adequate for injecting the satellites of the system into orbit.

Disadvantages—
(a) The service from any one point would not be continuous. The duration and time of occurrence of transmission breaks would, however, be predictable. In order to obtain a nearly continuous service (99.9%) a large number of satellites (50) would be required.
(b) Ground station aerials would be required to have high accuracy, all-direction, tracking capabilities.

Fig. 5 shows a satellite system with three satellites spaced at 120° intervals in an equatorial orbit. The orbit height is approximately 22,300 miles at which height the orbital period is 24 hours, that is each satellite would appear to remain above one spot on the earth—hence the term stationary or synchronous orbit. Advantages and disadvantages are summarised briefly as follow:

Advantages—
(a) Only three satellites would be required to cover the populated areas of the world. (There would be no coverage over small areas near the Poles.)
(b) Ground station aerial tracking requirements would be very simple—it would only be necessary to make small directional adjustments to compensate for movements of the satellites from their correct stations.

Disadvantages—
(a) A single hop transmission would result in a one-way transmission delay of at least 250 milliseconds. Two-hop transmission would be required for many world-wide connections and for these the resultant one-way transmission delay of 0.5 seconds may well be unacceptable for telephony.
(b) Currently available rocket capacities impose a stringent limit on the weight of a satellite that could be launched into synchronous orbit.
(c) Because of orbit perturbations arising from the gravitational attraction of the sun and the moon, station-keeping and attitude control may be complicated at synchronous altitudes.

The main application of this system appears to be for television and other forms of unidirectional transmission. In this regard, it is of interest that Japan is investigating the possibilities of using this system for relaying the 1964 Olympic Games from Tokyo. The proposal involves the use of Japanese developed satellites to be launched by the United States National Aeronautics and Space Administration.

Fig. 6 is an artist's representation of a system using 12 station-keeping satellites in equatorial orbit at medium altitude; it is currently favoured by British Commonwealth experts. The advantages and disadvantages of this system are briefly as follow:

Advantages—
(a) Because of the uniformity of the gravitational field in the equatorial plane at medium heights, station-keeping would be simplified and passive attitude control would be possible.
(b) An appropriate choice of orbit height could fix effective orbital time as a sub-multiple of 24 hours, thus resulting in a regular appearance of satellites. This would simplify satellite switching.
(c) All satellites in the system would follow nearly the same apparent track as viewed from each ground station so that simplified ground station aerial tracking would be possible.
(d) Two-hop transmissions would be possible without exceeding permissible limits of transmission delay for telephony.

Disadvantages—
(a) Does not give continuous coverage to high latitude areas. This can-

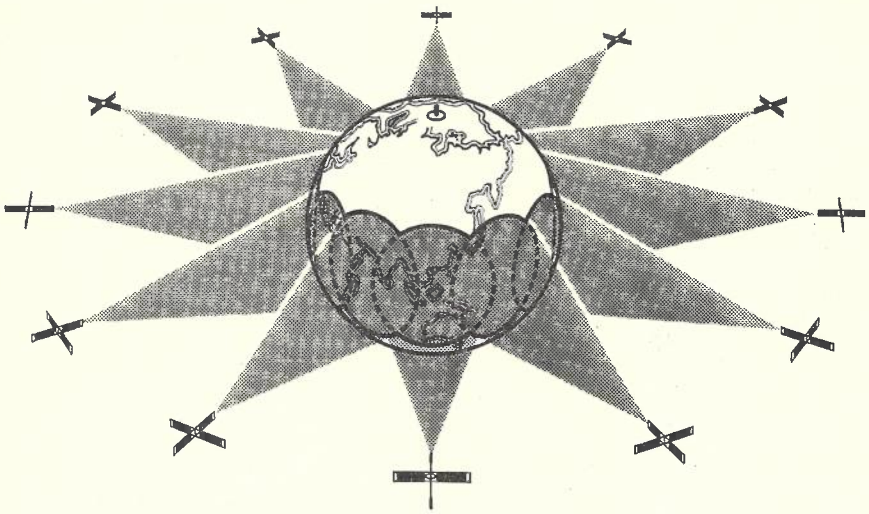


Fig. 6.—Equatorial Orbit System.

not be overcome completely by increasing orbit height because heights greater than about 10,000 miles give excessive transmission delay for telephony, where two-hop satellite transmission is involved. Two-hop transmission is required for some links in any world-wide system.

Fig. 7 shows a satellite system of this type combined with landline systems to interconnect CT1's in a world-wide switching plan of the type described earlier. The satellite scheme shown uses 12 satellites in station keeping circular orbits at a height of approximately 8,600 miles. The apparent orbital time as seen by a ground observer is 12 hours so that the same satellite will appear regularly over the same place on the ground twice per day, and switching from one satellite to the next by each ground station will be required regularly once per hour.

The scheme would provide for Sydney, Tokyo, London, Moscow, New York and Montreal, all to communicate directly with each other over a one- or two-hop transmission path via satellite. In this scheme, one-way transmission delays up to about 250 milliseconds would occur. By comparison there would be a total one-way transmission delay of approximately 180 milliseconds on a call from London to Singapore via the Atlantic, Pacific and SEACOM cables, the trans-Canada microwave system and the Sydney-Cairns microwave and coaxial cable link as planned. In the scheme illustrated, intermediate ground stations have been introduced at Karachi, Honolulu and San Francisco. These points would then achieve a rating of CT2 in a world-wide switching network. Once established, such a scheme is flexible, for example, main centres in Africa could easily be served if it were desired to do so.

The scheme as outlined does not attempt to make full use of the satellite system and by sharing the bandwidth available, each satellite could work with, say 10 ground stations simultaneously, and direct connections between many centres could be arranged in addition to the CT1-CT1 links.

Impact of Space Communication Systems on Global Automatic Network Plan

Any network plan needs to be based on a knowledge of the actual capabilities of available communication systems—both transmission and switching—with economic implications being kept closely in mind. Conversely, the capability of known systems is one of the parameters controlling the network plan.

Nevertheless, as plans tend to become out-of-date as soon as they are prepared, they must be sufficiently flexible to achieve two things:

(a) be capable of embracing any new technological development that can be judged to be in the offing or possible in the future.

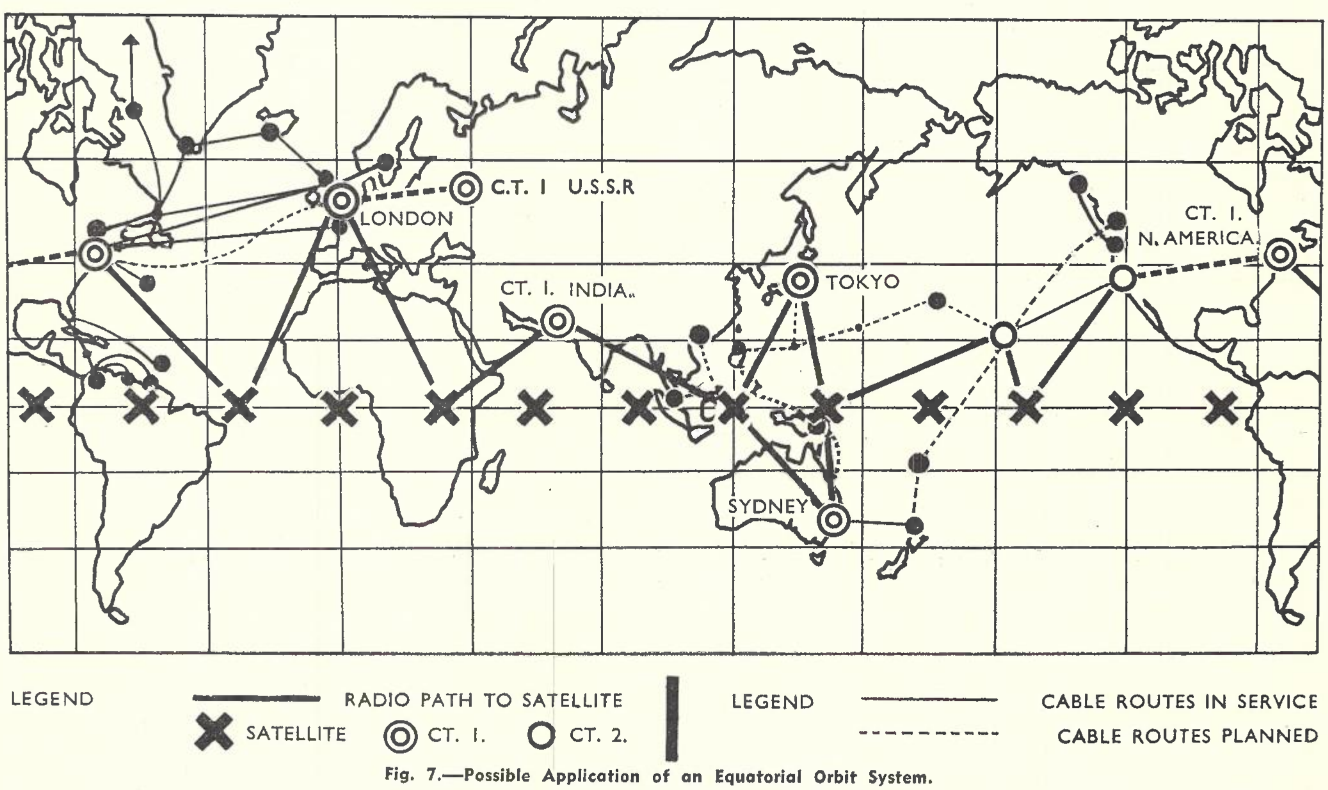


Fig. 7.—Possible Application of an Equatorial Orbit System.

(b) be capable of coping effectively and without redundancy with continually increasing traffic or a changing pattern of traffic.

To date, the development of the plans for a global automatic network has necessarily been based on currently accepted principles and on the availability of the new long distance telephone cables. However, space communication system engineering is probably approaching the stage where it may be possible to make some interim assessment of facilities possible, of reliability, and of cost structure.

As yet it is difficult to foresee the relative place of submerged repeater cable systems and space systems in the global network although it is fairly obvious that there should be plenty of room for both. The cables are, relatively speaking, a known factor but capable of being developed to carry greatly increased bandwidth and capable no doubt also of lower cost of production, as this is the trend of new developments. The space system is still, relatively speaking, an unknown factor, but with immense possibilities. It is possible that basic national considerations and political considerations will obscure the true relativities in performance and cost for some years to come.

Submerged repeater telephone cables are conventional in their application, being essentially usable only along a defined path, but a space communication system will offer a universal relay facility capable of providing simultaneously a number of separate bi-directional links. The universality of the system can be further extended through sharing of the total bandwidth available. A transmission system with a new dimension will thus be introduced to network planners and when practicable this will require some re-examination of the currently accepted routing concepts for most economical handling of network traffic.

Some significant conclusions that can already be drawn as to the effect of space telecommunications on a world switching plan are as follow:

(i) The provision of large blocks of satellite channels, available on a point-to-point basis between ground stations, will greatly increase the extent of "direct" routing in the world switching plan.

(ii) There will be a corresponding reduction in the extent of overflow and transit routed traffic which will reduce the significance of international CT switching centres.

(iii) A co-ordinated world network will always be necessary—

(a) to switch traffic carried on submerged repeater cables and other international systems and integrate this as necessary with traffic carried on space systems;

(b) to switch traffic for centres without ground stations;

(c) to amalgamate small amounts of traffic into sufficiently large entities to utilise efficiently the minimum size channel blocks which, in the light of the ground space station costs, can economically be justified with satellite working.

(iv) It follows from (iii) that major communication centres in a world network, in particular CT1 centres, should have joint access to both cable and space systems.

(v) With the diversity of switching paths available in a satellite system it will be possible, when justified under conditions of heavy load, to exploit the changing traffic patterns which occur with changing coincidence of daylight hours; for example, in the morning busy hour, Sydney-Tokyo circuits could be augmented by inter-connecting at Singapore idle Singapore-Sydney and Singapore-Tokyo circuits. This would mean time-switching of circuit blocks in the three centres. (A certain amount of this type of flexibility would be inherent in a submerged repeater cable system following an East-West direction.)

(vi) The alternative paths available on two-satellite connections will contribute to the reliability of intercontinental calls; for example, Sydney-San Francisco traffic could be divided between different paths, using either Wellington or Honolulu as the intermediate ground station. If this were arranged on a time-switched basis, further traffic efficiencies could be achieved.

(vii) A space telecommunication relay facility fully loaded on one section of its service path (for example, across the North Atlantic) may have considerable spare capacity in other sections (for example, in the Southern Hemisphere) and this capacity may be offered to users at attractive rates. Such a situation could strongly influence the world pattern of traffic flow.

(viii) Where large traffic loads are involved (and where alternate routing facilities are not provided), parallel routing facilities of a different nature need to be available to avoid a complete breakdown of service in the event of a major failure. This could well bring about the same relationship between submerged repeater cables and space systems as already exists with some land based coaxial cable and microwave systems.

AUSTRALIA AND SATELLITE COMMUNICATION

The British Commonwealth has long held a leading role in world communications. It was to be expected therefore that the countries of the Commonwealth would collaborate to investigate the effect on their interests of this new technique. Early in 1961, Britain, following an agreement with the U.S.A. authorities to participate in trans-Atlantic tests of American satellites, built up a research and development team which has been joined by men from Australia, Canada and New Zealand. One of the results of this group's work—the Goonhilly Downs ground station—is described in another article in this Journal.

The Commonwealth Telecommunications Board studied the implications of satellite communications during 1961 and drew the attention of partner Governments to the need for an early exploratory meeting. Such a meeting, convened by the British Government in London, took place in March 1962 and examined the possibilities and advantages of satellite communications for Commonwealth purposes, and recommended the opening of talks with the United States and European countries with a view to collaboration. The results of the London meeting have been submitted to the partner Governments for their consideration.

In the meantime, in this country, a Liaison Committee comprising representatives of the Postmaster-General's Department, Department of Supply and The Overseas Telecommunications Commission (Australia), has been set up to facilitate the exchange of information and views. There are, under the control of the Department of Supply, Mercury tracking facilities at Woomera in South Australia and Muchea in Western Australia, and Deep Space observation facilities at Woomera.

CONCLUSIONS

The vision of a world-wide automatic network opened up by the successful introduction of the new submarine cables has been strengthened by the rapid advances being made with experiments in space communication systems.

The U.S.A. and the U.S.S.R. seem committed to huge programmes of space experiments and a seeming by-product of this—at least in the case of the U.S.A.—has been the intensive development work on space communication systems. Other nations, including Great Britain and the Commonwealth partners, are also active.

A space system needs to be shared with many users and the first system meeting commercial requirements is likely to have a profound effect on world telecommunications. Through the International Telecommunication Union, nations are co-operating voluntarily in order to apply new advances in technology to their mutual advantage. Progress by seeking out common ground for agreement is slow work, but very sure, and results are lasting. The Union operates in a field where there are major investment interests and technical issues can become confused at times, but a measure of the success it has achieved over 97 years is the willingness and energy with which its members continue to face up to the great new problems of the day.

Only time will tell whether the work of the Union on the world plan will be limited to the specification of a network plan and whether this plan will initially encompass in a realistic way the utilisation of space systems, or whether the Union will also play an effective role in guiding the practical application of the plan to world needs in the interests of all nations, great and small.

The answer might well be foreshadowed by the measure of support given to the Plan Committee and Sub-Committees of the Union in the immediate future. Following meetings of the Sub-Committees in their regions, the Plan Committee is at present due to meet either prior to or concurrently with the C.C.I.T.T. Plenary Session in Moscow in March, 1964.

BRITAIN'S NEW SATELLITE COMMUNICATION STATION

R. E. HILL, Assoc. Brit. I.R.E.

EDITORIAL NOTE: This article is substantially a reprint of an information bulletin kindly made available by the United Kingdom Information Service. It is published because of the general interest of satellite communications to readers, and a contribution made by an engineer of the Postmaster-General's Department to the project described.

INTRODUCTION

The equipment of the British Post Office ground station at Goonhilly Downs, Cornwall, England, was completed on 1st July, 1962, one year from the date of obtaining access to the site. The station is all-British in design and manufacture with the exception of a high power transmitting valve obtained from the U.S.A. The team of British Post Office engineers engaged on this project was augmented by Australian and Canadian engineers.

The first experimental communications satellite, Telstar, developed by the American Telephone and Telegraph Co. was launched successfully by the United States National Aeronautics and Space Administration on 10th July, 1962. The Telstar satellite, which is 34½ inches in diameter and weighs about 170 lbs., was placed in an elliptical orbit inclined at about 45° to the equator (1). The maximum distance from the earth's surface is about 3,500 miles and the orbital period about two and a half hours, giving a maximum period of mutual visibility of approximately 30 minutes between ground stations in the United States and Britain. The Telstar satellite and the Relay satellite, to be launched later in 1962 by the National Aeronautics and Space Administration, are both of the active type containing radio receivers and transmitters enabling signals received at the satellite from one ground station to be amplified before retransmission to a second ground station.

Three ground stations are participating in the communication satellite experiments. These are the United States station at Andover, Maine, the British Goonhilly station and the French station at Plemeur-Bodou in Brittany. The French station is a direct replica of the American one. The Goonhilly station cost about one-quarter of that of the American design.

After an initial difficulty of short duration due to a misunderstanding arising out of an ambiguity in the accepted definition of the "sense" of rotation of the circularly polarised satellite transmission, the Goonhilly station has been used to demonstrate successfully the following types of transmission over the Telstar satellite:

(a) Reception of high quality black and white TV pictures from U.S.A. and France.

(b) Transmission of high quality TV pictures to the U.S.A.

(c) Two-way telephony of high quality to the U.S.A.

(d) Transmission of facsimile pictures from London to New York and vice versa.

(e) Derivation of a group of 600 high quality telephone channels.

(f) Transmission of colour TV from Goonhilly to Andover.

After rectifying the initial trouble by adjustment of an aerial feed component, the performance of the Goonhilly station has been excellent in every respect. The satellite has been "acquired" by the aerial within one degree of the local horizon and tracked with great accuracy through every scheduled pass involving Goonhilly. The complex electronic equipment, much of which is of new design, worked very well. The results to date have proved the design of the station and justified the expectations of obtaining high quality telephone and television circuits via satellite relays.

FACILITIES AT THE GOONHILLY STATION

The station is located in the extreme south-west of England, at latitude 50 degrees 2 minutes 52 seconds north, longitude 5 degrees 10 minutes 30 seconds west, the site being approximately 800 yards square and some 350 feet above sea level. The horizon angles are predominantly negative with a maximum positive value of about 0.5 degrees.

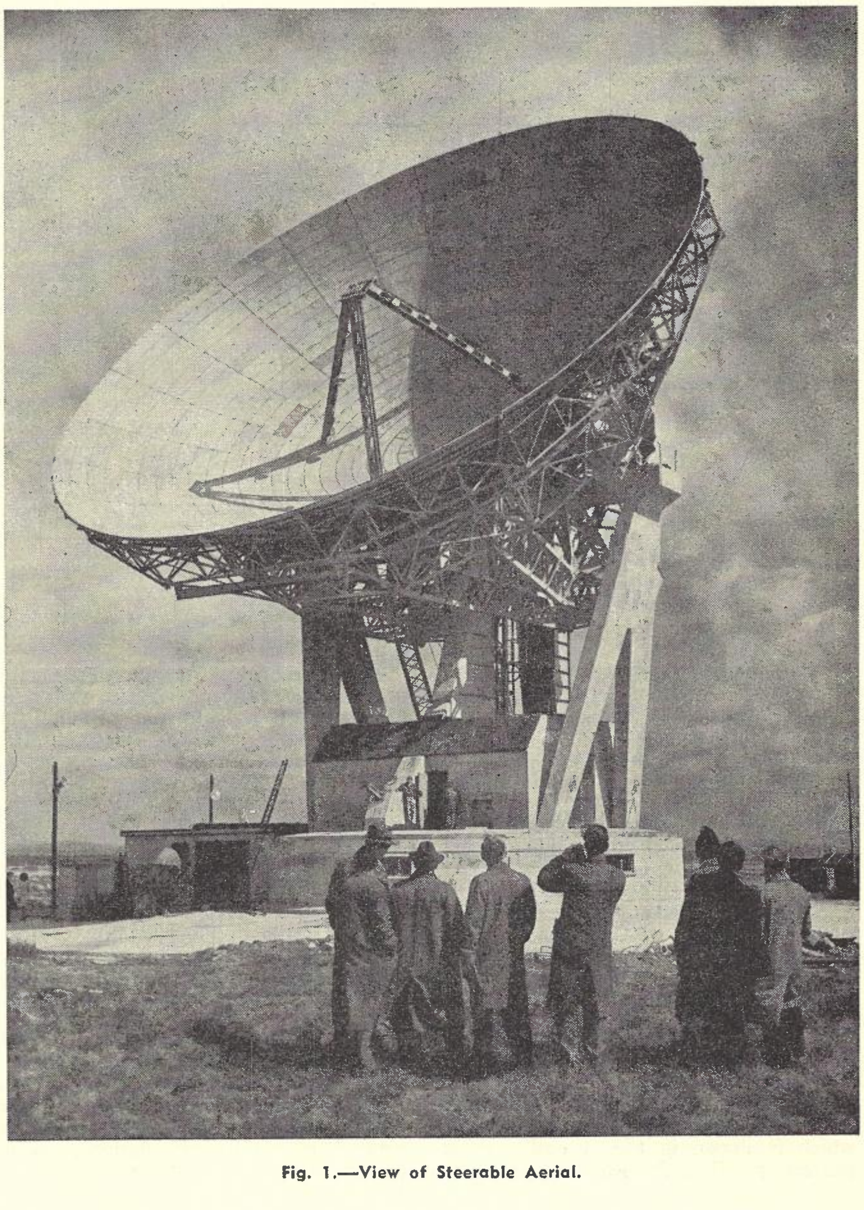


Fig. 1.—View of Steerable Aerial.

The siting of the equipment does therefore enable satellite orbits involving low angles of elevation to be used, while noise interference from the ground is minimised.

The following facilities are being provided initially, although the site is large enough to accommodate additional aerials without significant mutual obscuration:

(a) An 85 feet diameter paraboloidal-reflector aerial with full steerability over the hemisphere above the horizontal plane.
(b) Means for steering the aerial automatically on the basis of predicted orbital data; manual control is also provided for re-setting purposes.
(c) A 10 kW transmitter operating at 1725 Mc/s for Project Relay.
(d) A 5kW transmitter operating at 6390 Mc/s for Project Telstar.
(e) Low-noise receiving equipment for the 4170 Mc/s signals and the 4080 Mc/s beacon signal transmitted from the satellites.

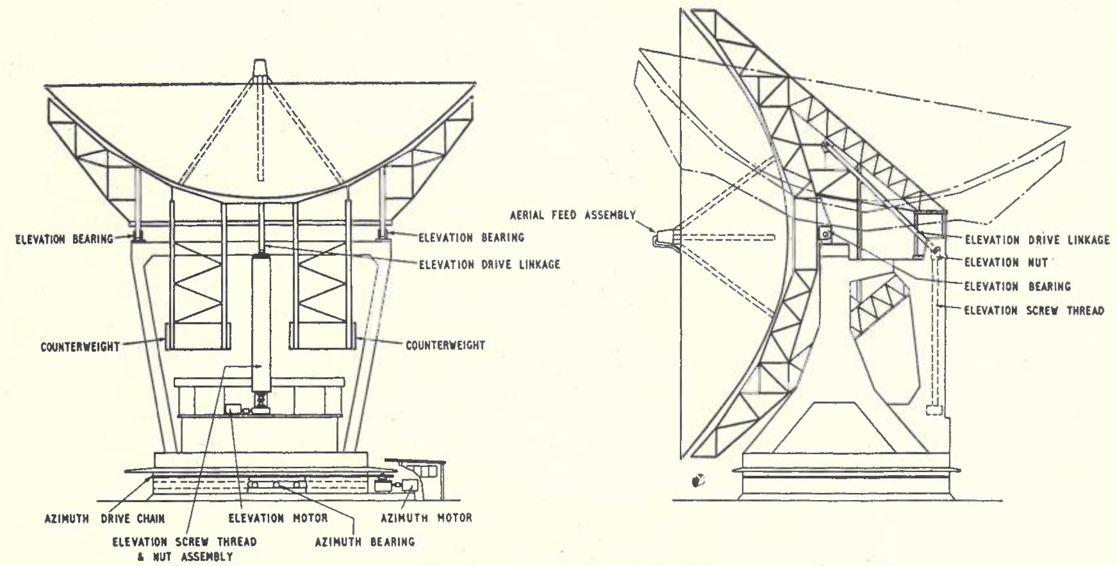


Fig. 2.—Cross-sections of Aerial.

(f) Terminal equipment for transmission and reception of multi-channel telephony and television signals.
(g) A two-way microwave link to Britain's main television network.
(h) Multi-channel telephony links.
(i) Teleprinter links to the Post Office Research Laboratory in London, to the United States, to a meteorological station, and a connection to the international Telex service.
(j) A comprehensive range of measuring equipment for objective assessment of the performance of satellite links.
(k) Time and frequency standards involving the use of a quartz clock mounted on a concrete plinth resting on bed rock.

THE STEERABLE AERIAL

The steerable aerial, a photograph of which is shown in Fig. 1 and a cross section in Fig. 2, was designed by Husband and Company, Consulting Engineers, London, England, and is of the paraboloidal dish form, the aperture diameter being 85 feet. The dish is designed with the necessary dimensional tolerances, within 3/16 inch, for operation at radio frequencies up to some 6000 Mc/s, the 3 db beam-width at 6000 Mc/s being some 0.15 degrees. The feed for the dish is in the plane of the aperture, an arrangement which, with appropriate feed design, reduces the levels of the minor lobes of the radiation diagram. This consideration is of great importance, for unless minor lobe levels are very small, noise would be picked up from the terrain surrounding the aerial, thereby significantly degrading the signal-to-noise ratio of the very weak signals received from the satellite. Since the beam-width of the aerial is about 1/6th of a degree and communication satellites move fairly rapidly across the sky, the aerial is required to track a moving satellite with considerable precision.

The mechanical arrangements for steering the 870-ton aerial are shown in Fig. 2; they provide for variation of azimuth by rotation of the complete aerial structure on a circular horizontal turntable and for variation of elevation by tilting the dish about a horizontal axis. The drives of the 100 h.p. motors for steering the aerial in azimuth and elevation are of the close-loop servo type. A chain drive is used to the final azimuth gear wheel and a screw thread and nut drive to the elevation control. The angular positions of the azimuth and elevation shafts are indicated by digital shaft-angle encoders and compared with the required angle, also in digital form, thus enabling the feedback control loop to be completed.

The aerial is steered primarily on the basis of predicted orbital information derived from the N.A.S.A. world-wide network of "Minitrack" stations, one of which is operated by Australia's Department of Supply at Woomera, Australia. In addition, manual control and an automatic "lock-on" control operating from a radio beacon (4080 Mc/s) on the satellite are provided.

Immediately behind the reflector there are two apparatus cabins; one of these is used to accommodate a travelling-wave MASER amplifier operating at 4170 Mc/s. The necessary low temperatures for this device are obtained by using liquid helium and liquid nitrogen. Evaporated helium is recovered, stored and compressed by equipment housed in the azimuth-drive motor room. The cabin behind the reflector also accommodates filters for separating the beacon signal (4080 Mc/s) from the communication signal (4170 Mc/s), so that the latter may be amplified separately in the MASER. Means for determining the system noise temperature are also provided.

On the horizontal turntable there is an apparatus room accommodating the high-power stages (1725 and 6390 Mc/s), the low-power drive equipment for the two transmitters and some of the frequency-shifting equipment. A cylindrical enclosure in the middle of the apparatus room accommodates the loops of flexible cable used to make connection between the equipment in the moving apparatus room and fixed equipment elsewhere. Rotation of the turntable around the vertical axis is restricted to ± 250 degrees to enable cable loops rather than slip-rings to be used.

AERIAL FEEDS

Two separate aerial feeds (each for simultaneous transmission and reception) are provided, one for Project Relay and the other for Project Telstar. The appropriate feed is on four-legged mounting, at the focus in the aperture plane of the dish. Both feeds are designed for circular wave polarisation.

The feeds are movable mechanically to provide a small amount of beam direction adjustment, additional to the major changes achieved by the mechanical movement of the dish as a whole. Two forms of continuous scan are available, (a) a small conical scan of 0.12 degree total apical angle produced by electric motor drive, and (b) an adjustable spiral scan, produced by hydraulic ram drive, with a maximum amplitude of about ± 1 degree. The spiral scan is used mainly to aid initial acquisition of a satellite beacon signal, while the conical scan permits the determination of small errors of beam direction and the application of the appropriate corrections, introduced either manually or automatically, to the aerial steering.

A diplexer is used to combine the 6390 Mc/s transmitter output and the 4170 Mc/s receiver input for connection to the Telstar aerial feed. A separate diplexer is not required for the 1725 Mc/s transmitter and the 4170 Mc/s receiver as the larger frequency ratio permits sufficient discrimination to be built into the feed itself.

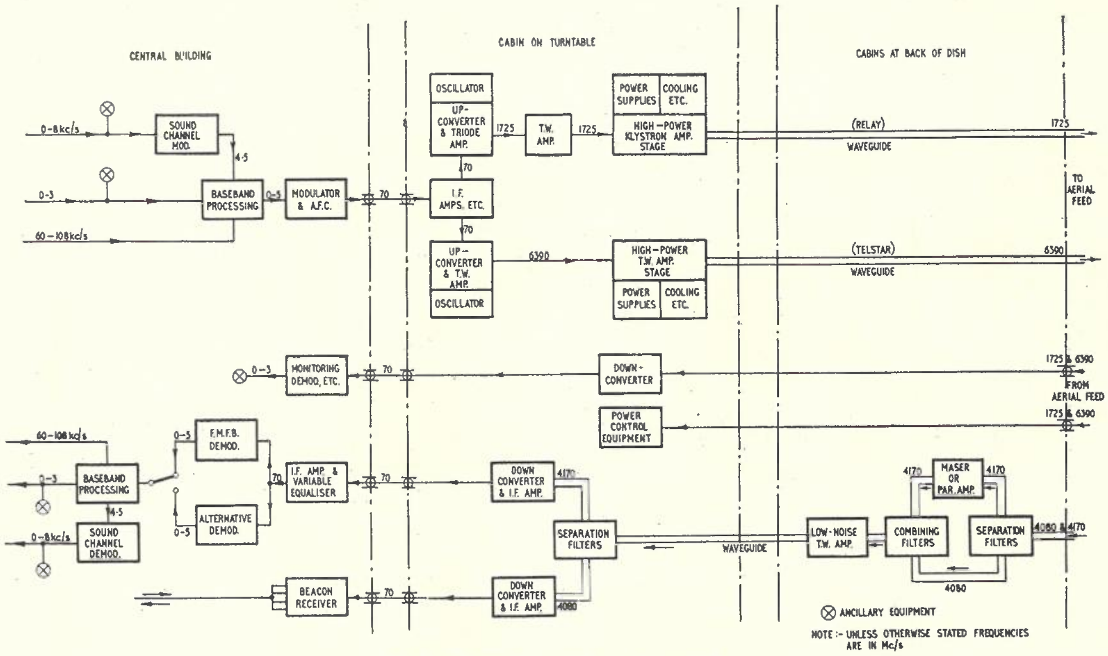


Fig. 3.—Block Schematic of Equipment.

EQUIPMENT

A general block schematic of the equipment is shown in Fig. 3.

Low-Noise Receiving Amplifiers: The MASER amplifier has a gain in excess of 25 db and a bandwidth of more than 25 Mc/s. Initially, the unit employs a permanent magnet but this will shortly be replaced by an electro-magnet using super-conduction. This will enable the consumption of liquid helium to be reduced. When using the permanent magnet MASER a charge of cooling liquids will last for at least twelve hours; the use of the super-conduction device should extend this period to 24 hours. A feature of the MASER is that it has been designed to operate satisfactorily with a movement of ± 45 degrees about the vertical axis, to allow for changes of reflector elevation angle. The overall receiving system noise temperature is expected to be not greatly in excess of 100 degrees K.

High-Power Transmitters: An Australian Post Office engineer working with the British Post Office team on the satellite project has been concerned with the provision and testing of the high power transmitters. The transmitter for the Relay tests, which has an output capability of 10 kW at 1725 Mc/s, uses a multi-cavity klystron of United States manufacture to provide the requisite power output. The 5 kW 6390 Mc/s transmitter for the Telstar tests uses a high power travelling wave tube of British design and manufacture.

Frequency-Changing and Transmitter Drive Stages: The frequency-changing stages, which convert signals from and to an intermediate frequency of 70 Mc/s, and the transmitter low-power drive stages, are modified versions of similar equipment used in commercial microwave line-of-sight radio-relay systems.

CENTRAL CONTROL BUILDING

Control and Experimental Apparatus Room: Consoles are provided for a Controller of Experiments and other staff responsible for carrying out tasks, aerial steering, and transmitter/receiver supervision. The equipment in this room includes:

(a) Base band and frequency-changing equipment.
(b) Receivers for the reception of domestic television broadcast signals.
(c) Measuring equipment.
(d) Magnetic tape and other recorders.
(e) Satellite beacon signal receivers.
(f) Microwave, video and multi-channel telephony terminals.

The received signals reach the central building as a wide deviation carrier centred on 70 Mc/s. The carrier-to-noise ratio is extremely low, and the recovery of video and multi-channel telephony signals with a satisfactory signal-to-noise ratio has involved devising two alternative forms of demodulator; one of these employs frequency-modulation negative feedback while the other uses a system of tracking the frequencies of maximum energy and varying the instantaneous bandwidth.

Telegraph Room: Separate teleprinters are provided for:

(a) reception, on a private-wire basis, of orbital prediction data from, and operational traffic with, the Goddard Space Flight Center, United States, and the satellite ground station at Andover, Maine, United States.
(b) Telex facilities.
(c) The receipt of meteorological information (to enable aerial safety precautions to be taken if necessary).

Computer Room: The principal item in this airconditioned room is a National-Elliott 803 electronic computer. Orbital data received in punched-tape form from the United States provides X, Y, Z versus time co-ordinates at one-minute intervals. The computer processes the data to produce aerial steering instructions in punched-tape form, the output information for each one-second interval including time, azimuth bearing, rate of change of azimuth, elevation, rate of change of elevation and the slant range to the satellite. The computer programme also makes allowance for changes of apparent satellite bearing due to atmospheric refraction and applies any other systematic corrections that may be necessary.

Aerial Steering Apparatus Room: The apparatus in this room enables a comparison to be made between the aerial steering input data in digital form and digital signals derived from read-out units on the aerial azimuth and elevation drives, thus enabling the servo feed-back loop to be completed. A temperature-controlled annexe accommodates quartz-crystal timing oscillators of high accuracy, which in conjunction with time signal radio-receivers, provide a precise time source adjustable to Universal Time Two. Steering tapes are received from the computer room for input to the aerial steering apparatus, initiation of aerial movement being dependent upon synchronism between time as recorded on the tape and as generated by the precise time source.

Aerial Steering Console Room (Control Tower): The aerial steering console room (See Fig. 4) in the Control Tower has been designed and placed to give uninterrupted visibility over the whole site. Though every precaution has been taken to ensure safety of personnel by the provision of mechanical and electrical interlocks, it has been considered desirable that those controlling the movement of the aerial should have full visual surveillance. The aerial is flood-lit at night. Though aerial steering is fully automatic, it has been arranged that the mechanical and electrical conditions of the aerial are displayed to an operator who can observe fault conditions, apply corrections and over-ride the automatic system should any abnormality occur.

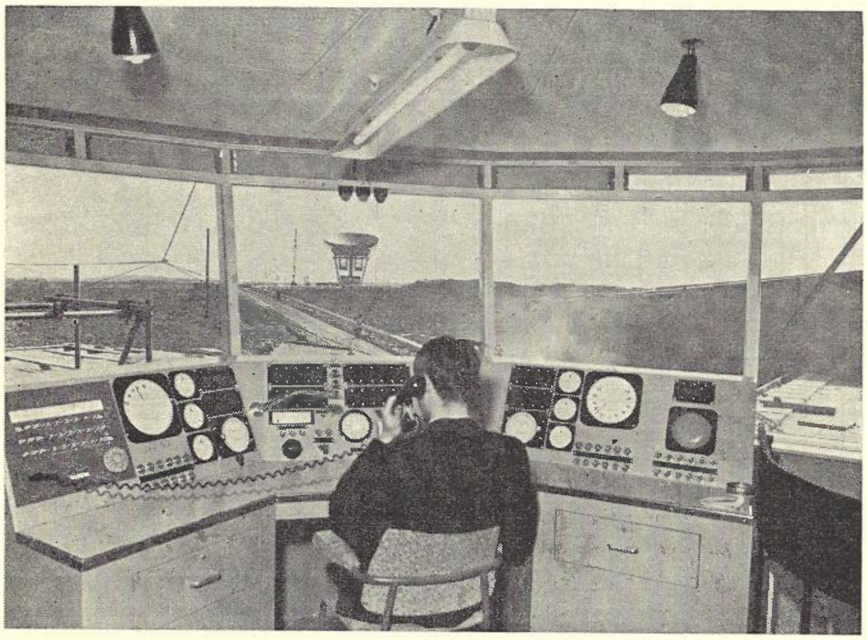


Fig. 4.—View from Aerial Steering Console Room.

SYSTEM CHECKING FACILITIES

It is necessary to be able to check periodically the mechanical alignment of the aerial, the electrical bearing of the aerial beam and the behaviour of the electronic equipment. For these purposes the aerial is fitted with a boresight telescope for ranging on local and distant points of accurately known bearing. In addition there has been installed, some 21 miles away, apparatus capable of simulating the Relay and Telstar satellites, thus enabling comprehensive overall system tests to be made.

CONCLUSION

Goonhilly Satellite Communication Radio Station has been planned and equipped, not only for participation in the initial experimental Projects Relay and Telstar, but also to be suitable for modification and extension as required for later experiments and for a wide range of satellite system studies. The aim has been to provide considerable flexibility in the design of equipment, and accommodation and services capable of expansion to meet future needs, including the possibility of operational use at a later date. The station will play a useful part in the acquisition of the information and experience needed for the design and construction of successful operational satellite communication systems.

REFERENCE

1. F. P. O'Grady and E. R. Craig, "Radio Communication by Artificial Satellites"; Telecommunication Journal of Australia, Vol. 13, No. 1, page 2.

TECHNICAL NEWS ITEM

420-CIRCUIT TRANSISTORIZED REPEATERS FOR A SUBMARINE TELEPHONE CABLE

Submarine Cables Limited of England has been awarded a contract for the supply of transistorized repeaters and terminal equipment, and for their installation in an existing submarine telephone cable system between England and Belgium. This equipment will make possible a very considerable increase of the telephone traffic capacity of the cable. It is planned that the cable will carry initially 420 simultaneous telephone conversations using standard 4 Kc/s CCITT channels; with 3 Kc/s channels the potential capacity is 560 two-way circuits.

Submerged repeaters lying on the ocean bed at intervals along the route are now a normal feature of submarine telephone cable systems. Hitherto specially designed amplifying valves have been employed in such repeaters; the present project will be the first major use of transistors for the same purpose in submerged repeaters. Extensive study and testing will be necessary to create the confidence essential for the use of transistors in this application, in which the repeaters are required to operate for many years at the bottom of the sea without maintenance of any kind. The repeaters have been designed entirely by Submarine Cables Ltd. in their laboratories at Erith, Kent.

A further feature of the project is the first use of completely transistorized submarine terminal transmission and power feeding equipment. This equipment has been designed and will be manufactured and installed by Associated Electrical Industries Ltd., a parent company of Submarine Cables Ltd. The Anglo-Belgian project, which is due for completion in two years' time, represents a major technical advance on previous systems. This demonstrates the ability of the submarine cable to be adapted to the newest techniques and the ever-increasing demand for the provision of circuits at a lower cost.

THE TELEPHONE DIRECTORY

*R. J. BROWNING**

INTRODUCTION

The telephone directory is a most important feature of the telephone system. Over the years, directories have generally been thought of as just catalogues of names and numbers. Too often when a new directory was delivered, it was put away out of sight and the important information in the front pages was never read. The year 1962 has seen a remarkable change with the new policy of adopting an attractive picture as a cover feature for Australian directories. Examples are shown in the figures on this and the following pages.

The eye-catching pictures used have focussed attention on the directory and this is regarded as a step towards making subscribers more aware of the value of the directory to them. There is a greater need than ever before to encourage telephone users to consult the directory because of the move, in accordance with the Community Telephone Plan, towards automatic dialling of all calls, both local and trunk. The directory was very much involved in the introduction of the all-figure telephone number system. The all-figure system has much more significance than being merely a new way of quoting telephone numbers, and the technical aspects have already been covered in previous articles (1, 2 and 3).

From the public relations viewpoint, the introduction of four-colour pictorial designs has been the subject of much favourable comment at home and abroad. As the books have a fairly wide circulation overseas, the innovation should attract more attention to Australia in the business sphere and could also stimulate the tourist trade. Although the design of the cover plays an important part in the overall attractiveness of the telephone directory, there are many other facets to be taken into account. The clear presentation of the vital information regarding dialling procedures and codes, as well as the accuracy and completeness of individual entries for subscribers, are essential to the quality of a directory. Some of the more important features of telephone directory compilation, publication and distribution will be dealt with in this article.

* See page 432.

OBJECTIVE OF THE DIRECTORY

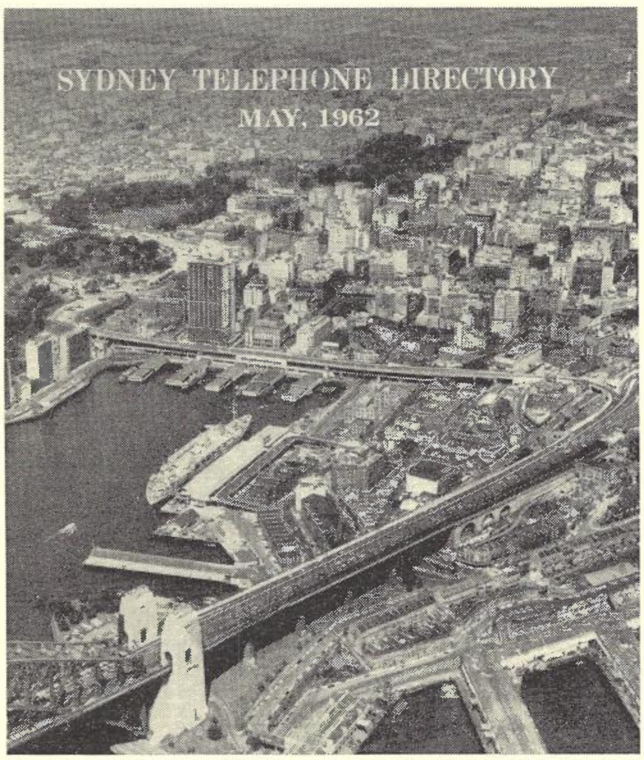
Stated simply, the directory is aimed at providing telephone users, subscribers in particular, with the means of ascertaining every other number connected to the Australian telephone system. It is not technically nor reasonably practicable to meet the spirit of this objective in full and the aim must be modified, therefore, to that of providing subscribers with ready access to a list containing the numbers of other telephone subscribers they are most likely to call, usually those in fairly close proximity, and clear directions on how information concerning other numbers can be obtained.

Experience shows that the modified objective can be achieved satisfactorily from the viewpoints of the subscriber and the Department by publishing directories in sections having regard to geographical and other divisions which have significant effects on the calling habits of subscribers. Traffic statistics are used extensively in this connection as they reflect the community of interest, both commercial and social, which exists between different centres.

DIRECTORY PRODUCTION IS BIG BUSINESS

The directory costs money to produce; conversely, it produces revenue. It is worth while looking into these contradictory things to see which way the balance falls. Happily, it is on the credit side, otherwise the deficit would have to be made up from other sources of revenue. The revenue is derived from block type entries, additional entries and extra matter in alphabetical listings and, of course, from advertising announcements.

In the Post Office, not only those directly working on the directory are involved, but also many other officers in the fields of finance and stores. In addition, the Post Office has enlisted the aid of private enterprise to print its directories and to handle the advertising business. The contracts are essentially business arrangements with firms suitably equipped to handle that part of the work entrusted to them. The contracts are entered into for specified periods following the calling of public tenders.



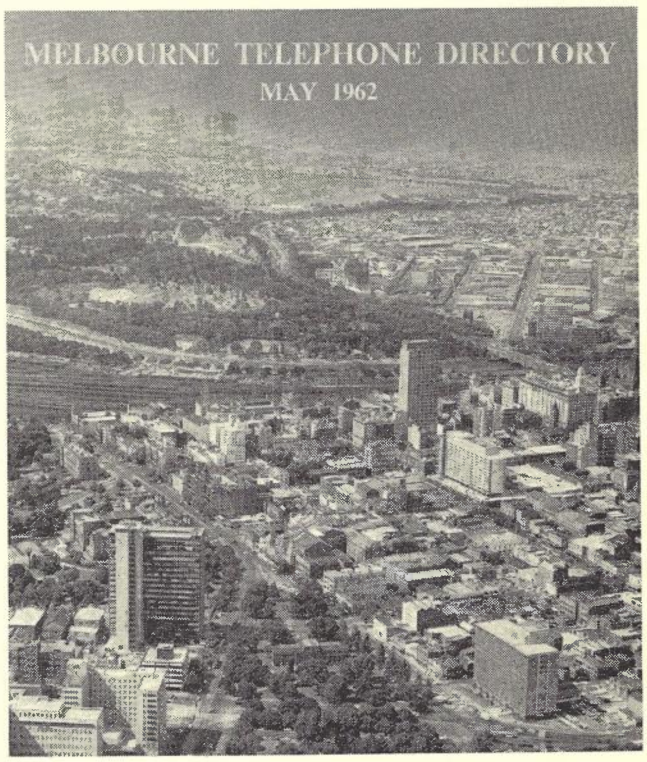


TABLE I

Directory	Circulation	No. of Pages	Quantity of Advertising (pages)	No. of Entries	Quantity of Paper Used (tons)
Sydney Alphabetical	736,000	1,092	79	414,000	1,160
Sydney Classified	681,000	764	740	138,000	750
Melbourne Alphabetical	651,000	916	57	400,000	850
Melbourne Classified	609,000	660	634	111,000	570
Brisbane Metropolitan	204,000	524	217	142,172	224
Adelaide and South Australian Country	245,000	756	267	181,000	272
Perth and Western Australia Country	161,500	546	188	130,000	134
Hobart and Tasmania Country	85,000	412	132	62,000	64
New South Wales Country	385,600	1,804	506	250,000	144
Victoria Country	286,500	1,492	531	193,000	92
Queensland Country	179,000	896	264	122,330	61
Northern Territory	6,800	80	49	—	1
Totals	4,230,400	9,942	3,664	2,143,502	4,322

The extent of the work of the three parties is demonstrated by the statistics in Table I which relate to the 1961/62 issue.

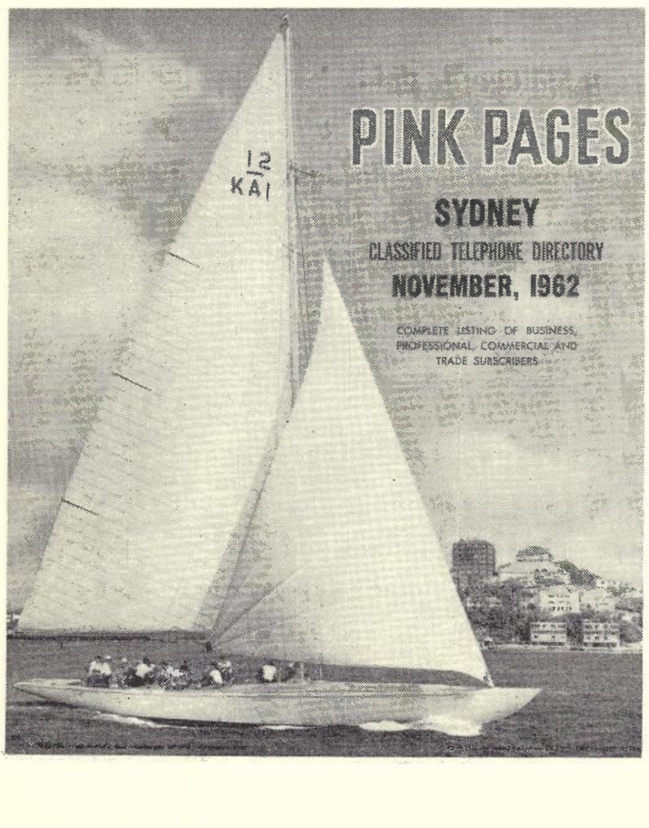
METHOD OF PRINTING

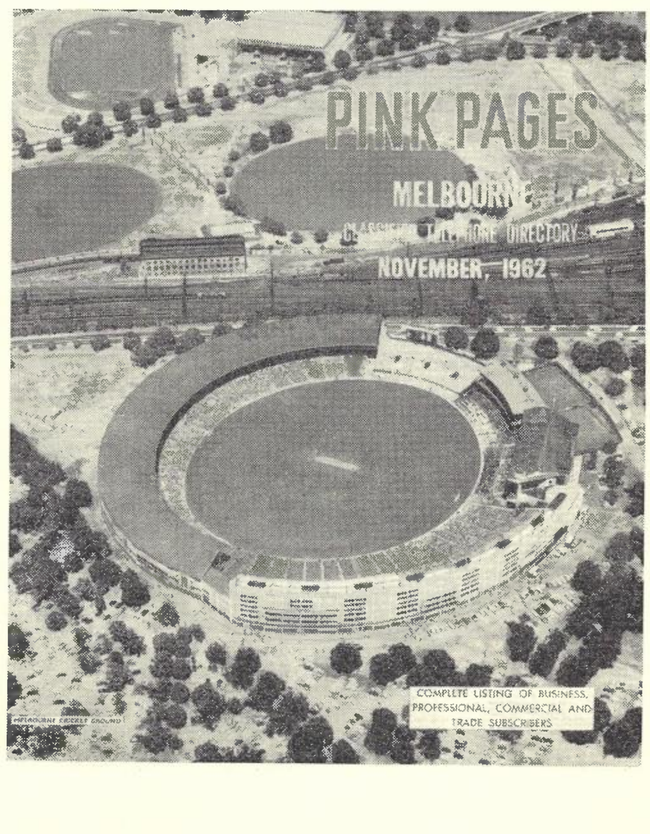
The primary factor is to have a directory printed in the most efficient and economical way. The various printers observe different methods of achieving this end, and for reasons as different as the methods. Because of this, some directories or parts of directories are printed on letterpress equipment while other directories are printed by the lithographic process. The South Australian book is the only Australian telephone directory printed wholly by the offset-lithographic process; the others are mainly letterpress printed. Within the letterpress method there are different machine systems, for example, flat-bed machines printing direct from type or from plates and rotary machines using curved stereotype plates. There are advantages and disadvantages of both letterpress and lithographic processes. Lithography ("writing on stone") is an old name which has been carried on for a process invented almost 2,000 years ago despite the fact that stone has been replaced almost completely by metal or glass. It seems that, to be modern, we should use the term "planography" but the description "photo-lithography" is the most used today to describe an idea which, history tells us, was developed from the imprint on the seat of the trousers of a man who sat on some writing on a stone step.

We have dwelt on lithography and this is merely because there is greater flexibility in the basic nature of the copy material. For instance, as a general rule to print letterpress, metal type or metal plates must be made even if the details are recorded in a style or kind of print which would suit the final article. With the photo-lithographic method (that is lithography coupled with photography), the original details can be photographed and plate making can be undertaken without type-setting. One of the minor, yet important, differences is that if a stereotype plate is faulty, a new one must be made. Photo-lithographic plates can be touched up. It is reported that James Osborne, a photographer in the Victorian Crown Lands Department, in 1859 invented a variation of photo-lithography, now known as offset printing, which earned him £1,000 for the patent rights.

THE COMPOSITION OF THE ALPHABETICAL DIRECTORY

Basically, the directory contains listings made up of names and numbers and one such listing is given free to each subscriber. A business subscriber is allowed, also free, one occupation in his listing but may add extra listings and extra matter to the book—this is one source of revenue. Company names, trading names and surnames all take their place in the list. Some Company and trading names are so unusual as to be almost incredible but they are authentic, otherwise they would not be allowed to appear in the book. Without much trouble, it is possible to find business names that are both straightforward





and informative and others that do not seem to have either of these characteristics.

The ordinary entries are printed in a special directory type, technically known as 6-point Bell Gothic Two Letter Type. If we take that title apart, 6-point means that the distance between the shoulders of the type slug is equal to one-twelfth of an inch. Bell Gothic is the designation containing a credit to the Bell Telephone Company whose engineers in collaboration with the Mergenthaler Linotype Corporation designed the type, using existing Gothic types as the basic pattern. The "two-letter" part of the title covers the two slightly different type faces used in an entry—the name and number are just a shade heavier than the other details. In 1957, the British Post Office, after several years of independent research on directory type faces, adopted the 6-point Bell Gothic type.

Subscribers who seek prominence for their entries can have their names, addresses and occupations shown in a heavy face block type. This brings in appreciable revenue.

Details of each new entry reach the Department in various ways and forms but they are all converted to the simple slug of metal. Irrespective of whether the entry is put in its correct position before or after being converted to metal, this process is checked by Departmental officers and the printer's readers. Generally speaking, each issue is simply the preceding issue with all subsequent alterations and additions. Regular resetting of standing type is necessary because of wear. Alterations and additions in all the books average about 650,000 per year.

THE COMPOSITION OF THE CLASSIFIED OR "PINK PAGES" DIRECTORY

The "Pink Pages" represent a valuable adjunct to the telephone service and are of great benefit not only to business subscribers who can use them to advertise their goods or services, but also to the ordinary householder. The grouping of subscribers' entries and announcements under headings, according to the particular trade or profession, provides a quick and easy reference for those in need of a commodity or a service. The "Pink Pages" have their own characteristics and compilation is a good deal more complicated than for the Alphabetical Section (White or Yellow pages). Although the Classified Directory is more popular than the Alphabetical Directory as an advertising medium, the advertising space in the Alphabetical Section totals 1450 pages.

The "Pink Pages" tell a story of their own both in popularity and individuality. How many people have been influenced in the careers they have chosen for themselves or their children by what they have seen in the "Pink Pages"? Whilst they may not have been intested in becoming "China & Glass Riveters", experts at "Concrete Breaking, Cutting and Sawing", they might be attracted to the occupations of "Crumpet Makers" or "Engineers—Electronic". The future scope of classifications is obscure but the present is clear in that the Sydney Pink Pages contain 1,700 headings supported by 2,000 cross-references. The Melbourne Pink Pages follow closely with 1,650 headings and 1,800 cross-references.

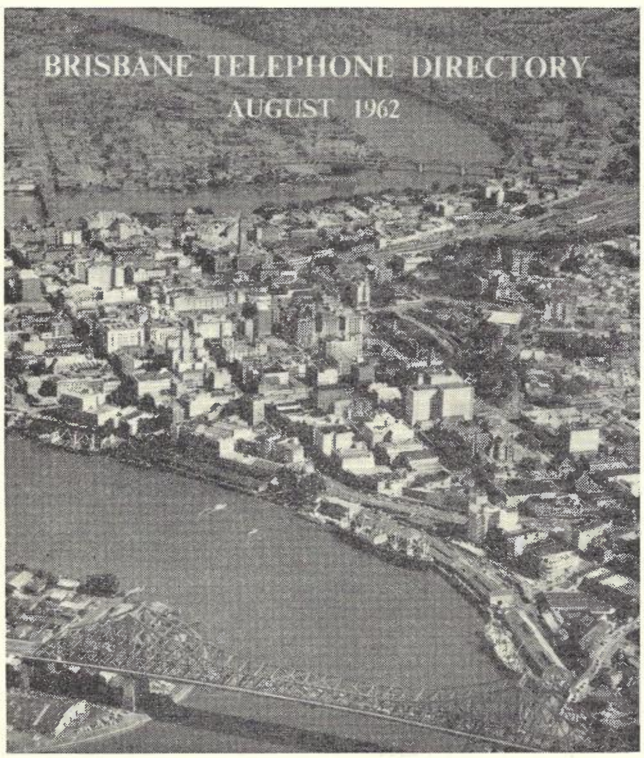
DIRECTORY DETAILS FOR INFORMATION SERVICE

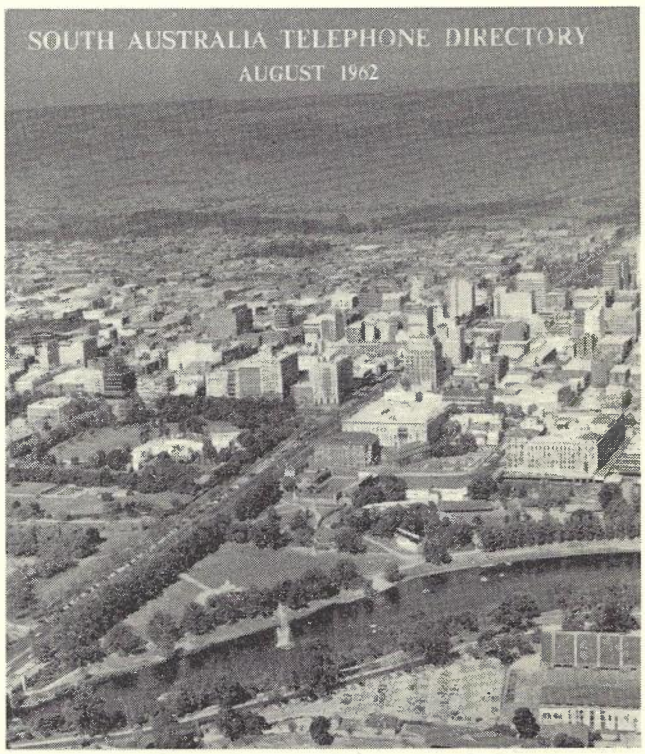
It is essential for up-to-date Directory details to be readily available at the "Information Service" positions. Consequently, there is a close link between directory production and the Information Service. The system in use in Brisbane, Perth and Hobart, and formerly in the other capital cities, utilises rotary indexes containing details of new entries and copies of the ordinary directory pages pasted upon oversize sheets to permit handwritten alterations to be made.

The Directory Printer required only one set of type and theoretically at least it was not necessary to advise him of alterations and additions to the then current issue until the next issue was to be printed.

A new system adopted in Sydney and Melbourne in recent years, requires the Printer to make a duplicate set of type of the whole alphabetical directory. One set is reserved for the normal directory issue and the other provides the "Information" lists—we like to call them lists because they are in five columns and are not paged-up as neatly or as tightly as the directory. In case we seem to be critical of the five column layout, let us explain that the extra column means 20% less pages and, therefore, quicker reference.

Details of new entries are teletyped each day to the Directory Printer who immediately makes two sets of type for each entry. One set is put aside for interpolation with the type reserved for the normal directory and the other is used to produce, at the end of each week,





a supplementary list. This supplement is re-printed each week on a cumulative basis up to the thirteen weeks' stage. At the end of each quarter, the type from which the last supplement was printed is fed into the full set reserved for the "Information" lists and a fresh record (which is in effect a reprint of the directory with all known alterations made) is obtained. This procedure is repeated each quarter.

The Adelaide system which was evolved prior to the new systems in Sydney and Melbourne is based on somewhat similar principles, but the "Information" lists are derived photographically from the normal directory manuscript which is maintained on roneo stripdex equipment.

Irrespective of the system followed, probably the most interesting story would be one written about the questions asked by some telephone users but they are the secrets of the "Information" staff.

DISTRIBUTION OF DIRECTORIES TO SUBSCRIBERS

In addition to the resources of the Department's own postal service, the aid of private enterprise is enlisted to secure prompt distribution and the work is allocated under public tender principles. Private contractors handle distribution in the outer city and suburban areas in all mainland State capitals, but the Department distributes the books in the city areas proper and in country districts. The Tasmanian book is distributed wholly by Departmental officers.

Each subscriber receives one copy of the directory in which his name appears for each telephone instrument leased from the Department. Subscribers who require extra copies, copies of other Australian directories, or overseas directories may order accordingly.

THE DIRECTORY IS DELIVERED! WHAT NEXT?

This certainly is the stage at which most questions are asked, suggestions offered and criticisms (fortunately few) made. All those people in the Post Office throughout Australia whose work has something to do with the compilation of the directories are keenly anxious to produce an error-free book and it is to their credit that the incidence of errors is so low. Converted to figures, the incidence of errors is only one per 2,400 entries in a total of something like 2,150,000 entries but, despite the good results achieved, there is no complacency and everybody works towards eliminating the few errors which do occur.

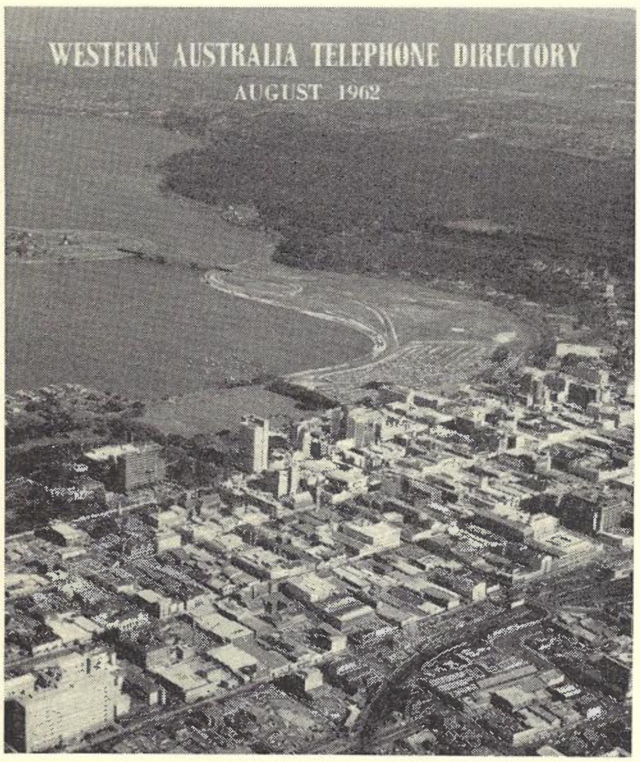
When an error does happen, remedial measures are taken immediately. On some occasions, remedial action is simple, particularly where technical arrangements permit calls to be diverted from a number shown wrongly to the correct one and, in such cases, there is not the slightest inconvenience to either the subscriber or the caller. On other occasions, the errors are of such a complex nature that the corrective action is also complicated but, in any case, no effort is spared to alleviate inconvenience to the subscribers concerned. (Early administrators wisely secured legislatory exemption from responsibility for errors and, naturally, this is essential to protect the Department's interests where subscribers see fit to seek damages or other retribution because of an error.)

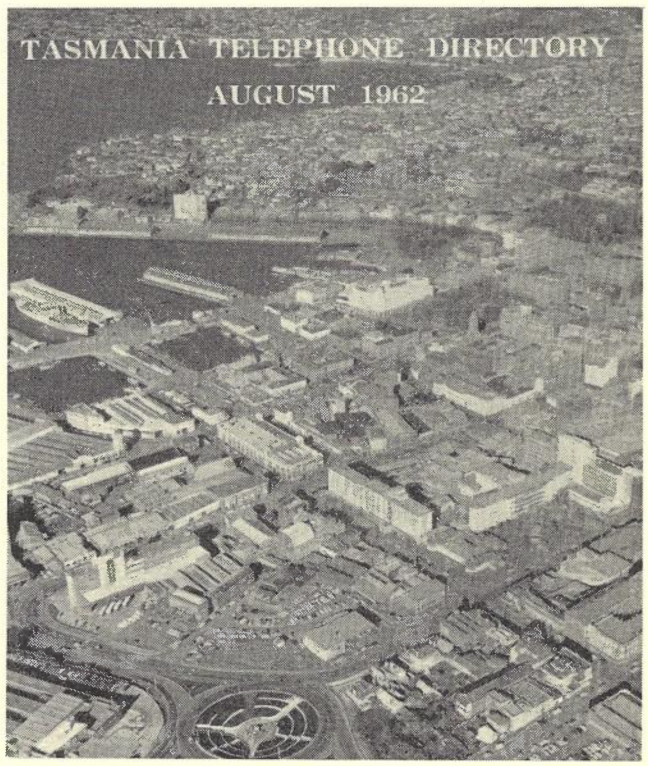
SUGGESTIONS

It is only to be expected that any book like the telephone directory which reaches into so many homes and the lives of such a large proportion of the population should generate a great number of suggestions from all areas. Many of the ideas are based on sound principles but not all can be adopted because of technical factors or other considerations such as cost, delay in production, or their effect on other sections of the community. Naturally, all telephone directory people are proud of their part in the project and are constantly striving for improvements. However, as in numerous other everyday things, it is often the layman, who need not know anything about printing a book, who presents the excellent idea. Those who are interested enough to put their ideas to the Department may be consoled with the thought that, even if their particular idea is not accepted, the principle could generate some other worthwhile improvement or variation.

OTHER POST OFFICE PUBLICATIONS IN THE DIRECTORY FAMILY

Viewed from any angle, the Telephone Directory is the senior member of the Directory Family and there is no chance of it ever losing this position. It is well protected by copyright and the Post and Telegraph Act precludes the unauthorised publication of any list purporting to be a list of the subscribers connected with any telephone exchange. Other members of the family are the Telex Directory and the official purpose P.A.B.X. directories.





Another relation is the Telegraphic Code Address Directory which is somewhat unique in that it is compiled, printed and distributed for the Department by a private organisation.

TABLE 2

Year	Total Number of Copies (all directories)	Total Number of Pages (all directories)
1937	698,100	3,632
1942	859,100	2,602
1947	1,142,300	3,584
1952	1,692,400	5,734
1957	2,315,800	7,840
1962	4,230,400	9,942

CONCLUSION— WHITHER DEVELOPMENT?

Over recent years, development in the directory has been phenomenal. Some figures are shown in Table 2.

By present-day standards, Australian telephone directory production is an enormous task and the trend clearly shows that it will become progressively greater. A story about the telephone directory cannot have a real conclusion because, before one year's issue is distributed, thoughts are already turning to the next year's publication. Readers can speculate towards making their own conclusions by comparing the mammoth publications of today with those of even 15 or 20 years ago and perhaps try to visualise what the 1980 production might be.

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1. B. Marrows, "Why the Australian Post Office will Eliminate Letters from Telephone Numbers"; Telecommunication Journal of Australia, Vol. 11, No. 4, page 105.

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3. R. E. Bogner, "Telephone Numbers and the User"; Telecommunication Journal of Australia, Vol. 12, No. 5, page 318.

OBITUARY— MR. A. S. BUNDLE, A.M.I.E.Aust.

MR. A. S. BUNDLE, A.M.I.E.Aust.

It is with considerable regret that the Society has learned of the untimely passing of Mr. A. S. Bundle, Supervising Engineer, Regional Works and Services (South), New South Wales. Stan, who had a long and active association with the Society, died on 11th October, 1962, after a short illness, at the age of 57.

His series of articles on Aerial Line Construction, published in the Journal from Vol. 3, No. 3, to Vol 4, No. 6, was perhaps the most comprehensive series ever to appear in the Journal, and was for many years the "bible" of lines engineers. He also contributed other articles on cable identification to the Journal. At the time of his death he was one of the three New South Wales sub-editors for the Journal, a position he had held since 1956.

Stan entered the Department originally as a Junior Mechanic and served as a Mechanic in Sydney before transferring as Cadet Engineer. After qualifying as Engineer in 1933 he was located at Dubbo for some years and later spent eight years in the Lines Section at Central Office. He returned to New South Wales in 1945 as a Divisional Engineer, and was engaged mainly on external plant planning and works control.

Since 1955 Stan's normal job was Supervising Engineer in charge of the southern part of New South Wales, and in this capacity he was active in the initial planning and early stages of the work of laying the Sydney-Melbourne coaxial cable. Later he was detached from Regional duties to concentrate solely on the cable, and the success of this project was due in no small measure to his boundless energy and enthusiasm.

He was well-liked and well-respected amongst all levels of staff and there was a big gathering from all sectors of the Department at his funeral.

TECHNICAL NEWS ITEM

SECOND STAGE OF COMMONWEALTH PACIFIC CABLE PROJECT

The two cable ships, "Retriever" and "Monarch" which laid the trans-Tasman section of the Commonwealth Pacific large-capacity cable earlier this year, have completed the laying for the second stage of this project from Suva to Auckland, New Zealand. The "Monarch" undertook the actual laying of the 1,214 nautical miles of lightweight coaxial cable and 49 submerged amplifiers between Suva and Auckland in ocean waters to a maximum depth of 2,500 fathoms. She was accompanied by the C.S. "Retriever" which assisted in providing radio bearings along the route.

The Suva to Auckland section is scheduled to be opened for service in the first week of December, 1962, when it will interconnect with the trans-Tasman cable which commenced service on July 9 last. While these new cable links will provide a wide variety of telecommunications facilities, a major immediate improvement will be in the quality and availability of telephone calls through the cables between Australia, New Zealand and Suva. These improvements have been demonstrated on the new trans-Tasman cable which is now carrying a much greater amount of traffic than was the case over the previous radio and submarine telegraph cable channels.

With the continuance of the Commonwealth Pacific Cable project (COMPAC) via Hawaii to Vancouver next year, it will link Australia, by December 1963, through a micro-wave system across Canada and the CANTAT cable to Britain and Europe. The general scheme was described in the last issue of this Journal.

MAIN DISTRIBUTING FRAME FACILITIES FOR LARGE CITY EXCHANGES

*K. G. HARDY, A.S.T.C., A.M.I.E.Aust., A.F.A.I.M.**

INTRODUCTION

The need for large capacity exchanges in city locations has only become apparent in Australia in recent years. It has been occasioned by the steady growth of population and accentuated by continued flow of young people from country to city areas. A special problem is observed in the innermost areas of a city such as Sydney in that high density commercial and trading activities combined with the high cost of exchange sites and buildings, tend to add emphasis to the need for large capacity exchanges. Despite congestion, the inner city appears to maintain its growth roughly in proportion to the overall population. This is apparently occasioned by the unavoidable need to centralise certain commercial and retail activities. In order to meet the consequent needs for telephone services in the most economical manner, line cables are provided having ever greater numbers of copper conductors of smaller cross section. At the same time, improvements in transmission and signalling made possible by improved telephone instruments and exchange apparatus have tended to maintain the area, measured radially, which can be served from each individual telephone exchange. The nett effect of these factors in Sydney is to increase greatly the number of subscribers theoretically able to be connected to a given exchange.

However, practical design difficulties associated with increased connections can become severe. The present paper discusses one of these problems: that of providing suitable M.D.F. facilities for large city exchanges. A new design requiring little structural change to the existing standard M.D.F. has been developed generally, but requires special accommodation. With this design, three M.D.Fs would be provided and would be erected as required, one above the other on adjacent floors of a multi-storey building. Cable and jumpering flexibility would be maintained by the provision of suitable slots between floors. A field trial of the proposed design will be made in the Potts Point telephone exchange building now being constructed, and will determine its suitability for general use.

PRESENT STANDARD MAIN DISTRIBUTING FRAME

The means used to protect exchange equipment against lightning, high voltages and high currents determines the design of an M.D.F. to a considerable degree. In this regard the Australian Post Office has for many years followed the British Post Office practice of providing 1.5 amp fuses in 25 pair mountings on the line side of an M.D.F., with 20 pair protectors (combined lightning arrestors and heat coils) on the exchange side. The fuse mountings and protector mountings are attached on or between suitable horizontally fastened "U" section steel slats of which there are thirteen per M.D.F. vertical. Each vertical member of the standard M.D.F. is approximately twelve feet ten inches high, carrying 12 fuse mountings (300 line pairs) and 10 protector mountings (200 exchange connections). The verticals are spaced 6¾ inches apart and M.D.F. capacity can be increased by erecting additional verticals alongside existing ones as required.

Recent studies have indicated that fuses can be almost completely dispensed with in city exchanges, and this has enabled 50 pair link blocks to be specified instead of fuse mountings as formerly. The result has been to increase the number of line pairs which can be connected to a standard M.D.F. from 300 per vertical on fuse mountings as indicated earlier, to 600 using link terminations.

PROBLEMS IN LARGE EXCHANGES

In the early stages of planning a new city terminal exchange for Sydney in New South Wales, it was realised that the ultimate size of the planned facilities involved the need for an unusually large M.D.F. Survey data indicated a 20 year requirement of up to 40,000 subscribers, while an eventual capacity of 60,000 appeared likely. The provision of telephone services to 60,000 subscribers in such an exchange would, it was anticipated, require up to 300,000 line pairs. The associated ratio of five pairs per subscriber, giving a suitable basis for design, would take into account junction pair requirements and those for miscellaneous circuits including external extensions, fire alarms and Telex.

Since the exchange side of a standard Australian Post Office M.D.F. will accommodate 200 connections per vertical, and an allowance of about 20% must be made for junction and miscellaneous circuits, approximately 360 M.D.F. verticals would be required for exchange side needs. However, with 600 line connections per vertical on the lines side, 500 verticals would be needed. Thus line pair requirements would be the controlling factor in consideration of the length of the frame, and requirements of exchange side connections are of less importance. With each vertical 6¾ inches apart, an M.D.F. about 280 feet long would therefore be required in a 60,000 subscriber city exchange.

ALTERNATIVES

Without claiming to be exclusive, the following list indicates a number of methods by which 60,000 city subscribers could be given adequate M.D.F. facilities:

1. Establish a very long (280 feet) standard M.D.F. As indicated, later design requirements would inevitably result in difficulty which could only be overcome by extensive use of internal tie cables. The multiplicity of records and the additional labour of jumpering could make this scheme undesirable as a comparatively large M.D.F. staff would be required. In addition, tie cables must be terminated and would tend to increase further the length of the M.D.F.
2. Establish a gantry type M.D.F. This would be approximately 30% shorter than the standard M.D.F., but would still be more than twice the length already found desirable in practice. Again, tie cables would be required between portions of the M.D.F.
3. Establish parallel M.D.Fs and use tie cables between them to provide the necessary flexibility. Difficulties indicated above would still apply and in any case both M.D.Fs would need to be of the gantry type to provide the necessary capacity in a length of 90 feet or less.
4. Divide the exchange area into sectors and feed each to a separate M.D.F. The M.D.Fs associated with particular sectors could be arranged in one continuous length, in parallel or in some other suitable configuration. Difficulties associated with this procedure are lack of flexibility, possible need for number changes for subscribers moving from one sector to another, and provision of each of the M.D.Fs simultaneously. If ties are to be avoided, separate exchange equipment would be needed for each sector with attendant economic and operating disadvantages.
5. Introduce the multi-floor M.D.Fs discussed hereunder.

PREVIOUS EXPERIENCE IN SYDNEY

Over a period of years examination has been made of City North and City South exchanges in the inner City of Sydney, to determine the most economical means of reducing the density of jumper wires which has developed in M.D.F. horizontal jumper trays in those exchanges. The difficulties experienced include distortion of fuse mountings by weight of jumper wire and slowness of tracing jumpers when fault conditions are present. Furthermore, it would be most undesirable for the point to be reached where disconnection of a jumper could involve cutting each end and leaving the remainder in position as a temporary measure. This could become necessary where endeavours to remove old jumpers completely lead to the possibility of fraying of adjacent jumpers. The ever-increasing blockage resulting would eventually lead to inability to remove any jumpers and to complete blocking of the jumper trays. However, further growth above some size at which jumpering depth becomes critical is implied, but the precise point of occur-

* See page 433.

rence cannot be readily identified. In this regard, at City South, jumper depths of three inches have been measured on 20 inch wide trays, while four and a half inches has been noted at City North on fifteen inch trays. However, City North is not a standard M.D.F. and consequently its problem, although more severe, is not discussed further.

In City South, exchange line pairs terminate on a mixture of 20 pair and 25 pair fuse mountings with some smaller quantities of 50 pair link blocks. The M.D.F. is of standard height and is the longest M.D.F. (96 feet with 170 verticles) in any New South Wales exchange. It provides protection and terminating facilities for approximately 13,000 high calling rate city subscribers and the difficulties indicated in the previous paragraphs are strongly in evidence. It was as a result of the abovementioned studies that the decision has been taken to restrict M.D.Fs to a maximum length of 90 feet.

In other exchanges lack of space has been so restrictive that where more connections are anticipated than can be met with standard arrangements, a higher M.D.F. has been developed. The design in these cases is based upon the use of a gantry or catwalk around the M.D.F. at a level equivalent to the top of a normal M.D.F. Owing to structural difficulties, including strength of the M.D.F. room ceiling, the additional height is restricted to that which an average man can reach comfortably when standing on the gantry. The result has been to limit this type of M.D.F. to a height of approximately 18 feet and to obtain approximately 50% more connections per vertical, that is 900 line pairs and 300 exchange pairs in lieu of 600 and 200 for the standard arrangement. Fig. 1 shows an M.D.F. of this type.

There are four such gantry type M.D.Fs in the Sydney metropolitan area, and the oldest has been in service for approximately twelve years. Each was carefully examined to see if deductions could be drawn as to the effect of increased height upon jumper densities, but the result gave no indication that the quantity in vertical jumper runs was excessive in any case. Furthermore, it was noted that for the same number of cables, there were fewer jumpers per horizontal jumpering tray because the number of trays had increased from twelve to eighteen.

DEDUCTIONS FROM EARLIER INFORMATION

Empirically, the maximum permissible depth of jumpers in horizontal jumper trays has been determined to be 2¾ inches. Further, from the evidence available, it has been assumed that this jumper depth will not be exceeded provided the M.D.F. concerned is restricted to a maximum length of 90 feet and thus contains no more than 160 verticals.

As indicated earlier, M.D.Fs are constructed with verticals on 6¾ inch centres and as the slats forming the verticals are ⅜ inch wide, the maximum horizontal spacing between them on adjacent verticals of an M.D.F. is about six inches. However, the clearance available to permit entry of a technicians arm is four inches, measured between inner surfaces of protector mountings on the exchange side of the M.D.F., and it is considered that this clearance should be maintained up to the jumper rings. The two inches taken up by protectors is not lost but is utilised partly by permanent line and exchange cables designed to occupy not more than one inch, and partly by jumpers which can therefore also have a maximum thickness of one inch. In passing, it might be stated that no direct evidence is available that this vertical jumper thickness of one inch would in fact result in satisfactory jumper conditions. In none of the cases examined was it noted that more than a quarter of an inch thickness of jumpering existed.

Assuming then that jumpers are distributed randomly over an M.D.F. and that, whether they are or not, the jumper depth tends to be fairly average on all verticals, the following deductions can be made—

(a) The theoretical ratio of connections on the vertical or exchange side of a standard M.D.F. to those on the horizontal or line side is approximately 12 to 55. This is made up from the ratio of depths 1 to 2¾ or 4 to 11 (assuming that jumper depth is the controlling factor) modified by multiplication by further factor, 12/20, allowing for the usable length of the standard arrestor slat being 12 inches and the fuse slat being 20 inches.

(b) The fewer the verticals comprising an M.D.F. for a given number of

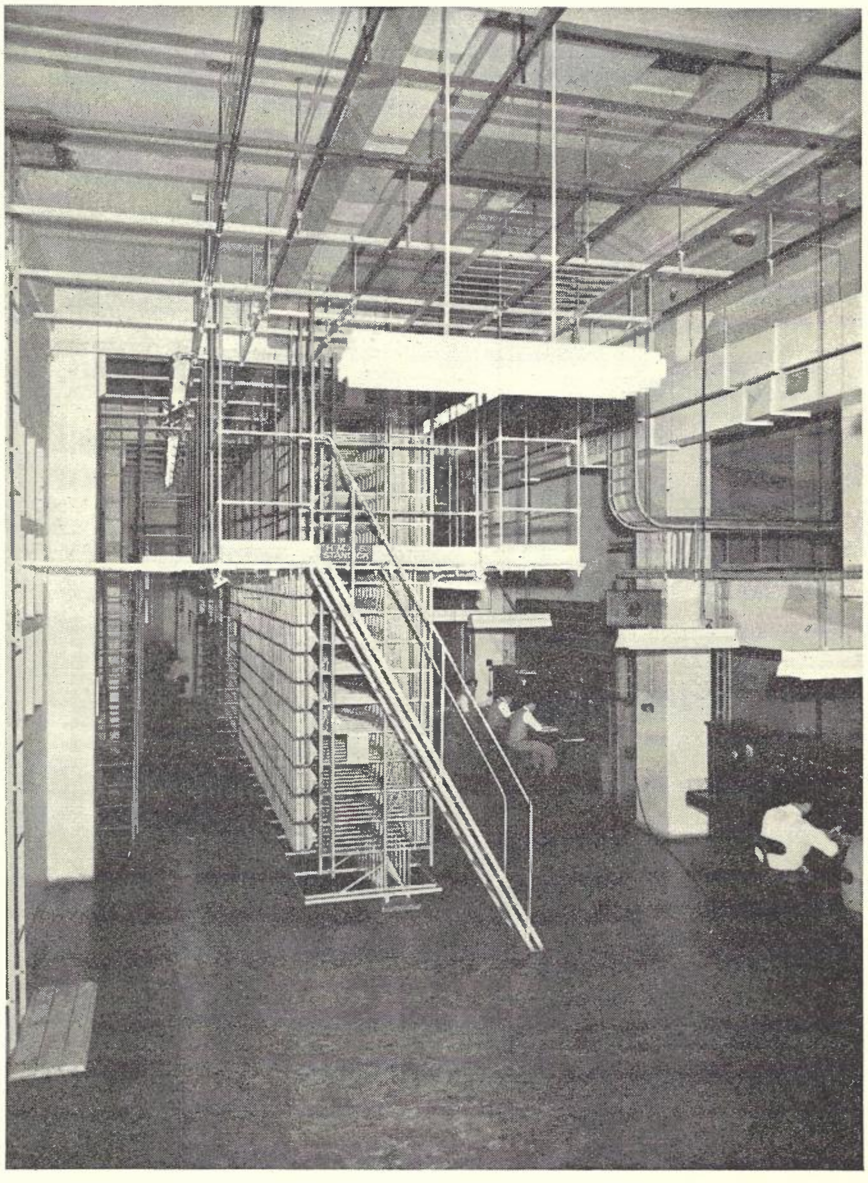


Fig. 1.—Gantry Type M.D.F. with Capacity for 300 Arrestors, and 400 Fuses or 800 Link Connections.

line cables, the less the depth of jumpers in horizontal jumper trays. This merely implies that an M.D.F. should grow in height as well as length and that the height to length ratio could approach 12 to 55 (approximately 1 to 4½ or alternatively 4½ to 1 line side space to arrestor side space for jumpering).

Now, if the worst possible case were to occur on the arrestor side of one M.D.F. vertical of standard height, 200 pairs of jumper wires would pass a given point. Under equivalent circumstances, for equal density in a horizontal line side jumper tray, 4½ times as many pairs of jumper wires (900) would pass a given point. Using link blocks, 50 line pairs per block can be terminated and hence 18 blocks on 18 separate verticals would be required, occupying a 10 feet long M.D.F. for this condition to obtain.

Each additional 10 feet of M.D.F. would increase the line side density 100 per cent and, as in the practical case 90 feet length of M.D.F. is considered the maximum desirable, the greatest average density would be 9 times as many jumper wires per horizontal tray on the line side as those in any vertical jumper tray on the arrestor side of a standard M.D.F. The means then of further increasing M.D.F. capacity is clearly to increase the M.D.F. height, and the three M.D.Fs one above the other, as proposed in the new design, would effectively increase the vertical jumper wire density by three while leaving the horizontal density unchanged. Possible M.D.F. arrestor hardware modifications could increase standard vertical capacity to say 600 (a factor of three) and thus increase vertical jumper wire density in proportion. Under these circumstances the proposed three M.D.F. arrangement would still appear to satisfy requirements of jumper densities which would now be equal on both sides of the new M.D.F.

DESIGN CONSIDERATIONS FOR A HIGH M.D.F.

As mentioned earlier, the maximum height of a single M.D.F. so far installed in New South Wales is approximately 18 feet with a capacity of 300/900 connections per vertical. Structural alterations to the standard M.D.F. required by this arrangement are comparatively minor; the height of vertical members would be increased from approximately 12 feet 10 inches to 18 feet, using the same section of steel and the same overall depth of frame. The M.D.F. itself must be tied to the necessarily high ceiling of the exchange building in such a way as to place the M.D.F. structural members under tension, and so distributing the additional load of line and exchange cables between floor and ceiling. The catwalk or gantry is tied to the side wall and also suspended from the ceiling.

However, proceeding to greater heights using the same steel sections appears to be impractical, even if additional bracing were used to give adequate rigidity. In addition, structural building problems would increase including the need for ever higher ceilings and, in the case of multi-storey exchange buildings, greater strength per floor. Furthermore, ladder access to gantries in existing high

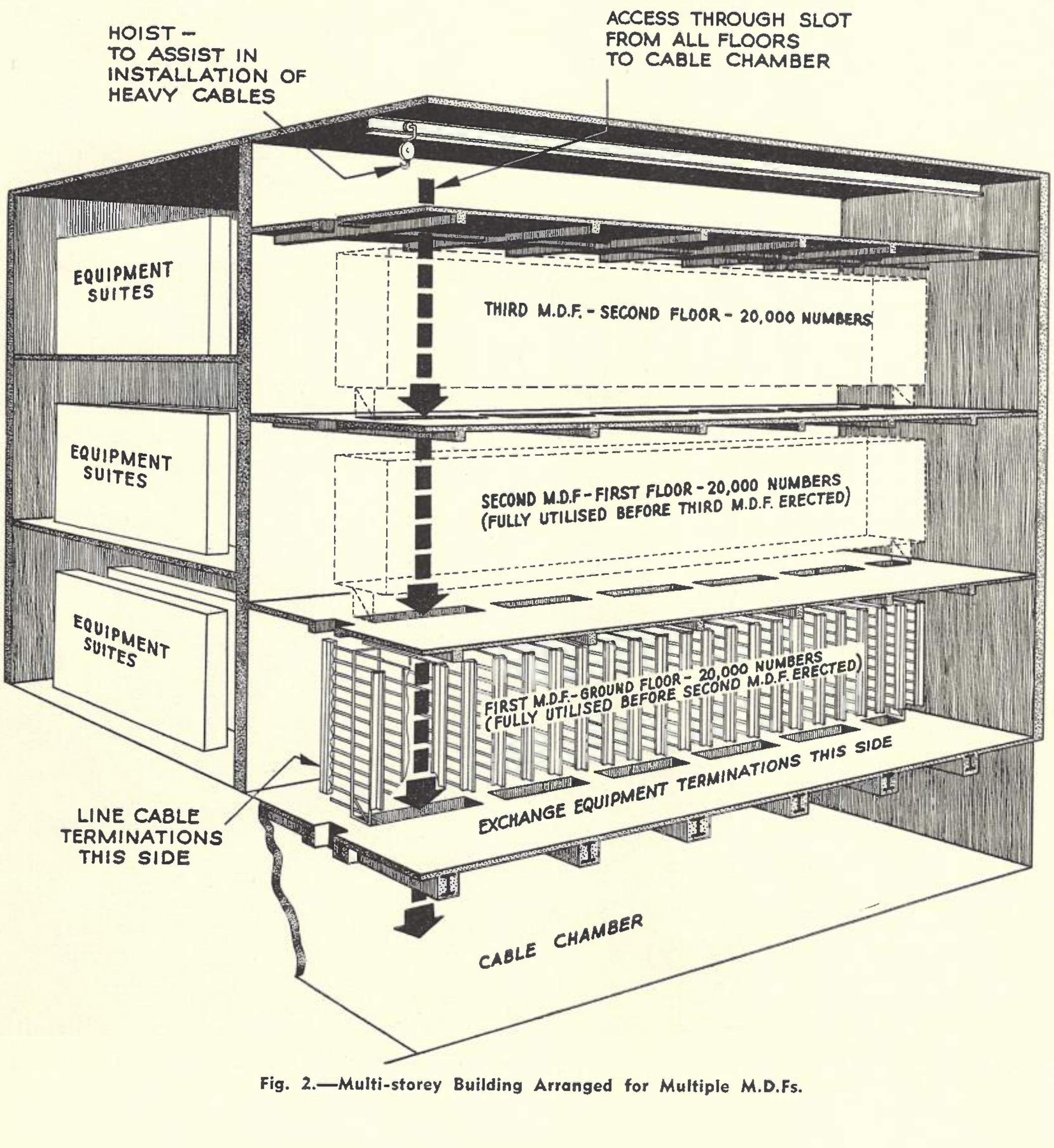


Fig. 2.—Multi-storey Building Arranged for Multiple M.D.Fs.

M.D.Fs has never been completely satisfactory owing to space and clearance requirements causing their slopes to be excessive. Another disadvantage in merely having a higher M.D.F. would be the need to install each vertical at its full height initially, and hence even where only a few verticals were required a gantry would be necessary and the problems associated with jumpering and terminating over more than one level would be experienced from the outset.

Careful examination of the principles behind the design of existing M.D.Fs in respect to distance between vertical members and distance between horizontal members, indicates that optimum conditions have already been achieved in the standard frame, having regard for the physiological characteristics of the average person who would be expected to work on it. To manufacture a stronger M.D.F. would involve sections of steel appreciably bigger than those at present used and could therefore result in the need for a complete redesign of the apparatus.

Finally, it was noted that for M.D.Fs higher than 18 feet, the standard lacing slat for line and exchange cables formed on each M.D.F. vertical by the arrestor mounting slats, would not be long enough to accommodate the number of cables necessary. However, in this case the slat length can be increased by up to 12 inches without introducing the difficulties indicated earlier.

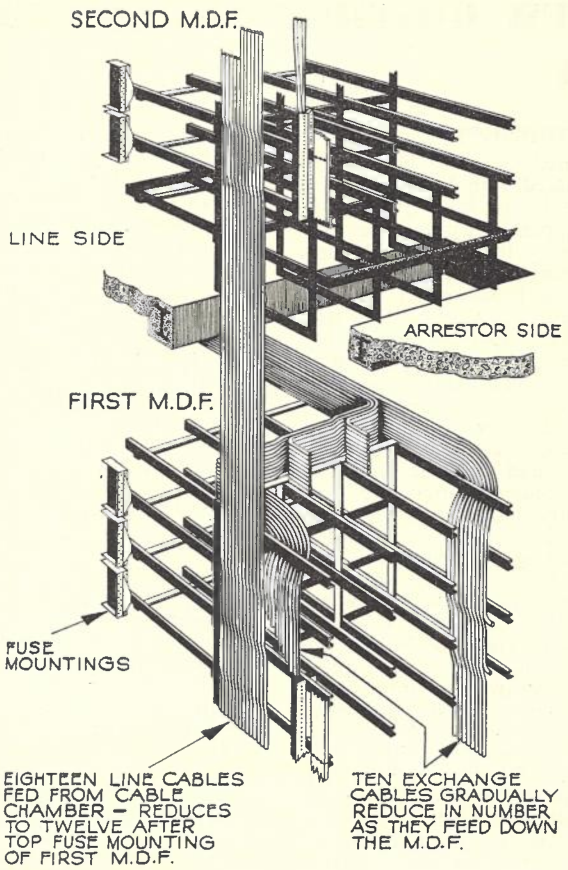


Fig. 3.—Portion of Multiple M.D.F. Indicating Cable Arrangements.

SELECTED DESIGN

The considerations mentioned previously led to the design depicted in Fig. 2. Facilities are to be provided in the structure of the building to enable three separate standard M.D.Fs to be erected one above the other. Each will be up to 90 feet long and it has been determined that the structure of the exchange building can include suitable slots in each floor to provide adequate space for both jumpers and line cables to be run between the individual M.D.Fs. The general arrangements looking at the top few slats of the first M.D.F. and the bottom ones of the second M.D.F. are indicated in Fig. 3. Plastic or lead covered 100 pair line cables, each feeding two link blocks, will be run upwards from the cable chamber to the first M.D.F. in such a way as to enable it to be completely equipped, with space left for line cables to proceed upwards to the second and later, to the third M.D.F. as required.

Fig. 3 also indicates the arrangements with respect to exchange cables. The M.D.F. will be oriented with its line side adjacent to the exchange equipment. Hence exchange cables will be fed to the top of the line side of each M.D.F. and along it, crossing only to the arrestor side at the particular vertical on which they are to be terminated. These arrangements will have two advantages; firstly, clear jumpering space will be maintained from one M.D.F. through the floor to the one above and secondly, there will be no cable runways above the Technician's head to obstruct the work associated with feeding jumpers through the slots between the floors. Operations will also be facilitated by suitable structural design of the building in that beams above the M.D.Fs are to be as shallow as practicable.

The weight of the line cables is to be taken by an appropriate steel frame resting on each floor directly above the slots. In addition to being securely held at these points, cables will be laced to each horizontal slat as they proceed up their particular M.D.F. vertical. As shown in Fig. 2, a steel beam will be provided on the ceiling of the uppermost floor. It will be fitted with a hoist to assist positioning of line cables and to ensure safety during their installation.

CONCLUSION

A structural arrangement similar to that detailed has been designed for the new Potts Point building now being erected in Sydney. Here the limit will be two M.D.Fs, and when this building is completed in the next twelve months and the initial M.D.F. has been installed a trial is proposed to ensure the practicability of the overall scheme. Should the trial prove the scheme to be impracticable in some respect, alternative arrangements will be made for access to M.D.Fs other than the first. Thus if jumper access proves difficult, jumpering between floors can, if necessary, be abandoned and recourse made to tie cables. If the means of feeding line cables to each frame proves too hazardous, alternative access will be provided in the upper M.D.F. rooms and alongside the external wall. Line cables will then be fed in from the top of each of these latter M.D.Fs instead of from the bottom as usually arranged. Notwithstanding the abovementioned precautions however, a fairly high degree of confidence is felt in the proposed arrangements. They are expected to prove both a practicable and acceptable means of providing M.D.F. facilities in situations where restrictions on the number of M.D.F. terminations would otherwise be the limiting factor in the size of an exchange.

ACKNOWLEDGMENTS

The co-operation and assistance of Engineers of the Internal Planning Section, N.S.W. Engineering Division of the Australian Post Office is gratefully acknowledged. Valuable data used in the general investigation of the problems was also obtained from the D. J. Mahoney-J. Liiv Report (1957) on "Main Distributing Frames".

THE NEW ROSEHILL SOUND BROADCASTING STUDIOS, PERTH

A. COHEN, B.Sc.*

INTRODUCTION

The Postmaster-General's Department became associated with broadcasting in Western Australia in June, 1929, when it assumed responsibility for the technical operation of the studio and transmitter equipment for 6WF, one of the first Australian broadcasting stations. Since that date a succession of temporary premises, none of which had been designed for the purpose, were used as studios. The building occupied immediately prior to the opening of the new Rosehill Studios was inadequate for broadcasting purposes, with poor sound-proofing and acoustic treatment and limited accommodation for both staff and equipment. A new Western Australian headquarters for the Australian Broadcasting Commission had become a matter of urgency, and work on the design of an administrative and studio block was commenced during 1957. The Department of Works was responsible for the design of the building and the Australian Broadcasting Commission's own Buildings Branch provided designs for the acoustical treatment of the studios. The Postmaster-General's Department, which is responsible for the provision, maintenance and operation of all sound technical services, also commenced work on the design of a new technical installation towards the end of 1957. All work was completed before the target date of June 1960.

GENERAL DESIGN

From the outset several aspects of design were considered to be of prime importance. These were firstly the use of new equipment of the best quality available and circuitry incorporating the best of past designs together with new important features which would lead to reduced fault liability and an optimum in ease of operation. Secondly the housing for the equipment, that is control and announcers desks, record and tape replay cabinets, etc., was to be designed with the utmost attention to both pleasing appearance and harmony with the studio interior treatments. The use of small plug-in amplifier equipment and the subsequent need for less jacking facilities has allowed great improvement in this respect, and the familiar equipment racks in control rooms and tape booths have been eliminated.

The building as shown in Fig. 1 consists of a five-storey office block facing St. George's Terrace, with the operational floor containing all studios and technical equipment at the rear. The office block thus screens the studios from street noises. All studios and associated technical facilities are arranged on the ground floor as shown in Fig. 2. The studios, nine in all, each with a control booth, have been divided into two main groups. Four announcing studios are arranged along the western wall and the five larger studios each designed for a particular type of production occupy the eastern wall. Together they vary in size from the large orchestral studio measuring 80 x 60 ft. and 30 ft. high with a long reverberation time, to the announcing suite 25 x 15 ft. and 9 ft. high with a short reverberation time. The usual important features for good studio design have been incorporated in the building, that is all studios are built on individual foundations giving a maximum of acoustical isolation. Observation windows, cable entries and air-conditioning ducts have all been carefully designed to assist this important aspect, and wall and ceiling treatments have been chosen and adjusted to give optimum diffusion and reverberation characteristics.

The technical installation has been designed using the continuity suite system of operation. The continuity suite system involves the use of a number of key presentation studios, each with its associated control booth, from which all programmes leaving the studios are controlled. This system has been adopted in other studio centres and offers many advantages for modern sound broadcasting techniques. Each combination of studio and control booth forms an individual continuity suite. The two officers controlling each suite have complete control of and responsibility for the programme associated with that suite, and the responsibilities of the main switchroom staff are reduced to the setting up of certain external connections some time before the commencement of a programme. The presentation officer or announcer is responsible for the programme continuity, that is the accurate and artistic timing of his programmes, and he must make appropriate decisions concerning over and under running of programmes, poor quality and complete failure, etc. As it is the policy of the Australian Broadcasting Commission to have announcers controlling the replay of disc recordings, a comprehensive desk has been provided for this officer. The desk has three 12-inch disc replay machines with long playing and standard pickups spaced for optimum operation from the sitting position. The technical officer in the control booth has control of levels and programme pre-selection, maintains overall technical monitoring and takes the necessary steps when any equipment fails. He is responsible for the correct channelling of external programmes through his suite. The successful operation of these suites involves a maximum of co-operation between both officers and it is considered that the new desks, shown in Figs. 3 and 4, provide optimum facilities.

PROGRAMME AND NETWORK SWITCHING

General

One of the major problems associated with any studio installation is the design

Fig. 1.—Rosehill Radio Studios Building showing Administrative Block facing Adelaide Terrace.

* See page 432.

of the switching systems that convey programmes from any of the different sources to the final destination. The use of the continuity suite system of operation necessitates the use of two switching systems, and these have been called the Programme Switching Scheme and the Network Switching Scheme. The general arrangement is shown schematically in Fig. 5 and a more detailed schematic is given in Fig. 6.

Network Switching Scheme

The number of programmes leaving the studios for distribution to the different National Broadcasting System transmitters throughout Western Australia varies, and reaches a maximum of four for certain periods of the day. The National and Light Programmes serve the Perth metropolitan area, and the regional and short wave transmitters generally take either of these two. However, facilities must be provided for four separate programmes and the equipment has been designed for six to take into account future expansion. With the building as it is, four continuity suites fulfil the present requirements and the four small operational studios shown in Fig. 2 are used for this purpose. Any future increase will involve the conversion of other studios to continuity suite operation. The transmitters which receive these programmes are nine in number, namely 6WF, 6WA, 6WN, 6AL, 6NM, 6GF, 6GN, VLW, VLX. Added to these is an outlet to the commercial stations (this is used for nation-wide broadcasts and news bulletins), a channel feeding the West-East line, and some general purpose outlets for testing purposes. Expansion in this direction could be considerable, particularly in the service to the country. It is likely that two separate programmes could be sent to each regional centre and with this in mind the equipment has been wired to take 24 outlets.

Briefly then, the Network Switching Scheme must connect any of six sources

Fig. 3.—Continuity Suite Desk Equipment—Announcer's Desk.

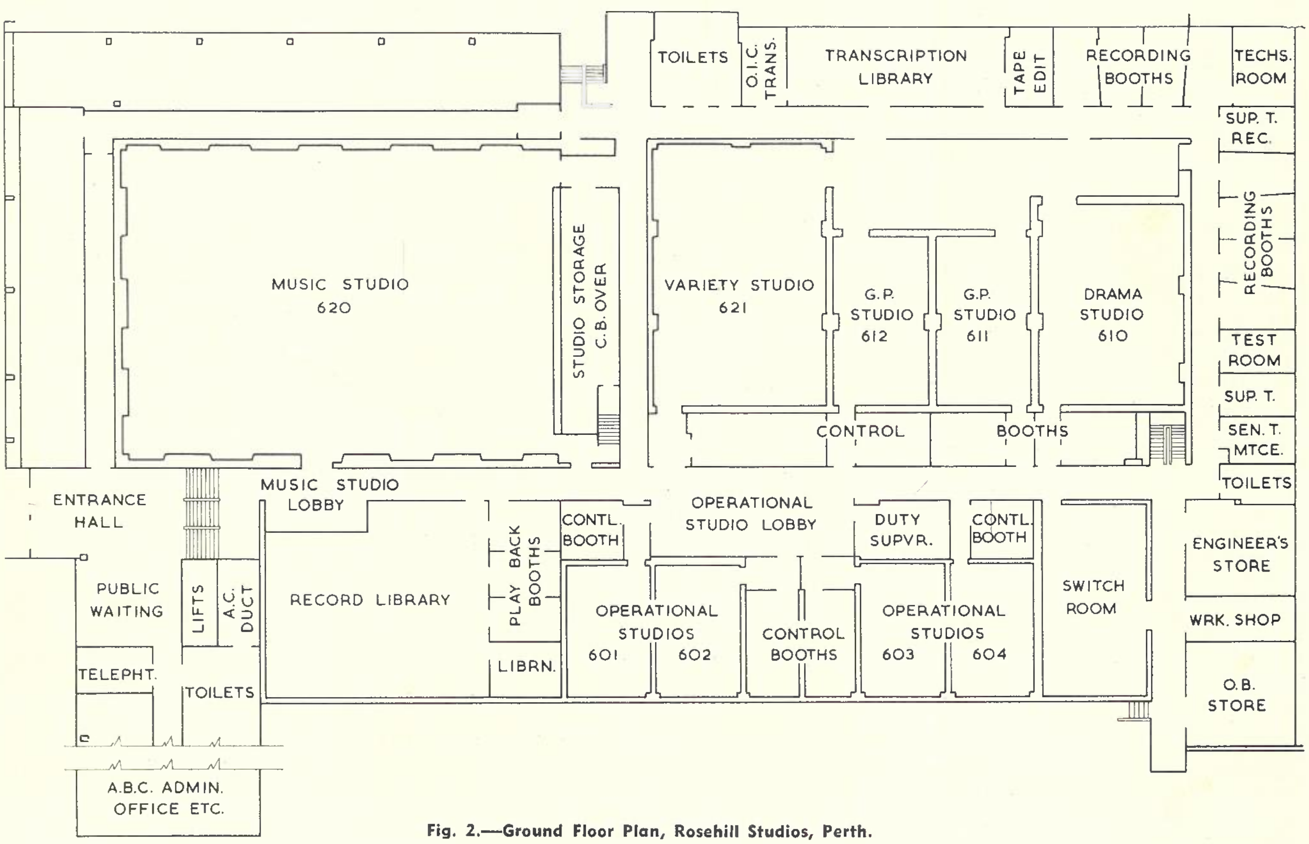


Fig. 2.—Ground Floor Plan, Rosehill Studios, Perth.

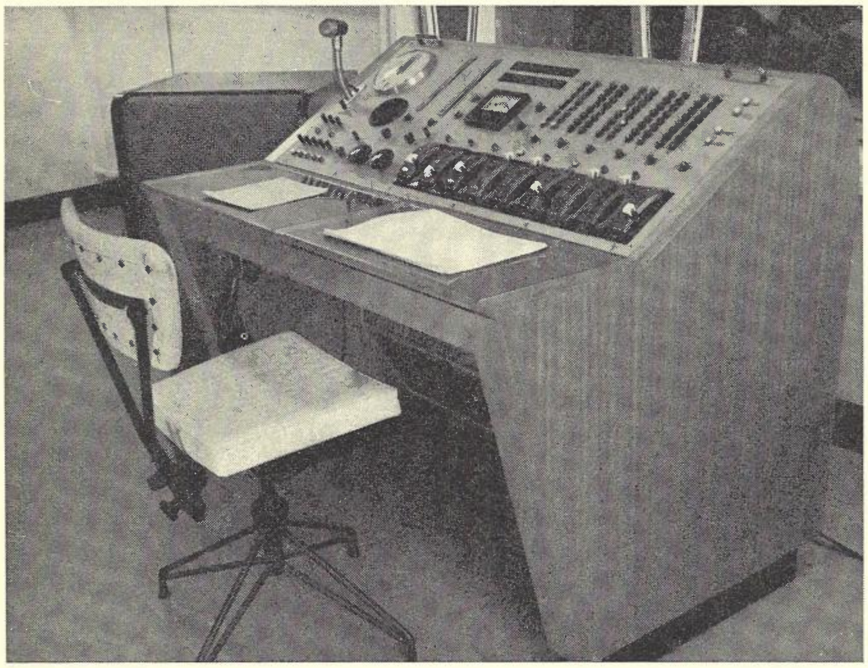


Fig. 4.—Continuity Suite Desk Equipment. Control Booth Operator's Desk.

(present and future continuity suites) to twenty-four outlets (transmitters, etc.). It has been customary throughout the National Broadcasting Service to use relay "crossbar" switching for this purpose and this system has been retained in the present installation. The method of mounting the equipment and the layout of the control panel enables an increase to a 6 x 30 system, and this should take care of expansion for some considerable time to come. Each input to the system represents a continuity suite and is referred to as a "horizontal", and it can be connected to any combination of the 24 station outlets referred to as "verticals". The operation of the system is from the remote control panel at the switchroom operator's desk shown in Figs. 7 and 8. The latter gives a closer view of the control panel together with the Network Switching Rack (showing vacant shelf positions) and the Programme Switching Rack with its four banks of high speed motor uniselectors.

The switching of continuity suite programmes to different combinations of transmitter outlets must be instantaneous, and consequently presetting operations must be carried out some time before the switch is due. It is possible to preset for an operate or release operation and this does not interfere with the combination of outlets already taking the continuity suite's programme. At the time the change is required, "Release" and "Operate" relays operate the circuit and the suites are automatically connected to the new combination, at the same time dropping those outlets preset for release. "On Air" lamps glow to show the new connection. It is important to note that the preset combination remains even after the switch has taken place. This is a precaution against faulty switching and obviates the necessity of establishing the presets again. The preset combination can be altered by cancelling via the "Preset Cancel" push button and a new combination set up by the row of locking lever keys on the switchroom panel.

The actual operation of the "Operate" key is done by the continuity suite control booth operator. On this officer's control panel is a network switching display which shows which outlets he has "preset" to him and which are actually "on air". At the scheduled time he depresses his "Operate" key and the programme switch takes place. The "preset" combination remains till it is altered by the switchroom operator.

Programme Sources

Programme sources can conveniently be grouped under the following headings:

- Continuity Suites
- Production Studios
- Tape Recording Machines
- Outside Broadcast Lines
- Programme Lines
- Miscellaneous

The types of programme originating in the continuity suites can be announcements, news readings, replay from gramophone records, or talks from the special talks table within the studios. In addition, programmes from production studios, tape recorders, outside broadcasts, etc., are normally channelled through a continuity suite. The control booth operator moreover has facilities for handling tape replay machines, so that although the outputs of these suites normally go straight to the network switching scheme, they must still be considered as programme sources.

Production studios are the source of all live and rehearsed programmes, that is music, variety, drama, discussion, etc.

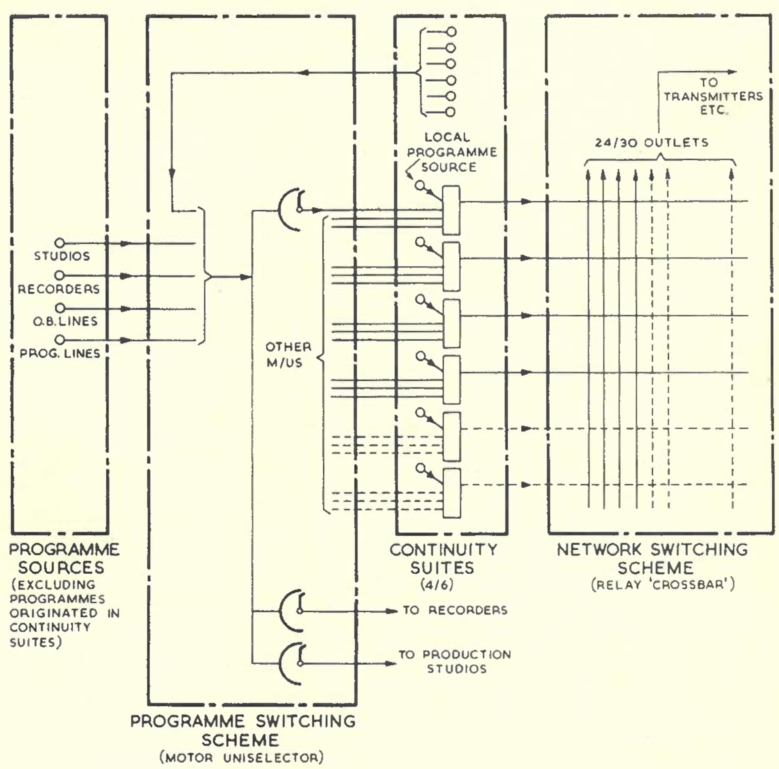


Fig. 5.—Simplified Schematic of Switching Arrangements.

The control room equipment is different from that of a continuity suite in that more microphone channels are provided and disc and tape replay facilities are available for insertion into live programes. The control desk is designed to seat the technical operator and the producer. Monitoring, "talk back", and access to microphone pattern controls, etc., are provided to assist the production. These features are illustrated in Fig. 9.

Replay from tape machines plays a very important role in modern studio practice, allowing a very high degree of flexibility in programme arrangement. At the rear of the building is a group of small rooms which contain the tape and disc recording apparatus. Five of the rooms house the console tape recorders, two per room, and these can be used independently for either record or replay. One of the rooms has a pair of disc cutting machines, one a group of portable tape recorders, and another contains apparatus for tape editing and dubbing.

Outside broadcast lines are used to send programme material to the studios from specific points throughout the city and country areas, and a comprehensive system of Post Office lines is used for this purpose. The number of these outside broadcast links entering the studio is 60 and these terminate on a jack field from where up to seven can be connected for use in programme selection. There are several other miscellaneous sources of programme, namely a line from the television studios for simulcasts, and special stereophonic replay lines from the four continuity suites.

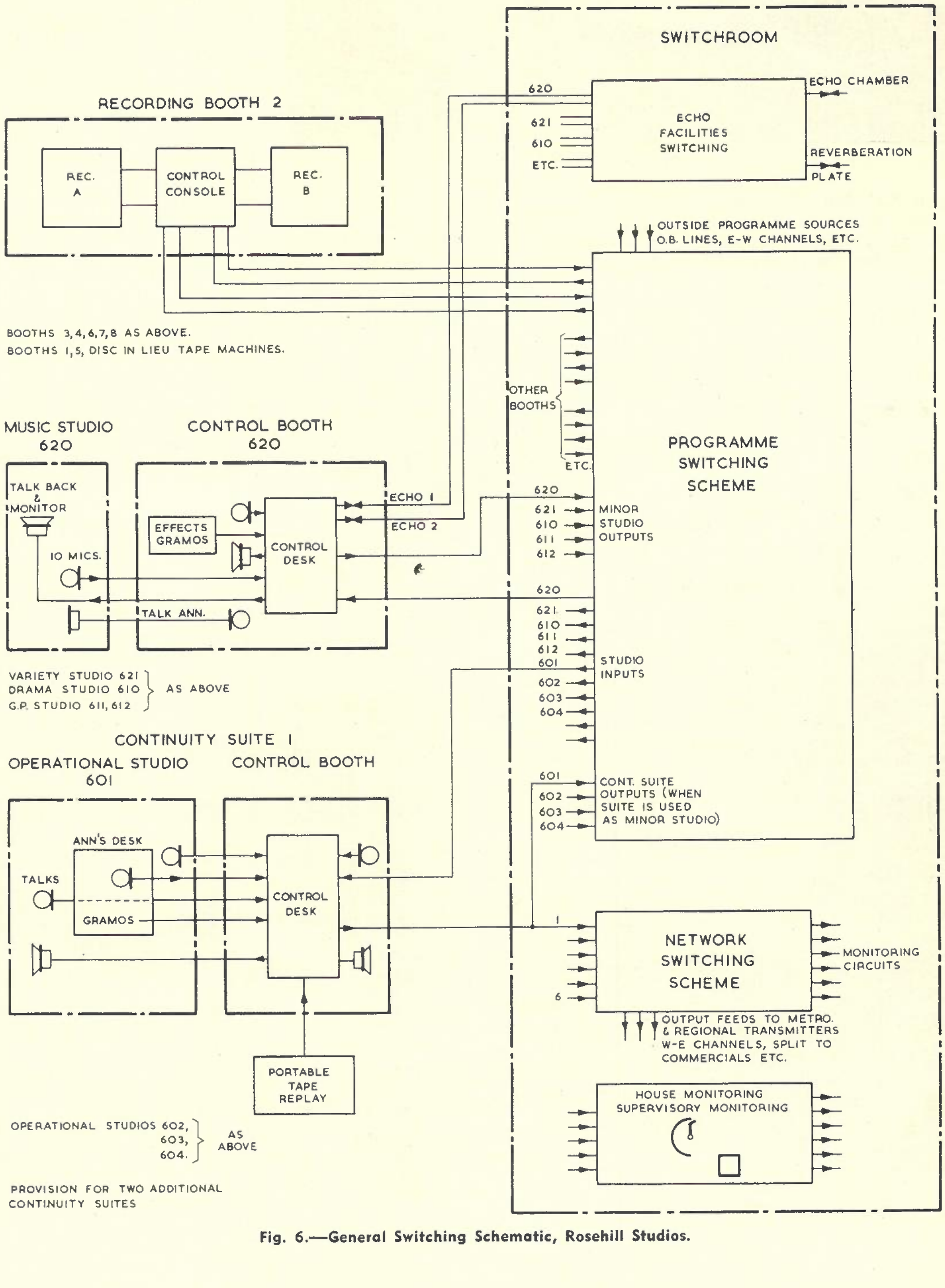


Fig. 6.—General Switching Schematic, Rosehill Studios.

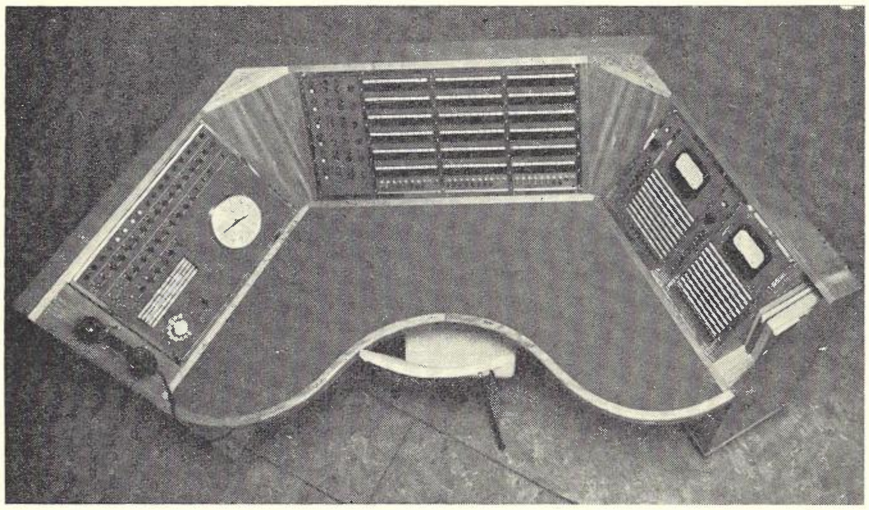


Fig. 7.—Switch Room Operator's Control Desk.

Programme Switching Scheme

Access to the programme sources is limited to Continuity Suites, Production Studios, and Recorders, and the method of channelling any of the sources into these is termed the Programme Switching Scheme. If all these programme sources were multipled on the banks of a group of uniselectors and each of the above positions had control of a uniselector and its wiper outlets, then a convenient means of programme channelling could be evolved. The use of high speed motor uniselectors has many advantages over ratchet uniselectors, transistors or relays, and their use has been adopted. Each selector used can connect 16 wipers to 50 contacts making a total of 800 possible connections. The equivalent number of relays or transistors necessary to perform a similar number of switching functions presents a formidable problem when wiring and mounting has to be considered, and their total cost is many times the cost of the uniselectors. Because 16 wipers are available, other facilities may be switched simultaneously with the programme, which takes only two wipers. Order wire and monitoring connections are made and this greatly improves the operation and simplifies the circuitry. As an example, a suite can be about to take an outside broadcast from a hall. In this case the uniselector is marked and preset on the appropriate bank number. The operator in the control booth of the suite then has automatically a telephone connection to the operator at the hall, and the announcer in the hall receives the programme from the suite via the monitoring connection. He can then cue his programme correctly. Similarly if a recording booth has been selected by the control booth operator of a suite, then both operators are in telephone contact, and the recording Technician can cue his tape replay correctly by connecting his monitoring selector across the incoming monitoring line.

The marking operation consists of simply placing an earth on the bank required. For 50 banks, 50 different keys would be needed, but advantage is

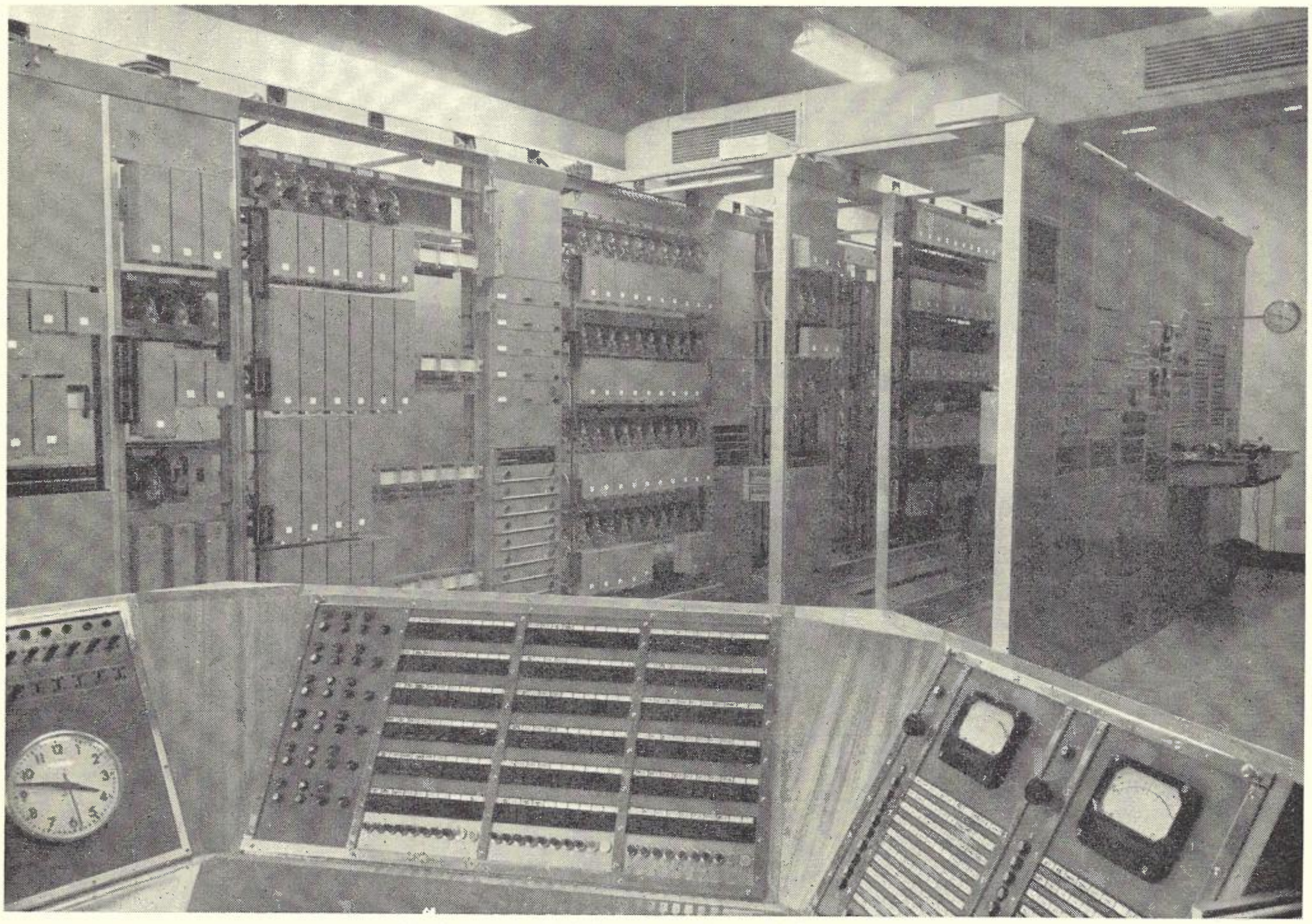


Fig. 8.—View of Switchroom from Operator's Control Desk.

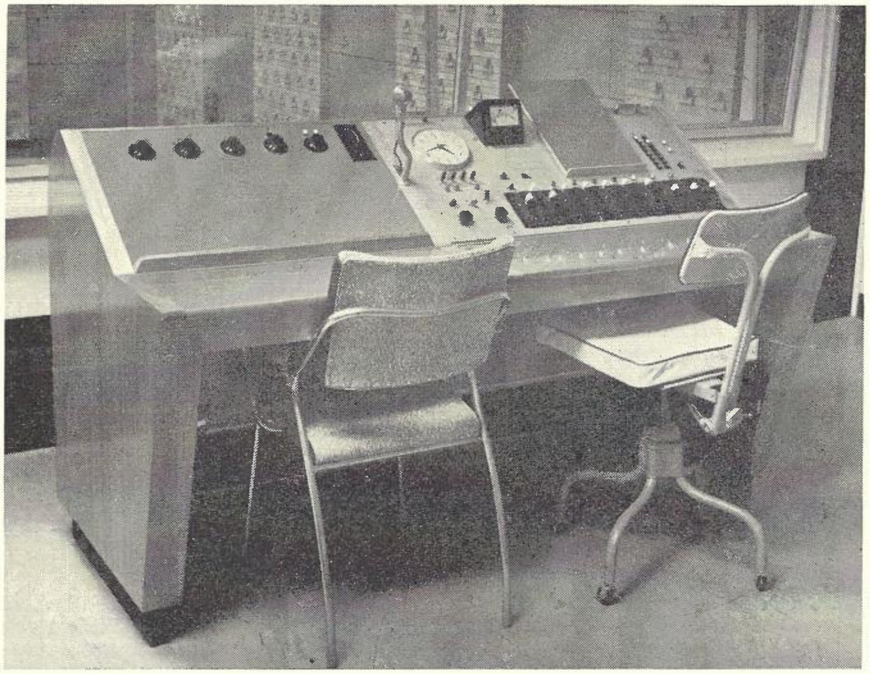


Fig. 9.—Production Studio Control Desk. Showing Facilities for Operator and Producer.

taken of the convenient groups of seven that the programmes fall into. By dividing the programmes into seven groups of seven, only 14 keys are needed to mark 49 positions, that is—

C.S.—(Continuity Suites),
St.—(Studios),
RECD. 1—(Recorder Group 1),
RECD. 2—(Recorder Group 2),
RECD. 3—(Recorder Group 3),
P.L. & Misc.—(Prog. Lines & Miscellaneous),
O.B.—(Outside Broadcast Lines),
1, 2, 3, 4, 5, 6 and 7.

For example if a recorder wishes to record the programme coming from Continuity Suite No. 4, he first depresses the C.S. button and then the 4 button. The switch is then ready for operation.

For optimum operating, each continuity suite has three switches, thus enabling three different programmes to be preselected. At the specified time the control booth operator can open the appropriate fader to broadcast any of these channels. In the case of the continuity suite used for Sporting Panels, five switches are available. On sporting days the control of these switches is extended to the announcer who can then handle five different outside broadcasts. With monitoring and talk back facilities to each of these O.B. points provided, excellent presentation is achieved despite the continuous changing of programme.

The production studios have access to one switch which will be used principally to carry tape replay for use in live programmes, and to add flexibility to the system. Tape recorders naturally must have access to all programme sources available, and these have one switch per machine. In all cases, operation of the switch is in the hands of the control or recording booth operator, thus relieving the switchroom staff of any responsibility as far as programme switching is concerned.

CONTINUITY SUITE DESK EQUIPMENT

The desk equipment in the sporting panel suite is shown in Figs. 3 and 4. The announcer can perform the following functions from the seated position:

(a) Use his own microphone for announcements and control a microphone over a small talks table within the studios.

(b) Use any of the three disc replay machines for playing records. The long section to the left of the desk is available for two stacks of records—nominally used and unused. The storage space below is used for theme records and others that are required frequently. Cueing facilities for each machine are provided through a small loudspeaker mounted within the desk clock housing. The three quadrant faders on his panel are used for record fading only and are either fully on or fully off.

(c) The announcer can also control up to five channels of the Programme Switching Scheme, during sporting programmes. The selection and signal level is still controlled by the technical operator in the control booth. He may also monitor each of these five programme lines via keys and the left hand headphone. The right hand headphone is connected to a comprehensive monitor source switch, the position of which is shown on an illuminated panel display. The loudspeaker within the studio is in parallel with that in the control booth, and it is worth noting that the announcer is provided with four different monitoring systems designed to help the officer perform his various tasks efficiently.

Other features of this desk are the movable reading slopes and complete intercommunication facilities with the control booth operator, studio supervisor, and commentators at any outside broadcast point. The assembly of equipment immediately in front of the announcer may perhaps be not ideal

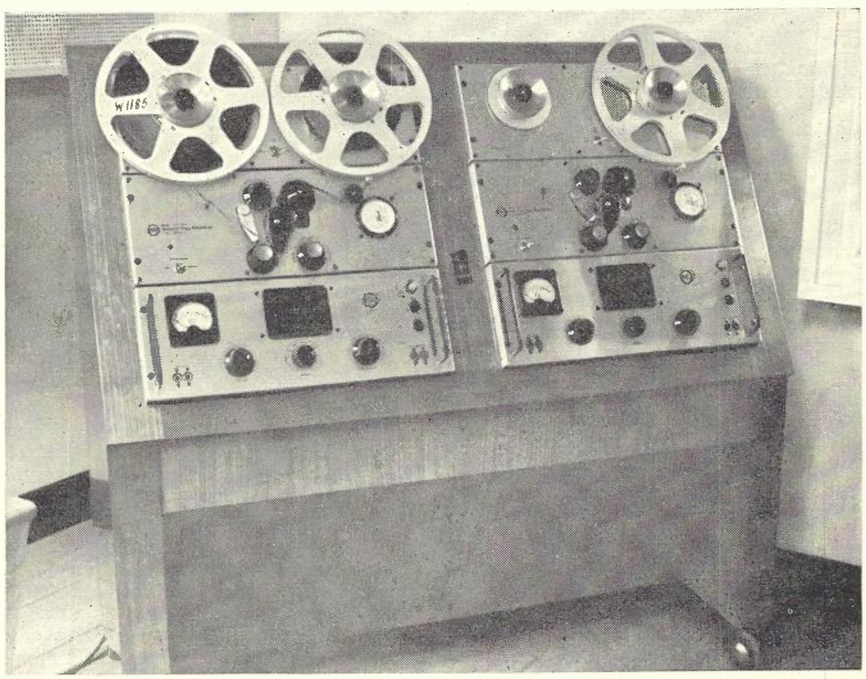


Fig. 10.—Transportable Tape Equipment Trolley. Used in Control and Tape Booths.

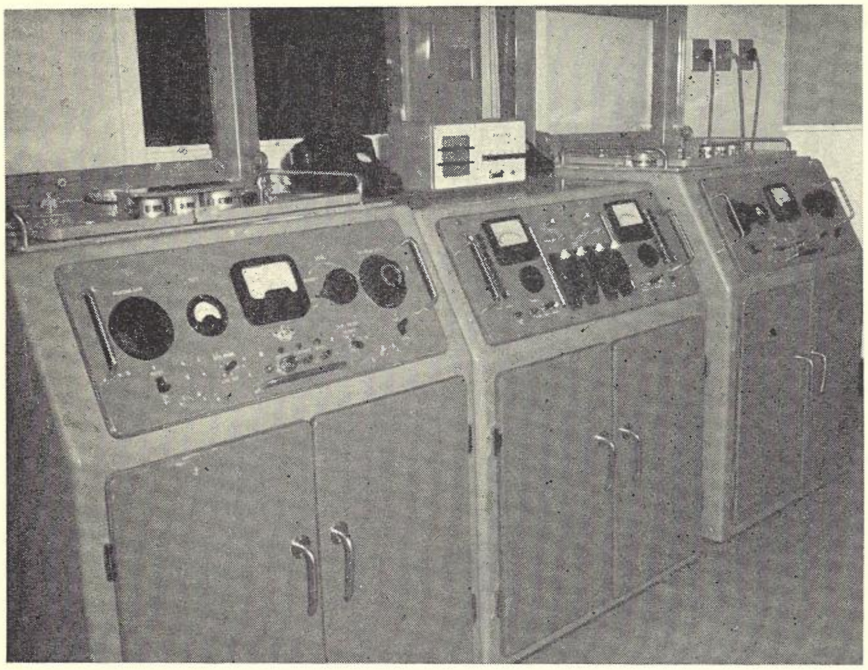


Fig. 11.—Console Tape Recorder Installation showing Two Recorders and at Centre a Matching Control Console.

from a voice reproduction aspect because of the possibility of complex reflections. However, the designers were confronted with specifications which made this unavoidable and an excellent compromise is achieved by using unidirectional microphones.

The control booth operator's desk shown in Fig. 4 illustrates the great advance in studio techniques made possible by the introduction of small plug-in units. As stated previously, the necessity for the familiar equipment rack within the control booth was eliminated, and design emphasis was placed on optimum operating facility and harmonious appearance. All the plug-in amplifiers and associated equipment are mounted in the lower part of the desk, and are accessible from the rear.

The operator performs four main functions which can be summarised as follows:

(a) Control the level of programme leaving the associated suite (that is announcer's or talks microphones and gramophone pick-ups).

(b) Select, actuate, and control the level of up to five external sources of the Programme Switching Scheme.

(c) Actuate the preset combination of outlets of the Network Switching Scheme to the "on air" condition.

(d) Control a transportable tape recorder system for either recording or replaying of programme material. Fig. 10 shows one of these units.

Comprehensive monitoring is essential to this officer and this has been made available in four different sources as in the case of the announcer, namely right and left hand headphones, panel and floor mounted loudspeakers. Illuminated displays of monitoring points are provided and both the preset and actuated combinations in the Network Switching Scheme are also indicated by illuminated displays. Intercommunication facilities with the announcer, senior officers and other control booth operators are provided, and automatic telephone connections to any programme source connected to his suite complete the system. These facilities have proved successful in enabling excellent programme changeovers to take place.

TAPE AND DISC RECORDING AND REPLAY EQUIPMENT

In the initial installation the following units were installed:

(a) Ten console tape recording machines arranged in five pairs. Each pair is installed in a recording booth and a control console is used to channel and control programmes to and from each machine. Access to the programme banks is provided through one switch per machine. A typical group is shown in Fig. 11.

(b) Two disc recording machines. These are mounted in a cabinet which also contains all the associated amplifier and control equipment. Access to the programme banks is provided.

(c) A "Portable Tape" Booth. This room contains four Byer 77 machines housed in two of the standard transportable cabinets. The control unit for these machines is similar to that of the console recorders.

(d) Tape editing and dubbing equipment, consisting of:

(i) a pair of portable tape recording and replay machines

(ii) a pair of portable tape replay machines

(iii) one transportable disc replay machine.

The recorder control consoles provide separate recording and replay channels for each machine. Each channel is fitted with quadrant fader and type 1 amplifier. The monitoring circuit returned to the Programme banks is taken from the playback line via a type 2 amplifier. When two machines are required for a long programme, both replay outputs from the machines must be channelled into the one playback line and this is achieved by a "couple" key and a hybrid circuit. Monitoring circuits are switched to the loudspeaker in the booth by a rotary switch and a lamp display is provided. The replay outputs of any recorder are available to all sections of the studios equipped with programme switches. Monitoring and telephone circuits are established between the recorder and the first person to select this recorder. All other switches subsequently connected to this recorder can then only pass programme and cannot return monitoring and telephone circuits. Consequently, for the system to operate correctly, it is the responsibility of the recorder operator to test for correct channel connection, with the person receiving his programme, prior to programme time. This problem has been overcome by the addition of facilities at every programme switch control point, which enable the operator to over-ride all monitoring connections that may be established.

When replaying to a control booth, monitoring is received back through the Programme Switching Scheme and the monitor selector switch on the control console. This enables the recorder operator to cue properly and to check his replay programme at the output of the recorder and the output of the control room to which he is playing. This system provides an excellent means of checking programme continuity and in the case of failure, the recorder operator can quickly tell whether his equipment is functioning correctly. In the recording condition the programme to be recorded is channelled to the recorder via the console equipment. The output of the replay head is used as a source of monitoring which is returned to the switch banks via the replay fader on the control console. This feature provides instantaneous replay.

CONCLUSION

The Rosehill radio studios have now been in operation for two years. The success of the installation has been borne out by greatly reduced fault incidence and ease of maintenance. The standard of workmanship by all sections of the Postmaster-General's Department involved in the installation is held in high regard, and forms a notable contribution to broadcasting in Australia.

MONITORING LOUDSPEAKERS FOR THE NATIONAL BROADCASTING SERVICE

*E. L. BROOKER, B.Sc., A.M.I.R.E.Aust.**

INTRODUCTION

With over 100 main studios and their associated control booths, in addition to transmitting stations and offices, the National Broadcasting Service makes heavy demands on high quality monitoring loudspeakers and, in fact, several hundred such loudspeakers are now in service. Since the loudspeaker is such a vital component in the broadcasting chain, while at the same time being probably the most imperfect, it has been the practice to review periodically the standards of monitoring facilities and improve them in the light of recent technical advances. A review of this kind was begun some two years ago when it was apparent that a substantial purchasing programme for monitoring loudspeakers lay ahead. As a result, a completely new design for a very high quality loudspeaker system was developed and some improvements were made to the small medium quality system already in service. This paper describes the characteristics of these two loudspeaker systems which are now in general use in the National Broadcasting Service. Fig. 1 shows the production versions of the two systems.

* See page 432.

CURRENT "HIGH FIDELITY" TECHNIQUES

The Meaning of "High Fidelity"

Before describing the new standard loudspeaker system, it may be useful to review the present state of the loudspeaker art and outline the current techniques and principles. The ultimate objective of realism is still generally accepted as the criterion for a loudspeaker and the introduction of technically satisfactory stereo (and pseudo stereo) has taken the art one step closer to this objective. Stereo reproduction is particularly useful in that it enables us to distinguish between faults which are inherent in the loudspeakers and faults which are a product of "hole-in-the-wall" monophonic reproduction.

In the search for realism, it is usual to measure such basic loudspeaker properties as frequency response, harmonic distortion, transient distortion and polar response. A good loudspeaker must be satisfactory in all these respects. However, superimposed upon these characteristics are the undefined properties, commonly called "colourations," which are so easily manifest to the ear but so difficult to locate by measurement. Certainly it is well known that a loudspeaker with excellent frequency and transient responses may sound quite objectionable on programme. A probable explanation is to be found from a close examination of the complex ripple pattern in the frequency response. The frequency response of a loudspeaker is strikingly reminiscent of the response of a room or enclosure, and the ear may well draw upon its wealth of experience to interpret the complex loudspeaker response in terms of similar acoustic environment. This may explain why loudspeakers are commonly said to have a "boxy" or "pipe" quality. Nevertheless, whatever interest lies in the fine detail of the frequency response, the ear is also very sensitive to the smoothed response, and a general tilt of only 2 db over the upper or lower portion of the spectrum can be detected readily by a discriminating listener.

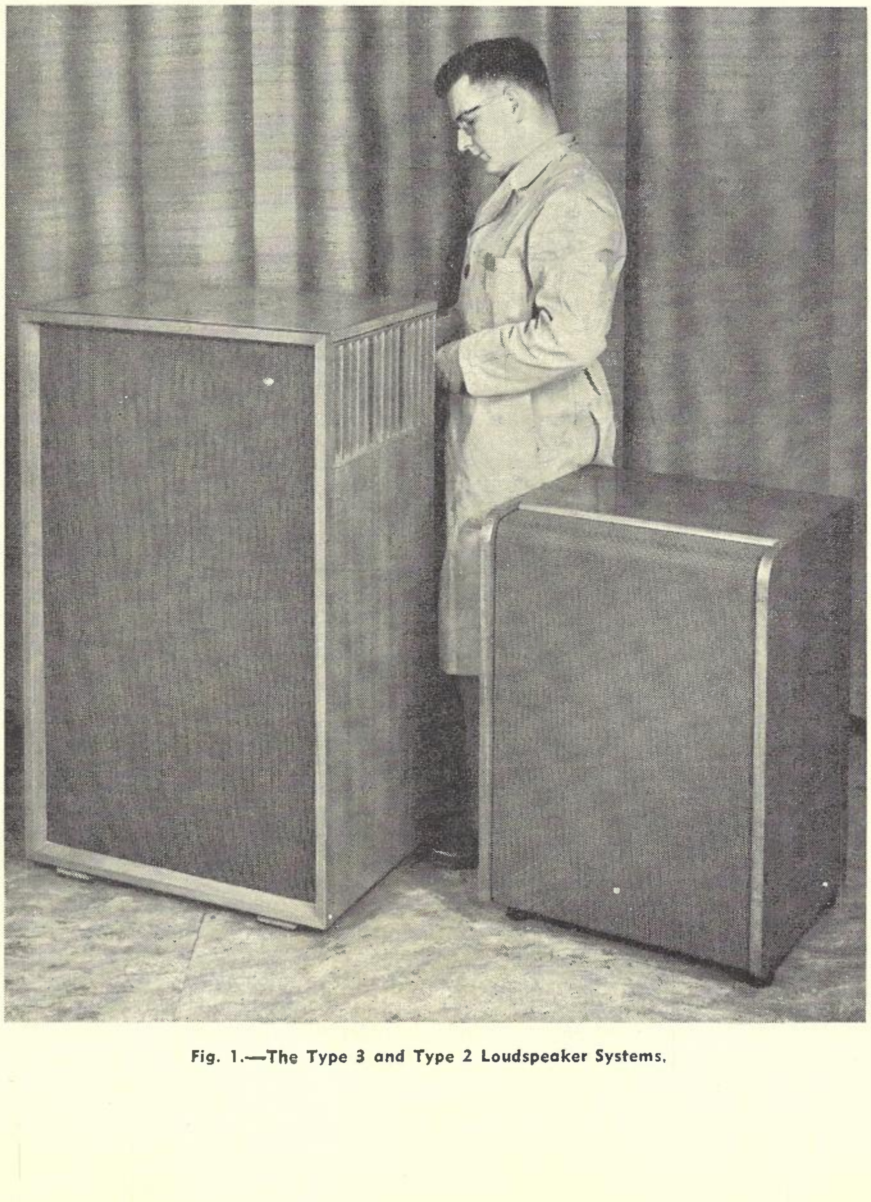


Fig. 1.—The Type 3 and Type 2 Loudspeaker Systems.

Low Frequency Response

The smoothed frequency response of a loudspeaker system divides into three separate regions of difficulty which may be classified as the low, middle and high frequencies. In practice, most attention has been given to the two extremities at which the low frequency response becomes an enclosure problem and the high frequency response a diaphragm problem.

At the very lowest frequencies, all loudspeakers work as simple pistons and the problem is to couple the piston to the air. Electrostatic diaphragms have been produced and, like the multiple bass speaker arrangements, have achieved some success due to their abnormally large area. Horns of various shapes can be used but are never able to achieve very low bass response in enclosures of normal size. Other experimental enclosures have appeared from time to time but it can be fairly said that the reflex enclosure is still the most efficient in terms of bass response per unit of volume.

A recent development has been the appearance of "bookshelf" size enclosures of 1 or 2 cubic feet with adequate bass response down to about 50 c/s. These units represent an integrated speaker plus enclosure design in which a high flux density speaker is designed to a lower electro-acoustic efficiency in

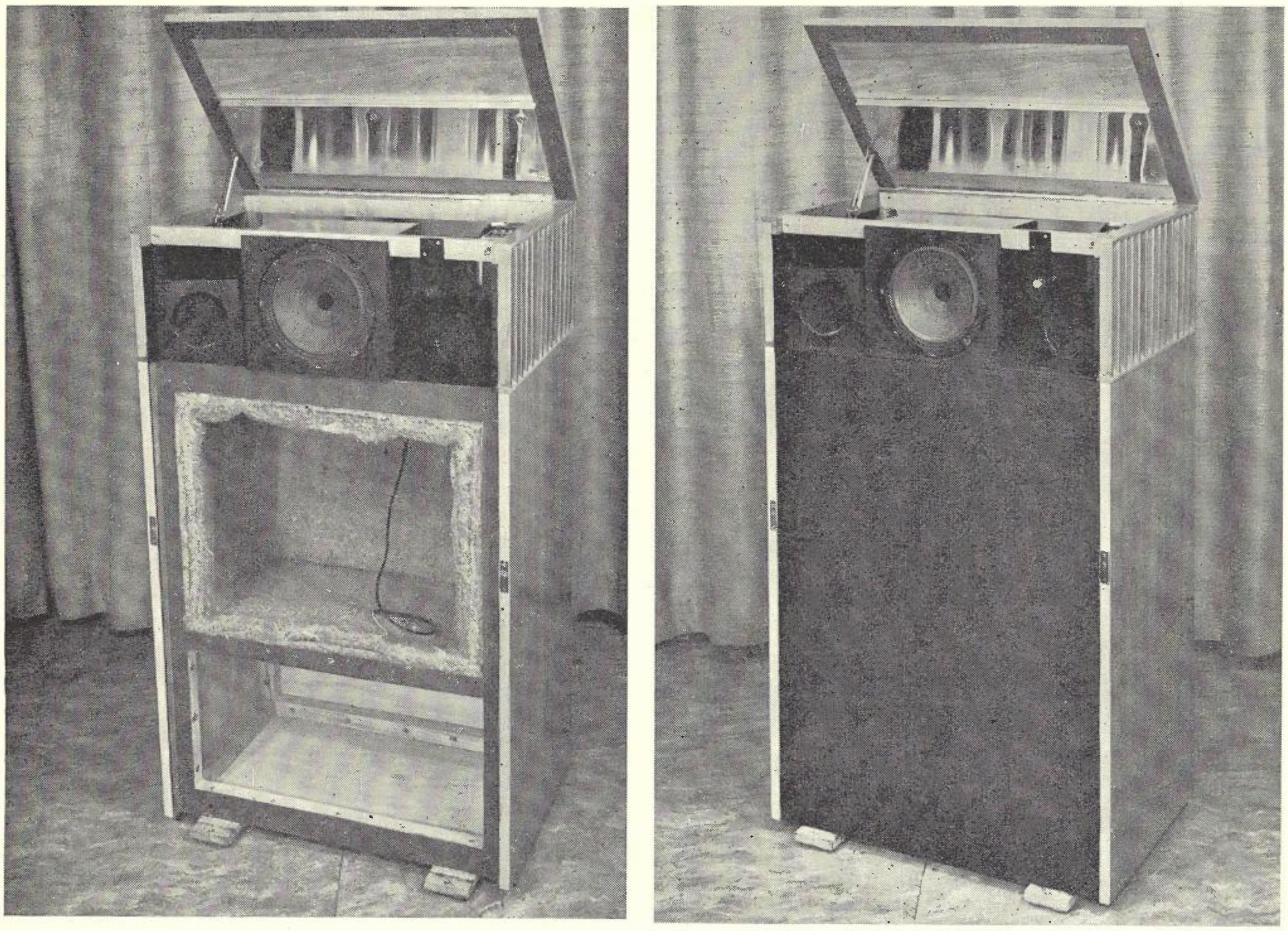


Fig. 2.—Type 3 Cabinet before and after Mounting the Loudspeakers.

the interests of obtaining bass response from the small enclosure. Given an adequate power source and moderate demands on acoustic volume, the design is most successful, particularly for domestic stereo applications. It is not possible, however, to obtain similar results from conventional driver units which have not been designed specifically for small enclosures.

Middle and High Frequency Response

Above about 300 c/s conventional loudspeaker cones break up into complex modes of vibration giving rise to the irregular frequency response referred to earlier. Various techniques are used to control this breakup, for example concentric compliance rings, variable hardening, superimposed domes and sandwich construction. Electrostatic units do not suffer from the same defect. It has recently been shown that the usual method of mounting a middle frequency unit behind a cut-out in the baffle is, in itself, a potent source of colouration. Extreme tapering of the cut-out or mounting the speaker from tbe front removes this effect. The middle frequency response remains, however, as the least understood part of the spectrum, and the one which contains the least well-defined defects.

At the high frequency end of the spectrum a number of "tweeter" types have appeared, including moving coil units (direct radiator and horn loaded), ribbons, crystals, electrostatics and others. The main practical limitations in all cases appear to be inadequate sensitivity and the inability to handle sufficient power in the important region between about 1 and 5 kc/s where most low frequency units are showing gross defects. However, as far as the higher frequencies are concerned, there is now little difficulty in achieving adequate response as far as the upper limit of audibility. The polar response however, is not always as broad as could be desired.

NEW TYPE 3 LOUDSPEAKER

Functions

The new Type 3 monitoring loudspeaker system has been designed for the most critical locations in the National Broadcasting Service where the balance of the programme is adjusted and its quality assessed in both aesthetic and technical respects. The studio control booth is one such location. For these applications, the wide range high quality properties of the monitoring loudspeaker are called upon to serve three quite distinct functions. A good low frequency response, extended flat to at least 50 c/s, is essential to show undesirable hum or rumble on the programme. An extended high frequency response is needed to display the existence of other noises such as clicks or hiss which have a predominantly high frequency spectrum, and also to show up harmonic and intermodulation distortion. A flat middle frequency response as free as possible from colourations is necessary to permit satisfactory judgments of the balance of programme material. Deficiencies in the middle frequency reproduction lead to false accentuations of some instruments and to false balances between soloists and accompanists.

Other properties are also desirable in certain situations, particularly for control booths where space is often limited. A wide beam width at high frequencies is most necessary, and sufficient electro-acoustic efficiency is required to operate comfortably from existing standard A.P.O. Type 3 (18 watt) amplifiers. Easy service accessibility, particularly to the amplifier, with a minimum of cabinet removal is desirable. The unit should also be of minimum size while preserving a loudspeaker height at or above ear level to permit unobstructed hearing.

The new Type 3 Loudspeaker satisfies all of these requirements with the exception that a further reduction in dimensions to take it into the wall-mounting or bookshelf category would have been acceptable. This could not be done with available driver units. Nevertheless, the Type 3 unit is appreciably smaller and much more convenient than the 12 and 14 cubic foot enclosures which it replaces.

Low Frequency Design

In the Type 3 System, a 15 inch low frequency unit is mounted in a conventional reflex enclosure having a volume of 6 cubic feet. With a vent area of 15 square inches, the enclosure resonates at 39 c/s, a little above the free air cone resonance, to give the optimum bass response. The main internal standing wave, in the vertical direction, is damped by a membrane stretched across the centre of the enclosure and the upper section of the enclosure is heavily lined with felt, as shown in Fig. 2, to remove other resonances.

The low frequency unit has the usual undesirable characteristics above about 500 c/s. and the cross-over network has therefore been designed to cut off at this frequency. Additional attenuation is obtained by means of an acoustic filter placed in front of the cone. When thus operated, the response falls slowly towards the low frequency end before reaching its normal cut-off point, and recourse has been made to an equaliser to optimise the response. The equaliser lifts the output by 6 db at 40 c/s. to give an overall response for the L.F. unit, as shown in Fig. 3(a).

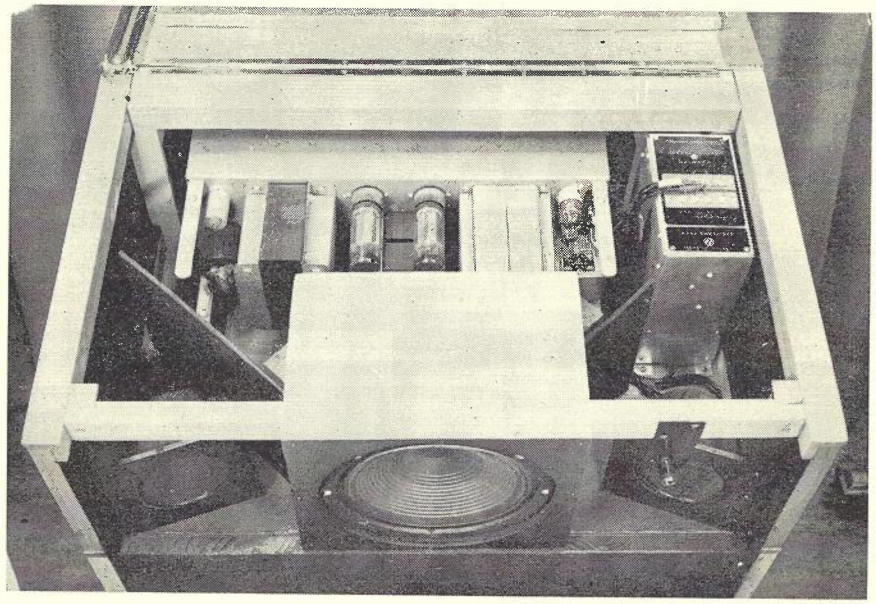


Fig. 4.—Type 3 System—Layout of Components.

Middle Frequency Design

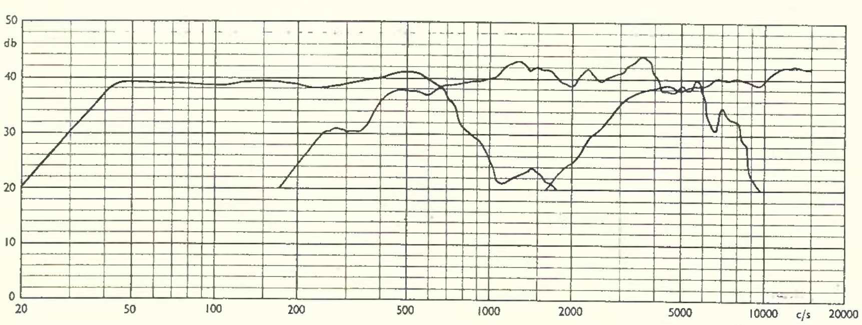
The middle frequency range, between 500 and 5,000 c/s., is handled by an inexpensive 8 inch loudspeaker mounted in a small fully enclosed, heavily padded box. In this frequency range, the mounting of a speaker behind a cut-out in a baffle has been found to be one of the prime causes of colourations, due to the cavity formed by the thickness of the baffle. The M.F. unit is therefore mounted on the front face of its enclosure and this also provides for very easy access from the front. The attenuation that must be provided in the cross-over network to reduce the level of the 8 inch unit to optimum balance provides an opportunity to equalise a depression in its response at 2,000 c/s.

High Frequency Design

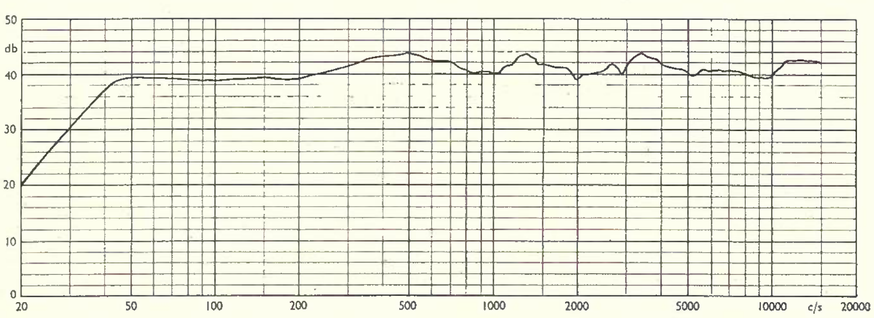
The arrangement of the high frequency speakers is an innovation whose purpose is to provide a very wide beam width and to avoid dissociating the source of the high frequency components from the source of the remainder. Two 3 inch "tweeter" units are driven in parallel through a high pass network with a cut-off frequency of 5,000 c/s. The interference pattern from two identical spaced sources would normally be troublesome and this has been overcome by separating the tweeters by the full width of the cabinet as can be seen in Fig. 4. With this spacing, the interference pattern (see Fig. 5) shows a large number of very closely spaced maxima, the separation between successive nulls being so small that the listener's two ears bridge the gap at normal listening distances. The phasing of the M.F. and H.F. units has been further chosen to provide a substantial degree of null fill-in in the 5,000 c/s. region where the effect is most troublesome. The tweeters are inclined inwards by 20 degrees to give a uniform polar response. The inwards rather than outwards inclination superimposes the high frequency image on to the M.F. unit and ensures that the image remains fixed when the listener moves around the cabinet.

Cabinet

The design of the cabinet involves a substantial departure from normal practice in the interests of better serviceability. With the exception of removing

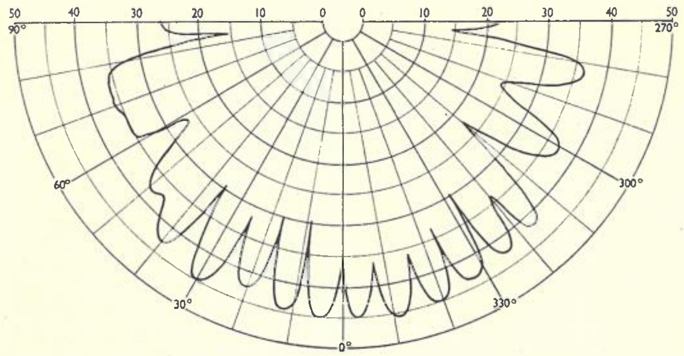


(a) Separate L.F., M.F., and H.F. Responses.

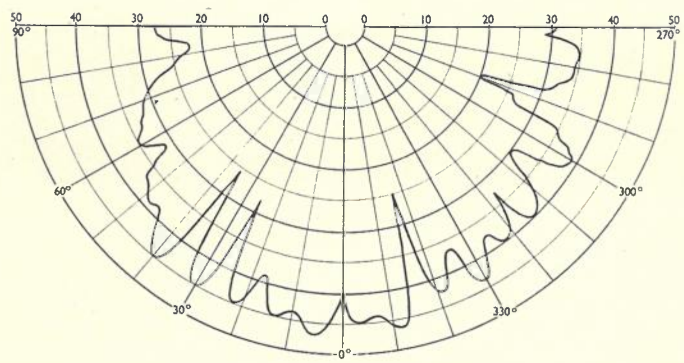


(b) Combined Response.

Fig. 3.—Overall Frequency Response of Type 3 System.



(a) H.F. units alone.



(b) M.F. and H.F. units.

Fig. 5.—Polar Diagrams at 5 kc/s of Type 3 System.

the amplifier complete, all servicing can be done from the front. The lid hinges up for valve changing and testing and the grille frame slips off to expose all four loudspeaker units. The L.F. unit is mounted behind a baffle board which screws on from the front and which includes the vent. Other L.F. units may therefore be substituted with the provision of a new baffle. A pilot light is visible through the grille fabric and the power switch is within finger reach at the back. The veneered surface of the cabinet is finished in a clear polyester plastic which is extremely hard and scratch resistant.

Use of the Equaliser

The equaliser improves the bass response of the system by applying a correction which rises below 150 c/s. to a value of 6 db at 40 c/s. The mid-frequency loss of the equaliser is 16 db and this leaves a standard Type 3 amplifier with sufficient gain to be fully driven from a + 8 VU line. In small studios and control booths, it is always difficult to generate enough very low frequency energy owing to acoustic properties of the small space. For these applications, the equaliser should always be used. A switch is provided however to enable the equaliser to be removed from circuit if it becomes necessary to do so. This situation would normally occur only where the maximum possible power output is required in a large room or where the unit is driven from a line level of less than + 8 VU.

Performance

The complete Type 3 Loudspeaker system gives a pleasing performance in all respects and is comparable with the best of the very high-priced commercial speakers. Its measured frequency response is as shown in Fig. 3(b). The unit is substantially free of transient defects and has an extremely wide beam width (greater than 90°) at all frequencies. Its efficiency is high, being of the same order as that of other high efficiency wide range moving coil systems, and it has good power handling capability and unusually low distortion over the full band width. The grouping of the several driver units leads to the illusion of a much larger source area than is obtained from a single coaxial speaker and it is this, as much as its other characteristics, that gives the Type 3 system abnormally good definition in the reproduction of complex orchestral music.

MODIFIED TYPE 2 LOUDSPEAKER

Purpose and Application

The initial design for the small Type 2 monitoring loudspeaker system was produced some years ago with the object of satisfying the need for large numbers of cheap units of adequate quality to meet the less critical applications. Many of these units have been used in offices and other places where space or cost rules against the use of a very high quality system. Following the development of the main Type 3 system, the opportunity was taken to bring the design of the earlier Type 2 system up to date. As a result, major changes have been made, although the original external cabinet design has been retained. The earlier Type 2 cabinets may be modified readily to incorporate most of the benefits of the newer design. The revised Type 2 system cannot be compared with the Type 3 system in terms of quality, but it does provide a reasonably wide range system with a satisfactory balance and at a very low price. Its bass response falls rapidly below 80 c/s. and it should not therefore be used as an arbiter when monitoring for hum on a programme.

Design

In the new version of the Type 2 system, advantage is taken of a low priced loudspeaker unit whose response is unusually good for its class. The 12 inch unit has a free air cone resonance of about 41 c/s. and a free edge cone for high frequency radiation. Its small magnet leads to a low efficiency and insufficient electromagnetic damping at low frequencies. The unit is mounted in a reflex enclosure of 2.8 cubic feet, tuned with a 3½ inch diameter hole and the response is as shown in Fig. 6. To avoid middle frequency colourations, the unit is mounted on the front face of the baffle. It might be noted that, in modifying the older Type 2 cabinets, the new loudspeaker mounts in the non-circular hole in such a way as to leave two triangular apertures of just sufficient area to tune the enclosure.

The main deficiency of the loud-

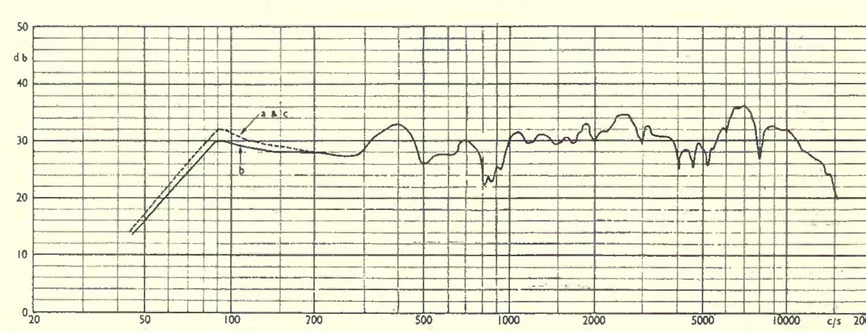


Fig. 6.—Frequency Response of Type 2 System.
(a) New design (3½" diam. vent without acoustic resistance).
(b) New design (3½" diam. vent with acoustic resistance).
(c) Modified existing cabinet (Triangular vents without acoustic resistance).

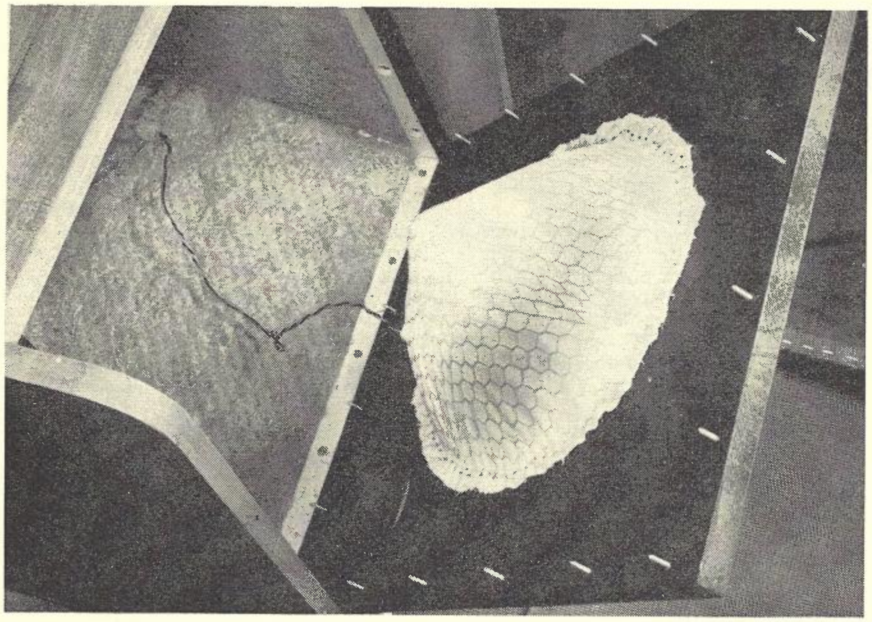


Fig. 7.—Interior of Type 2 System Showing Acoustic Resistance Element.

speaker is its lack of damping but this has been overcome by enclosing the rear of the cone with an acoustic resistance element as can be seen in Fig. 7. A layer of fabric, held rigid between layers of wire mesh, provides a resistive component for the air moved by the diaphragm. As can be seen from Fig. 8, this resistance unit removes the bass resonance peak and its associated transient to give a response equivalent to a loudspeaker with much better damping. The cabinet, as before, houses the power amplifier in the lower section. The loudspeaker mounting arrangement allows the adoption of the same approach as was used for the Type 3 system, in that both the loudspeaker and its baffle are attached from the front.

VARIATION TO THE DESIGNS

The Type 3 system is a closely integrated design involving the sensitivities, frequency responses and polar responses of its several driver units whose placement in the cabinet is also critical. It is recommended therefore that this system be not changed in any way unless comprehensive measuring facilities are available.

The Type 2 system on the other hand is very flexible and its geometry may be extensively rearranged to suit specific purposes. The response will be essentially unchanged for any configuration of the enclosure provided that the internal volume of 2.8 cubic feet is retained and that the ratio of maximum to minimum dimensions of the enclosure does not exceed about 3. The position of the vent hole is not critical as long as it has a clear path to the open air. The vent should not therefore be placed in the bottom of the cabinet near the floor or in the back of the cabinet which may be close to the wall. Ideally the vent should be close to the loudspeaker. Lining of the cabinet is of course essential, and mounting of the loudspeaker from the front of the cut-out has the advantages mentioned previously. The acoustic resistance element is equally suitable for any configuration.

The bass response may be extended by an increase in the volume of the enclosure provided that the vent area is increased in the same proportion. The resistance element may then need adjustment in the direction of increasing its resistance by the use of more layers of cloth. The purpose of this adjustment would be to retain control of the upper resonance peak which appears at a lower frequency in a larger enclosure. If the volume of the enclosure is increased substantially, experimental tuning of the vent area would be needed for optimum results.

CONCLUSION

The design of the new Type 3 monitoring loudspeaker followed an extensive review of current techniques. The outcome was a system which is fairly conventional in the bass region but which incorporates some innovations in the arrangement of the middle and high frequency units and also in the overall cabinet design. The result is a system having excellent objective and subjective characteristics, in a cabinet of moderate size and good accessibility. Attention has also been given to the aesthetic design in which the polished timber is relieved by the discreet use of metallic gold trim. The unit is being used extensively in studios, control booths and transmitters where high quality mounting is essential.

The design of the earlier Type 2 small monitoring system has also been revised to give a substantially improved performance at a considerably reduced cost. This unit will continue to find widespread application in the less critical monitoring locations.

ACKNOWLEDGMENTS

The development of the Type 3 system involved some hundreds of measurements, many of which had to be taken under free-field conditions in the open air. The work of the Headquarters Radio Section laboratory and particularly that of Mr. C. N. F. Jenkins, Mr. W. M. McNaught (who appears in Fig. 1) and Mr. K. J. Drew in making these measurements in the face of frequently unsympathetic weather, is acknowledged with appreciation. The members of the Headquarters Drafting Section must also be thanked for their assistance in the mechanical design of the two systems.

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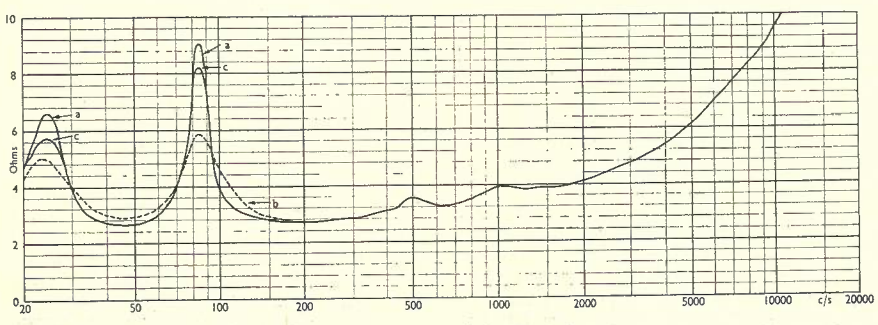

Fig. 8.—Impedance Response of Type 2 System.
(a) New design (3½" diam. vent without acoustic resistance).
(b) New design (3½" diam. vent with acoustic resistance).
(c) Modified existing cabinet (Triangular vents without acoustic resistance).

STEREOPHONIC SOUND IN THE NATIONAL BROADCASTING SERVICE IN WESTERN AUSTRALIA

*J. E. RULE, B.E., A.M.I.E.Aust.**

INTRODUCTION

The first practical experiments with stereophonic sound began about thirty years ago with the advent in the motion picture industry of "talkies" and culminated in productions such as Walt Disney's "Fantasia" and more recently the "Cinerama" series. The lack of a satisfactory commercial method of recording two simultaneous channels on gramophone discs, however, prevented development in the domestic field, even though the principles used today had been suggested many years ago by the British inventor, A. D. Blumlein. About 1954 a practical method was devised whereby two separate sound channels could be recorded in the one groove of a gramophone disc by the method commonly known as the 45/45 system. This is a system of disc recording in which the signals originating in the two channels are impressed on the separate sides of the record groove. The groove is cut so that the two sides are at 45° to the record surface and at 90° to each other. This, and to a lesser extent, twin track magnetic tape recordings, opened the way to a great potential market in the domestic field and this is being vigorously exploited in the U.S.A. and Europe.

It is natural that an interest in stereophony should have spread to broadcasting, and various methods of transmitting two channels simultaneously are being practised overseas. In Australia, however, broadcasts to date have been over two separate broadcast band A.M. transmitters for short periods on an experimental basis only. In this article a description is given of the system used to make stereophonic tape recordings at the N.B.S. Rosehill Studios, Perth.

PRINCIPLES OF STEREOPHONY

The aim of an ideal stereophonic reproducing system is to create for the listeners a sound picture similar in aural perspective to that which they would hear if located in an ideal position in the concert hall during the actual live performance. For this ideal system, a number of channels would be necessary, as have been used in motion pictures. However, economics limit home and broadcasting practice to two channels, which still give a marked improvement over the single channel monophonic systems with which we are all familiar.

There is, as yet, no general agreement as to the exact explanation for the mechanism of sound location. However, it is generally believed that the following quantities are used by the ears and brain to determine the direction from which a sound is coming:

(i) the relative loudness or intensity of the sound at the two ears,

(ii) the relative time of arrival of the sound at the two ears,

(iii) differences in the sound spectrum in the two ears; the head and outer ear are thought to restrict the travel of high frequency components to the ear remote from the sound source, and

(iv) the differences both in quality and time of arrival of the direct sound with any reflected sound, that is reverberation.

Whether these properties are used together or in part depends on the original nature of the sound and the manner in which it is modified by the acoustical environment between source and listener.

Early stereophonic experiments utilized two separate microphones with omni-directional polar patterns, spaced at distances of up to a few feet apart. In this way sound sources were located by intensity and time differences at the microphones. Also, microphones had been placed on either side of a dummy head to simulate ears; in this case (i), (ii) and (iii) contributed to the stereo effect. The opinion of most workers in this field is that sharper sound images are formed as the microphones are brought closer together, when the relative importance of time differences is reduced and intensity differences become the major locating factor. The logical development of this is to eliminate time differences altogether and to use coincident microphones, one placed immediately above the other and each with a strongly directional sound pickup favouring one side of the stage as shown for example by the cardioid patterns of Fig. 1. Figure-of-eight lobes also have been used successfully.

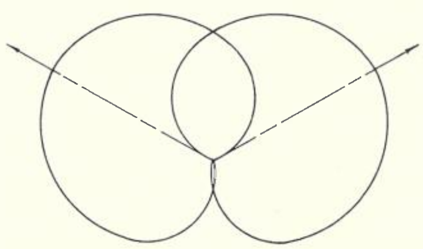

Fig. 1.—Directivity of Inclined Co-incident Microphones.

MID-SIDE STEREOPHONY

General System

In the Australian National Broadcasting Service, the so-called "mid-side" system is currently in use for making live broadcasts and tape recordings. Though apparently quite different from the method of Fig. 1, it is an intensity system which can be shown to provide the same information in the end. The chief advantage claimed for the mid-side system is that it permits the derivation of a satisfactory monophonic channel at the same time as the left and right stereo channels. Thus a programme can be broadcast to listeners who have only one receiver, for example, those in the country listening to the regional programme. The left or right channel on its own would make unsatisfactory listening for them.

The two microphones are of the condenser or electrostatic type, arranged one above the other in the same cylindrical case. Microphones with accurately matched characteristics are essential for stereophonic reproduction, and the condenser type has been the only kind capable of maintaining its directional pattern over a wide frequency range and of being free from resonances at high frequencies. At the same time the physical size can be kept small as can be seen from the example in Fig. 2. One of the condenser elements has a cardioid pattern facing towards the performers while the other element is capable of rotation, and is set at right angles to the cardioid with its figure-of-eight pattern sideways to the performers as in Fig. 3.

The cardioid and figure-of-eight microphones are connected, via separate pre-amplifiers built into the microphone case, to what are called the mid and side channels respectively. In common with all condenser microphones it is necessary for the microphone pre-amplifiers to be built into the case close to the condenser elements in order to isolate their very high impedance from the long length of microphone cable whose large capacitance would otherwise interfere with and ruin the performance of the microphones. The microphones are of the pressure gradient type which means that in the case of the figure-of-eight, the left and right lobes are 180° out of phase with each other, that is at any instant a sound from the left would give an output signal of (say) positive going potential, while a sound from the right would then give an output of negative going potential. The cardioid element gives an output signal of the same polarity irrespective of whether the sound source is on the left or right of the stage.

In Fig. 3, consider the output of the cardioid element to be A, and the output of the figure-of-eight element to be B on the left and $-B$ on the right. After amplification in separate amplifiers which control the relative amounts of mid and side signal and therefore the degree of stereo effect, a sum and difference matrixing operation is carried out in two transformers whose secondaries are arranged for series aiding and opposing as shown in Fig. 4. The output of the outgoing left channel always consists of the sum of the incoming mid and side channels, while the output of the outgoing right channel always con-

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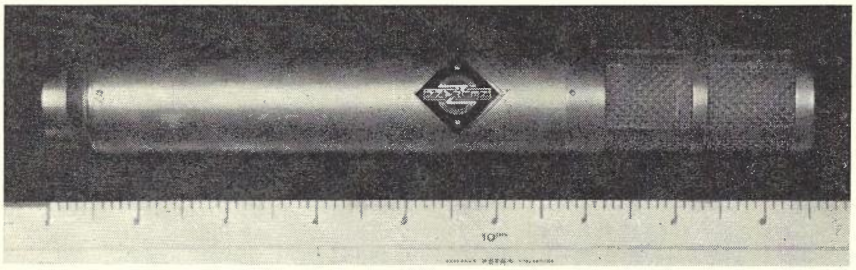

Fig. 2.—Typical Stereo Microphone consisting of Two Individual Condenser Microphone Capsules and Two Separate Pre-amplifiers. Total length is 8½ inches.

sists of the difference between the incoming mid and side channels. The result is that for a sound originating on the left of the stage, mid plus side = A + B is fed to the left channel and mid minus side = A − B is fed to the right, A + B being of greater sound intensity than A − B. For a sound originating from the right of the stage, we have mid plus side = A + (−B) = A − B feeding the left channel and mid minus side = A − (−B) = A + B feeding the right channel, which of course conveys the correct directional information to the listeners. For a sound originating from the middle of the stage the figure-of-eight microphone will have no output in this, its null plane, and the same level A + 0, A − 0 will be fed to left and right channels giving a central impression to the listener.

Gain and Phase Relations

Before a system can be put into operation, the equipment must be correctly phased and the gains of the channels adjusted to the required degree. The relative gains of the mid and side amplifiers determine the desired degree of stereo effect. With the side channel completely closed off there can be no stereo; only monophonic sound is obtained from both speakers which are driven equally loudly by the mid channel. After conversion of mid and side to left and right, the amount of gain in each channel must be the same, otherwise spurious directional information would be conveyed. Line-up tone in each channel is used to carry out this adjustment.

Correct phasing is also necessary. It can be shown that if the two loudspeakers of a stereo system are fed with signal from a common source, so that their acoustic outputs are equal and in phase, the resultant sound will appear, to an observer centrally placed, to emanate from a point midway between the loudspeakers. If on the other hand, the polarity of the signal fed to one loudspeaker is reversed, the observer will experience a sensation of the sound source being dispersed or spread out in the room. Of course, this effect would not be so noticeable with a sound source located on one side of the stage, for then that loudspeaker would be working at a much higher level than the other.

In the system used to make the stereophonic recordings in Perth, the monitoring amplifiers and speakers were arranged in phase by feeding a single tone source to both amplifiers, placing the cabinets side by side for maximum effect, and making the observations referred to in the previous paragraph, both by ear and by microphone pick-up feeding a studio programme level meter. The higher of the two levels indicated the desired in-phase condition. A similar technique was used to check that the tape recorder left and right channels were in phase. In this case a tape on which tone had been previously recorded to full track width became the common in-phase source of tone for left and right channels. After checking the replay channels it was an easy matter to put the recording channels in order.

The second part of the phasing procedure consisted of a check from each

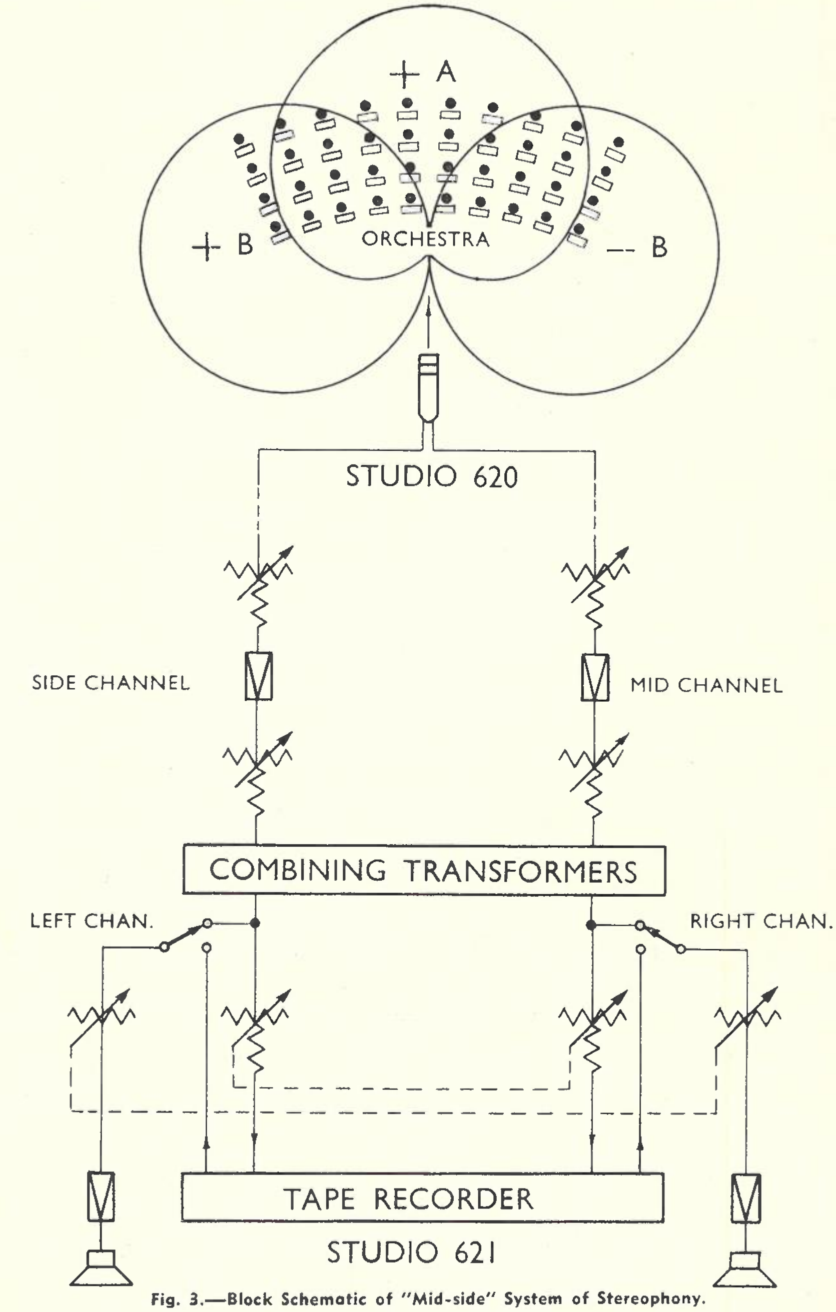

Fig. 3.—Block Schematic of "Mid-side" System of Stereophony.

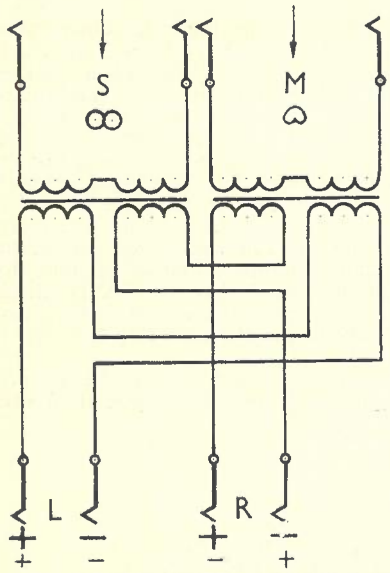

Fig. 4.—Matrix Network to obtain LEFT and RIGHT Channels in "Mid-side" System.

microphone input circuit to the output of the combining transformers. Each of the microphones had a pattern changing feature operated by remote control, that is with a switch located on the microphone power supply on the end of the microphone cable. This switch varied the magnitude and polarity of the D.C. driving voltage associated with each condenser element. In this way any one of the three polar patterns, omni-directional, cardioid or figure-of-eight, was possible. Taking one channel at a time, flicking the switch from omni-directional to figure-of-eight produced a positive going pulse in its microphone input circuit which could be observed with a D.C. voltmeter placed across the transformer secondaries, as a flick starting in a definite direction. The required phase relations are shown in Fig. 4. The larger polarity signs represent conditions due to the mid channel while the smaller signs indicate conditions due to the side channel.

Having completed the phase checks in two stages, before and after the output jacks of the combining transformers, these two sections were then joined together, left to left and right to right. The final test was to ensure that sound sources located in certain positions on stage actually appeared to be in those positions through the system. A reassuring check consisted of making phase reversals at a number of points in the system and observing that the sound then came from the wrong position on the other side of the stage.

Recording Procedure

For the recordings at the Perth N.B.S. Studios, the performers played from the large orchestral studio No. 620 (see Reference 7), the stereo microphone being placed about 12 ft. behind the conductor and 9 ft. high, a position which was not critical. Studio 621, close by and fairly large, was ideally suited for monitoring the programme and setting up all the equipment. The mid and side channel amplifiers were of an identical type normally used for outside broadcast purposes and were chosen because of their adjustable gain feature. The tape recorder had a standard tape deck with twin sets of heads for the left and right channels, each of which was to be recorded half track width. Monitoring loudspeakers, type 3 were used for the left and right loudspeakers. Several tapes were recorded, including the orchestra alone and with a large choir. One of these tapes, "The River" by Dr. E. C. Ford was chosen as the Western Australian contribution to the Australian Broadcasting Commission's all States quest for the best tape to represent Australia in the Italia Grand Prix, an international competition for radio programmes recorded stereophonically.

CONCLUSION

In the studio it was possible to make a tape recording in which many of the qualities claimed for stereo were evident. Not only sense of direction but spaciousness and a subtle clarity and definition gave the stereo performance a feeling of real life which is lacking in even the best monophonic system. At home the listener is not so fortunate. His receivers and loudspeakers are usually unmatched and do not permit the full advantages of stereo to be realized. In any case the present experimental system of broadcasting utilising the two N.B.S. transmitters in each capital city can, of necessity, present stereo only for very limited periods.

Most of the stereo broadcasting systems proposed or in use overseas allow for the simultaneous transmission of stereophonic and monophonic versions of the same programme from one transmitter. Usually some form of multiplex transmission is employed whereby the sum of left and right (L + R) signals is transmitted at the same time as the difference between left and right (L − R) signals. For example, a system applicable to V.H.F. frequency modulated transmitters has the difference signal radiated by a sub-carrier about 40 Kc/s away from the main carrier which handles the sum signal. No special equipment is required for the reception of the sum signal which is regarded as monophonic. An adaptor is necessary to extract the difference signal and convert sum and difference to left and right for stereophonic reception.

Stereophonic sound is a powerful new addition to the means available for realistic sound reproduction but its provision as a regular, full-time broadcasting service in Australia presents certain economic and technical problems. With increasing public demand these will no doubt be overcome in the not too distant future.

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THE ECONOMICS OF MOTOR VEHICLE FLEET OPERATION

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INTRODUCTION

In connection with the operation of Telecommunication and Postal Services the Post Office operates over 9,000 motor vehicles which constitute the largest vehicle fleet in Australia. The fleet is divided into two main sections — one fleet of some 7,800 vehicles used on engineering work in connection with the installation and maintenance of Telecommunication plant, and the other fleet known as the Postal and Transport Services Division fleet, which comprises about 1,200 vehicles, and is used for mail collection and handling and general transport services. This article will not deal with the mechanical aid fleet, which involves an entirely different type of problem.

The fleet ranges from Mini-Minor sedans to 25 ton semi-trailers (see Fig. 1)

Fig. 1.—(a) Semi trailer and small sedan.

and includes sedans, vans, trucks and a range of four-wheel drive vehicles; many of the vehicles are fitted with special bodies and many others are used to carry special equipment such as the hydraulic work platform and the post hole borer shown in Fig. 1. The replacement value of the vehicles exceeds £10,000,000, and the fleet covers annually 77 million miles at a cost of approximately £3,000,000. It will be seen from these figures that critical cost control of fleet operations is of vital importance; even a saving of one-tenth of one penny per mile represents over £30,000 per annum.

The purpose of this article is to set down the main factors which govern the economics of owning and operating the fleet, and then to deal in some detail with the problems of plant ownership.

While primarily concerned with Post Office fleet operations some observations are included, as a matter of interest, which have more application to the operations of commercial and semi-government fleets.

ELEMENTS OF VEHICLE COSTS

General

Ownership involves a number of costs, some of which are direct and obvious, and many which are not so obvious. Table I lists the various components of vehicle operating costs and shows at the top of the columns the factors which affect these various components of cost. The second column indicates the range of costs which may be expected under the best and the worst conditions, and the symbols in the squares indicate which factors affect each component. The letter "S" indicates some effect, and the letter "M" indicates a major effect. For example, the table shows that replacement policy has a major effect on oil cost which, however, at its worst is only a minor cost, but replacement policy also has a major effect on maintenance cost which can be a very considerable cost.

Typical costs for one year of operation of vehicles of various sizes, and the range of mileage covered by those classes of vehicles are:—

	Annual Cost	Annual Mileage Range
Sedans	£150	5,000 to 15,000
Utilities	£200	5,000 to 12,000
30 cwt. trucks	£300	4,000 to 10,000

The individual items of cost will now be examined.

Overhead

Overhead includes all those costs such as administrative staff, office costs, inspection costs, etc., which cannot be included under any of the direct subdivisions, and there is little variation in this figure as a rule.

Oil and Lubrication Cost

The variation in cost between the best and the worst conditions is less than ½d. per mile and the main controlling factor is the replacement policy, although all other factors have some effect. This item tends to reduce as other costs reduce. However, since the total under this heading could rise as high as £25 per annum per vehicle, on a large fleet this cost is worth costing and watching.

Fig. 1.—(b) Hydraulic work platform.

Interest on Capital

Interest will vary according to the price paid for the vehicle and the amount by which it is allowed to depreciate before being replaced. This charge could be reduced to bedrock by running a very old fleet but of course other factors such as maintenance, downtime, etc., would rise. The replacement policy therefore is the major factor on this component. In general, little can be done to lower interest without causing an undue rise in other costs; any plan to decrease capital investment (and therefore interest) by extending vehicle life must take into account the effect of this change on other costs, particularly downtime and maintenance costs. Once considered in formulating the replacement policy therefore, this factor requires little attention except perhaps to ensure that money made available for financing the fleet is obtained always at the lowest possible rate.

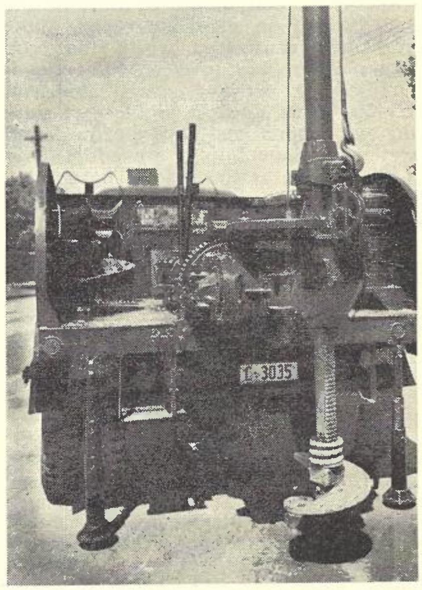


Fig. 1.—(c) Truck mounted post hole borer.

Petrol Costs

Under this heading the possibility of running diesel vehicles for this fleet of vehicles has not been seriously considered, as diesels are usually economical only for vehicles of higher annual mileages. Assuming petrol to be the fuel, the range of costs varies about 1.3d. per mile and is affected mainly by the size of vehicle chosen, but to a lesser extent by other factors. This cost over one year on a fleet of 50 vehicles amounts

* See page 433.

to nearly £3,000 per annum, or £60 per vehicle, and is therefore worthy of consideration.

Tyres and Tubes

Tyre and tube costs can vary by about the same amount as petrol costs. These again are affected mainly by the choice of vehicle to fulfil the task. Vehicles of lower power and lighter construction can show savings of up to £25 per annum on tyre costs over heavy vehicles, and one significant factor is that while driver skill and attitude also is a major factor on tyre and tube costs, the extent to which driver abuse will increase costs is limited to some extent on vehicles of lower power and weight. In other words, the effect of vehicle power and weight on tyre costs is accentuated by driver abuse.

Depreciation

Depreciation is affected mainly by replacement policy but also by driver attitude. As the variation under this heading will be as much as 1.5d. per mile, depreciation is worthy of a good deal of attention and is certainly worth continuous oversight in the form of an adequate record. Resale value, which is affected by vehicle condition, has a bearing on depreciation.

Unstandard fittings or special bodies and equipment tend to increase depreciation, and often the need for these can be avoided. Drivers generally are inclined to request the provision of fittings which add to the comfort of the vehicle, and on a private vehicle these are often considered worth the cost. However, a fleet owner with several hundred or perhaps several thousand vehicles faces quite a problem of finding extra capital and paying extra depreciation if these fittings are adopted on a wide scale, as the cost of unstandard fittings could exceed £60 per vehicle. Most fleet owners tend to oppose the general use of unstandard fittings; usually if particular fittings are in sufficient demand, vehicle manufacturers tend to embody them in the standard vehicle, at which time they are provided at much lower cost than as unstandard fittings. Stop lights, screenwipers and flashing turn indicators were all introduced as unstandard extras but are now provided on practically all vehicles.

Even the choice of colour is important for its effect on depreciation—a popular light shade is easier to maintain and will often help to achieve greater resale price than a darker colour which more readily becomes shabby unless extra care is spent on cleaning. Lighter colours are also safer than darker colours because of better visibility under most conditions.

Driver Maintenance Costs

These costs, which represent the cost of time charged by a driver to items such as cleaning, general maintenance, tightening, etc., can constitute a major source of waste in vehicle operation. While it is of utmost importance to encourage a driver attitude of reasonable care, vehicle care can be taken to extremes by the driver who looks upon his vehicle as the main reason for his presence on the job. While a well polished vehicle may be good publicity, as with all management problems, the task is to strike a balance between the amount spent and the amount of benefit which will accrue therefrom. Experience indicates that in this field close attention is necessary to the following facets of the problem:

(i) The cost must be recorded or available for extraction if required.

(ii) Driver maintenance must not be reduced to the stage where drivers lose all interest in their vehicle but definite standards for the maximum time to be spent should be established.

(iii) The driver's responsibility should be clearly defined.

(iv) Methods of cleaning should be studied and demonstrated to drivers and proper equipment provided. With proper equipment most vehicles can be adequately cleaned in one half hour, whereas a driver left to his own resources or with poor equipment can devote two hours per week to this task. Cleaning should not be considered as a routine weekly task, but should be done as required and if possible fitted into odd periods available between other tasks. The need for cleaning arises according to work, weather and other factors and not according to elapsed time. If a set time each week is allocated to vehicle maintenance, "Parkinson's law" will ensure that this time is used for vehicle maintenance whether it is necessary or not.

(v) Steps should be taken to ensure that time charged to vehicle maintenance is in fact used for this purpose. There can be a tendency, where other costs are closely controlled, to use an uncontrolled vehicle maintenance account as a sink for concealing costs incurred for other purposes.

Maintenance

In this field we move into a higher component of cost; perhaps it would be better to say costs which can be very high, but which need not necessarily be so. Maintenance costs are affected mainly by the replacement policy and by driver skill and attitudes, and the variation over a range of 1d. to 1/- per mile is not overstated. 1/- per mile for 10,000 miles represents £500 per annum and many fleet owners can ruefully point to vehicles which have cost this amount, and even more. In these days a complete mechanical overhaul including body work can reach this figure. It is significant that the amount by which the driver can affect the maintenance cost is limited as a rule by the replacement policy; it is noticeable also that newer vehicles in good condition tend to suffer less from abuse than older vehicles. Efficiency of repairs has not been recorded as having a major effect on maintenance, because it is general experience that while inefficient repairs can be expensive, the variation due to this factor can be kept under control most effectively by limiting repairs as far as possible, and the best field for this operation is by attention to the replacement policy and to driver attitudes. This does not obviate the need to also watch repair workshops costs closely.

It goes without saying of course that maintenance costs are worth recording individually as well as in group costs; these costs should also be supported by a mechanical history record which can be examined in connection with individual cases of high cost. Some will doubt that the figure of 1.0d. per mile can be achieved for maintenance costs but many private owners do in fact better this figure and some fleet owners are equally successful on a few of their vehicles where all factors of operation are under control.

Accident Repairs or Insurance

This item represents a very large variation in possible costs, and is taken to refer only to insurance against physical damage, and not to claims by other parties, third party risks, or to damages arising from injury or loss of life. The figure zero is quoted as the minimum, and would apply to those fleet owners who carry their own risks in this regard, who will record some vehicles which go through their life without accident damage. On the other hand, two or three accidents over the life of a vehicle can easily bring the average as high as £300 per annum. Driver selection, supervision and education are the main steps which can be taken to reduce this cost but it must be admitted that there is also an element of chance involved. Even those operators who cover this cost by insurance will have some variation due to no-claim bonuses and the cost of downtime.

Cost of Interference with Functions of the Vehicle

If a vehicle is withdrawn from service because of breakdown or any other reason, usually some disorganisation of the function which depends on the vehicle will result. This disorganisation can be costly. In fact, although overlooked by many fleet operators where separation of fleet management from the general functions of the organisation is too rigid, this cost can be by far the most important single cost in fleet operation. Under this heading, costs are seldom recorded but they cover all those losses arising when the normal function of the organisation is interrupted because a vehicle is unfit to carry out its work, and the costs are highest when vehicle unavailability arises without notice through breakdown. If the vehicle happens to be in an isolated area, costs can be extremely high and may include recovery of the vehicle by tow truck, replacement of the service by expensive alternative means, loss of business, loss of time, etc. It is most affected by the replacement policy, the driver and also by general efficiency of maintenance. To keep these expensive unrecorded losses under control, the least that should be done is to keep an accurate record of fleet downtime and probably also of a list of breakdowns. Some

TABLE I
ELEMENTS OF COST OF VEHICLE OPERATION, AND THE FACTORS AFFECTING THEM

Components of Cost	Range of Costs per mile (Australia 1962)	Factors which Affect Cost Components: Replacement Policy	Size of Vehicle	Driver skill and attitude	Overall Control and Fleet Management	Quality of Field Inspection	Efficiency of Repairs
Overhead	0.5d. to 1.5d. per mile	S	—	S	S	S	S
Oil	0.1d. to 0.5d. per mile	M	S	S	S	S	S
Interest	1.2d. to 2.0d. per mile	M	S	S	S	—	—
Petrol	1.2d. to 2.5d. per mile	—	M	S	S	S	S
Tyres and Tubes	0.25d. to 1.5d. per mile	S	M	M	S	S	S
Depreciation	0.5d. to 2.0d. per mile	M	S	M	S	S	S
Driver Maintenance Costs	0.5d. to 3.0d. per mile	S	S	M	S	S	—
Maintenance	1.0d. to 12.0d. per mile	M	S	M	S	S	S
Accident Repair or "Insurance"	0 to £300 per mile	S	—	M	S	—	S
Interference to job.	£10 to £500 per year	M	—	M	S	S	S
Total	£300 to £1,800 per year						

progressive fleet owners consider a breakdown report and analyses to be more important than a downtime record, because breakdowns are much more expensive than other downtime, and if breakdowns are few, downtime also will be low.

THE FACTORS WHICH AFFECT COST

General

Having examined the various items of cost in relation to the factors which affect them, it would be interesting now to examine each of the factors affecting the cost, and to make some general comments on their overall impact on fleet economy. Each of these is dealt with hereunder.

Replacement Policy

It is clear from Table I that replacement policy, driver skill and attitude, and the size of vehicle have the most far-reaching effects on fleet economy and of these three, replacement policy is the most important by far because:—

(i) Replacement policy affects every vehicle in the fleet.

(ii) An enlightened replacement policy can limit the rise of costs caused by incorrect choice of vehicle, etc., and can also limit the waste attributable to most other factors which affect the cost.

Although a number of considerations such as the incidence of taxation, availability of capital funds, etc., can cloud the issue regarding the replacement, in general it can be considered that maintenance costs, downtime, and some other direct costs remain at a fairly low level for the first 30,000 miles of the life of a vehicle and tend to rise sharply at some period after 30,000 miles depending on the annual mileage, general maintenance and driver skill. The total of direct costs (fuel, tyres, repair, depreciation and interest) follows somewhat the curves shown in Fig. 2.

The cost which does not show in the top curves in Fig. 2 is the cost of down-

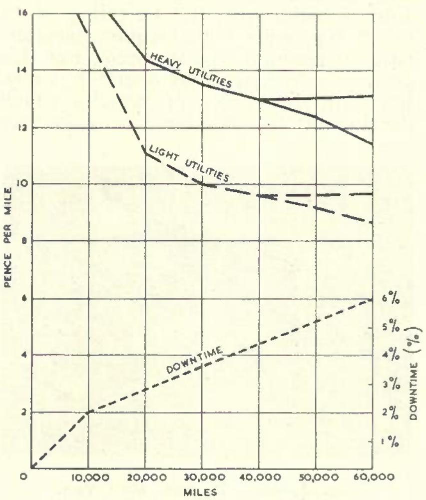


Fig. 2.—Typical costs and downtimes for vehicles up to 60,000 miles.

Notes on Fig. 2

NOTE 1. Cost charts represent the cost per mile up to the mileage indicated, excluding estimated cost of downtime. The dotted line indicates percentage downtime at various mileages.

NOTE 2. The lower cost lines for each class of vehicle beyond the 40,000 miles represents the costs which will be incurred if the vehicle maintenance is reduced in the **knowledge that** disposal will definitely occur. If it is necessary to maintain the vehicle as if it will be kept indefinitely and then dispose of it at 60,000 miles, the higher line will represent the costs. The significance of these two cost lines is that to achieve maximum economy, the disposal time must be planned, and must actually take place at the planned time.

NOTE 3. For authorities who operate without payment of Sales Tax the cost per mile turns upward at a much earlier mileage. There is still a similar pattern of differential costs depending on whether it is possible to determine the mileage of disposal some time ahead thus limiting maintenance for the last 10,000 miles.

time, because this varies widely depending on the function of the vehicle and other factors. It will be found, however, that for many conditions under which vehicles operate, and particularly where the vehicles operate in small groups or in isolated areas, the cost of downtime will be the most significant factor in determining the optimum point of replacement; if a relief vehicle is always available, the cost of downtime would be low and the ideal point of replacement might be 50,000 miles whereas under other conditions where the cost of downtime is high, the point of replacement would be nearer 30,000 miles. The replacement point could also be affected by such factors as the average annual mileage, the cost of special body work or unstandard fittings and the earning capacity of capital in other sections of the business. In general, a replacement policy should permit the vehicle to be disposed of before the sum of **all** costs, including downtime, rises. To choose the precise moment for most advantageous replacement is difficult because each individual vehicle in the fleet will reach this point at a different mileage and time, whereas replacement policy can deal only with the average of the vehicle in a group.

In practice the best compromise is to work out an economic point of replacement for each group of vehicles (such as sedan cars or 15 cwt. utility trucks) and then, when the time comes to replace a vehicle, to appraise each vehicle in the group and dispose first of the one most likely to incur future costs above the average. If because of the smallness of the fleet the replacement vehicles can be purchased "off the shelf" without any advance ordering procedures, it is possible to defer replacement of most of a group for a few months or miles if all of the vehicles obviously are not going to require any extensive repairs or to incur downtime. The benefit of having declared the replacement policy is obvious; in these circumstances the money is available for replacement as soon as its need is apparent, and it will not be necessary to run vehicles into uneconomic mileage while awaiting funds.

One point which is important to remember in examining a replacement policy, and particularly in examining the advisability of replacing a particular vehicle, is that costs which have already been incurred are not very important in the decision except as an indication of likely future costs. The only cost which can be affected by selling or not selling a particular vehicle is the cost which is likely to be incurred in the future. This is important to note, because fleet owners have been known to replace vehicles on which the cost per mile has been excessive whereas, because of the money already expended, the cost per mile for the following 12 months could be expected to be very low. The time to make a decision for replacement therefore is before heavy costs are incurred and not afterwards. If a vehicle of a group which can be expected to cost 1/- per mile for maintenance can be sold at a time when its maintenance has averaged only 6d. per mile, then the average cost per mile for the whole group will be reduced and on the particular vehicle a specific saving will be made. If, on the other hand, a vehicle which has averaged 1/6d. per mile is sold, the average cost for the group will be raised and a loss incurred on the particular vehicle. It may be possible without materially affecting depreciation and reliability to run such a vehicle a further six months without repairs and thus reduce the average costs to say 1/3d. per mile thus achieving an actual saving.

Size of Vehicle

Next to replacement policy one of the biggest fields for savings lies in the choice of the correct vehicle for the task to be carried out. There was a period when in this country the general American practice of using a high-powered, large and fairly heavy vehicle for any purpose was considered to be good policy. This trend had its roots in conditions which existed perhaps up to 1950 when American vehicles generally were more suited to Australian conditions than were most English vehicles. In those days there was a tendency to run vehicles for high mileages, and in general vehicles tended to be less reliable than today. Therefore, ruggedness and the general capacity to "take it" over rough roads, often with drivers who were not very skilled, were more important in giving overall economy than low fuel and other costs. Under rough conditions, the lighter vehicles tended to involve repair costs which outweighed other savings.

Today the picture has been changed by the following factors:—

(i) Lighter vehicles manufactured by Continental, English and Australian firms are much more reliable and rugged.
(ii) Some prominent firms including American firms are manufacturing lighter vehicles with many of the advantages previously found only in heavy vehicles.
(iii) Vehicles generally are more reliable.
(iv) There is a tendency today to run vehicles for shorter times at higher annual mileage before replacement.
(v) Roads are better than in 1950, particularly in areas where the majority of the vehicles operate. For areas where road conditions are bad, the heavy vehicle is still preferred for many tasks although there are notable exceptions.
(vi) More fleet drivers today own their own private vehicles, and although it is difficult to be conclusive, the writer feels that, despite the exceptions, today's fleet driver on average is better than the fleet driver of 20 years ago.

Whatever the reasons, figures are available in the fleet records of a number of operators to indicate that today it is cheaper to operate the lighter vehicles for many tasks than to operate the heavier vehicles. Perhaps the outstanding example of this is trucks and vans in the 15 cwt. field, where up to about 1950 it was generally conceded that the lowest running cost could be achieved by vehicles powered by engines with R.A.C. rating of 25 to 30 h.p., whereas today more economical service with at least equal reliability is obtained from vehicles with R.A.C. rating of 14 to 18 h.p. with high torque characteristics at medium engine speed. For this class of vehicle the fleet operator is now left with the choice of vehicles which develop 50 to 70 b.h.p., or a heavier

Fig. 3.—(a) 15 cwt. Mail Van.

vehicle with engines developing from 120 to 150 b.h.p. The latter vehicles are substantially heavier on fuel, tyre costs and maintenance and with the traffic conditions existing today, the extra power gives little compensating advantage. For many purposes for which the 50 to 70 b.h.p. engine is not quite sufficient, an engine in the 80 to 100 b.h.p. range would be useful.

Examples shown in Fig. 3 demonstrate how motor vehicles have replaced

Fig. 3.—(b) 20 cwt. Van.

heavier vehicles for certain functions. Fig. 3A is a high capacity 15 cwt. mail van with 16 h.p. engine; this vehicle replaces 20 cwt. vans with 30 h.p. engines, (Fig. 3B) which were necessary earlier because light vans were not available with large bodies. Fig. 3C shows a modern vehicle with 18 cwt. carrying capacity and a large body with low floor. This vehicle powered by a 14 h.p. engine is ideal transport for a mobile cable jointer, and for this function

Fig. 3.—(c) 18 cwt. Mobile Jointers Van.

replaces a vehicle similar to the large mail van shown in Fig. 3B. The difference in running costs is of the order of 6d. per mile.

The light sedan shown in Fig. 3D is modified by removal of the rear seat and squab, and fitting of a tray in the rear compartment, to carry tools and telephones. Light modified sedans such as this one replace 8 cwt. vans and utility trucks; depreciation and running costs are lower than on the commercial type of vehicles, and the resulting saving is about 2d. per mile.

Fig. 3.—(d) Modified Sedan.

Driver Skill and Attitude

These factors are extremely important in overall fleet economy because they affect nearly every facet of vehicle cost, and can have very substantial effects on a number of these factors. Fortunately, it has been found that the attitude of most drivers, particularly those who have been driving for more than two or three years, is quite satisfactory and it is merely necessary to ensure that they have the necessary knowledge and skill to handle a vehicle properly. The mistake should be avoided, however, of assuming that having educated a driver with the necessary skills, he will automatically drive well. As well as the skill it is most important that he appreciate the need to use his skill. In this regard one organisation has achieved very good results by allocating a sum for repairs to each vehicle and handing to the drivers at the end of the year any part of this allocation which has not been spent. This type of incentive scheme could be subject to abuse but it does seem that there is room, perhaps on a group basis, for giving incentives to the better drivers in a fleet. Some fleet operators go part way towards the scheme by registering their drivers for participation in national safety council safe driver awards.

Detection of those drivers who cause excessive fleet operating costs is dependent upon proper repair records and proper supervision of drivers, but the problem is quite difficult in a fleet where vehicles are not allocated to particular drivers. Where drivers change vehicles frequently it has been found, however, that petrol consumption which can be measured over short periods does give a fairly good indication of driver skill. It can be stated that as a general rule where petrol consumption is above average, tyre costs and general maintenance costs also will be above average. This must be so because the same factors affect all of these costs.

Overall Control and Fleet Management

Although this has not been highlighted as a factor likely to directly cause substantial changes of cost under a number of the cost headings, in fact fleet management is by far the most important of all factors because, by means of fleet management, all of the other factors are controlled, and money-saving techniques are used to best advantage. The manager of a fleet must be continually alert for the savings which can be achieved by attending to all of the other factors, and above all must establish a series of yard sticks to measure the performance of his fleet under the various headings so that his actions in the interest of economy and efficiency are clearly guided and are not made by rule of thumb.

It is surprising how often the task of managing a fairly large fleet is left in the hands of a foreman who has grown up with the fleet. Such a man may be energetic and capable in the skills for which he is trained, but the manager of a large fleet of vehicles requires a much broader training than is needed by a shop foreman. The fleet manager must have adequate technical qualifications of course, and if the fleet is in excess of 50 miscellaneous vehicles, at least part of the time of a professional engineer is warranted on the problems which will arise. In addition to the technical qualifications, the fleet manager needs a thorough understanding of the financial problems involved, including costing procedures, and in addition needs to have a thorough appreciation of the practical field problems of fleet operation. As with all people operating in management capacity he must also possess a fair share of drive and tenacity to continually watch all phases of the economics of fleet operation. This man more than anyone else will determine at which end of the possible range of total cost (£300 to £1,800 per annum per vehicle) the vehicles in the fleet will operate.

At this stage the writer would like to sound a warning against making the management of a fleet a secondary task for some other administrative officer such as a stores or accounts executive, as so often happens. Even a fleet of 20 vehicles requires that some particular person in the organisation accept responsibility for its overall management, and while this may not be a full-time job, it should be clearly understood that fleet management is one of the important aspects of the business and not merely a task to be tacked on to some other main function.

Quality of Field Inspection

Field inspection is of more important on dispersed fleets than on fleets which operate from a central headquarters. A trained inspector visiting dispersed vehicles under their operating conditions approximately once each year can inspect the vehicles and make arrangements for any necessary repairs, and at the same time can carry out minor adjustments and if necessary assist drivers with their problems. An inspector who has a good manner with drivers can achieve a great deal of driver education and will have a marked effect on overall fleet efficiency. It is significant that in America some fleets in excess of 10,000 vehicles are operated under dispersed conditions without central repair organisation; the travelling inspector visits all vehicles twice each year and arranges all repairs at local private repair workshops.

Efficiency of Repairs

To those who contend that a first class base workshop is the heart of a successful fleet operation, it will come as a surprise that efficiency of repairs is considered by the author as being one of the less important factors in total fleet costs. Not for a moment would it be contended that a workshop may be allowed to become inefficient — under these conditions repairs can be very costly indeed. However, the prime function of a fleet manager is to keep vehicles out of the workshops, and only as a last resort should the vehicles appear in the workshop for repairs. If because of lack of capital or a poor replacement policy or to driver attitudes repairs are excessive, then the efficiency of the workshop becomes more important. However, if all of these other factors are kept under control the workshop repair costs then assume less importance than would otherwise be the case. From the analysis shown in Fig. 1 and from other information available to the writer it will be seen that repairs can make up as little as 15% of the total vehicle operating costs. This is still a figure worthy of attention, and one penny per mile for repairs could easily become 2d. per mile if the repair shop itself is inefficient. In this regard much has been written about the management of a repair shop and this article will not deal in detail with the problem except to emphasise that a repair shop should operate on standard times, and information should be recorded in such a way that, if the cost of particular groups of vehicles is unsatisfactory, facilities are available for analysing repair costs in detail.

THE FIELD FOR FURTHER SAVINGS

If all of the costs of factors outlined above are taken under strict control, the total cost will be reduced to a figure very close to the irreducable minimum. Just what can be achieved by controlling these costs is shown in the graph (Fig. 4) which shows the decline in cost of the engineering fleet of the Australian Post Office over the last six years.

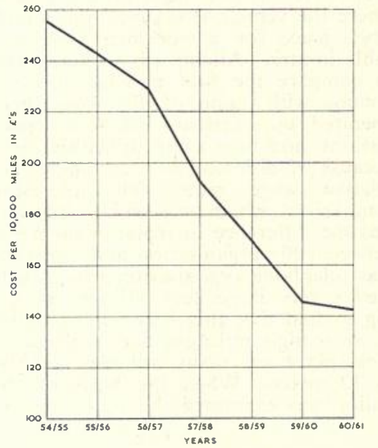


Fig. 4.—Maintenance Costs of Engineering Vehicles Per 10,000 miles. (Note: 10,000 miles in approximately 15 months of operation for the average vehicle).

The main way of then further reducing costs will be to purchase more suitable and economical vehicles and the fleet operator may achieve something in this direction by carefully analysing the merits of various vehicles available for his tasks. The further reduction which can be achieved in this direction will be small—probably of the order of 5% of total running cost. However, there is one field which must not be overlooked where the savings can be quite high. No matter how low the cost per mile, it will be still cheaper to **not** run the mile if it is not really necessary. Only those people in charge of the operation of the vehicles can control this aspect of expense, but the savings can be so great that no effort should be spared to ensure the elimination of all unnecessary mileage in fleet operation. The costs that will be saved are not only those of the vehicle mileage but also the driver's time, or in the case of a work vehicle carrying a gang of five men. the time of the whole gang. The costs per mile then assume figures of the order of 6/- to 8/- which provides ample incentive for close management control.

PRACTICES OF OTHER FLEET OWNERS

It is very difficult to draw comparisons between fleets of this Department and other fleets in this country because there are few other fleets of even 1,000 vehicles, and these other fleets work under entirely different conditions. It is not practicable for example to compare the economics and the policies of "home based fleets", with highly dispersed fleets such as that operated by the Engineering Division of this Department. Other conditions which vary between fleets are predominance of heavy types as against passenger vehicles, the extent of off road work, and the proportion of the fleet used on tasks where the vehicle is essentially a mobile work place for a workman such as a cable jointer. Attempts have been made to compare the fleet policies and economics with some of the large fleets operated by overseas telephone organisations, and here again difficulties arise because of differences in currencies and relative wage rates. One interesting comparison which was made, however, was the difference in replacement policy between this organisation and one overseas telephone organisation which operated a very large fleet. It was surprising to find that this fleet tended to run to very high mileages and replacement took place on many vehicles as high as 12 years. When the basis of this policy was examined the following factors were found to have some bearing.

(a) Capital was in great demand for high earning uses in other parts of the organisation.
(b) Spare parts and spare replacement assemblies such as engines and gear boxes were readily available and comparatively low in cost.
(c) Downtime was not measured regularly and was not taken into account in calculating the economics of the replacement policy. It is considered that this was by far the most important factor—the writer inspected this fleet in the field and discussed the problems with some of the field operators, and was convinced that an assessment of the unrecorded costs of running old vehicles would have resulted in a policy of earlier replacement.

CONCLUSION

It is quite clear after studying the problems of fleet management for a number of years that, while there are a number of definite areas in which savings may be achieved and while there are some management techniques which will almost invariably produce savings in some directions, the overall problem is a complex one and maximum savings will be achieved only by continuous study and continuous effort to find and eliminate the various sources of waste. The writer was encouraged by an article by Mr. W. V. Benjamin, the General Supplies and Motor Equipment Supervisor of the Wisconsin Telephone Co., published in the American Journal "Telephony" (April 15, 1961). From this excellent and comprehensive article it was obvious that the problems in America are much the same as the problems in this country, and it was of particular interest to note that American operators also are seeking smaller and lighter vehicles to carry out various tasks in the fleet. This article mentions a prejudice against the lighter and smaller vehicles but emphasises the need for the fleet operator to persist in providing the vehicle which performs each particular task with minimum cost.

Finally it is necessary to warn fleet owners against the complacency which tends to develop when operating costs are low. Some fleet owners are quite prepared to provide staff to take control to reduce costs when these are noticably high, and when savings of many thousands of pounds per annum can be foreseen. If costs are low, it is considered to be much better and more economical practice to provide sufficient staff to keep these costs low, rather than to allow the problems to get out of hand and then provide a large staff to reduce them. By then much irretrievable waste will already have occurred, and it takes years to develop the controls and attitudes needed to achieve optimum economy.

BOOK REVIEW

RADIO TRANSMITTERS

Laurence F. Gray & Richard Graham
McGraw-Hill Book Company. pp 462
(Australian price £6/9/6).

Chapter Headings: Introduction—Frequency-control Techniques—R-F Power Amplifiers—Power Tubes—Coupling Circuits — Amplitude Modulation — Angle and Pulse Modulation—Power Supplies —Control and Protective Circuits—Cooling—R-F Components—Transmitter Characteristics—Transmitter Measurement Techniques—Hazards Associated with Transmitters—Appendix—Index.

Review: To the best of the reviewer's knowledge, this book represents the first English language text book to be devoted exclusively to radio transmitting equipment. The authors state that the purpose of the book is to collate material which is of particular interest to transmitter designers and to those engaged in the operation and maintenance of transmitting station equipment. The book assumes that the reader has attained knowledge to a standard which is approximately that of technician, Postmaster-General's Department, and no attempt has been made to deal with the elementary principles of electricity nor does the book give mathematical derivations of the equations presented throughout the text. The authors provide, however, a wealth of technical information on their chosen subject. In simple, easy to understand terms, the book presents a practical analysis of transmitter design and operation in all its various phases, usable information pertaining to specific problems, and describes typical testing and measurement techniques for complete transmitters.

The equipment, standards and practices referred to in the course of describing working systems are American, but as Australian equipment and techniques are in most cases similar to the American, the book loses none of its value on this score. It should be noted however that the Australian television standards are different from the American, and certain of the television transmitter information (particularly that relating to performance testing) is not applicable to Australian equipment.

The book is generously provided with circuit diagrams, tables, and explanatory figures, but there is a complete absence of photographic views of any of the equipment described. The conventions, terminology and abbreviations used follow standard American practice and users of other standard American radio engineering text books (for example, Radio Engineering by F. E. Terman) will already be familiar with the terminology. The book contains a most adequate table of contents, a comprehensive index, is well-bound and printed, and contains references at the end of each paragraph which represent one of the most extensive listings of radio transmitter references yet provided in this field.

In the opinion of the reviewer, the authors have achieved their aim of presenting to readers a specialised text book giving a comprehensive coverage of just that area which is of interest to the "transmitter man". The book fills a long felt need in radio engineering literature and, apart from its value to workers in the transmitter field, has both the subject matter and method of presentation to cater for the needs of students for Technician, Senior Technician and higher examinations within the Australian Post Office.

—E. J. Wilkinson.

THE MELBOURNE-MORWELL COAXIAL CABLE SYSTEM — PART II

L. A. WHITE,*
R. K. EDWARDS, B.E.E.†, I. L. McMILLAN†, and J. R. WALKLATE, B.Sc.‡

STRUCTURAL COMPONENTS AND INSTALLATION DETAILS

General Description

The equipment at the terminal and fully regulated attended repeater stations is accommodated in cabinet type racks 8′ 6⅜″ (2,600 mm) high, 1′ 11⅝″ (600 mm) wide and 8⅞″ (225 mm) deep. At the unattended repeater stations the rack height is only 5′ 1″ (1,566 mm) but the width and depth are the same.

All cabinet racks are uniform with double access doors. All components of the racks which contain valves or serve as power supply units are designed as plug-in type chassis units for ease of replacement. In addition to the plug-in chasses, each rack contains a terminal panel, control or multiple panels, and a relay slide-in chassis or power supply incorporating fuses and supervisory relays. Access to all components on each rack is from the front only and this allows two of the cabinet type racks to be placed back-to-back.

Although a large number of Z12N cable carrier systems which employ this type of cabinet rack design have been installed in Victoria (Ref. 6), this was the first time use had been made of the German type "combining frame" for assembling the racks into rows. The Sydney-Melbourne installation described in a previous issue of this Journal also uses similar racks and combining frames, but installation of the Victorian section of that project was commenced slightly later than the Melbourne-Morwell equipment. The combining frame, which is shown in Fig. 22, is suitable for combining back-to-back two rows each of 3 to 10 cabinet racks, thus providing for the accommodation of up to 20 racks in one double row.

The combining frame consists of two "lateral supports" and the "combining frame shelf". The combining frame shelf which is used to support the racks in a vertical position as well as for cabling between the individual racks, consists of two horizontal angle bars which rest on and are attached to the lateral supports. The angle bars are equipped with the required number of cable rungs which have guide grooves at each end to allow displacement along the angle bars to suit cable drop off. The cable rungs have a nominal spacing of 8 to 10 inches and they are fixed in position by clamping screws. Cylindrical rods, suitably arranged in longitudinal slots in the cable rungs, facilitate grouping of cable runs. Fig. 23 shows details of the combining frame shelf. Easily removable sheet-metal plates are used to cover the combining frame and station cable shelves on both sides and top.

The cabinet racks are attached by angle brackets at the top to the angle bars of the combining frame shelf. Suit-

* See Vol. 13, No. 1, page 80.
† See Vol. 13, No. 4, page 348.
‡ See Vol. 13, No. 3, page 269.

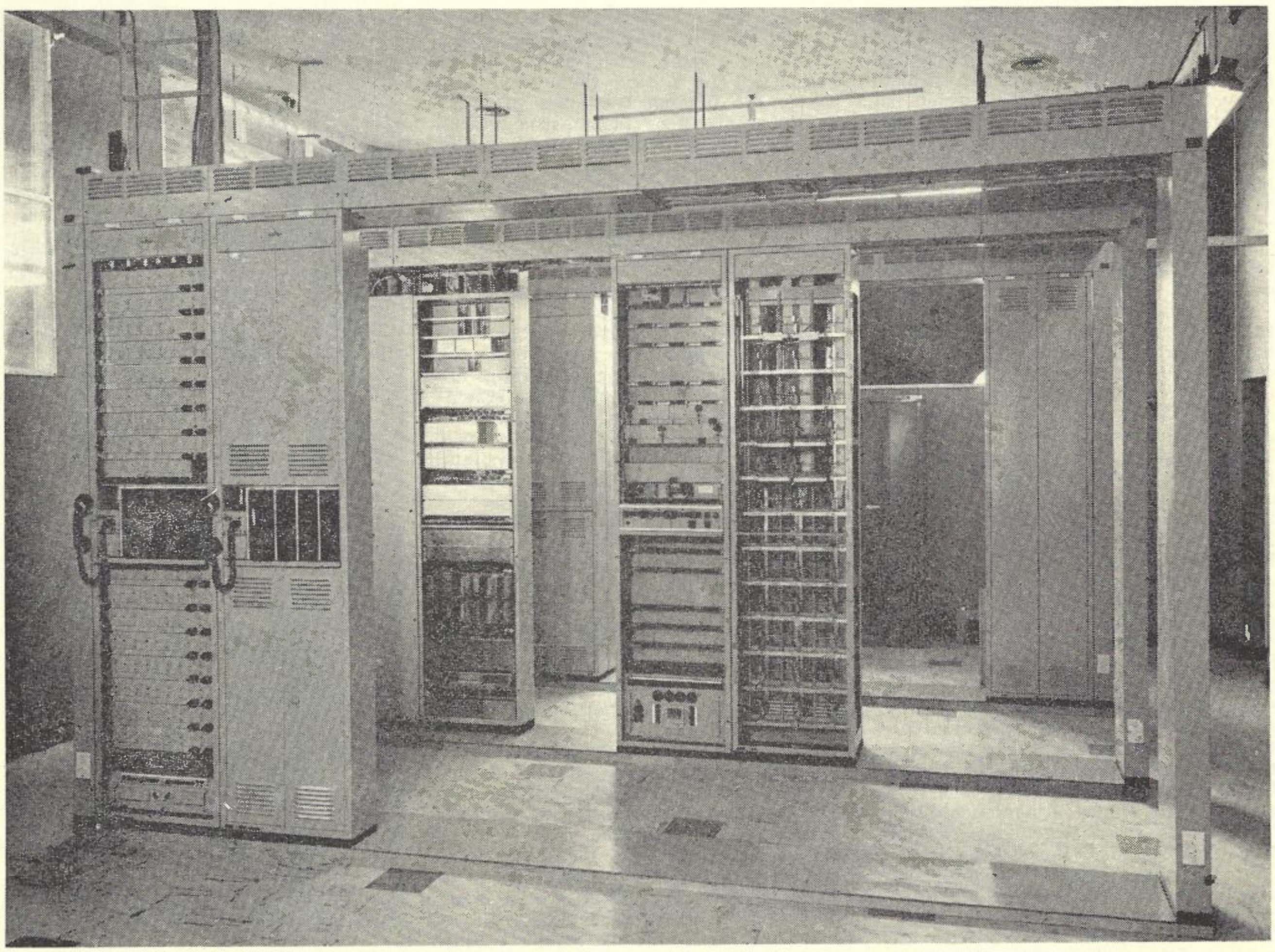


Fig. 22.—Warragul Attended Repeater Station, General View of Equipment showing Combining Frame Shelf and Lateral Supports Top Left and Right.

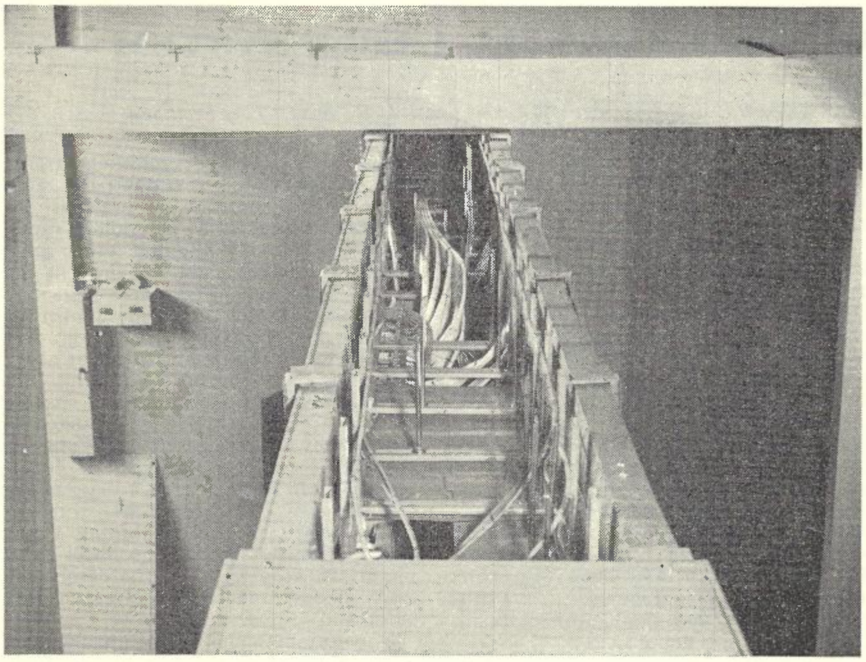


Fig. 23.—View along Combining Frame Shelf with Top Cover Plate Removed.

ably spaced tapped holes are provided in the angle bars. The racks placed between the lateral supports also help to carry the cable shelf. The weight of each rack rests on two ball-cup supports which can be adjusted easily to bring the rack to vertical position and thus take care of floor unevenness. Another adjustment also allows for equalising of rack heights. It has still been considered desirable however in Australia to install the racks and lateral supports on plinths.

The lateral supports of the combining frames are also of cabinet design, the height corresponding to that of the equipment racks, the width being twice the depth of a rack (450 mm), and the depth 4⅛" (104 mm). Two doors, one above the other, are provided in each lateral support. Use is made of the top half of the lateral support at the main aisle side of the station for mounting the "fuse and signal panel" (See Fig. 24). This frame contains 4-amp circuit breakers, through which the 220 volt A.C. is distributed to each rack, and a luminous signal device for visual and audible supervision of the rack alarms. The space behind the lower door has been used to mount the 240/220 volt auto-transformers necessary to convert the standard AC voltage used in this country to the 220 volt which is standard in Germany, and is the voltage for which the racks have been designed. The top half of the lateral support at the other end of the frame accommodates the "carrier and signalling voltage distribution panel" tagblocks as shown in Fig. 25. The space behind the lower door can be used for storing spare parts.

For interconnecting rows of racks, a "station cable shelf" is provided which runs at right angles to the direction of the rows of racks and is situated at one or both ends of the rows on top of the combining frame shelf as shown in Fig. 23. The station cable shelf also serves for bracing the rows of racks against each other; channel iron bracing bars are installed at the other end of the row of racks if a station cable shelf is not also provided there. The centre to centre spacing between rows in Germany is 6' 4¾" but this is dictated mainly by floor loading and in Australia it has been reduced to 5' 6".

Setting-up a Combining Frame and Racks

The two lateral supports are erected and the longitudinal angle bars are placed in position. The cable rungs are inserted at equal intervals. When several rack rows are set up they are interconnected by the station cable shelf running at right angles to the rows, and the combining frames are braced against each other and the wall by special channel iron bars. The empty racks are now placed at the intended location, adjusted to accurate vertical position, and bolted to the combining frame by the two angle brackets at the top of the rack. In setting up the racks a space of 6 mm is left between adjacent racks to take care of slight irregularities in the racks and to facilitate installation and removal of individual racks from a fully installed row.

Distribution of 220 Volt A.C. to Racks

Individual connection of A.C. power is made to each rack. To facilitate this a 3" x 2" metal duct has been installed in the combining frame shelf between the vertical portion of the cable rungs and vertical bracket supports for side cover plates. The location of these ducts can be seen in Fig. 23.

On the lower side of the ducts 3-pin sockets were provided, one directly above the location of each rack to be installed in the combining frame. Connection of 220 volt A.C. to the racks is then via a short length of 3-core flex. Each 3-pin outlet is wired to an individual 4 amp. Siemens circuit breaker located in the fuse and signal frame. These circuit breakers are shown on the right of Fig. 24. The three phases from the no-break distribution board are wired to the fuse and signal frame, where connection is made to the circuit-breakers in a manner to ensure balanced loading on each phase of the 3 phase supply.

In the case of the supergroup modem and both carrier supply racks, the rack A.C. power units cater only for supplying the filament and alarm voltages. The 212 volt D.C. for valve anode supplies is fed from A.C. power units located on a central "power supply" rack.

Cabling Arrangements at Terminals and Attended Repeater Stations

Carrier frequency "distribution frames" are provided to facilitate interconnection of equipment at the basic group (60-108 Kc/s) stage and at the basic supergroup (312-552 Kc/s) stage.

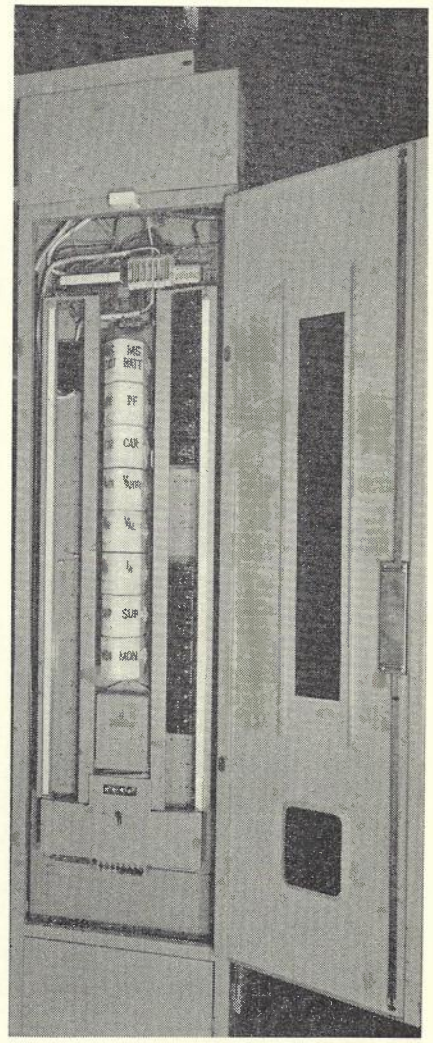


Fig. 24.—Fuse and Signal Panel in Top Half of Combining Frame Lateral Support.

The carrier frequency distribution frames for groups and supergroups are designed in cabinet style similar to the equipment racks but with twice their depth, and are accommodated in the combining frame in the space normally occupied by two equipment racks mounted back to back. Fig. 28 shows a carrier frequency distribution frame used as a combined group and supergroup frame. The distribution frame is arranged with connecting strips horizontal on one side and vertical on the other. The horizontal side terminates cables from the line side of equipment racks while the vertical side terminates the cables on the station side of racks. Referring to Fig. 4, the output of a channel modulator rack is cabled to horizontal tag blocks. The input to a group modulator rack is cabled from tag blocks on the vertical side of the distribution rack. The output from a group modulator is cabled to shielded distributor strips on the horizontal side,

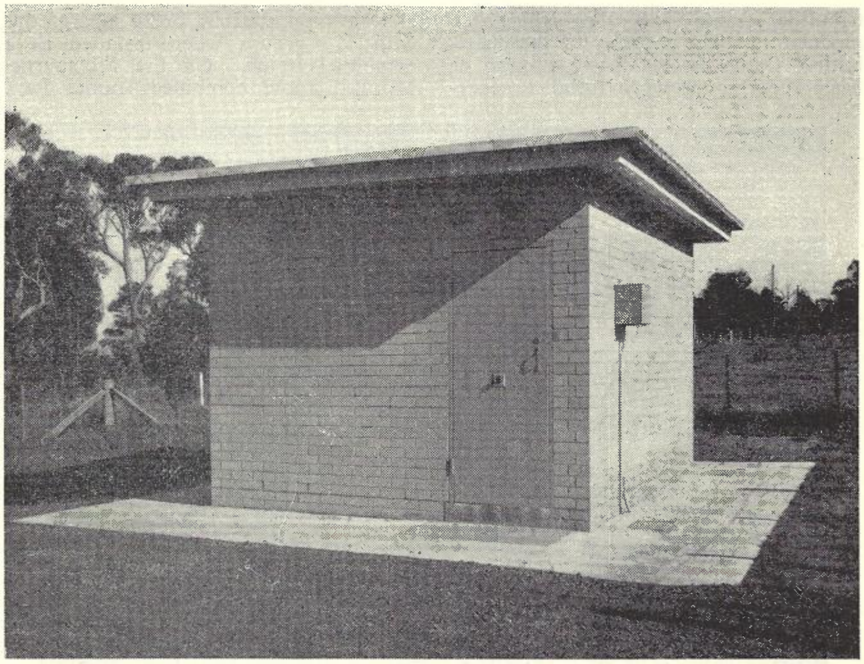


Fig. 26.—External View of Unattended Repeater Station.

while the input to a supergroup modulator is cabled from similar strips on the vertical side of the distribution rack. These shielded distributor strips are shown at the top of the rack in Fig. 28. Balanced pair screened cable (150 ohm impedance) is used for all cabling between the outputs of the channel modulators and inputs to the group modulators where the frequency range is 60-108 Kc/s. The outputs of the group modulators occupy the frequency range 312-552 Kc/s, and coaxial station cable (75 ohm) is used for wiring to the screened distributor strips with similar cable used for wiring between the dis-

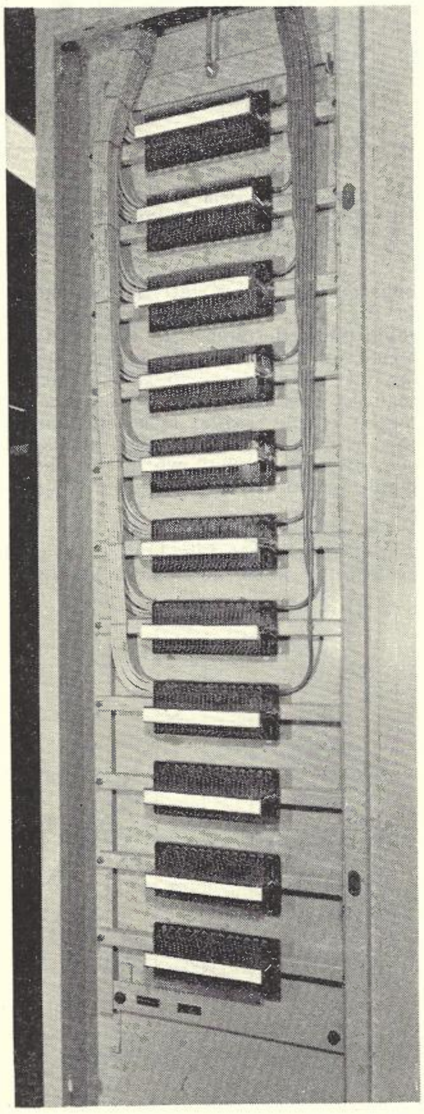


Fig. 25.—Distribution Panel in Top Half of a Combining Frame Lateral Support.

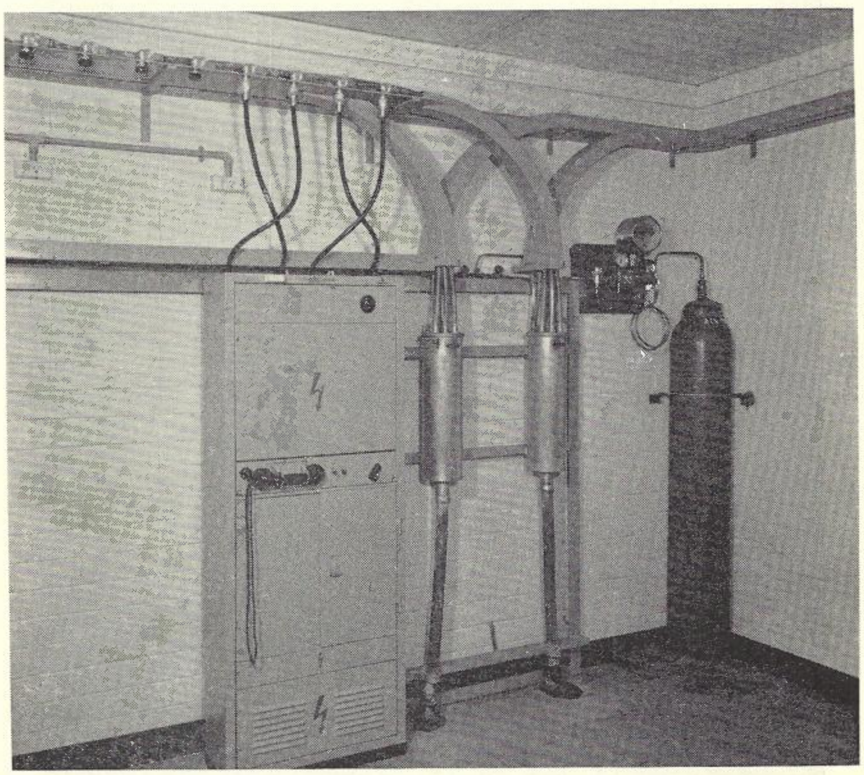


Fig. 27.—Inside View of Unattended Repeater Station showing Cable Terminations and Power Feeding Rack.

tribution frame and the supergroup modulators. The capacity of the distribution frame is 144 basic groups or basic supergroups when installed separately in large stations, or 24 supergroups with 120 groups when installed as a combined frame. On the Melbourne-Morwell route combined frames have been installed at Morwell, Warragul and Dandenong. At City West the cabling is to be integrated with the Sydney-Melbourne installation on separate Group and Supergroup frames as soon as practicable, and so for the initial installation, temporary cabling only has been provided directly between the equipment racks. Coaxial tube termination is carried out as described for unattended stations in the following paragraph.

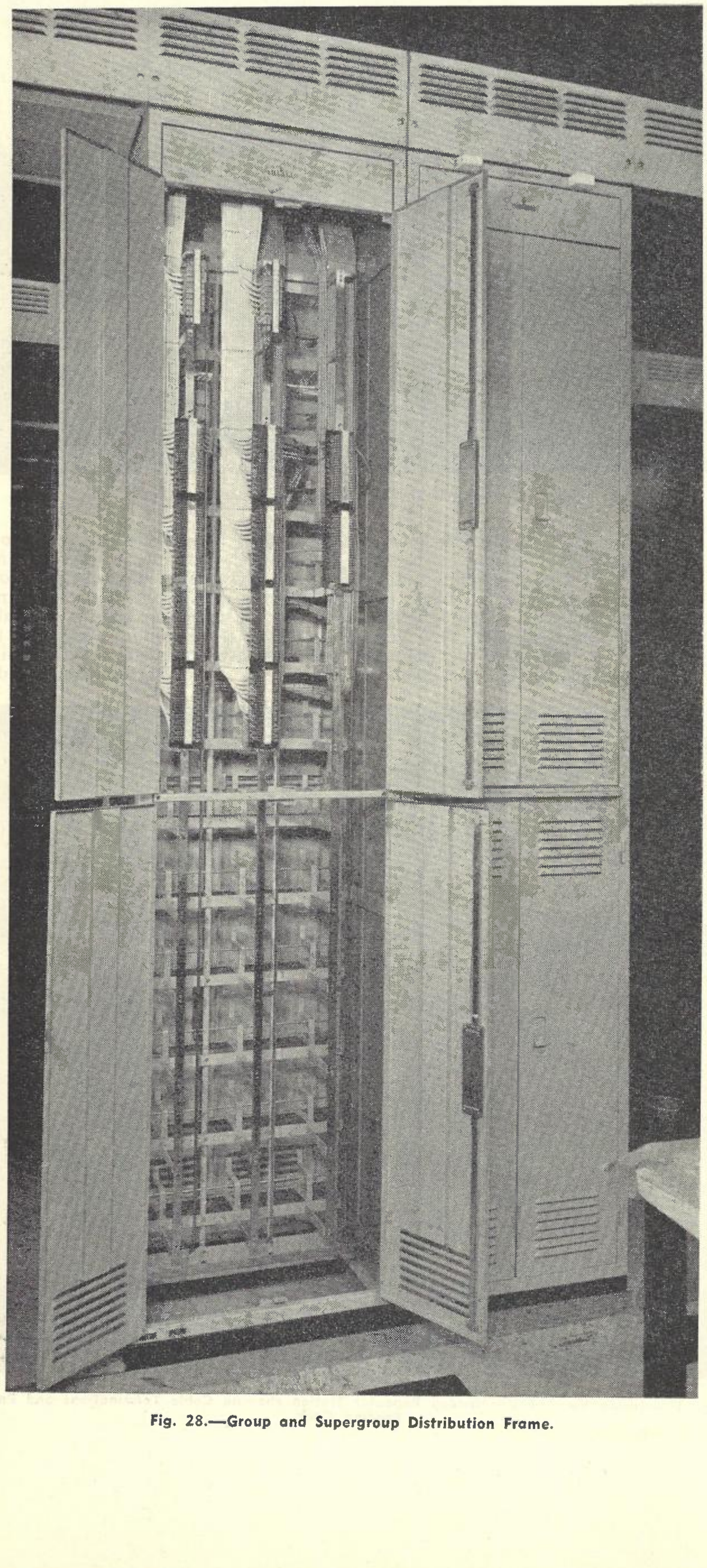


Fig. 28.—Group and Supergroup Distribution Frame.

Unattended Repeater Stations

An external view of a typical unattended repeater station on the Mel-

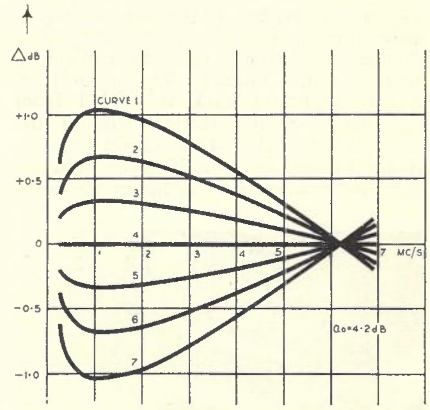
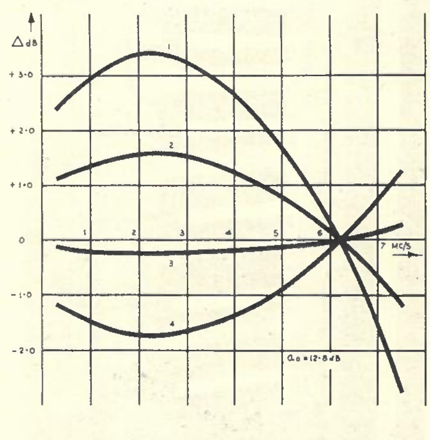


Fig. 29.—Fixed System Equaliser to Correct for Systematic Distortion between Line Building-out Networks and Line Amplifiers over Main Repeater Sections.

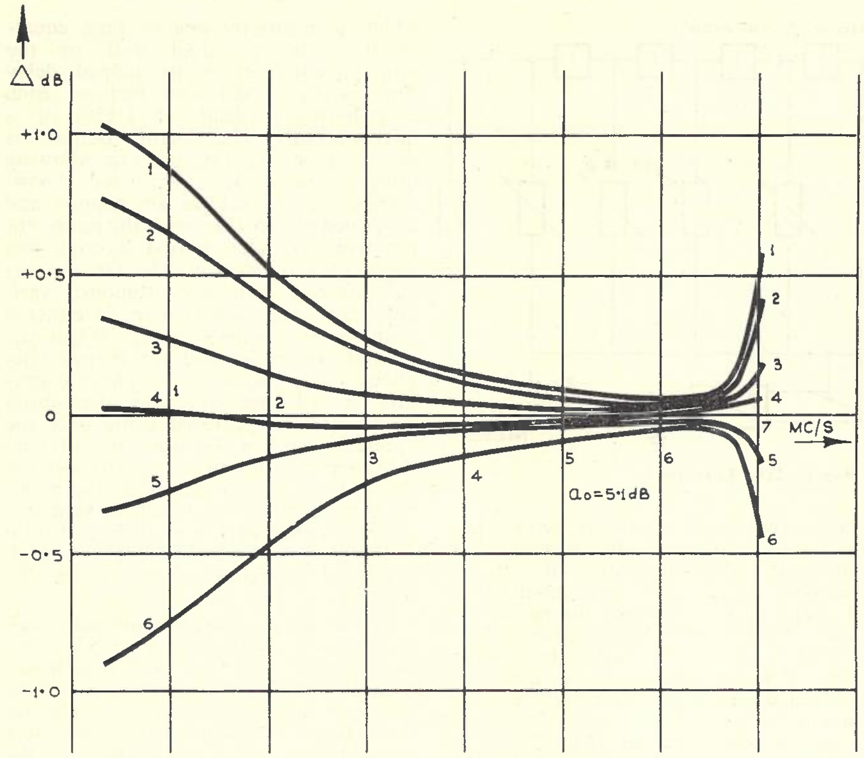
bourne-Morwell coaxial route is shown in Fig. 26. In Fig. 27 is shown the cable pothead frame with the extension lengths of single lead-covered air-spaced coaxial tubes leading to gas-tight terminations, from which connection is made to the power feeding rack via connectors and semi-flexible solid dielectric coaxial cable. Also shown in this photograph is the cable gas pressure equipment.

The power feeding rack and line amplifier rack (see Fig. 11) are installed against the walls, and cables for inter-



CURVE	CONDUCTANCE	CONTROL POSITION	THERMISTOR RESISTANCE
1	> 16·3 mA/V	≈ 105°	600 Ω
2	16·3 mA/V	≈ 130°	245 Ω
3	13·5 mA/V	≈ 158°	118 Ω
4	12·0 mA/V	≈ 190°	63 Ω

Fig. 30.—Pilot Controlled Equaliser for Valve Ageing.



CURVE	TEMPERATURE	REGULATOR POSITION
1	10° F	≈ 130
2	31° F	≈ 140
3	51° F	≈ 150
4	77° F	≈ 160
5	118° F	≈ 175
6	>122° F	≈ 190

Fig. 31.—Pilot Controlled Equaliser for Ambient Temperature Variations.

connecting these racks are located in 3" x 2" metal ducts placed on brackets attached to the wall above the racks. Two ducts are used, one carrying the H.F. cables for the transmission path and the other for the 220 volt A.C. power wiring.

At Balaclava and Oakleigh the unattended repeaters are located in existing telephone exchange buildings, but similar installation procedures apply.

HIGH FREQUENCY BEARER LINE-UP

The work of aligning the high-frequency bearer fell into two main categories, namely adjustment of the line pilot equipment, and adjustment of the equalisation.

Pilot Alignment

The pilot alignment for each direction of transmission commences at the transmitting terminals with the setting of each pilot level at the line output of the transmit amplifier. A simplified block schematic of the H.F. line pilot equipment is shown in Fig. 6. Each pilot is fed to line at a level of –24.3 dbm, which is monitored by the appropriate pilot receiver. The pilot receivers in the transmit rack differ from those at unattended stations in that they are equipped with indicating meters, and serve only to provide supervision of the outgoing pilot levels.

At each repeater the first adjustment carried out is that of the line building-out network. Principally, this adjustment brings the 6.2 Mc/s pilot level within the regulating range of the line amplifier "E". There is a further refinement necessary, however, since the attenuation/frequency characteristic of the amplifier is not exactly identical with that of the cable. Since the regulating amplifiers always correct the level at the pilot frequency (6.2 Mc/s) to a fixed value of –24.3 dbm, there will be a small residual distortion of the attenuation characteristic over the lower frequency range. Reference to Fig. 14 shows, furthermore, that the curvature of the line amplifier characteristic varies over the regulating range. Depending upon the resultant cable length (after building out) the attenuation distortion can therefore be positive or negative. From a graph supplied by Siemens and Halske which shows the positive or

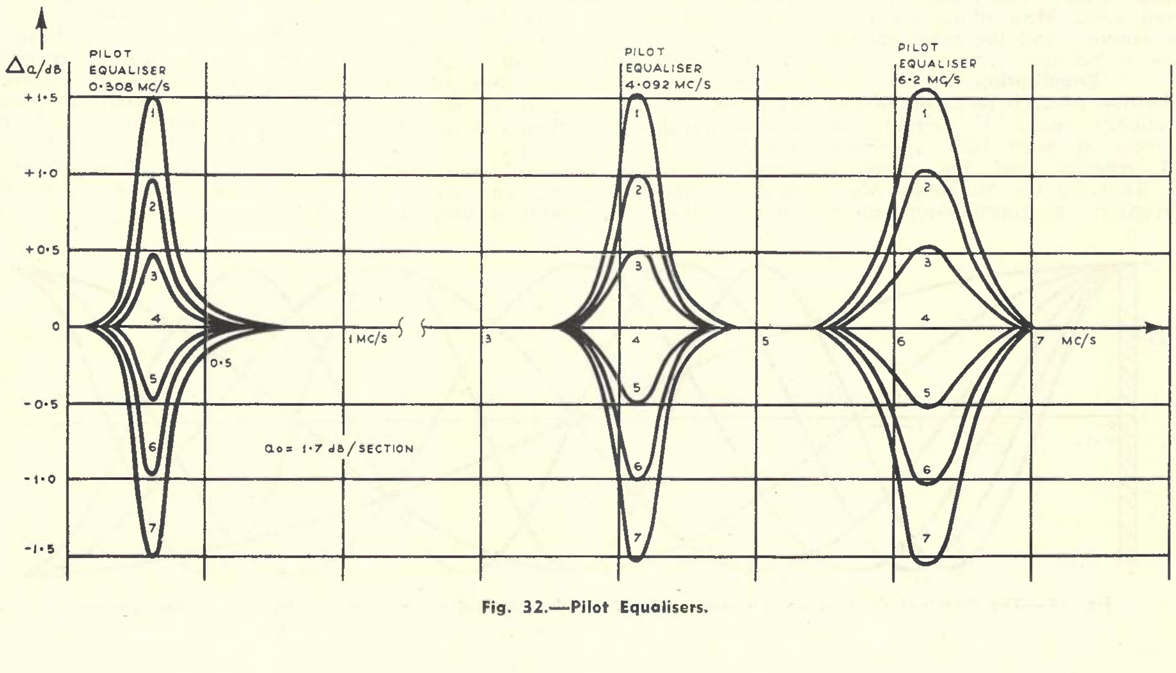


Fig. 32.—Pilot Equalisers.

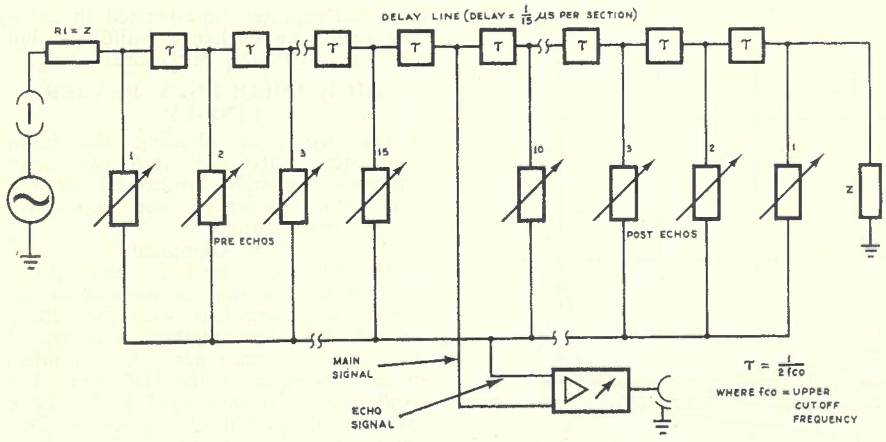


Fig. 33.—Block Diagram of Mop-up Echo Equaliser.

negative attentuation distortion at 1 Mc/s as compared with 6.2 Mc/s, which varies for different values of cable attenuation within the regulating range of the amplifier, the correct building-out network for each minor repeater section can be selected to achieve the maximum possible cancellation of the systematic distortion over each main repeater section.

If the repeater is one with automatic regulation, this feature is disabled to allow the adjustment of the amplifier gain to give a 6.2 Mc/s pilot level of -24.3 dbm to line. This adjustment is performed using the manual control on the regulator. Next, the pilot receiver is adjusted to give a specified voltage at the measuring jack (Fig. 7) which corresponds to the "no drive" condition of the motor regulator. The same procedure is followed at a repeater with manually set regulators, but it is unnecessary to disable the pilot circuit during the amplifier adjustment. At the main repeaters where all three pilots are used for regulation, a temporary connection is made which virtually converts the repeater to a manually controlled unattended station. This means that the 0.308 and 4.092 Mc/s pilots are temporarily ignored, and the pilot line-up continues as before.

Equalisation

Equalisation of each direction of the high-frequency bearer is carried out progressively at each fully regulated attended repeater and the terminal station. Thus for the Melbourne-Morwell direction of transmission three stages were necessary, these being Melbourne-Dandenong, Melbourne-Warragul and Melbourne-Morwell. It is necessary to describe the equalisation of only one station, since the procedure is the same in subsequent stations. This procedure has three parts, the adjustment of the system equaliser, the pilot controlled equalisers and the mop-up equaliser.

The system equaliser (Fig. 29) is a fixed equaliser which corrects for systematic attenuation distortion over a main repeater section which has not been cancelled by the appropriate selection of the line building out networks.

The pilot controlled equaliser is in two sections; one (Fig. 30) corrects the changing frequency response due to the decreasing transconductance of the line amplifier valves as they age; the other (Fig. 31) compensates for the change in attenuation characteristics which result from variations of equipment component values with ambient temperature changes.

The mop-up equaliser (Fig. 33), as its name implies, corrects any residual attenuation distortion resulting, for instance, from cable impedance irregularities, and for this purpose, it is made to be continously variable over the whole frequency range. Although its function, in this case, is to equalise attenuation distortion alone (because the coaxial system is used for telephony only), the design is aimed to correct both group-delay (phase) and attenuation distortion, by adopting an approach which is primarily one of time equalisation. The principal unit of the mop-up equaliser is its tapped delay line, having twenty-five sections each contributing a delay of 1/15th of a micro-second. The main output is derived from the fifteenth tap, allowing fifteen "pre-echoes" and ten "post-echoes". These echoes are tapped and combined at low level with the main output which is then passed through two stages of amplification. The tapping circuit for each echo is continuously variable from zero to maximum in either a positive or negative sense. When the coaxial system is used for carrier telephony only, correction of phase distortion is not necessary and attenuation equalisation is achieved using only the "pre-echoes". Fig. 34 shows the attenuation/frequency characteristics for each of the first six echo controls in the maximum positive setting. It will be seen that a combination of fifteen such curves in suitable proportions will allow a high degree of correction of attenuation distortion.

The actual procedure of overall equalisation is carried out with all pilot control circuits disabled and commences with the fixed system equaliser. This equaliser has seven circuit configurations (Fig. 29), selected by adjustable solder links. The correct setting of the equaliser is determined by an examination (by means of the 15 Mc/s attenuation/group-delay level tracer, described later) of the attenuation characteristic as it appears at the output of E amplifier (Fig. 36). This characteristic includes the distortion to be compensated by all three equalisers, and some experience is necessary in analysing the trace to determine the relative contribution to the overall equalisation of each individual unit. Fig. 36 shows a typical trace before equalisation, and the general trend of the curve can be seen to correspond to curve 6 for the fixed equaliser as shown in Fig. 29.

Having selected the appropriate value for the fixed equaliser, the pilot-controlled equalisers are adjusted. The motor-regulators are set manually to positions determined by referring the known values of ambient temperature and valve transconductance (both averaged for the main repeater and the preceding unattended repeaters) to the curves in Figs. 31 and 30 respectively.

The attenuation characteristic is now

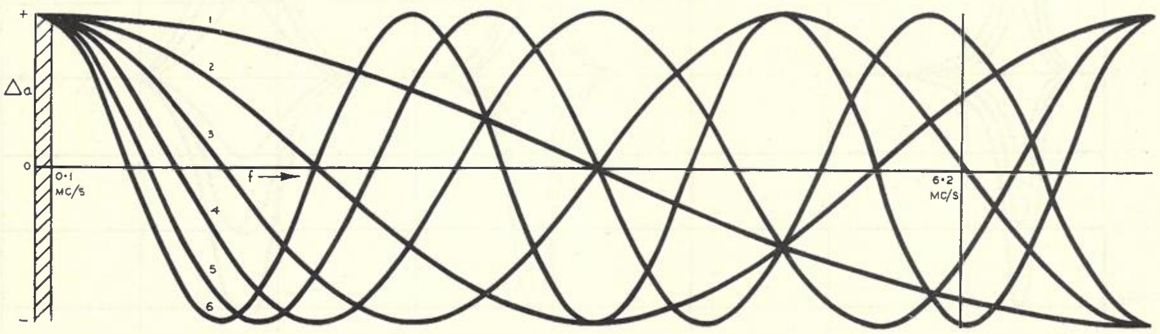


Fig. 34.—The Effect of Controls on the Mop-up Equaliser, Controls 1-6 being Maximum Positive in One Direction

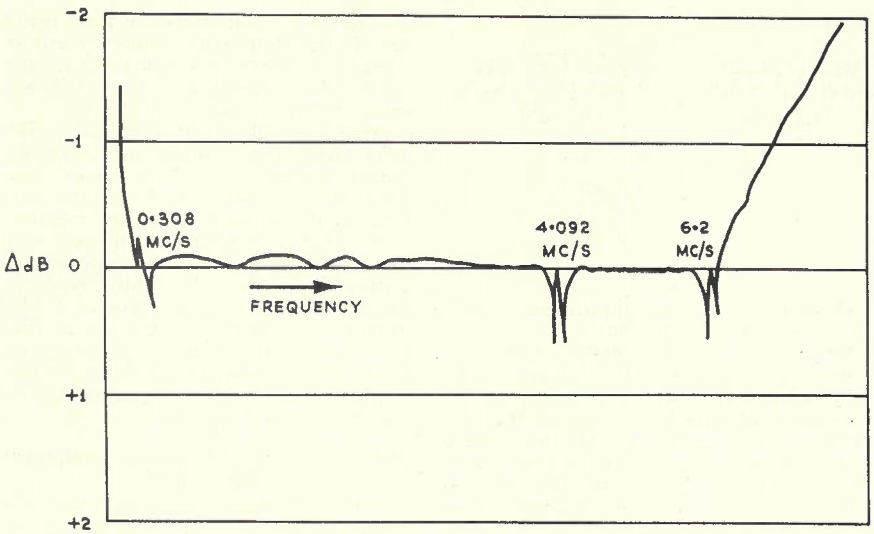


Fig. 35.—H.F. Line Response Displayed by Level Tracing Receiver after Adjustment of Echo Equaliser in Melbourne/Dandenong Section.

examined, with the level tracer connected to the output of the final G amplifier, and the fifteen "pre-echo" controls of the mop-up equaliser are adjusted for a maximally-flat curve. The initial adjustments are made with the controls corresponding to the low-numbered curves of Fig. 34 to correct overall slope and convexity or concavity of the characteristic. Then, individual bumps and dips in the curve are eliminated by adjustments with the higher order controls. Subsequently the process is one of trial and error, the time taken depending upon the previous experience of the operator. When this operation has been completed, the optimum overall equalisation of the main repeater section is obtained (Fig. 35), but the output level to line at the reference frequency is not necessarily the nominal level of -11.3 dbm. This is now corrected by sending a line-up signal frequency of 1 Mc/s from the terminal station at correct level and adjusting the continuous gain control of the mop-up equaliser amplifier and the fixed pads in the pilot-controlled equaliser.

The pilot equaliser which is provided to allow restoration of the pilot frequencies to their relative levels is adjusted to give pilot output levels of -24.3 ± 0.3 dbm to line. Fig. 32 shows the seven adjustments available for equalising each of the three pilots. Finally, with the line terminating the transmit side of the repeater, the three pilot receivers are adjusted to obtain 0 db on the indicating meters, which corresponds to an output from the pilot receivers of zero volts. The outputs are then applied to the D.C. amplifier, which in turn is also adjusted to zero. Reconnecting the regulation paths then results in the motor regulators remaining stable.

The overall response of the high frequency line in both directions on the Melbourne-Morwell coaxial system after equalisation was within ± 0.5 db over the frequency range 300 Kc/s to 6.2 Mc/s.

OVERALL TESTS

In addition to the normal end-to-end channel measurements of frequency response, noise, harmonic distortion and signalling, an overall measurement was made of the basic and intermodulation noise on the H.F. line.

A block schematic of the random-noise intermodulation measuring setup is shown in Fig. 37. The random-noise intermodulation measuring equipment, supplied by Siemens and Halske, combines high measuring accuracy with very simple operation. It consists of a random-noise generator, a set of three bandstop filters for use at the transmitting end, three band-pass filters for use at the receiving end, and a noise level meter.

The random-noise generator allows the traffic load of all the speech channels on the coaxial system to be simulated by random noise covering the transmitted band of line frequencies. In its basic design the random-noise generator is designed for a frequency range of 60 Kc/s to 12 Mc/s. As shown in Fig. 37 however, a low pass filter limits the upper frequency of the noise band to 4.188 Mc/s which corresponds to the line frequency band of the V960 system. In this noise band three gaps, each having a bandwidth of 3.1 Kc/s, are provided by the band-stop filters at the transmitting end to simulate three "idle" speech channels. Reference to Fig. 37 shows that the band-stop filters are provided at the centre and extremities of the frequency range. At the receiving end three band-pass filters exclude all but these three channels and the noise power appearing in each of these "idle" channels can be read separately on the selective noise level meter. With the system input terminated, the level meter reads only the basic noise contribution of the bearer to each channel. When the random-noise generator is connected the reading indicates the combined result of basic noise and intermodulation noise. The selective noise level meter is calibrated to read directly in picowatts and dbm according to the C.C.I.T.T. 1956 psophometric weighting curve.

In carrying out the intermodulation noise tests on the H.F. bearer, the recommended C.C.I.T.T. noise level at the sending terminal of a coaxial system is $-15 + 10 \log_{10} N$ dbm at a point of zero relative level, where N is the number of channels. For a V960 system this becomes $-15.0 + 10 \log_{10} 960 = + 14.8$ dbm at a point of zero relative level. At the transmit terminal input the channel level is -20 dbm ("F2in" on trans. amp. rack), so that the level of the transmitted noise signal at the transmit amplifier rack should be $- 20 + 14.8$ dbm $= - 5.2$ dbm.

The results obtained from these measurements on the Melbourne-Morwell system were as shown in Table II.

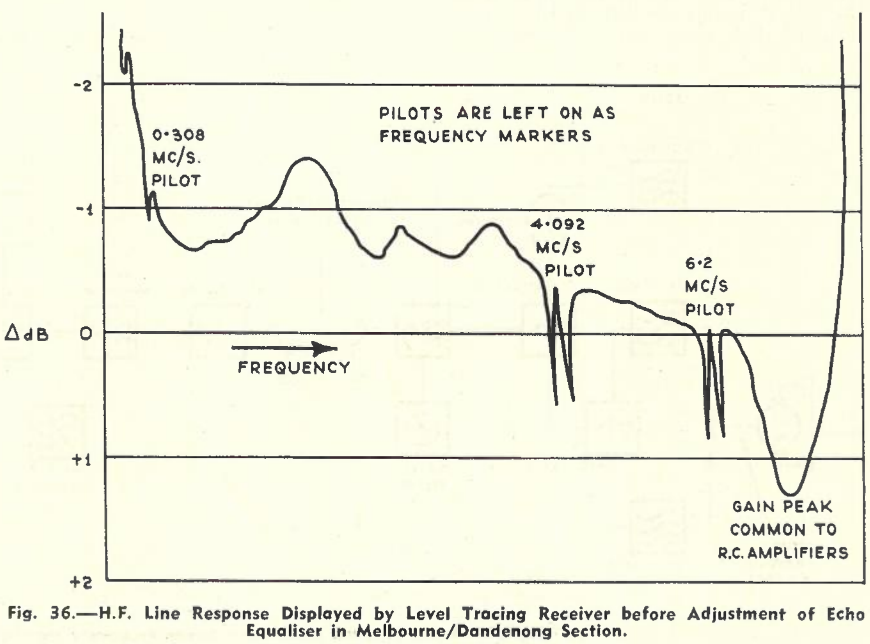


Fig. 36.—H.F. Line Response Displayed by Level Tracing Receiver before Adjustment of Echo Equaliser in Melbourne/Dandenong Section.

TABLE II

Measurement	Mid-frequency channel (2,438 Kc/s)	Upper frequency channel (3,886 Kc/s)
Basic noise Melbourne to Morwell	– 71.2 dbm	– 66.3 dbm
Basic noise Morwell to Melbourne	– 71.3 ,,	– 66.3 ,,
Basic plus intermodulation noise Melbourne to Morwell	– 71.0 ,,	– 66.2 ,,
Basic plus intermodulation noise Morwell to Melbourne	– 70.0 ,,	– 65.5 ,,

The C.C.I.T.T. limits for the noise contribution from the H.F. line to any single speech channel is 4.8 picowatt per mile, which for this coaxial system of 100 miles length represents a noise power of 480 picowatt or –63.2 dbm.

Noise measurements for the lower frequency channel (70 Kc/s) could not be obtained as the line amplifiers at present installed have a lower limit of 300 Kc/s. Also the noise testing equipment available did not allow the bearer to be tested with the noise over its full bandwidth of 6 Mc/s with 1,260 channel loading. The results obtained were, nevertheless, very satisfactory.

TEST EQUIPMENT

Not the least interesting aspect of the installation of this system was the introduction of testing instruments and techniques not generally encountered previously.

30 Kc/s-15 Mc/s Level Measuring Equipment

The level oscillator 3W518 operates on the beat-frequency principle and allows the desired frequency range to be covered in a single band without switching. Very high frequency accuracy and stability are obtained by a circuit arrangement whereby the variable-frequency oscillator has an automatic frequency lock-in adjustment, at 100 Kc/s intervals, to the harmonics of a crystal-controlled 100 Kc/s reference frequency. The frequencies in between the lock-in points are obtained by variation of the fixed-frequency oscillator which gives accurate adjustment of any frequency to within 200 c/s.

The selective level meter, 3D335, is designed as a heterodyne detector. As the selectivity requirements are easier to satisfy at the lower end of the frequency range than the high, the voltage to be measured is brought in four stages of modulation to a final intermediate stage of 3 Kc/s which allows alternative selection of bandwidths of 200 c/s and 3.1 Kc/s, the latter representing the width of a carrier speech channel (300 to 3,400 c/s). This selective level meter has similar automatic frequency adjustment and crystal control to that provided on the level oscillator, and will detect levels as low as –115 dbm.

A very useful facility provided in this level measuring setup is the automatic tuning system of the level meter when both the oscillator and detector are located at the same place of measurement. This is arranged by interconnecting both units with the appropriate connecting cords, after which both the oscillator and level meter are controlled by the same variable generator. Under these conditions of automatic tuning the advantage of selective measurement is available with continuous adjustment of the frequency range.

Sweep-Frequency Measuring Equipment, Type 33L63

This equipment is provided to measure envelope delay and attenuation distortion in the frequency range of 0.1 to 15 Mc/s. Fig. 38 shows a block schema-

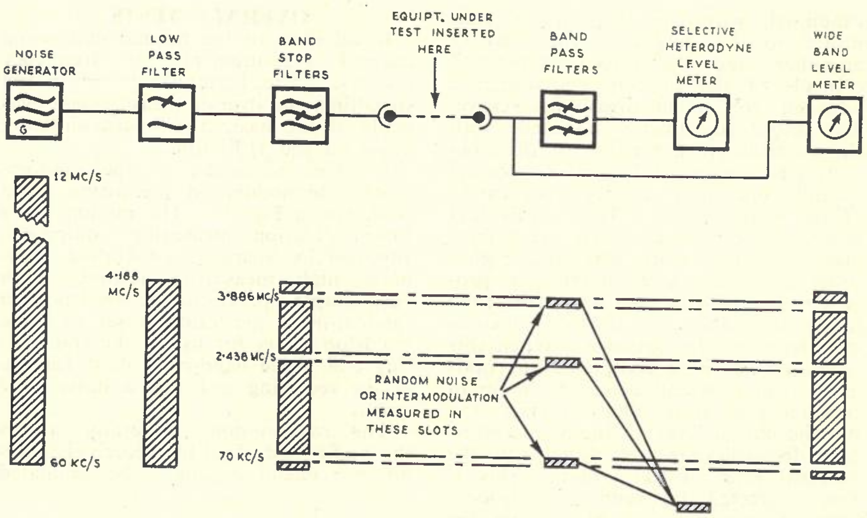


Fig. 37.—Random-noise Intermodulation Measuring Set-up.

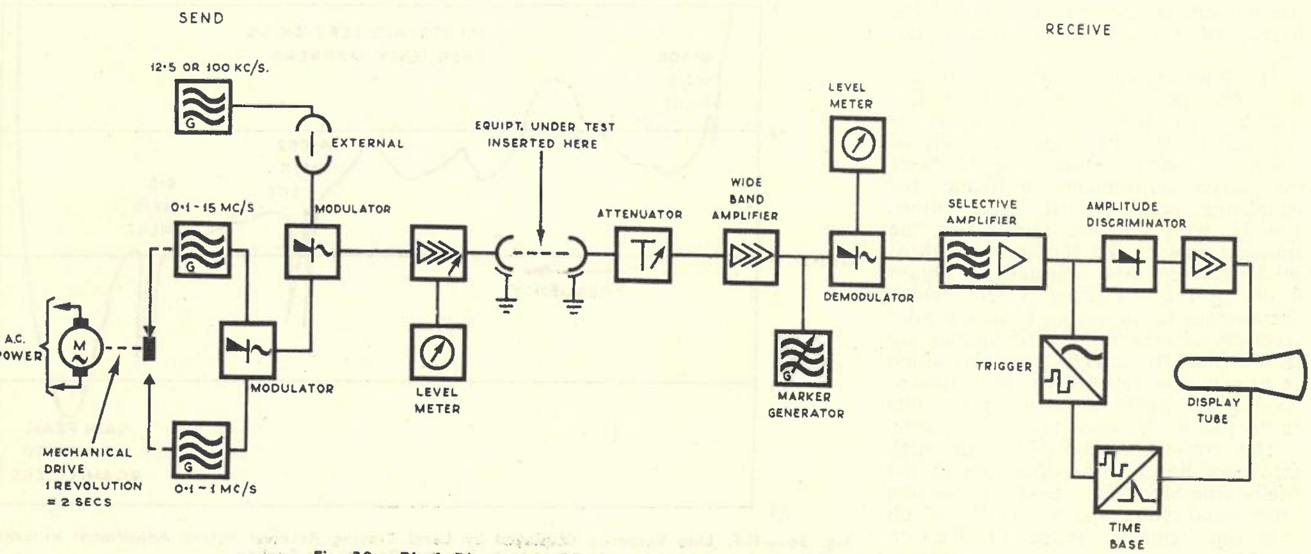


Fig. 38.—Block Diagram of 15 Mc/s Sweep Frequency Measuring Equipment.

tic of the measuring setup with the sections concerned with group delay omitted for clarity.

The send unit originates a signal which traverses the frequency band from 100 Kc/s to 15 Mc/s, (or any 1 Mc/s band in that range, depending upon whichever oscillator is being swept), and which is modulated by a frequency of 100 Kc/s (or 12.5 Kc/s, if higher resolution is sought). The receiver detects this modulation, which is itself now modulated by the frequency response of the intervening line. A further detection stage gives an output which varies in time as the line attenuation varies with frequency. This output is displayed on a cathode ray tube whose horizontal sweep is a one-second sawtooth triggered by the wave front of the incoming signal. Exact horizontal calibration is achieved by a marker generator in the receiver.

CONCLUSION

A comprehensive description has been given of the initial equipment installation on the Melbourne-Morwell coaxial cable system. Aspects included cover the initial planning and engineering, system and equipment design, and installation, line-up and overall testing of the system, which was the first coaxial cable system to be installed by staff of the Postmaster-General's Department in Australia.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance and information given by Siemens and Halske A. G., Munich, and by their representatives in Melbourne, Siemens Halske - Siemens Schuckert (A'asia) Pty. Ltd. Special thanks are due to Mr. G. Fink, Line-up Engineer, and Mr. A. Hammerlindl, Installation Supervisor, of Siemens and Halske, for their invaluable advice and friendly co-operation in the task of commissioning the system.

REFERENCE

6. M. W. Gunn and R. W. E. Harnath, "Short-haul Cable Carrier Systems; Part II"; Telecommunication Journal of Australia, Vol. 12, No. 1, page 18.

ARTICLES BY P.M.G. DEPARTMENT STAFF APPEARING IN OTHER JOURNALS

The Coding of Visual Signals to Achieve Channel Capacity Reduction* by A. J. Seyler, Dipl. Ing., M.E.E., S.M.I.R.E. Aust.

Present-day communication channel requirements for the transmission of visual information are based on fixed and independent threshold criteria for spatial, motion and contrast resolution. If in accordance with the dynamic characteristics of the human sense of vision, time variant and interdependent thresholds are introduced for these parameters, the required channel capacity may be reduced, provided it is assigned adaptively to the three parameters as demanded. This concept is developed into an integrated coding system for visual signals making use also of intraframe and interframe correlations existing in television signals.

Although it was possible to establish a formal system design, certain phychophysical data as well as signal statistics have still to be measured to enable a reliable numerical evaluation of the attainable channel capacity reduction.

* This is an abstract of an article which appeared in the July, 1962, issue of the Proceedings of the Institution of Electrical Engineers.

Visual Communication and Psycho-Physics of Vision* by A. J. Seyler, Dipl. Ing., M.E.E., S.M.I.R.E.Aust.

This paper discusses the effects which result when man is considered to be a constituent part of electrical communication systems in general, and in particular of systems designed for visual communication. These effects can be divided into those which affect man's visual sensory functions due to the presence of the communication system, and those which affect the design of communication systems required to match the psycho-physics of vision. In present-day visual communication systems maximum-contingency criteria are applied to the capacity of the communication channel for each of the visual parameters of spatial, contrast-and motion-resolution independently. However, it appears from psycho-physical data so far available that man's sensory capacity is shared adaptively between those parameters, with the result that at any time, a maximum contingency can exist only for one parameter at a time.

This adaptive behaviour can be applied to signal coding methods which are designated as "Adaptive Parameter Codes" and which may be used alone or in conjunction with statistically matched codes arising from the concepts of Information Theory. It is shown that, by employing such adaptive codes, the channel capacity required for the transmission of visual signals may be reduced, but also that additional investigations are still necessary to acquire and evaluate psycho-physical data in a form suitable for quantitative communication system design.

* This is an abstract of an article which appeared in the May, 1962, issue of the Proceedings of the Institution of Radio Engineers, Australia.

CONZINC P.A.B.X., MELBOURNE

*A. MORTON, A.M.I.E.E.**

INTRODUCTION

February, 1962, marked the opening of the new Melbourne Headquarters for Conzinc-Riotinto of Australia Limited. The offices of this large company occupy the tallest building so far built in Victoria. Located half way up this 324 ft. 6 in. building is a crossbar P.A.B.X. which is the first of its type to be installed in Australia. LM Ericsson installed this ARD. 151 P.A.B.X. which has a capacity of 800 extensions and 80 exchange lines.

GENERAL DESCRIPTION

The P.A.B.X. is register-controlled, there being two registers for each group of one hundred extensions. The brain of the P.A.B.X. is the marker unit; this comprises a number of sections dealing with the testing and selecting of the switching route to be used, plus other special facilities. The operator's positions work on the link principle; three positions have been provided to deal with 20 incoming exchange lines and 400 extensions.

Double sided equipment racks 7 ft. high by 3 ft. wide are bolted directly into the vinyl tile floor. Overhead ducts are used to house the inter-rack cables, whilst the M.D.F. is a standard type using link mountings. Power for the equipment is obtained from 24 volt rectifiers with two sets of 200 A.H. batteries.

A general view of the equipment along one side of the P.A.B.X. room is shown in Fig. 1, whilst Fig. 2 shows the rectifiers, battery cabinet and M.D.F. The room, which is air-conditioned, has good natural light along the south side, whilst fluorescent lights have been let into the acoustic ceiling tiles, providing excellent illumination for maintenance.

OPERATION

The trunking of the P.A.B.X. is shown in simplified form in Fig. 3. The extensions are split up into two groups of 400 lines; typical extensions in the two 40 line groups are illustrated in Fig. 3. The subscriber's stage, L.R.V. consists of a crossbar switch and associated line relays (Fig. 4). Each vertical of the L.R.V. switch corresponds to one extension so that there is one switch for every ten extensions or ten switches for each one hundred line group. Each L.R.V. rack can carry a maximum of eight switches, that is, 80 extensions. To cater for each 100 line group there are two registers, the traffic being distributed evenly between them by means of the register allotter R.A.; Fig. 5 shows two registers in position on a rack. The register transmits dial tone, stores the dialled impulses, sets up the calling and called numbers on the crossbar switch and calls in the marker.

One marker only caters for the entire P.A.B.X.; this unit tests the condition of the called extension (internal call) and selects free connecting circuits (SNR) and group selectors (SGV) as required. After the connection has been set up the marker and register release. The marker also plays other rolls, such as setting up priority calls. A view of four sections of the marker is given in Fig. 6; other sections appear on racks appropriate to the particular function of the section. The tone generator and relays associated with supervision are also shown in Fig 6, occupying the lower portion of the rack.

For internal calls within the same 400 line group the call is switched directly from one extension stage (LRV) to the other via a connecting circuit in the S.N.R. multiple. However, a group selector stage S.G.V. is brought into use for calls between the two 400 groups. Each extension in a 400 line group has access to a maximum of 29 connecting circuits, which in addition to being multipled in the extension stage, are also connected to the multiple of the group selector stage. A maximum of 60 connecting circuits can be provided for each 400 group. For each connecting circuit there is an S.N.R. relay set which comprises three relays and provides the transmission battery.

When an extension dials the operator, the marker selects either a free operator or an individual operator depending upon the particular code dialled. The extension number is registered by the operator's register and the call is signalled visually on the operator's set F.M.A. When the operator answers, the calling number is displayed on the F.M.A. One of the operator's units can be seen clearly in Fig. 7. The unit comprises keys, lamps and a dial; the associated relays and operators circuit being housed in the F.M.T. set located in the equipment room.

The exchange lines are connected to exchange line relay sets F.D.R.C. and on an outgoing call the extension dials "O", the marker selects a free exchange line and F.G.V. stage, after which the register and marker release. The remaining digits are then dialled directly into the F.D.R.C. which repeats them to the public exchange.

Incoming calls enter the P.A.B.X. via F.D.R.C. and line finder stage F.M.S. which connects the exchange line to a free operator's link. The operator is signalled visually and answers by pressing a key associated with the particular link. Each operator can deal with up to three incoming exchange lines at any one time. The operator can either key or dial the required extensions. The operator's register receives the impulses and calls in the marker which tests the required extension and selects a switching path if the extension is free. The called number is displayed on the operator's position, so the operator can see if she has dialled or keyed up the

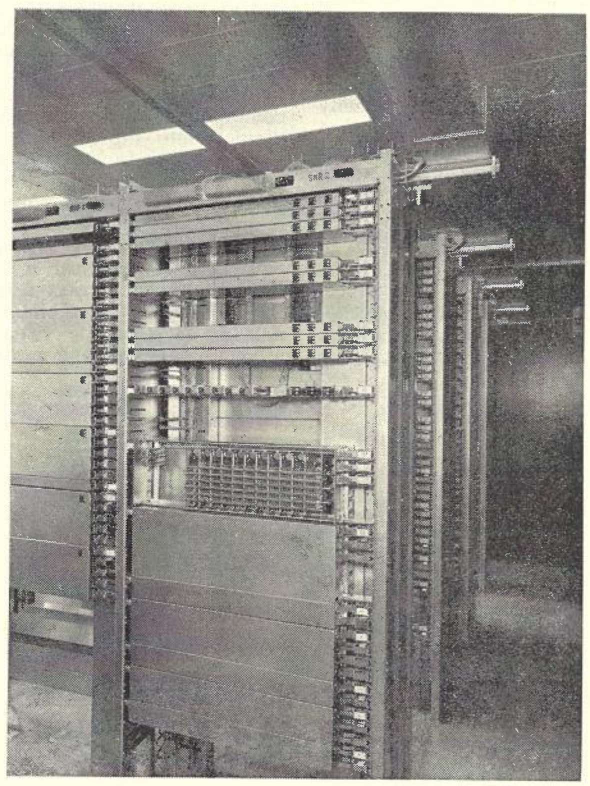


Fig. 1.—General View of Equipment along One Side of P.A.B.X. Room.

* See Vol. 13, No. 2, p. 155.

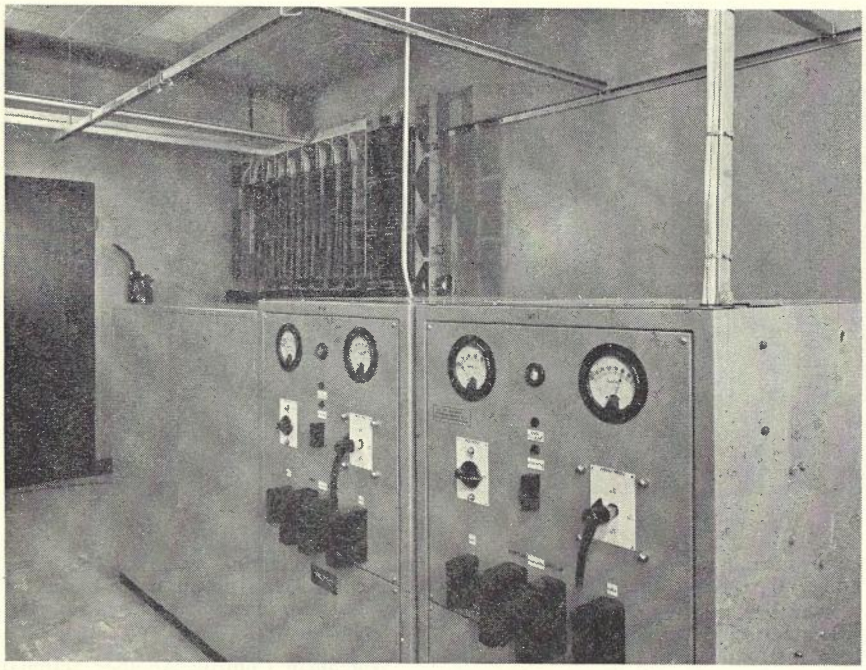


Fig. 2.—M.D.F. and Power Equipment.

number correctly. If the operator wishes to announce the caller to the called extension she sends the ring signal by pressing the appropriate key and waits for the extension to reply; after announcing the call she connects the caller through to the required extension.

If the call does not require announcing the operator presses a key on her set so that ring current is automatically applied and when the extension answers the marker switches the extension through to the exchange line and the link circuit is cleared for other calls.

If the call is not answered within a certain time the operator is automatically recalled so that the caller can be either switched to another extension or advised to call later.

If the required extension is engaged an appropriate signal is given to the operator. The operator can either advise the caller to ring later, switch the call to waiting or "park" the call. Waiting means that the call is held on the operator's link and is automatically switched through to the required extension when free. If the caller has not been switched through within a certain time, the operator receives an appropriate signal and is reconnected to the caller. The operator can put the call back into "waiting" if necessary. If the operator has one call in waiting, then a caller coming in on another link who requires an engaged extension is usually put into the "park". This frees the link for further calls and the caller is automatically connected to a free operator's link after a certain time delay. The operator can, if necessary, enter an engaged circuit and advise the appropriate extension that a caller is waiting.

SPECIAL FEATURES

Priority Calls: Extensions can be given a facility which enables them to cut in on an established internal call. This is called priority and can be given to extensions having unit digit 9, that is, extensions 109, 229, etc., can be given priority.

Call Back: If an extension receives busy tone after calling another extension the call back facility can be used. The caller momentarily depresses his

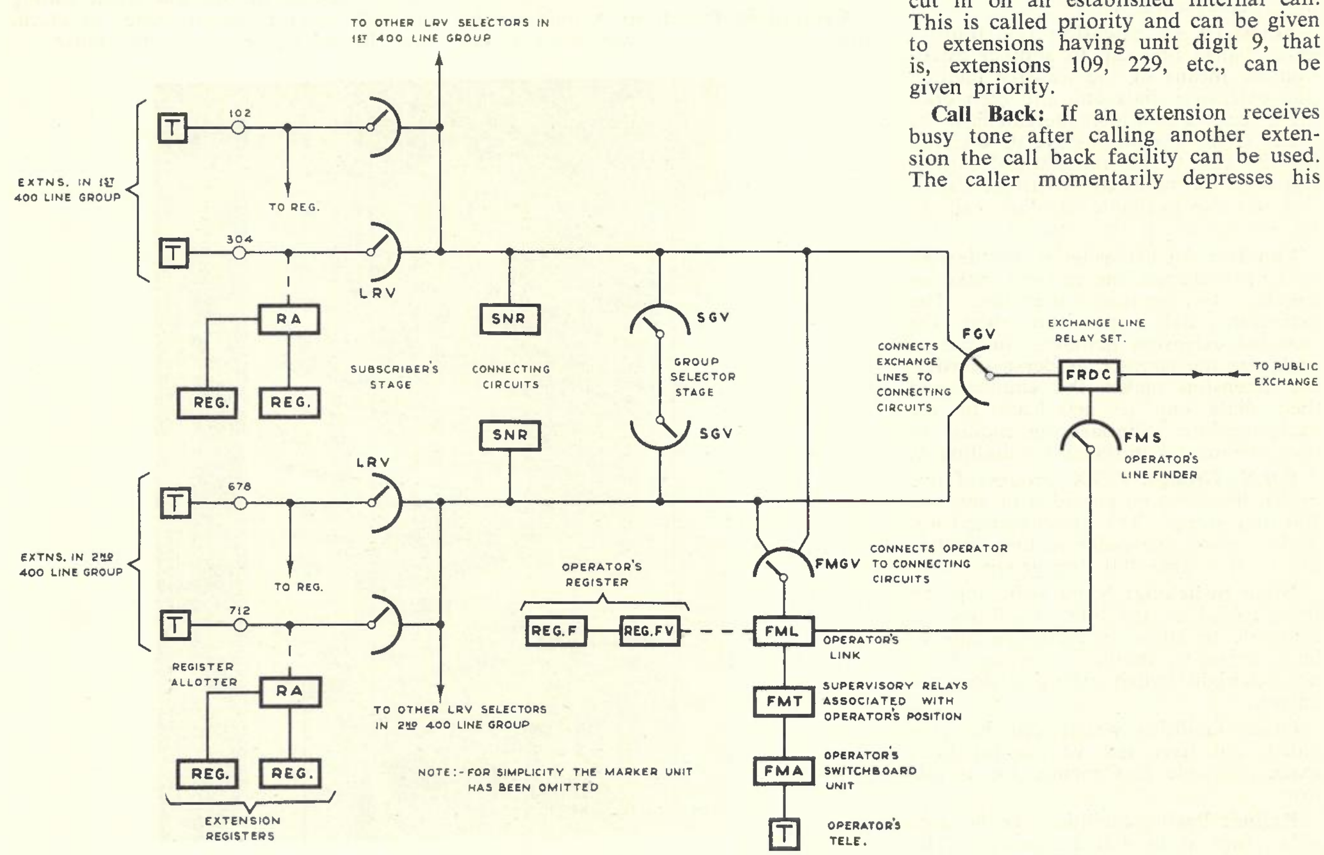


Fig. 3.—Trunking.

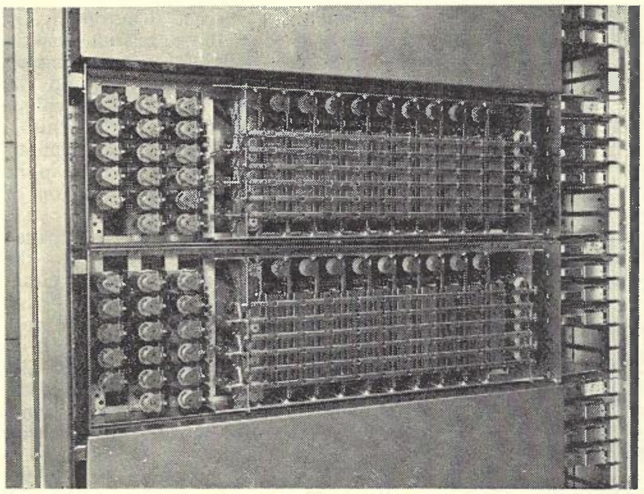


Fig. 4.—L.R.V. Units.

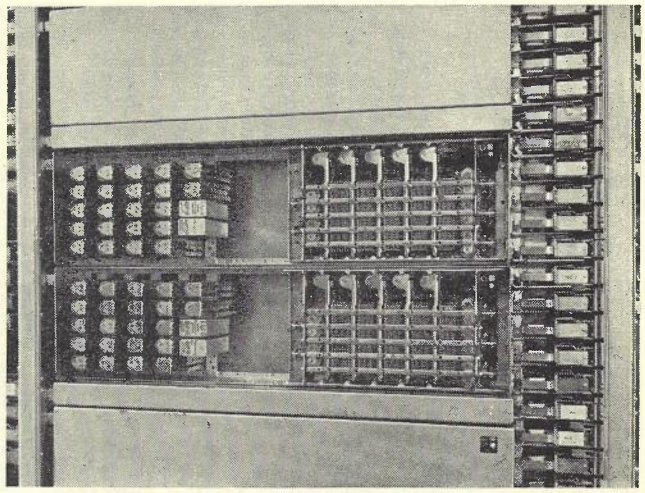


Fig. 5.—Registers.

switch-hook and then dials 82, thereby taking into use the call back unit. The caller then redials the required extension, the digits being stored in the call back unit. The caller is then free to make any other calls. When the required extension becomes free the caller is automatically rung (when free) and connected through to the required extension. This facility has been found extremely useful at Conzinc.

Conference Calls: Facilities are provided whereby up to a maximum of five extensions can be connected together for a conference.

Transfer: An extension can transfer an exchange line call to another extension by means of the transfer facility. The extension dials one and then dials the extension to which the call is to be transferred. Conditions are then set up for the call to be automatically transferred to the required extension. Facilities are also available to allow calls to be transferred to the operator.

Enquiry: An extension whilst dealing with an exchange line call can make an enquiry to another extension. The extension dials one and then the required extension number. Instead of replacing the handset, as per a transfer, the extension makes the enquiry and then dials one to get back to the exchange line. Similarly an enquiry to the operator is initiated by dialling 9.

P.B.X. Groups: P.B.X. groups of five or ten lines can be provided in any one 100 line group. The numbers need not be in consecutive order so long as they are in the same 100 line group.

Night Switching: Night switching can be provided on any line. Facilities are available to allow an incoming line to be switched to another extension if the normal night switch extension does not answer.

Other facilities which can be provided, but have not yet so far been made available at Conzinc, are as follows:

Paging: Paging facilities can be provided for up to 400 extensions. The required person is signalled by a five lamp combination located at suitable points throughout the building.

Interception: By simply dialling a special code an extension can arrange for his calls to be automatically redirected to another extension or redirected to an automatic telephone answering machine.

Trunk Ticketing: As a check on extensions making trunk calls, equipment can be provided which records details of the calling extension, the called number, date, time and duration of call.

Centralized Dictation: A unit can be provided which will switch an extension to a dictating machine. The caller can control the machine by means of his dial, for example, dials 1 to start the machine.

Watchman Control: Another optional facility is that of the watchman control service. In this case a watchman calls a certain extension number or operates keys located at suitable points throughout the building. The information is typed onto a printer so that a record of the watchman's rounds is available for checking. If anything happens which results in the watchman failing to call in at a certain time, an alarm can be set up to signal the police.

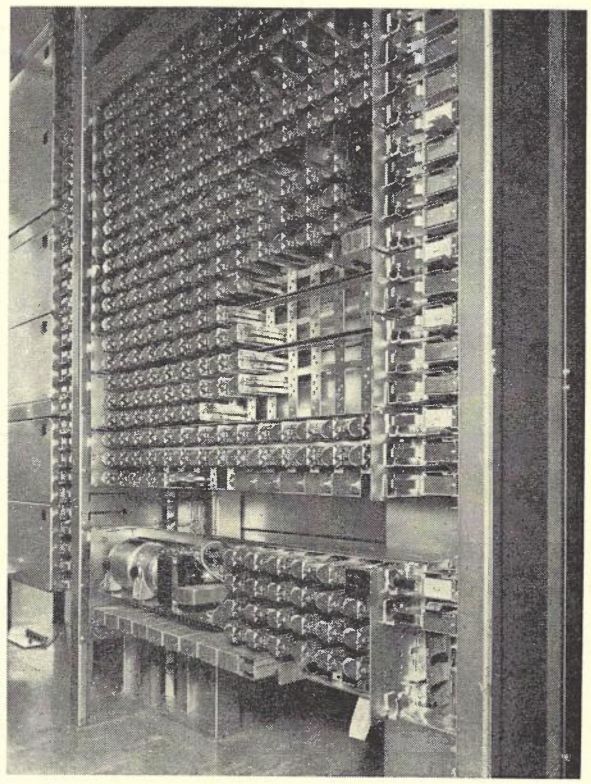


Fig. 6.—Marker.

Fig. 7.—Operator's Unit.

TRAFFIC

Facilities can be provided to enable traffic readings to be made in the P.A.B.X. LM Ericsson are arranging for a unit to be tried out at Conzinc. It will be interesting to see how two registers for 100 extensions cope with the traffic. So far the maximum number of extensions in any 100 line group is 70, and there have been no complaints of having to wait for dial tone. Also, there have been no complaints of congestion on exchange lines, etc. If an extension does not answer an incoming exchange line call within 45 secs. then the call is automatically switched back to the operator. This has led to a quick speed of answer by the extensions, which is necessary in order to ensure that the operators' link circuits do not become congested.

The operators at Conzinc have remarked about the complete difference in operation between their modern boards and the standard cord type boards. They find the link type working very satisfactory and less exhausting.

MAINTENANCE

The equipment was thoroughly tested both by LM Ericsson and the P.M.G. acceptance staff prior to cutover. However, during the first few months of operation, a few faults showed up which were mainly due to human error, either during manufacture or installation of the equipment. Although the P.A.B.X. has only one marker unit, apart from a few faults during the settling in period, the marker has given satisfactory service. L M E. expect the mean time between failure of the marker to be at least 10 years.

Ericsson staff have given a great deal of assistance with training of maintenance staff and location of difficult faults. Our staff still have to acclimatize themselves fully with the new switching techniques and circuits and a great deal of training of suitable technicians will be required. Experience has shown however that after the initial settling down period, the maintenance effort required by this type equipment is extremely small.

CONCLUSION

This type of P.A.B.X. offers to the customer attractive facilities which have not previously been available. These facilities have been obtained by means of advanced circuit techniques and experience to date has shown that there is no doubt that any of the problems which may arise with these units can be overcome.

BACK COPIES

The Society has available in quantity, back copies of most issues of the Journal from Volume 5 onwards. Volume 12, Number 1 is out of print, but reprints of the two articles on coaxial cables may be obtained for a total cost of 3/-.
These Journals may now be supplied, on demand from State Secretaries* at 10/- per set of three or at 4/- per single copy. Back copies of some earlier numbers are available, but it is recommended that inquiry first be made to the State Secretary,* as to the availability of any particular number. In the event of the Society being unable to supply any number, it will act as an agent to assist subscribers in obtaining a copy. The society does not repurchase Journals, but readers having copies which are no longer required should give details to the State Secretary,* who may thus be able to advise other readers where the back copies may be obtained.

*For addresses see inside back cover.

AN EXCHANGE FAULT CAUSED BY HIGH INDUCED VOLTAGE ON A JUNCTION CABLE

W. O'KEEFE, B.E.*

INTRODUCTION

In recent years the problem of interference between power and telecommunication services has increased because of the growth and expansion of both services. Interference in the past has been principally in the voice frequency range and due to voltage unbalance in power circuits. This type of interference is still prevalent but 50 c/s magnetic induction is now becoming a much more serious problem. This article discusses an example of this type of interference.

On New Year's Eve, 1960 a Senior Technician at Windsor Exchange, Melbourne, noticed an electric arc discharge across a terminal strip on the main distributing frame. Further investigation showed that approximately 200 junctions between several main exchanges were out of service due to being earthed at the arrestors. A number of repeaters at Windsor and a third selector at South Oakleigh were faulty due to the application of an excessive voltage across the line terminals. After investigations, it was found that the faults were due to induction caused by an earth fault at the 66kV busbars of a power substation at Ormond (see Fig. 1).

LAYOUT OF TELEPHONE CABLE ROUTES

When the interference was first reported it appeared to affect exchanges over a very wide area and could have been due to any one of a great number of power parallels. However, when the junction routes were plotted on a street plan (Fig. 1) it was noted that, in one section, all the junctions affected were in the same cable. This section is in Poath Road, between Dandenong Road and North Road, East Bentleigh. Fig. 2 is a photograph taken in the vicinity. The route of the junction cable is directly underneath a 66kV single circuit power line in Poath Road for a distance of 1.4 miles. The cable (800 pair) is laid in a 4-inch asbestos duct and contains 400 working junctions.

LAYOUT OF POWER TRANSMISSION LINES

The layout of the power transmission lines in the area is also shown in Fig. 1. The lines of interest are those connecting Malvern terminal station and Ormond, North Brighton and Moorabbin substations. These substations are supplied by 66kV lines but they are not equipped with circuit breakers on the 66kV side. To disconnect these circuits under certain fault conditions, a fault throwing switch at the substation short circuits one phase to ground, and the resultant earth "fault" is then cleared by the 66kV breakers at Malvern Terminal Station. This system is designed to clear a fault in less than two seconds.

CONDITIONS UNDER WHICH FAULT OCCURRED

On New Year's Eve a car struck a pole of the 66kV double circuit line between Ormond and North Brighton substations. The fault throwing switch at Ormond operated and placed a phase to ground earth fault on the incoming 66kV No. 1 circuit from Malvern Terminal station.

Under this condition it was calculated later that the single phase to earth fault current on the power line would be approximately 3,500 amps., and that the induced voltage on the telephone cable would be 1,536 volts (see Appendix I). The extent of the damage indicated that the cable was, in fact, subjected to a voltage of this order, as some standard carbon arrestors which were installed failed completely. (Standard carbon arrestors fire between 750-1,000 volts).

PROTECTIVE MEASURES

It was decided in the interests of safety and future protection of the circuits, to apply further protective measures pending the outcome of negotiations with the power authority. These measures were:

(i) All working junctions (approximately 400 pairs) were equipped with Ericsson Gas Arrestors, at both ends of the circuits.

This type of arrestor is shown in Fig. 3 and consists of a tubular discharge chamber, filled with a rare gas mixture at a low pressure and including a number of electrodes between which discharges occur at a certain voltage. In the glass envelope is a bimetallic strip which is heated by a prolonged A.C. discharge and causes the internal contacts to make and short circuit the arrestor. These contacts can be seen at the left in the photograph. The arrestor is capable of discharging a current of 18 amps. indefinitely and will carry considerably higher currents for a short period. When the voltage across the arrestor has decreased to about 25 volts the arrestor returns to normal. This gas arrestor will fit in

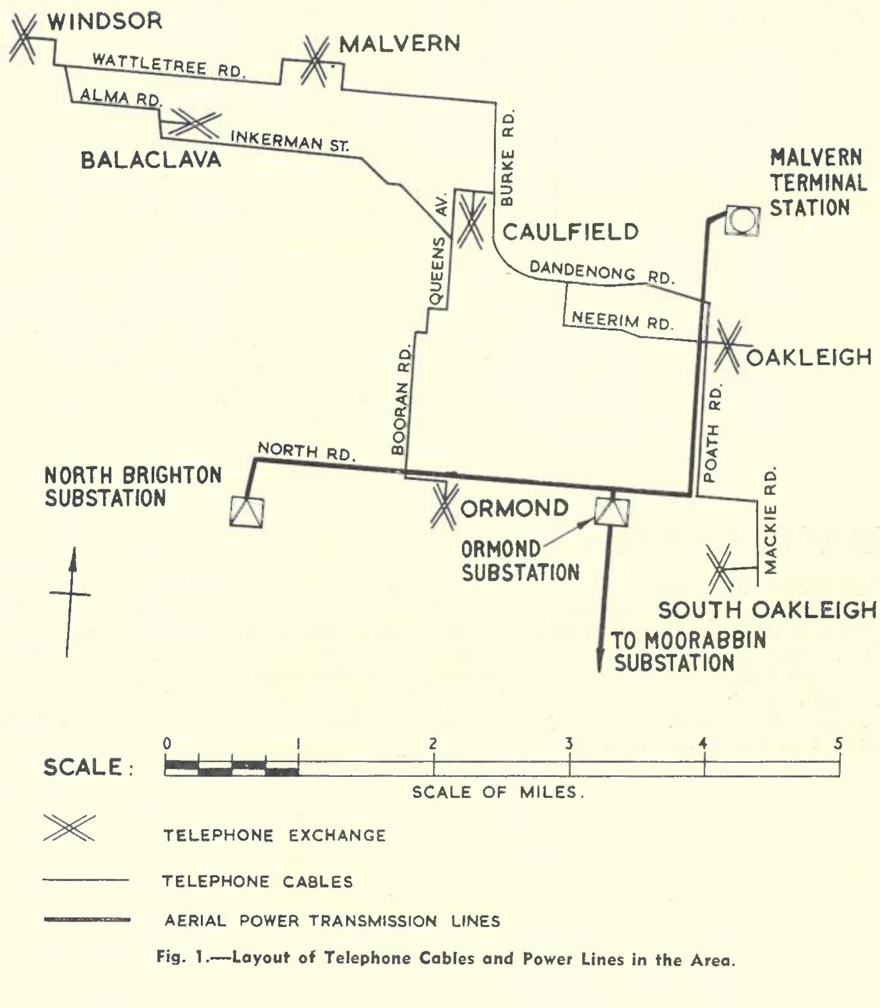


Fig. 1.—Layout of Telephone Cables and Power Lines in the Area.

* See page 433.

place of carbon protectors as shown in Fig. 4 and requires no special mounting arrangements.

(ii) All spare pairs in the cable in Poath Road were earthed. This was to conserve the Ericsson Arrestors which were then in short supply.

(iii) The resistance of each exchange earth was measured to ensure a resistance of not greater than 2 ohms.

Following the provision of these protective measures, earth faults again occurred on the 66kV transmission line in Poath Road on 23rd and 25th January, 1962. These faults were phase to ground and the fault currents were at least equal to those experienced during the original fault in 1960. During the fault of 23rd of January, 1962, some circuits were lost due to fuses being blown by the induced current flowing to ground through the arrestors. These were replaced by dummy fuses and no circuits were affected during the subsequent fault on 25th January. There was an unconfirmed report of a subscriber having received a severe acoustic shock during the fault on 23rd of January. The subscriber's cable was not affected by the fault but the call was routed via one of the junctions in the Poath Road cable. The acoustic shock may have been due to both arrestors on the affected pair failing to fire simultaneously.

The protective measures adopted in this case have proved effective under actual fault conditions. However, reduction of voltage by increased separation or greater shielding would be much more satisfactory.

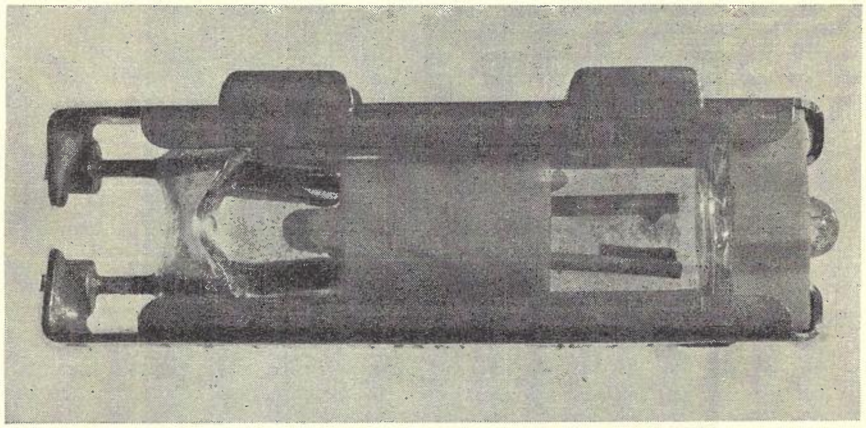


Fig. 3.—Ericsson Gas Arrester.

CONCLUSION

In Victoria, with an ever increasing demand for power, the level of earth fault currents on the power system is increasing rapidly, particularly as the 220kV system is being extended. Fault currents of the order of 8,000-15,000 amps., are expected on the 220kV Melbourne ring main which extends 45 miles from Rowville Terminal Station near Dandenong on the east in an arc around the city to Brooklyn on the western side. This line passes through areas of urban development which will ultimately extend along the easement for most of its length. It is known that 500kV lines are planned between Melbourne and Yallourn, and even larger fault currents are probable as a result. With these developments the problem of protecting both existing and future telephone plant is not small, and will increase with time.

The problem of inductive interference is difficult and generally expensive to solve and is best combated by the co-odinated efforts of both power and telephone engineers. In the past there has been a feeling amongst telephone engineers that fully underground circuits are "safe" and do not need protection. This is not correct; the location of telephone plant in the vicinity of power wires must be carefully watched and suitable protection provided at the exchange termination if necessary.

Fig. 2.—66 kV Line in Poath Road.

An important observation from the Poath Road faults is that the cable itself was not damaged. The damage was confined to exchange plant. The breakdown voltage of cable insulation to earth is of the order of 2,000 volts for paper insulated cable and several times this figure for plastic insulated cable. These values are substantially higher than the breakdown voltage of the insulation of exchange equipment and perhaps warrant a re-examination of the insulation resistance specifications of exchange equipment connected to line. It is evident that protective measures which are adequate to protect external plant, such as protecting devices at the junction of open wire and cable, may fail to prevent excessive foreign voltages reaching the exchange equipment. Proposals, therefore, to remove exchange protective apparatus from the exchange itself and fit it somewhere into the external plant route, such as at the junction of the aerial and cable portions, must be treated with great caution and require a full knowledge of the local circumstances of each particular case.

APPENDIX I

Low Frequency Induction

The term low frequency induction is applied to induction at the fundamental frequency of the power circuit, that is 50 c/s. When the voltages and currents at this frequency are balanced, no troublesome inductive effects are experienced. However when a fault occurs, particularly on a system with neutral grounding, a heavy flow of current which uses the earth as a return circuit, causes induction into a paralleling communication system. Because of the effective width of the loop traversed by the fault current there is a wide dispersion of the magnetic field and damaging effects may be experienced at wide separations between the power and the telephone line.

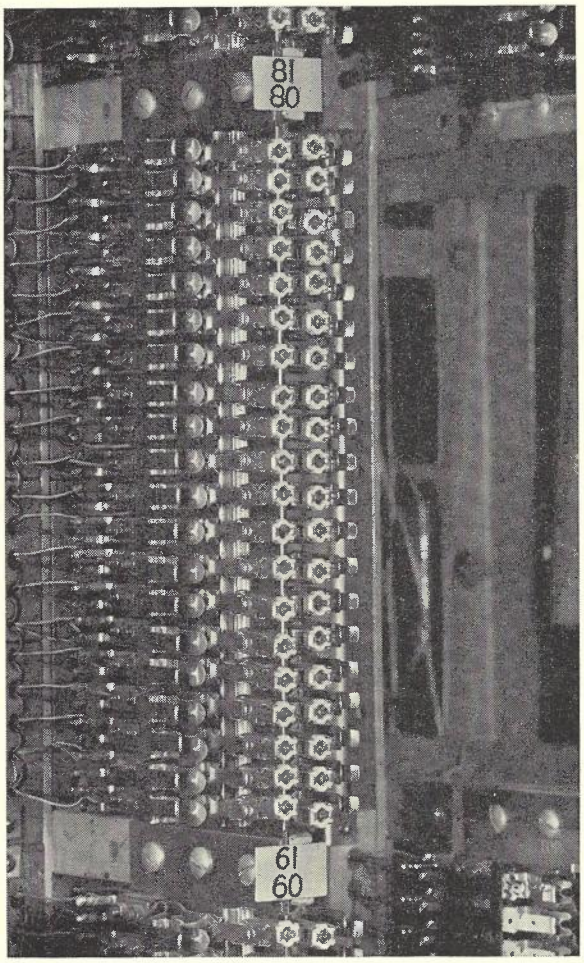


Fig. 4.—Gas Arresters Fitted in Place of Carbon Arresters.

Calculation of Longitudinal Induced Voltage on Telephone Circuits

The magnitude of the induced longitudinal voltage in a telephone circuit due to an earth fault on a power line is dependent upon the maximum value of the earth fault current in the power line, the mutual impedance per mile between the earth-return circuits in the power line and the telecommunication line, and the length of exposure in miles. Since the voltage induced is dependent upon the length of exposure, the highest voltages are generally experienced when the power fault occurs at the end of the exposure remote from the source of supply.

The mutual impedance per mile can be calculated as shown in Reference 1, and depends upon the spacing between the power and telephone lines and also on the earth resistivity. Nomograms are available which simplify this calculation (1). All the formulae for mutual impedance between conductors assume that there are no other conductors in the vicinity in which induced current can flow. In the practical case screening effects due to other metallic services, for example water mains, railway and tram rails, etc., must be considered, as such conductors reduce the voltage on other conductors in the vicinity. The effectiveness of this reduction is indicated by the "shielding factor" or the ratio of the resultant induced voltage in a circuit when shielded to that which would be induced in it under the same primary conditions if it were not shielded.

Details of the Exposure in Poath Road

Length of exposure = 1.4 miles.

Separation = 20 ft. (the cable is laid almost directly under the power line.)

Resistivity of Soil = 100 ohm-meters. This value had been checked by previous measurements in the Melbourne Area.

Mutual Impedance = .52 ohms/ml. from Nomogram.

Calculated Fault Current = 3,500 amps. at Ormond substation.

Induced Voltage = 0.52 x 1.4 x 3,500
= 2,560 volts.

To allow for shielding from a 12-inch C.I. water main (which parallels the cable for approximately $\frac{1}{4}$ ml.) and other unknown earthed metallic services a shielding factor of 0.6 can be used.

The Nett Induced voltage thus
= 2,560 x 0.6
= 1,536 volts.

In built up areas it has been found that it is extremely difficult to calculate the shielding for any given exposure due to number of other metallic conductors in the ground, both known and unknown. The above shielding factor was chosen from the results of previous tests carried out in areas of similar development in the Melbourne metropolitan area.

REFERENCE

1. Engineering Instruction, Lines, General, P. 2001—"Design of Protection of Personnel and External Plant against Dangerous Voltages caused by Low Frequency Induction."

PUBLIC ADDRESS PAGING SYSTEM—PERTH MAIN TRUNK EXCHANGE

C. F. COOK

INTRODUCTION

The continued increase in the provision of public address and paging systems throughout the Department is an indication of their convenience and usefulness in locating personnel and conveying messages. Simplicity of operation, with as many facilities as a simple system will allow, have been the guiding principles in the design and installation of new paging equipment installed recently for the technical staff of the Perth Main Trunk Exchange. The paging system is operated from a central switchboard to loudspeaker units located throughout the areas in which the technical maintenance staff of the Exchange are distributed.

SWITCHBOARD

The switchboard, shown in Fig. 1, is installed at the Fault Recorder's position and provides concentration of all the fault reporting circuits from the various sections, such as Trunks, Central Telegraph Office, etc. Fault dockets are distributed and details subsequently recorded at this position. Included on the switchboard are incoming service lines where calls are received for various technical staff. These non-metering lines are gained by callers dialling 2379 and subsequent extension is made by operating the relative extension key. This connects an automatic ring to the required extension. Supervision is given upon answering and during the call. Should a different extension be required on the same incoming call, provision is made to re-ring by operating a push button switch. This restores the automatic ring to the new extension. The switchboard has two answering circuits, the second one being used by the M.D.F. and cable recording officer.

The inclusion of the paging system on this switchboard has made efficient provision for every type of incoming call and provides valuable assistance in attending to requests for staff and information.

PAGING SYSTEM

Speech Input: Because of the greater convenience, the speech input to the paging system is by means of the ordinary handset provided for answering calls on the switchboard. Access to the public address system is by a three position key as the switchboard has two answering positions. The operation of this key also holds the incoming call while the public address system is in use. As the public address amplifier is designed for a low level microphone input, it was necessary to provide an input attenuator of approximately 30 db to cater for the higher speech level obtained from the telephonist's handset.

Loudspeakers: The loudspeakers are placed in the most effective positions for the distribution of sound. In most cases they are located on the tie bars of the equipment racks. Other speakers are placed lower down the racks, and are provided with volume controls so that individual levels can be set and no interference caused to neighbouring staff such as in the manual exchange operating room. The audio distribution is by individual one pair cables in existing ducts, but where this is not possible, use is made of cable pairs in the house cabling of the G.P.O. building, in which the Trunk Exchange is located. No crosstalk into adjacent circuits has been caused.

The loudspeakers are eight inch permanent magnet units and are assembled in metal boxes, as shown in Fig. 2, with a transformer between line and voice coil. The line side impedance is 5,000 ohms and a 2MF capacitor is in series at this point, as shown in Fig. 3. There are at present eight loudspeakers in use but more can be added if required. The public address amplifier has a 6 watt output and a 600 ohm output impedance.

Answer-back Facilities: It was realised quite early in the design of the facilities that it would be necessary to have an answer-back circuit. This would prevent any unnecessary announcements in the many scattered areas after the called person had heard that he was required. The usual method on paging systems is to operate a key on the loudspeaker and use it as a microphone via a pre-amplifier to a loudspeaker on the switchboard. This seemed unnecessarily complicated, so ordinary telephone circuitry was substituted.

At convenient points, an answering handset has been installed. This consists simply of a handset and switch-hook mounted in a metal box. In some cases this is fitted in the loudspeaker box as shown in Fig. 2. The receiver and transmitter of the handset are in series through the switch-hook springs and no induction coil has been found necessary. The answering set is connected directly to the loudspeaker cabling network as shown in Fig. 3. Fig. 4 shows a detached handset, its associated speaker being mounted on the tie bars.

Relay Set Switching: The distribution of sound from the switchboard to the loudspeakers is made through a relay set shown in Fig. 5. This relay set also supplies 50 volt speaking battery to the handsets. Battery supply is on the loudspeaker network at all times, but the 2MF capacitors on the line side of each loudspeaker prevent any current flow until a handset is lifted and switch-hook contacts are made. Before a handset is lifted, the operator is connected to the input of the amplifier and is provided with speaking battery from battery feed relay B. After a handset is lifted, its speaking current operates the battery feed relay A which switches the amplifier out of circuit and connects the loudspeaker network and the operated handset directly to the opera-

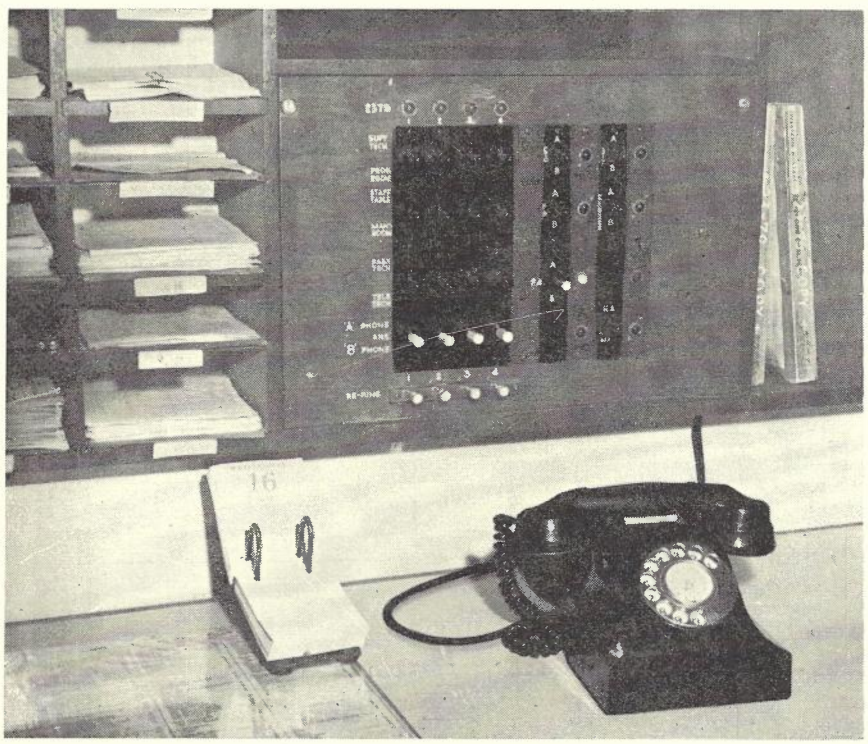


Fig. 1.—Switchboard.

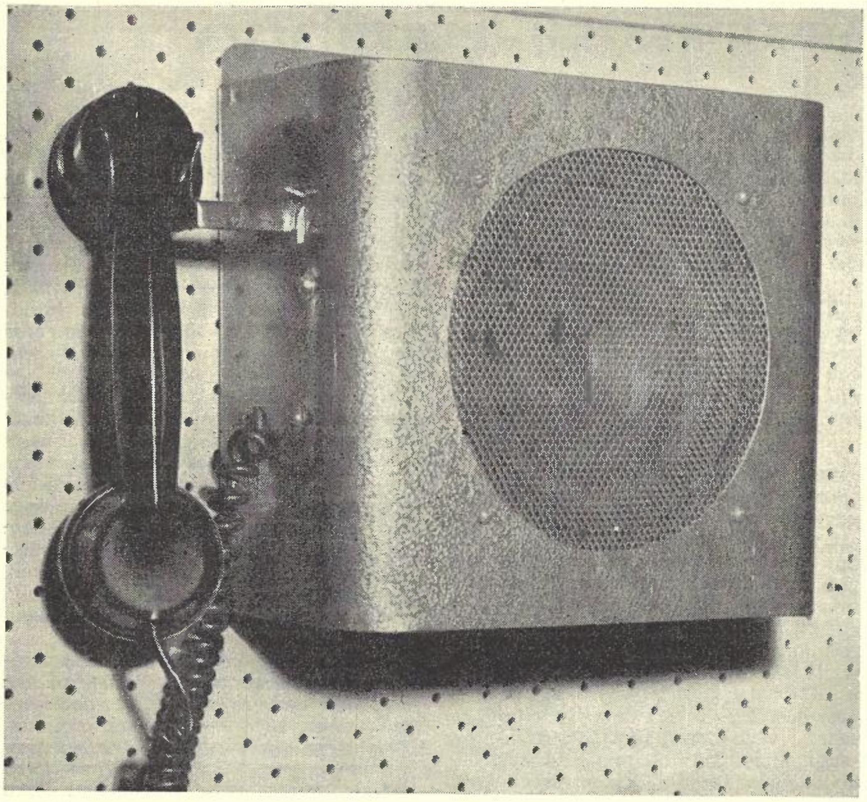


Fig. 2.—Loudspeaker with Answering Handset.

Fig. 4.—Detached Handset. Associated Loudspeaker is Mounted on Tie-Bars.

tor on the switchboard. The two relays A and B are now connected by capacitors in the usual bridged impedance (Stone) method, and conversation can take place between operator and wanted person without being broadcast over the public address system. The immediate access to a normal telephone conversation is much more convenient than other methods which involve the necessity to operate keys for changing the direction of the conversation.

Other Facilities: Additional facilities for making announcements from points other than the switchboard can be arranged by a parallel connection to the input side. For instance the Trunk Testing Officer has an input connection because many enquiries originate at this position. The Supervising Technician-in-Charge has an input and also an answering key connecting the public address system to the ordinary telephone. He can thus originate calls or answer them.

Another feature is that the switchboard can be called from any handset simply by lifting it. The relay then operated has a contact which operates a lamp and buzzer on the switchboard.

If necessary an announcement can be made which calls staff in remote areas and conversation can take place in the style of a conference circuit. At all times when the handsets are in use for conversations the amplifier is out of circuit and there is no unnecessary use of the loudspeakers. Furthermore, there is some measure of privacy.

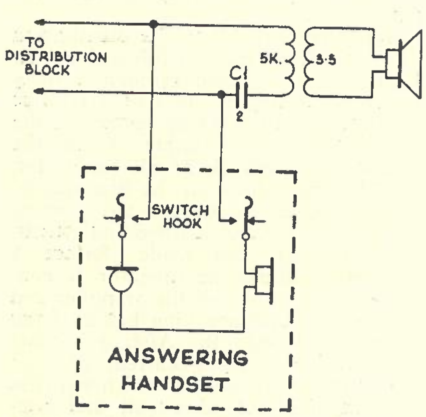


Fig. 3.—Connection of Loudspeaker and Answering Handset.

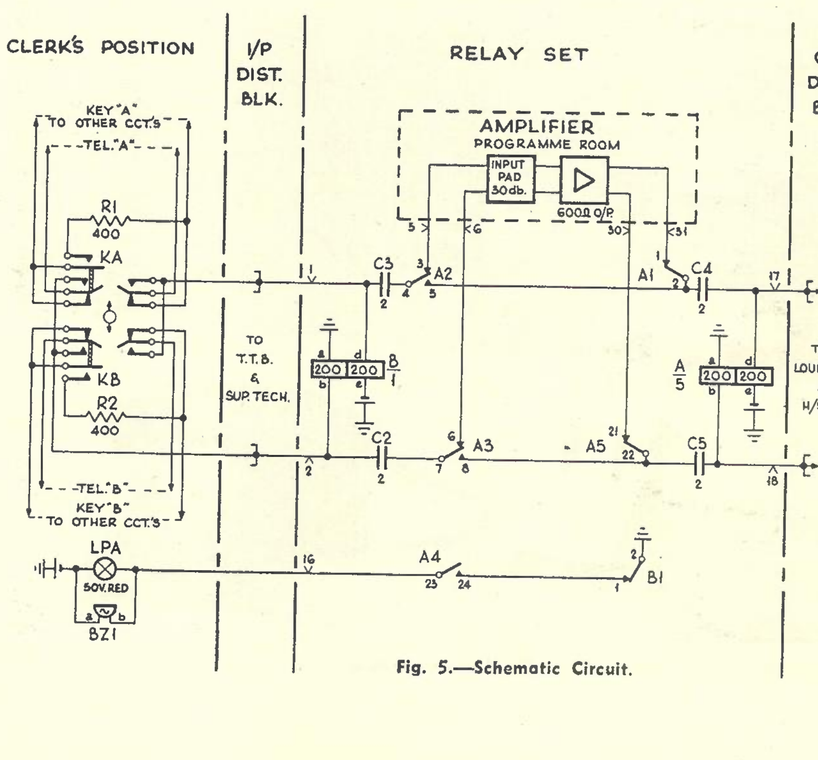


Fig. 5.—Schematic Circuit.

DESIGN ASPECTS OF TRANSISTOR AND DIODE SWITCHING CIRCUITS — PART II

*F. W. ARTER, B.E.E., M.Eng.Sc.**

5. SWITCHING CIRCUITS USING TRANSISTORS AND SEMICONDUCTOR DIODES

Electronic switching circuits are concerned with the presence or absence of a particular switching potential rather than with the made or broken circuit paths of switching circuits using physical switches such as relays. Two-state electronic "switches" or "gates" operate between two such switching potentials, one being designated the "1" potential and the other the "0" potential. The existence of the "1" potential at an input or output of a gate corresponds to the "1" state at this input or output. The absence of the "1" potential, and therefore the presence of the "0" potential since such gates have only two stable states, corresponds to the "0" state. Transition times from one state to the other are much smaller with electronic devices than with the physical switches. This fact, coupled with advantages obtained from lack of mechanical wear, no lubrication or adjustment requirements, etc., makes electronic switching circuits more desirable than relay or similar physical switching circuits in many instances.

The behaviour of the transistor as a switch when overdriven is now well known. Its low collector to emitter voltage drop when overdriven to saturation and its low collector current when cut off make it superior to most other electronic switching devices. The semiconductor diode also possesses similar properties of low forward voltage drop when forward biassed and low leakage current when reverse biassed. It is thus a suitable complement to the transistor for use in switching applications. Both devices offer the properties of long life, small size, rugged construction, low supply voltage requirements, absence of heaters, and fast switching performance. In one or more of the above aspects, they can therefore be considered superior to other common switching devices such as vacuum tubes, gas tubes and magnetic materials in the majority of general purpose applications.

Switching circuit modules using transistors and diodes can be divided into three classifications. These are:—

(i) Semiconductor diode AND and OR gates.
(ii) Transistor INVERTED AND and INVERTED OR gates.
(iii) Transistor INVERTERS and NOR gates.

These three classifications will now be considered in turn.

6. SEMICONDUCTOR DIODE AND and OR GATES

A wide variety of types of semiconductor diodes is now obtainable. They may be broadly classified as germanium or silicon diodes. Considerations of switching speeds, maximum inverse voltages, forward current and forward voltage drop, reverse currents and device dissipation must enter into the choice of the type of diode for a particular application. In general, silicon diodes have lower leakage currents when reverse biassed than their germanium counterparts. On the other hand, germanium diodes have lower forward voltage drops for similar forward currents than their silicon counterparts. For most general applications involving low currents up to about 10 or 20 mA, point-contact germanium types suffice. Where higher switching speeds (with transition times less than about 1 microsecond) are required, gold bonded germanium types are better than the general purpose point-contact varieties. Junction diodes have lower forward resistance and are suited to larger current applications. Silicon types are more expensive and are usually used when their property of low reverse leakage current is required. These general remarks are included as a guide to the choice of a diode for a particular application.

In general, the forward voltage drop across a conducting diode is small (less than 0.5 volts) when compared with other voltages in a circuit, and can be neglected. Also, the leakage current in the reverse biassed condition is very small and can generally be considered negligible when compared with other currents in a typical circuit. It is only when a number of these small quantities add that they become important. The forward voltage drop across a number of diodes in series may no longer be negligible when compared with other circuit voltages; nor may the sum of the leakage currents of a number of reverse biassed diodes in parrallel be truly negligible. However, in general, where diodes are not in long cascades or in parallel in large numbers, it is sufficiently accurate to consider a conducting diode as a short circuit and a reverse biassed diode as an open circuit connection.

For purposes of description, two switching potentials of −8 volts and −16 volts will now be assumed. The −8 volt potential is designated the "1" potential and the −16 volt potential as the "0" potential. These voltages are chosen as typical for diode gates which are working in conjunction with transistor switching circuits using p-n-p transistors, and with power supply voltages typically 0 and −24 volts. However, the polarity of these voltages can be changed, as can also their magnitudes or the designations of the 1 and 0 states, without invalidating the electrical behaviours of the gates which are described in the following paragraphs. The principal difference which can occur with such changes is that the switching functions of the two types of gate may be interchanged. This merely requires a slight re-orientation of thought at the outset of a design.

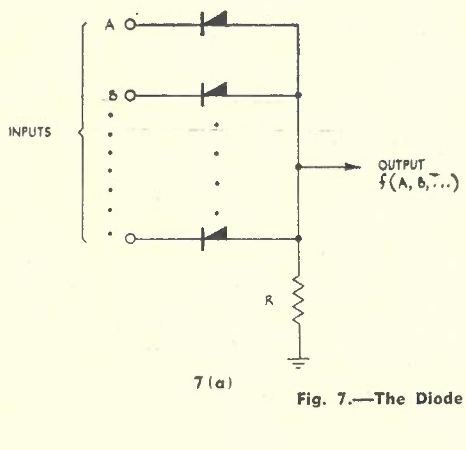
6.1. The Diode AND Gate.

A diode AND gate is shown in Fig. 7(a) for the chosen switching potentials and for the designations of the 1 and 0 states as:

1 = presence of −8 volt potential
0 = presence of −16 volt potential.

With these designations, it can be seen that the truth table of Fig. 7(b) itemises the four possible combinations of input states for such a gate with two inputs A and B, and the resulting output state f (A, B) for each of these input combinations. This truth table is seen to be the same as that arising from the definition of the AND function for Convention I in the previous article of this series. It can be seen that the most negative input voltages determine the output potential. Hence the output potential cannot be at the more positive "1" potential unless all inputs are at this more positive potential. Thus, the number of inputs can be greater than two with no change in the output AND switching function.

In practical circuits, some combinations of the input states and slight differences in the forward characteristics



7 (a)

A	B	f (A, B)
1	1	1
0	1	0
1	0	0
0	0	0

$f(A, B) = A \cdot B.$

7 (b)

Fig. 7.—The Diode AND Gate.

* See Vol. 13, No. 4, page 350.

of individual diodes and in the input potentials, even when they are supposedly of the same nominal magnitudes, could cause one diode only to be conducting. The input source associated with that diode would then be supporting the whole load presented by the gate, all other diodes being reverse biassed. Since this possibility can arise and it is not known which diode is likely to be favoured in this way, a design must ensure that all input sources are capable of withstanding alone the load presented by the gate.

An analysis of the loading presented by and that which can be withstood by this gate is now given and Fig. 8 pertains. Only one input is considered, it being assumed that this is the one which supports, and thus controls the output state of, the gate, with the other input diodes reverse biassed and passing negligible currents. Any conclusions pertaining to the loading on this controlling input must also be applied to the remaining inputs.

The load capacities are defined as the currents which can be tolerated at the input and output without degeneration of the switching potentials. These potentials are therefore considered not degenerated and the limits on the currents are set for both the 1 and 0 states at the input and output. For no degeneration, the controlling diode must always conduct. Since the drop across this conducting diode is negligible, the input and output potentials are closely equal. The Current I_R in the gate resistor R is thus obtained from the output (or input) state potential and the magnitude of R. Two directions of external load current I_L shown in Fig. 8(a) and 8(b).

For the case of Fig. 8(a), the currents sum to give the basic relation:

$$I = I_R - I_L$$

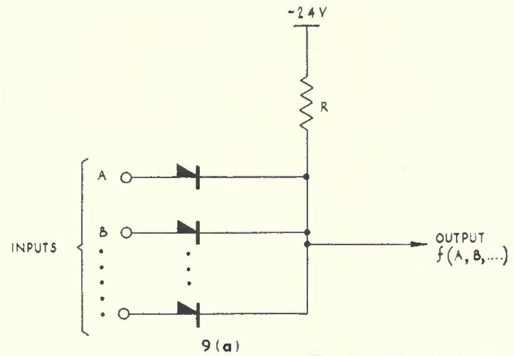
The limits for I are given by:

$$0 \leqslant I \leqslant I_R$$

where I_R must be determined for both the 0 and 1 states. The corresponding limits for I_L are given by:

$$I_R \geqslant I_L \geqslant 0 \ .$$

Hence knowing either a source load capacity or a desired gate loading capacity, the other can be determined, and I_R and R are consequently obtained. These limits must be considered for each of the 1 and 0 states and the worst overall loading possibility considered.



9(a)

A	B	f(A,B)
1	1	1
0	1	1
1	0	1
0	0	0

f (A,B) = A + B

9(b)

Fig. 9.—The Diode OR Gate.

For the case shown in Fig. 8(b) in which the direction of the external load current has been reversed, the basic relation holds:

$$I = I_R + I_L \ .$$

Since it is possible for I_L to vary over the range,

$$0 \leqslant I_L \leqslant I_{Lmax},$$

where I_{Lmax} must be determined for both the 0 and 1 states, it is necessary that I can vary over the corresponding range

$$I_R \leqslant I \leqslant (I_R + I_{Lmax})$$

for both switched states.

It can be seen that I_R is merely a wastage current since R shunts the load. Hence R can be chosen to minimise I_R. The magnitude of I_R is determined from the output potential and the magnitude of R. Hence, knowing the limitation on I for both states, a resultant limitation on I_{Lmax} can be determined for both output states. Alternatively, the required source loading capacity can be determined from the desired maximum output load capacity for both states.

It is possible for applications of the AND gate to require that the external load current be in either direction. In this event, the separate considerations above must be taken together and the extremes of loading for both states must be determined for both directions of external load current. On the basis of these determinations, the gate can then be designed to fulfil all loading requirements.

Loading on the AND gate as shown in Fig. 8(a) is typical of that presented by diode OR gates or by emitter followers using n-p-n transistors. That shown in Fig. 8(b) is typical of that presented by further diode AND gates, transistor NOR gates or emitter followers using p-n-p transistors.

6.2. The Diode OR Gate

With the switching potentials designated as previously, the diode gate circuit shown in Fig. 9(a) performs an OR switching function. The truth table of Fig. 9(b) summarises the possible combinations of input states for two inputs A and B. The resultant output f(A, B) can be seen to be the same as that arising from the definition of the OR function for Convention I given in the previous article of this series.

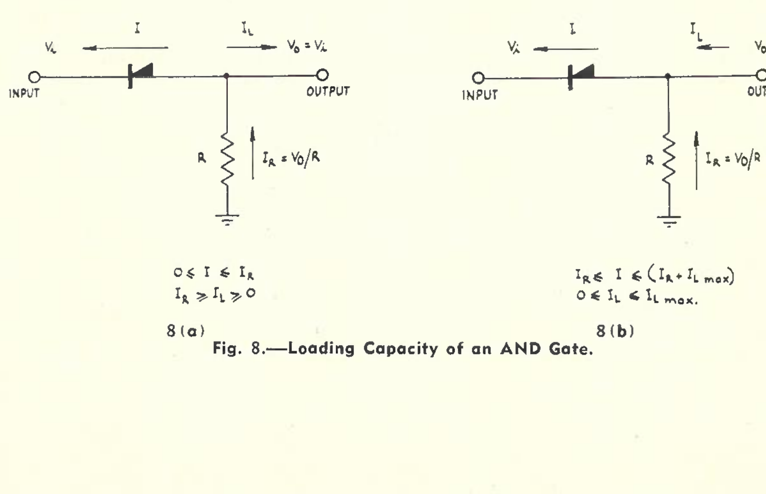
The most positive input determines the state of the output for this gate. Hence, the more negative 0 state cannot appear at the output unless all inputs are at this more negative state. All other combinations of input states contain at least one more positive 1 input state and hence the output is in the 1 state for these combinations. Thus, the switching function is an OR function whatever the number of inputs.

As in the case of the AND gate, it is possible that any individual input source could be required to support the whole of the load presented by the gate. Hence as before, the design must ensure that this worst condition of source loading be accommodated. Thus, the analysis of the gate considers only one input as supporting the gate load and requires all inputs to be able to withstand the resultant loading determinations for both 1 and 0 states.

The analysis of the loading on the OR gate follows from Fig. 10 with the currents and voltages as labelled. It can be seen that the gate resistor R is returned to a supply potential more negative than both the "1" and "0" potentials—it is shown here as typically –24 volts. Thus the diode supporting the gate load always conducts in the forward direction to maintain the output potential (state) closely equal to its input potential (state). All other diodes are considered reverse biassed with negligible leakage currents.

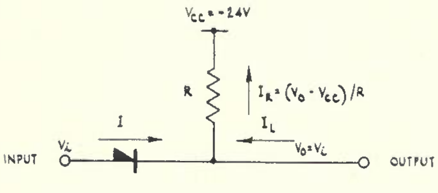
As for the AND gate, two directions of external load current I_L are shown in Figs. 10(a) and 10(b). In both cases, the current I_R in the gate resistor R is given by:

$$I_R = (V_o - V_{cc})/R.$$



8(a) 8(b)

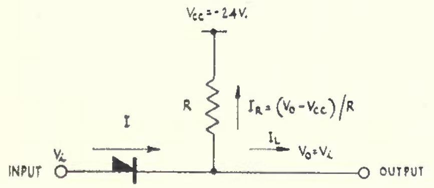
Fig. 8.—Loading Capacity of an AND Gate.



$0 \leq I \leq I_R$

$I_R \geq I_L \geq 0$

10(a)



$I_R \leq I \leq (I_R + I_{L\ max.})$

$0 \leq I_L \leq I_{L\ max.}$

10(b)

Fig. 10.—Loading Capacity of an OR Gate.

This must be determined for the output potential V_0 equal to both the 1 and the 0 potentials.

For the case shown in Fig. 10(a), the currents sum to give:

$$I = I_R - I_L .$$

The condition that the diode must always conduct to maintain gating control of the output potential yields the restriction on the source loading as:

$$0 \leqslant I \leqslant I_R .$$

The corresponding restriction on the output loading follows as:

$$I_R \geqslant I_L \geqslant 0.$$

Thus, relationships can be established between I, I_R and I_L for both the 0 and 1 inputs (and thus output) states, and the requirements for two of these determine the third. The worst loading condition in either of the switched states must be used to determine the gate performance capability as regards loading.

For the case shown in Fig. 10(b), the currents sum to give:

$$I = I_R + I_L .$$

Assuming that the maximum possible or desired external load current in this direction is I_{Lmax}, the limits on I and I_L can be written as:

$$I_R \leqslant I \leqslant (I_R + I_{Lmax})$$
$$0 \leqslant I_L \leqslant I_{Lmax} .$$

Hence the loading capabilities of the gate can be determined for both the 1 and the 0 states, any two of I, I_L and I_R determining the third. As above, the worst loading condition must be used in the design of such a gate.

As for the AND gate, it is possible that I_L can have either direction in a given application. In such a case, the separate cases above must be considered jointly for both the 1 and 0 states to determine the worst loading conditions at input and output. This then provides the basis for the design of such a gate.

Loading as shown in Fig. 10(a) is typical of cases where the gate load comprises diode AND gates, transistor NOR gates or emitter followers using p-n-p transistors. That shown in Fig. 10(b) is typical for loads comprised of more diode OR gates or emitter followers using n-p-n transistors.

6.3. Transition Times of Diode Gates.

Diode gates as a rule have low output resistance. The output resistance of these gates is closely the series combination of the low diode forward resistance and the output resistance of the source driving the gate. When fast transitions from state to state are required, this output resistance must be small so that the integrating time constant formed by this output resistance and any output shunt capacitance is smaller than the desired transition time. The effect of the shunt capacitance can be reduced by keeping the gate resistors R small. For transition times of short duration (less than 1 microsecond), gold bonded germanium diodes are used. These have lower forward resistance and smaller hole storage effects than ordinary point contact types.

6.4. Cascading Diode Gates.

In practical circuits, direct cascading of long chains of AND-OR-AND-OR gates alternately is impossible since the available load current is rapidly attenuated. It can be seen that the AND gate can sustain the greatest load when its output is in the 0 state. The OR gate presents greatest loading on the AND gate for a 1 output and in this condition the OR gate can sustain the greatest load. The following AND gate presents the greatest load to the OR gate for the 0 output state and so on. This alternation of maximum loading capacity from the 0 to the 1 to the 0 states from gate to cascaded gate thus attenuates the final available output current, and also requires that the gate resistors are successively increased as progress is made down the chain of gates. There is a practical limit to the largest value which a gate resistor can have (about 100 K ohms) when transistors are used in conjunction with diode gates. Hence, when a switching function is to be realised by long chains of diode gates, some form of impedance matching providing unity voltage gain with substantial current gain must be inserted at intervals in the chain. Direct coupled emitter followers or transistor gates can readily achieve such matching as will be seen from later considerations.

Similar impedance matching techniques can be used to provide current amplification when large numbers of diode gates of the same type are to be driven in parallel by the same source. This assumes that the source is unable to supply the necessary drive to the parallelled gates. In such instances, emitter followers using p-n-p transistors are best suited for driving paralleled AND gates, and those using n-p-n transistors for driving paralleled OR gates.

6.5. Change of Convention.

In the foregoing, the designations of the 1 and 0 states were:

1 = presence of –8 volt potential (more positive)

0 = presence of –16 volt potential (more negative) .

If these designations were reversed to give:

1 = presence of –16 volt potential

0 = presence of –8 volt potential

the switching functions of the gates must also be reversed. That previously specified as an AND gate becomes an OR gate and vice versa.

Both the above conditions use Convention I of the first of these articles for the definition of the AND and OR functions. If Convention II had been chosen as the basis of definition of the AND and OR functions, the dual statements of those above are true, with consequent reversals of the AND and OR roles of the gates in each of the above cases. However, the electrical behaviours of the gates are always the same as outlined. A suitable choice of convention and designation of switching potentials should therefore be made at the outset of a design and this should not then be changed.

7. TRANSISTOR AND and OR GATES.

The behaviour of the transistor when overdriven in the common emitter configuration is discussed in Appendix I. This configuration is that most commonly used in switching circuits. Summarising, it is seen that when the base current is in excess of that required to supply the required collector current to drop the whole supply voltage in the external collector load, the transistor is "saturated" and the collector-to-emitter potential difference is very small. The transistor in this state appears as a voltage source with a source potential equal to the emitter potential and a very low source resistance, provided that sufficient base current is available to maintain the transistor in its saturated state over the range of collector currents determined by the collector loading. Further, when the base-to-emitter junction is reverse-biassed, the collector-to-emitter circuit represents a high impedance path. For a p-n-p transistor, a positive base-to-emitter potential in excess of 0.1 volts limits the collector current to the value of the thermal and leakage current I_{co}. In this cut-off state, the transistor represents closely an open circuit, and the output voltage at the collector is then determined by the external collector load arrangements. For n-p-n transistors, the behaviour is the same as that of p-n-p transistors except that currents and voltages are reversed in direction and polarity respectively. At the present time, p-n-p transistors are most commonly used and hence the following discussion considers mainly p-n-p transistors. However, the remarks of this paper apply equally to n-p-n transistors and can be readily extended to these types.

This behaviour of the transistor in the common emitter configuration can be utilised to provide gate circuits with switching functions similar to those of diode gates. However, when a transistor is used in the common emitter configuration, there is an inversion from the base input to the collector output. Thus such transistor gates are better called transistor INVERTED AND and INVERTED OR gates.

7.1. The Transistor INVERTED AND Gate.

The circuit of Fig. 11(a) shows an INVERTED AND gate for the switching potentials as designated earlier. The corresponding truth table of Fig. 11(b) for two inputs A and B illustrates the inversion at the gate output. The output switching function f(A, B) is the complement of that of the diode AND gate. From the truth table, it is seen that:

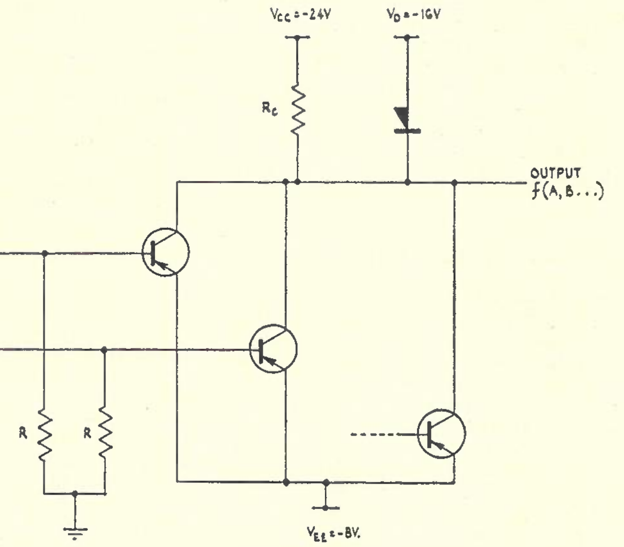
$$f(A, B) = (AB)'$$

This is extended to more than two inputs to give:

$$f(A, B, C, \ldots) = (ABC \ldots)'$$

The gate consists of a number of transistors in parallel sharing the same collector load. A catching diode is used on the output to stabilise the "0" potential. The base resistors, r and R, are chosen such that a 1 input to a particular transistor causes that transistor to be cut off. With a 0 input, the transistor is driven to saturation. It can now be seen that, for any one or more 0 inputs, the transistors associated with these inputs will be saturated with very low collector-to-emitter voltage drop, giving a 1 output. Only when all transistors are cut off, with all inputs at the 1 potential, will there be a 0 output.

The analysis of this type of gate is very similar to that for the transistor NOR gate which is presented in detail later. However, in the case of an INVERTED AND gate with a 0 output, all transistors are cut off but their thermal and leakage currents add to cause a potential drop in the collector load, R_c. With a large number of inputs, this drop could become significant, especially at elevated temperatures. Hence, the number of inputs to such a gate must be limited.

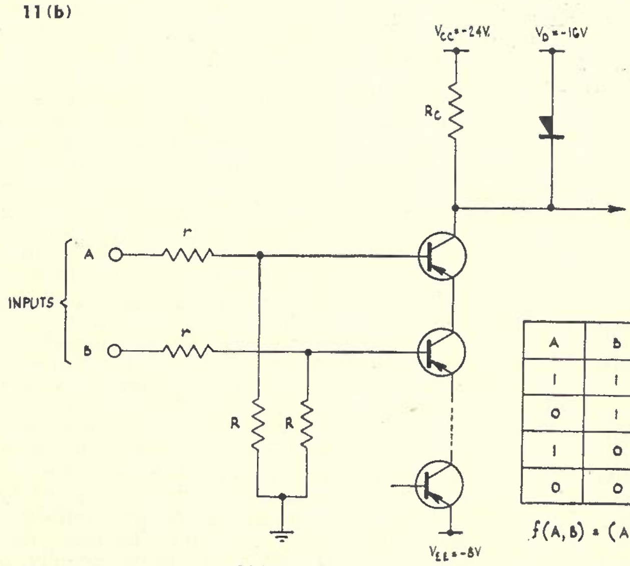


11 (a)

A	B	f(A,B)
1	1	0
0	1	1
1	0	1
0	0	1

f(A,B) = (A.B)'

11 (b)



11 (c)

A	B	f(A,B)
1	1	0
0	1	0
1	0	0
0	0	1

f(A,B) = (A+B)'

11 (d)

Fig. 11.—Transistor INVERTED AND and OR Gates.

7.2. The Transistor INVERTED OR Gate.

The circuit of Fig. 11(c) shows an INVERTED OR gate for the switching potentials assumed earlier. The truth table of Fig. 11(d) summarises the switching behaviour of this type of gate for two inputs, A and B. Once again, an inversion occurs in the output, f(A, B), such that it is the complement of that of the similar diode OR gate. That is:

$$f(A, B) = (A + B)'$$

For more than two inputs:

$$f(A,B,C, \ldots) = (A + B + C + \ldots)'$$

This gate consists of a number of transistors in series sharing the same collector load. The 0 potential is once again shown stabilised by a catching diode, and the base resistors, r and R, are so chosen that with the applied switching potentials of –8 and –16 volts, the associated transistors will be driven to the cut-off and saturation regions respectively. It can be seen that only when all transistors are saturated will there be a 1 output, that is, with all inputs at 0 potential. In all other cases, the output is at the 1 potential.

The analysis of this type of gate follows the same lines as that for the transistor NOR gate presented in the next section. However, in the INVERTED OR gate, each transistor in the saturated region contributes to the degeneration of the 1 potential. Even though each contribution is small, a significant amount of degeneration occurs when these are summed, especially if the number of inputs is large. Hence, this type of gate has also a restriction on the maximum number of inputs.

7.3. Some General Comments on Transistor INVERTED AND and OR Gates.

(a) If the designation of switching potentials is altered so that the 1 and 0 states are interchanged, that is such that:

$$1 = -16 \text{ volts}$$
$$0 = -8 \text{ volts},$$

the switching functions of the previous two gates must also be interchanged. The electrical behaviour of the gates obviously remains the same. Care must be taken, then, to check the switching function of a type of gate against the chosen designations of switching potentials.

(b) As has already been seen, the number of inputs to each of these types of transistor gate must be limited. Further, these gates also require one transistor per input—an expensive approach when it is considered that, in most cases, the use of diode gates or of transistor NOR gates (which use only one transistor) achieves the same results. Thus transistor INVERTED AND and OR gates do not find frequent application in the more general types of circuits. However, certain types of transistors are available which are suited to this type of circuit approach. This technique is used in Direct Coupled Transistor Logic (D.C.T.L.) circuits. These circuits use special types of transistors and enable many of the usual base circuit resistors, etc., to be discarded as unnecessary components. Details of these types of circuits are in the literature, suitable general reference being available in Reference 4.

8. THE TRANSISTOR INVERTOR and NOR GATE.

A single transistor can be used to achieve the same switching function as either of the gates of the previous section. This type of gate is called the NOR gate and complex switching functions can be realised by the use of this gate alone. Alternatively, it can be used in conjunction with diode gates. The INVERTER is a particular case of the NOR gate, being a NOR gate with only one input. Circuits of the NOR gate and the INVERTER are shown in Figs. 12(a) and 12(b) respectively.

The truth table of Fig. 12(c) shows the output switching function f(A,B) of the NOR gate for the previous choice of switching potentials.

1 = –8 volt potential
0 = –16 volt potential

for two inputs A and B. The output in this case is seen to be an INVERTED AND function of the inputs, so that, for the general case of more than two inputs, the output is given by:

$$f(A,B,C,....) = (ABC....)'.$$

If the switching potentials had been designated as below:

1 = –16 volt potential
0 = –8 volt potential

the switching function would have then been an INVERTED OR function. That is, in the general case, the output is given by:

$$f(A,B,C,....) — (A + B + C + ...)'.$$

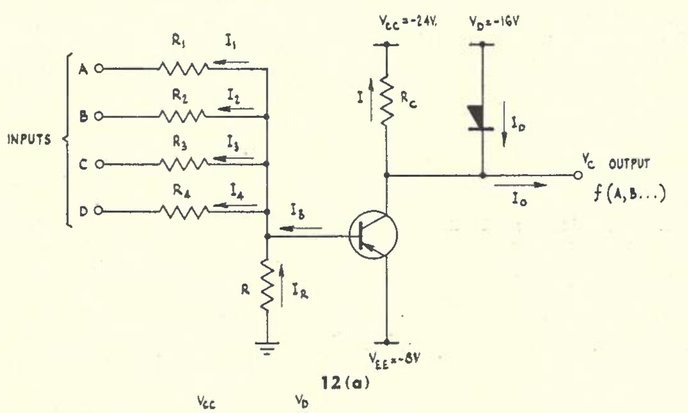
Whatever the designation of switching potentials, it can be seen from above that the output f(A) from the INVERTER is the complement of the input A, that is:

$$f(A) = A'.$$

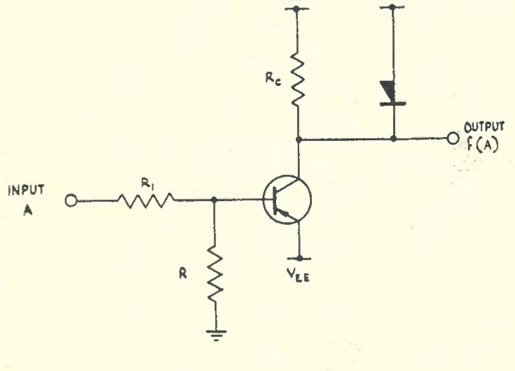
This behaviour of these two circuits is attained by the appropriate choice of the base resistors after consideration of the collector loading. With all inputs at the more positive 1 potential (–8 volts), the transistor must remain cut-off, and the output potential is then determined by the collector diode return potential V_D. In this case, the diode conducts since V_D is made more positive than the collector supply potential V_{cc}, and current flows through the diode into the collector resistor R_c and the external load. In this 0 output condition, it is desirable that the diode conducts for the possible range of external load currents to keep the output impedance at the low value presented by the conducting diode. In this way, stabilisation of the 0 potential is obtained by making V_D equal to this 0 potential (that is –16 volts).

If any one or more of the inputs is at the more negative 0 potential (–16 volts), the transistor must be driven to saturation. This state of the transistor must be maintained for all possible external load currents so that the output impedance is kept low and equal to the saturation resistance of the transistor. In this case, the output potential is closely equal to the emitter supply potential V_{EE} and this is therefore made equal to the 1 potential (–8 volts).

Summarising, the collector circuit is first considered to achieve the output loading requirements for each of the output states. Then, the base circuit resistors are chosen to provide the required base drive to fulfil these collector circuit conditions.



12(a)



12(b)

A	B	f(A,B)
1	1	0
0	1	1
1	0	1
0	0	1

1 = –8 VOLT POTENTIAL
0 = –16 VOLT POTENTIAL
f(A,B) = (A.B)'

12(c)

Fig. 12.—The Transistor NOR Gate and INVERTER.

8.1. NOR Gate Design.

A method of design is now presented for the NOR gate, using the symbols shown in Fig. 12(a) to represent the circuit currents and voltages. The current directions and the voltages are considered positive as shown in the figure. The chosen number of inputs is four, but this can be varied.

8.1.1. Cut-off Condition: In design, the cut-off condition of the transistor is first considered. This requires all inputs to be in the 1 state (that is, at a –8 volt potential). The output is then in the 0 state, the transistor being cut off.

In the collector circuit the diode conducts and the currents can be summed at the collector node to give:

$$I_D = I_o + I - I_c.$$

Provided that the cut-off condition is adequately maintained with sufficient reverse base to emitter voltage, I_c is closely equal to I_{co}, the thermal and leakage current. This current has the worst effects on this output state when it is at its maximum possible magnitude which occurs at the highest operating temperature. The magnitudes of I and R_c are related by Ohm's law, and, for this output state and neglecting the small forward drop across the conducting diode, this gives:

$$I = (V_D - V_{cc})/R_c.$$

The possible magnitudes and direction of the external load current I_o for this output state can vary and the nature of these variations must be determined from consideration of the overall switching circuit block schematic. This current can be either positive or negative in direction, and the circuit must be designed so that under all loading conditions, the diode conducts to stabilise the 0 output potential and provide a low source impedance. Thus, the diode current I_D for this output state must always remain positive.

(i) If I_o is found to be in the positive direction, that is, that shown in Fig. 12(a), the diode will always conduct if I_{co} is smaller than the sum of I_o and I. Thus, by making the current I in the collector resistor R_c an order larger than the maximum possible magnitude of I_{co}, I_{co} effects will be swamped and the possible loading on the gate merely depends on the diode forward resistance and the source V_D. No degeneration of the 0 potential will be produced if the diode has a suitably small forward resistance for the possible range of magnitudes of I_o.

(ii) If I_o is found to be in the opposite direction to that shown in Fig. 12(a) then the diode will conduct only if the magnitude of I exceeds the summed magnitudes of I_o and I_{co}. This condition must be fulfilled for the maximum possible values of I_o for this output state, as determined from a block schematic diagram of the whole switching circuit. Hence, a minimum required value of I is found for the limiting case where the diode just ceases to conduct with I_o and I_{co} at their possible maxima. When the diode ceases to conduct, I_D becomes zero and the minimum allowable magnitude of I is seen to be:

$$I = -(I_o + I_{co}).$$

The collector resistor R_c must be chosen so that this minimum allowable value of I can be provided for the maximum values of I_o and I_{co}. Hence, a maximum allowable value of R_c is defined for the cut-off condition (or 0 output state), and this must be later checked against any restrictions placed on the size of this resistor for the 1 output state. Having considered the collector circuit, the base circuit is next considered for this 0 output condition. At cut-off, the base circuit is independent of the collector circuit. With the chosen example using a p-n-p transistor the only condition to be maintained is that the base to emitter voltage remain more positive than 0.1 volts to ensure that the collector leakage current is kept to its minimum value of I_{co}. In this case, the base current I_B flows in the opposite direction to that shown and has a magnitude closely equal to I_{co}, that is:

$$I_B = -I_{co}.$$

This base current is a maximum at the most elevated ambient temperature expected to be encountered by the system, and the circuit design must ensure that the transistor remains cut off at such ambient temperatures. At these temperatures, the increased value of I_B tends to make the base-to-emitter potential less positive than at lower temperatures. Hence, the circuit is designed to maintain the base-emitter potential greater than or equal to 0.1 volts positive at the highest ambient temperature expected, as the worst case design for cut-off. Since the input potentials are all at the 1 potential which closely equals the emitter potential V_{EE}, and since V_B is only 0.1 volts more positive than V_{EE}, the currents I_1, I_2, I_3, I_4 flowing in R_1, R_2, R_3, R_4 are very small and may be considered negligible when compared with the maximum value of I_{co} for typical germanium transistors. If silicon transistors are used, or a large number of inputs is required, this last statement may be inaccurate and allowance for these currents must be made. Summing currents at the base node, we find:

$$I_R = I_1 + I_2 + I_3 + I_4 - I_B\ .$$

Assuming I_1, I_2, I_3, I_4 as negligible, then a minimum tolerable value of I_R is found to equal the maximum possible magnitude of I_B, which equals the maximum expected value of I_{co}. Since it was assumed that, in this limiting case,

$$V_B = (V_{EE} + 0.1) \text{ volts,}$$

the maximum tolerable magnitude of R can be found by inserting the minimum tolerable value of I_R in the equation:

$$R = -V_B/I_R.$$

In general, R is made one-half to one-third of this value as an additional safety factor.

8.1.2. Saturation Condition: The conditions for saturation are next considered. This is the case of a 1 output state, and is produced by one or more 0 input states, with the designations of switching potentials chosen earlier.

In the collector circuit, the collector diode is now reverse biassed and hence I_D is considered zero. Summing currents at the collector node, we obtain:

$$I_c = I_o + I.$$

Since, under maintained saturation conditions, the collector potential is closely equal to the emitter supply potential V_{EE}, the collector to emitter drop being negligible, the current I and the resistance R_c are related by Ohm's law as below:

$$I = (V_{EE} - V_{cc})/R_c.$$

As previously, the range of magnitude and direction of the external load current I_o can vary. The nature and extent of these variations must be determined from the block schematic of the switching circuit. The analysis of the collector circuit then follows the lines indicated below.

(i) If I_o is in the direction shown in Fig. 12(a), the magnitude of the collector current I_c is the sum of the magnitudes of I_o and I. This will be at its maximum when I_o is maximum and this is the worst design condition for the maintenance of the saturation condition. The collector resistor R_c appears in parallel with the external load and the current I through this resistor is not critical in this case. If no restrictions have been placed on R_c from considerations of the cut-off condition, then this current is chosen to have a value of similar magnitude that of I_o. This ensures that, even if the external load current I_o becomes zero, the transistor is still active in the saturation region, but not saturated to excess as it would be if I were much smaller than I_o. The condition that I_o is zero is quite possible and occurs when the output of this particular gate forms the input to other gates which are wholly supported by other of their inputs. Hence, a maximum required value can be assigned to the collector current I_c. It is required that sufficient base drive be provided to ensure that the transistor remains saturated for values of I_c up to this maximum value.

(ii) If the external load current is in the opposite direction to that shown in Fig. 12(a), the magnitude of I_c is equal to the difference between that of I and that of I_o. In order that the transistor should remain saturated and conducting, I_c must remain positive and greater than zero. In the limiting case with I_c becoming zero, the maximum load I_o which can be withstood by the gate is thus equal in magnitude to I but of opposite direction. Hence, a minimum tolerable value of I is obtained from the maximum likely value of I_o. This, in turn, gives a maximum tolerable value of the collector resistance R_c. The maximum collector current in this case occurs when I_o is zero. The saturation condition must be maintained at all collector currents up to this value, which is seen to be equal to I. Thus, the requirement on base drive is found. In the base circuit, currents can be summed at the base node to give:

$$I_1 + I_2 + I_3 + I_4 = I_B + I_R.$$

At saturation, the base to emitter drop is small, so that the base potential V_B is closely equal to the emitter potential V_{EE}. Typical base-emitter drops for germanium and silicon transistors are 0.3 and 0.6 volts respectively. Hence, the magnitude of I_R is given by the following equation, R having been determined from previous design for the cut-off condition:

$$I_R = -V_B/R.$$

The base drive current I_B is determined from the maximum required collector current I_c. These are related by the parameter β, which is the D.C. base to collector current gain measured at saturation. The magnitude of this parameter can vary widely in transistors of the same type in a given batch. Hence, a value of this parameter must be chosen such that it is low enough to include most of a batch or such that it will be achieved by selection of transistors from the batch. Having set this design value of β, the base drive current is determined from the equation:

$$I_B = I_c/\beta \ .$$

With β as the chosen minimum value and I_c as the required maximum collector current, the base current I_B will be a required minimum to ensure saturation. This ensures that saturation will be maintained up to the highest value of I_c with a transistor of the lowest design β value. With superior transistors, the maximum collector current which can be obtained will be greater by virtue of their better actual β values.

The worst loading on a previous gate occurs when the input associated with that gate is the only input supporting the gate. This corresponds to the case of one 0 input state and three 1 input states. If more than one input is at the 0 state the load presented by the NOR gate is shared by these inputs. However, each input must be capable of supporting individually the NOR gate. If we now consider input A in the 0 state and inputs B, C and D in the 1 state, input A alone supports the NOR gate. Since the 1 potential is very closely equal to V_{EE} and hence V_B, the currents I_2, I_3, and I_4 are very small and may, in general, be neglected. Hence, a minimum required value of I_1 is found as the sum of the magnitudes of I_R and the minimum required value of I_B. Since the 0 potential was seen earlier to be equal to the collector diode potential V_D, Ohm's law gives a maximum tolerable value of R_1 when the minimum required value of I_1 is inserted in the equation:

$$R_1 = (V_B - V_D)/I_1.$$

Generally, the circuit is symmetrical and R_2, R_3 and R_4 are made equal to R_1. This assumes that the input A sees an output with zero source impedance. If this is not so, then the source impedance must be subtracted from the value of R_1 above to give the corrected value of R_1. The assumption that the currents I_2, I_3 and I_4 are negligible may not always be valid. These inputs could be derived from cascaded diode gates or from a saturated silicon transistor with a high saturation resistance. In such cases, the input 1 potential may be too different from V_B to warrant this assumption and some allowance for these currents must then be made. Such considerations place a limit on the maximum possible number of inputs to such a NOR gate, especially when the requirements for cut-off are considered in this light. To compensate for these currents at cut-off, the value of I_R must be increased. A stage is finally reached where I_R is so large that little of the available input current at saturation is available as base drive current, most being lost into R.

8.2 Transitional Behaviour.

In cases where fast transitions from one stable switched state to the other are required, the transient performance of both the NOR gate and the INVERTER can be improved by shunting the input resistors R_1, R_2, R_3, R_4 with suitably chosen values of capacitance. The determination of these capacitance values can be made by the methods outlined in Reference 5. General reference to NOR gate design is obtained in References 6 and 8.

9. GENERAL COMMENTS ON CASCADING GATES.

(i) Diode gates cannot be directly cascaded in long chains as pointed out earlier. Emitter followers can be used to achieve the required impedance matching. Alternatively NOR gates can be used for the same purpose. However, the "cleanest" design uses emitter followers. This last approach offers a better transient performance for given transistor types since the emitter follower is not operated in either the cut-off or saturation region as is the NOR gate. Thus, the emitter follower, remaining in the "active" region, lacks the slowing effects of turn-on, turn-off, and storage times on transient performance as found in the NOR gate. These switching delays are mentioned in the Appendix.

(ii) NOR gates can be designed to cascade with other types of gates but the best system results when a system of NOR gates only is employed. An examination of the various possible combinations of gates in cascade leads to the conclusion that NOR gates can drive relatively large numbers of NOR gates. This gives a good facility for pyramiding gates in a complex system. When other types of gates are intermixed with NOR gates, this pyramiding facility is reduced.

APPENDIX I

SWITCHING BEHAVIOUR OF A TRANSISTOR IN THE COMMON EMITTER CONFIGURATION

The static behaviour of a transistor in a switching circuit using this configuration can be observed from the usual method of superimposing a load line on published collector characteristic curves of current against voltage with base current as a parameter. The first quadrant of Fig. 13(b) shows this collector-emitter characteristic for a germanium p-n-p transistor (Philips type OC71). The following symbols are used and are depicted in the circuit of Fig. 13(a), the circuit for which the operating curves are to be derived:

I_c = Collector current flowing out of collector lead

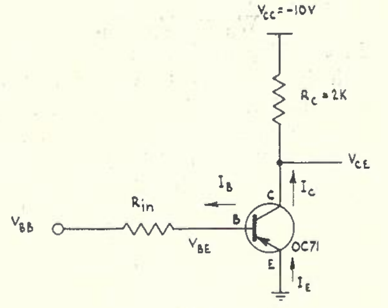
I_B = Base current flowing out of base lead

V_{CE} = Collector to emitter voltage

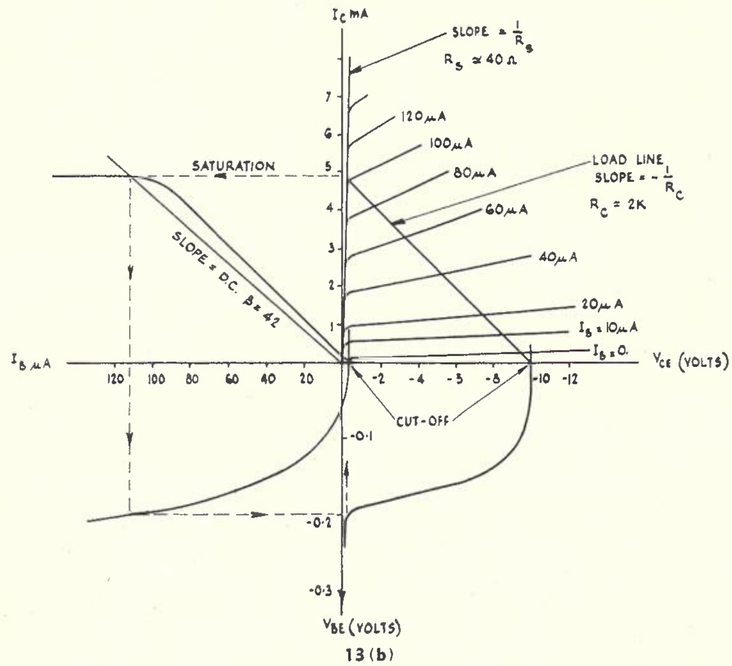
V_{BE} = Base to emitter voltage

V_{CC} = Collector supply voltage

V_{BB} = Base input voltage



13(a)



13(b)

Fig. 13.—Behaviour of the Transistor in the Common Emitter Configuration.

R_c = Total effective collector load resistance
R_{in} = Base input series resistance.

A load line of slope $-1/R_c$ is superimposed on the I_c versus V_{CE} characteristic, with I_B as the fixed parameter, shown in the first quadrant. From the intersections of the load line with this characteristic, the other quadrants have been filled in to give operating curves of

(i) V_{BE} against V_{CE}
(ii) V_{BE} against I_B
(iii) I_c against I_B, for the circuit shown.

The load line is of course the operating curve of I_c against V_{CE}. The values for R_c (2K-ohm) and V_{cc} (-10 volt) are chosen to lend reality to the curves.

As far as the static behaviour of the transistor in the common emitter configuration is concerned when the circuit is to be operated in the switching node, the two extreme ends of the load line are of most importance. These extreme ends represent the saturation condition and the cut-off condition of the transsistor in such a circuit, as labelled in Fig. 13 (b). In two-state switching circuits the transistor is maintained in either of these two conditions, one condition being chosen to represent the 1 state and the other the 0 state. Transition from one state to the other traverses the load line and this transition is generally made as fast as possible. From the curves of Fig. 13(b), it can be noted for each of the two extreme conditions that the following remarks apply.

At Saturation:

(i) I_B and I_c are positive in direction, and V_{BE} is negative.

(ii) V_{CE} is very small (typically -0.15 volts for a germanium transistor). Any increase of I_B beyond the value required to produce saturation causes negligible decrease in the magnitude of V_{CE}. Thus the collector current at saturation is determined by the external collector load resistance since V_{CE} is small enough to be negligible. Hence, at saturation:

$$I_c = -V_{cc}/R_c .$$

The base current to provide this collector current is given by:

$$I_B = I_c/\beta$$

where β is the D.C. base-to-collector current gain at saturation, referred to as the "D.C.β" in Fig. 13(b).

(iii) The collector to emitter circuit at saturation behaves like a small resistance R_S, the saturation resistance, whose magnitude determines the slope of the $I_c - V_{CE}$ characteristic when V_{CE} is very small. If the base current provided is insufficient to maintain the transistor in the saturated condition for changes of the D.C. collector current, the collector-emitter circuit rapidly becomes a higher resistance path. At saturation, the collector output can be represented by a voltage source whose magnitude is that of the emitter potential and a series source impedance of magnitude equal to R_S. A typical value of R_S for a low power germanium transistor is 40 ohms. In general, silicon transistors have higher saturation resistances than their germanium counterparts.

(iv) The collector dissipation W_c at saturation is given by:

$$W_c = V_{CE} I_c.$$

Since V_{CE} is small, large values of I_c can be tolerated at saturation without exceeding the collector dissipation rating. This current is much larger than that which could be tolerated on these grounds when the same transistor is used in an amplifier circuit, where V_{CE} is considerably larger.

(v) Increasing I_B beyond the value required to just drive the transistor to saturation increases the magnitude of V_{BE}, and hence the base junction dissipation W_B which is given by:

$$W_B = V_{BE} I_B.$$

In checking dissipation in the device, it is necessary to ensure that the sum of W_B and W_c does not exceed the device dissipation rating.

(vi) The collector and base of the transistor are effectively isolated.

(vii) The ratio I_c/I_B obtained from the $I_C - I_B$ characteristic gives the magnitude of the D.C. base-to-collector current gain β. It can be seen that at saturation this value of current gain is slightly less than that for the more linear portion of the characteristic used in amplifier circuits. This current gain parameter can vary appreciably from transistor to transistor even though the transistors are of the same type. Variations of -50% to $+100\%$ on the quoted nominal β values are possible. Hence, in design, a representative value must be assigned for the minimum β value likely to be met and all design based on this value.

(viii) In the saturated condition, voltage ratings of transistors are not likely to be exceeded, since all voltages are very small in magnitude.

At Cut-off:

(i) I_c is very small. If V_{BE} is maintained positive and greater than 0.1V, the collector current is approximately equal to I_{co}. If V_{BE} is less positive than this figure, the collector current increases and approaches I_{co}', where I_{co}' is equal to βI_{co}. The current I_{co} consists of the thermal and leakage currents from base-to-collector when the emitter is open circuit. It is thermally dependent, its magnitude doubling for every 11°C. change in junction temperature in germanium transistors and for every 8°C. change in junction temperature in silicon transistors. This thermal behaviour must be taken into account in design, and it is general to ensure that V_{BE} is greater than 0.1 volts positive over the working range of temperatures to ensure that the collector current at cut-off remains at a minimum value approximately equal to I_{co}. In a given batch of transistors, I_{co} can vary appreciably when this parameter is measured for each transistor in the batch at a given ambient temperature. Hence, design must assume the worst (that is largest) magnitude of I_{co} likely to be met for a given transistor type at the highest desired ambient temperature. At cut-off, the collector voltage V_{CE} can be seen to be given by:

$$V_{CE} = V_{cc} + I_{co} R_c.$$

When I_{co} is small enough to be negligible, the collector output circuit appears as a voltage source of magnitude V_{cc} with a series source resistance equal to R_c.

(ii) The base-emitter junction behaves in a very similar fashion to a reverse biassed diode and is high impedance. The base current is approximately equal to I_{co}.

(iii) It is unlikely that dissipation ratings of a transistor will be exceeded at cut-off, it being more important to ensure that the maximum voltage ratings of the transistor are not exceeded.

The above remarks apply to the transistor in an overdriven common-emitter configuration. It is important in switching circuits to achieve also a desired speed of transition from state to state. If transition times are not sufficiently short when compared with thermal time constants of the transistor, calculations of device dissipations must include consideration of these portions of a duty cycle. However, this is not generally the case, transition times being kept negligible compared with the minimum times that such a circuit is stable at the saturated or cut-off condition. Fast transitions are important in cases where trigger pulses are derived from them and when fast overall speeds are required for multiple switching operations.

Due to the physics of the electron and hole movements within a transistor, the collector current does not immediately respond to step changes in the base current. In switching a transistor circuit of the type shown in Fig. 13(a) from cut-off to saturation by the required current step input at the base, there is a definite delay before the final collector current is reached, and this is referred to as the turn-on time. Similarly, in switching from saturation to cut-off, there are two delays. The first is called the storage time, which is the time required for the transistor to come out of saturation, and then this is followed by the turn-off time, which is the delay before the collector current falls to its cut-off value.

These switching times are dependent upon the alpha cut-off frequencies of the transistors being used, the currents flowing, the amount of excess base drive provided, and the voltages involved in a particular circuit. In general, switching times are smallest for transistors with the highest alpha cut-off frequencies. With a given transistor type, turn-on and turn-off times can be reduced by further overdriving the base. However, such approaches increase the delay due to storage time, and this is reduced by keeping the collector voltage slightly more negative than when the transistor is allowed to saturate unchecked. Under unchecked saturation conditions, the collector potential is positive with respect to the base potential, and to reduce storage time, the collector potential is kept to a potential slightly more negative than the base potential. Various methods of achieving this result are to be found in Reference 4.

Quantitative approaches to switching times will not be discussed in this article but two types of approach to this aspect of switched transistors are found in References 7 and 5. The first reference considers the transistor as a current controlled device whereas the second considers it as a charge controlled device. Each of these approaches is well recognised, the second one being the more recent and thus being found only in the more recent texts.

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ARTICLES BY P.M.G. DEPARTMENT STAFF APPEARING IN OTHER JOURNALS

An X-ray Television System with Image Storage and Automatic Exposure-Release* by A. J. Seyler, Dipl. Ing., M.E.E., S.M.I.R.E.Aust.

The design of an X-ray television system containing an electronic recording storage tube is described. The sequence of storage tube functions and X-ray exposure is automatically controlled by a central timing device and all time intervals are synchronised with the vertical scanning period of the television system. By actuating a single exposure release button when a new image is required, erasure of the previous image and storage of the new one are completed within half a second. During this interval the X-ray source is energised for not more than one quarter of a second but generally less. Continuous display times of useful pictures of up to 30 minutes were obtained. Apart from the single-shot operation, provision is made for automatically repeating the exposure at intervals variable between 2 and 6 seconds. In this cycling mode, slowly varying phenomena and surgical manipulations may be observed in quasi-motion. Any number of ordinary television-display units may be supplied with composite television signals from the output of the storage unit, and one such device may be permanently set up for still or moving photographic recording of the images. The unit is presently undergoing tests for quantitative evaluation of its performance and for the investigation of its medical potential. One objective for further development is already under consideration, that is the exploitation of the potential of the storage tube for the storing of four images. Thus, when required, two images obtained in two planes of the object could be stored simultaneously with those of a previous exposure which would be retained for reference.

* This is an abstract of an article which appeared in the September, 1962, issue of the Journal of British Institute of Radio Engineers.

"The Saturating Core Oscillator"* by H. S. Wragge, B.E.E., M.Eng.Sc., A.M.I.E.E., A.M.I.E.Aust.

The theory and operation of the saturating core oscillator using square loop core material is considered briefly, followed by a discussion of behaviour in the case where conventional transformer material such as mumetal or stalloy is used. The effects of load and translator characteristics on frequency stability are examined, and methods of controlling this are indicated. Various commonly used starting circuits are examined in detail followed by suggested design procedures. In conclusion, the complete design and performance of a small 400 cycle oscillator is described in detail.

*This is an abstract of an article which appeared in the September 1962 issue of the Proceedings of the Institution of Radio Engineers, Australia.

"Simple Delta Modulation System"* by F. W. Arter, B.E.E., M.Eng.Sc.

The transmission performance of coded pulse modulation systems in the presence of high levels of channel noise is discussed, and Delta Modulation systems are compared briefly with Pulse Code Modulation systems. The design of an experimental Delta Modulation system for speech transmission is presented for a required set of performance specifications. A feature of the system is its fully transistorised circuitry.

*This is an abstract of an article which appeared in the September 1962 issue of the Proceedings of the Institution of Radio Engineers, Australia.

OUR CONTRIBUTORS

E. L. BROOKER

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E. L. BROOKER, author of the article "Monitoring Loudspeakers for the National Broadcasting Service", began an engineering Cadetship in Perth in 1947 after four years as a Technician-in-Training. After graduating with a degree of Bachelor of Science from the University of Western Australia, Mr. Brooker completed his cadetship in Melbourne and joined the Design and Development Division of the Headquarters Radio Section. In 1953 he became one of the first group of Australian engineers to be awarded Federation of British Industries post graduate scholarships, tenable in the United Kingdom for a period of two years. During this period he was concerned primarily with the design of broadband radio bearer systems. At the completion of the scholarship, Mr. Brooker returned to the Headquarters Radio Section and continued in the Design Division, including in his work design and measurements on audio and acoustic equipment. He is at present occupying a position of Engineer Class 4 in the Design Sub-Section and is an Associate Member of the Institution of Radio Engineers, Australia.

J. E. RULE, author of the article "Stereophonic Sound in the National Broadcasting Service in Western Australia", joined the Postmaster-General's Department as a Cadet Engineer and graduated Bachelor of Engineering at the University of Western Australia in 1953. After a period in the External Plant Planning Division, he worked in Metropolitan District Works Divisions as a Group Engineer for several years. Transferring to the Radio Section in 1957, he has been engaged on inspections of National and Commercial Broadcasting Stations for the Australian Broadcasting Control Board throughout Western Australia and at other times as Engineer Class II on the operation and maintenance of N.B.S. Studios and Transmitters, the position he now occupies. Mr. Rule is an Associate Member of the Institution of Engineers, Australia.

R. M. J. KERR, author of the article "The Early History of the Telephone in Victoria", first entered the Postmaster-General's Department in 1937 as a Telegraph Messenger, and after occupying positions of Junior Mechanic and Clerk, was promoted to Cadet Draftsman in 1939. After completion of this cadetship, he served for the next twelve years as Draftsman and Sectional Draftsman, Exchange Installation. In 1956 he took over the position of Assistant Supervising Draftsman, Internal Plant. At present he is appointed as Assistant Chief Drafting Officer, Victorian Administration, in charge of the Telephone, Radio, Telegraph, Building, and Planning sub-sections.

R. M. J. KERR

R. J. BROWNING, author of the article "The Telephone Directory" entered the Department in 1935 as a Telegraph Messenger at Bendigo, Victoria. He was transferred to the Third Division in 1938 and served in the Bendigo District Telephone Office for three years. After army duty, Mr. Browning served with the Engineering Division in Hobart for a short period and joined the Telecommunications Division at Headquarters in 1947. For the past seven years, as an Assistant Controller of the Commercial Branch, he has been responsible for the policy and standards relating to the telephone directory and has been associated with the many major changes made in recent years.

A. COHEN, author of the article "The New Rosehill Sound Broadcasting Studios, Perth", was born in Perth in 1930 and educated at the Perth Boys' School and Perth Modern School. In 1951 he graduated from the University of Western Australia with a Bachelor of Science Degree with Honours in Physics. From June, 1952, to September, 1953, he worked as a Development Engineer with E.M.I. (Australia) Ltd., and from December, 1953, to March, 1956, was with the Circuits Laboratory of Ediswan Electric Co., at Enfield, England. In this capacity he was concerned with the development of scanning circuits for television picture tubes. In March, 1956, Mr. Cohen joined the Postmaster-General's Department and worked in the Radio Installation Division, Perth. In 1957 he occupied the special position created to supervise the design and installation of the technical facilities for the new Rosehill Radio Broadcasting Studios. On the completion of this project he was appointed as Engineer Class 2, Television, in Perth. The duties of this position involve continuous attendance at the A.B.W. 2 Television Transmitting Station in Perth.

E. SAWKINS

E. W. CORLESS

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E. SAWKINS, author of the article "World Automatic Telephone Network", is Assistant Director-General (Engineering) and Engineer-in-Chief and is also currently Chairman of the Telecommunication Society of Australia. He represented Australia at the Administrative Council meetings of the International Telecommunication Union in Geneva in 1961 and 1962.

After joining the Postmaster-General's Department in New South Wales as a Cadet Engineer in 1928, he was awarded a Commonwealth Government Free Place in Science at Sydney University. As an Engineer he served mainly on exchange installation work and during the Second World War organised street lighting control for air raid purposes and worked on the production of signal and radar supplies for the Allied Services in Australia. In 1945 he was selected to establish the first Telephone Planning Division in the Department and in 1946 prepared a Rehabilitation Plan for Telecommunication Services in New South Wales, which later formed the basis for securing greatly increased funds for the expansion of engineering services. In this year also he prepared an interim plan for the development of the Sydney Metropolitan unit fee network. He was successively promoted as Supervising Engineer, Telephone Planning, Assistant Superintending Engineer, Internal Plant, and in 1955 Assistant Director (Engineering), New South Wales. During 1956 he acted for long periods as Director, Posts and Telegraphs, New South Wales. Mr. Sawkins was transferred to Headquarters in Melbourne in September 1956, promoted as Deputy Engineer-in-Chief, and in February 1957 as Engineer-in-Chief.

In the period that he has been at Head Office, policy objectives have been set for the National Telephone Service, a national plan for automatic service throughout Australia has been introduced, and new standards for telephone exchange switching equipment adopted. Wide band transmission equipment has been introduced and expanded on a large scale.

E. W. CORLESS, author of the article "The Economics of Motor Vehicle Fleet Operation" is Sectional Engineer (Automotive Plant), in the Engineering Division of the P.M.G.'s Department. He joined the Department in 1929 as a Technician-in-Training, and in 1942 to 1944 acted as Engineer on the Melbourne-Seymour Trunk Cable installation during which he did considerable developmental work on Gas Pressure Alarm systems. In 1944 he took charge of the Victorian engineering fleet. In 1947 he qualified as Engineer and was promoted in 1948 as Divisional Engineer, Transport, Victoria. In 1954 after a period as Divisional Engineer, Methods, he was promoted to the position of Manager, Automotive Plant, Central Office, with the responsibility of oversighting the provision and maintenance of the Commonwealth P.M.G. Engineering fleet. Over the last six years he has contributed substantially to the modernisation of the vehicle and mechanical plant fleets of the Department, and to the establishment of a comprehensive system of cost and management controls and procedures for controlling maintenance and operation.

Mr. Corless has always taken an active interest in Management and its associated techniques, and in 1949 conducted one of the earliest series of lectures in these subjects in the Engineering Division. He has recently been associated with the work of the Productivity Committee of which he is Convenor. He is an Associate Member of the Institution of Engineers, Australia.

K. G. HARDY, author of the article "Main Distributing Frame Facilities for Large City Exchanges", is a Class 3 Engineer (Divisional Engineer), in the Internal Plant Planning Section (Metropolitan) of the New South Wales Engineering Division. He joined the Department in 1938 as Technician-in-Training and following a period as Technician was promoted Engineer in 1948 after almost two years' duty as Acting Engineer. He gained his Electrical Engineering Diploma in 1949 and Management Diploma in 1959, both at Sydney Technical College.

Mr. Hardy was Engineer, Class 2 (Group Engineer) at P.M.G. Workshops from 1947 to 1949 concerned with production engineering and was transferred to Exchange Installation Division in 1949. Six years later he was promoted Engineer Class 3, after several years' acting duty in the position and was responsible for many large projects, chief of which were the establishment of a new co-tandem exchange at Dalley in the City of Sydney and the installation and establishment of a new tandem exchange in the Sydney suburb of Homebush.

In 1959 he was transferred to Metropolitan Internal Plant Planning activities where he is still actively engaged. For some years, until the work load became too great, necessitating the Sydney metropolitan area planning being split in two, Mr. Hardy was Divisional Engineer responsible for all Internal Plant Planning in the Sydney metropolitan area. He has been a member of a number of Headquarters committees including approximately four years on the Central Office Circuit Liaison Committee. He is a chartered member of the Institution of Engineers (Australia), the Australian Institute of Management and the Royal Institute of Public Administration.

W. O'KEEFE, author of the article "An Exchange Fault Caused by High Induced Voltage on a Junction Cable", graduated as a Bachelor of Engineering from the National University of Ireland in 1956. He then joined Ferranti Ltd., Manchester, England, where he was engaged on the design of medium sized power transformers. In 1959 he joined the Postmaster-General's Department as Engineer Grade 1, and spent twelve months on Country District Works. He was transferred to the Trunk Line Planning Division in 1960 as Group Engineer, Power Co-ordination, Victoria.

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