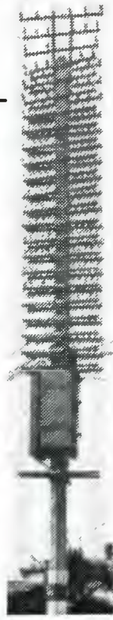
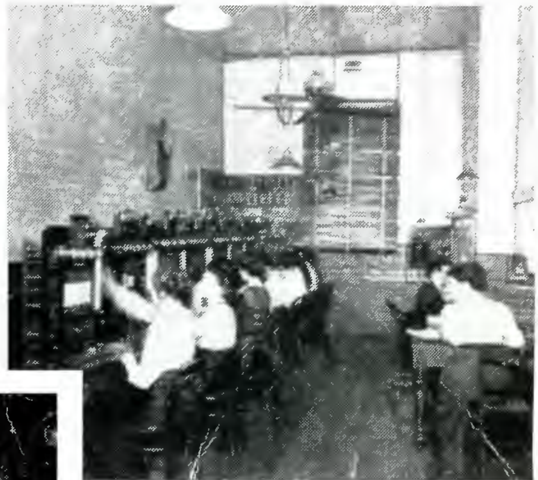
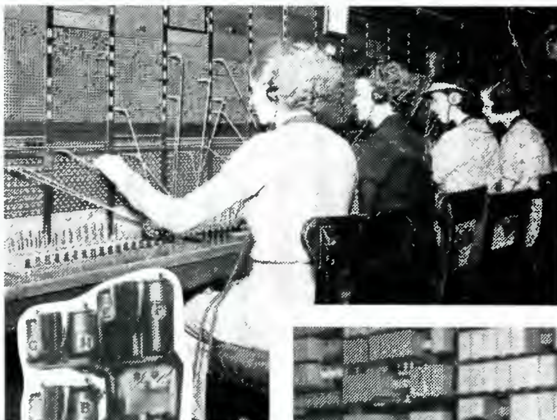
HISTORY OF TELEPHONE SWITCHING TECHNOLOGY IN AUSTRALIA

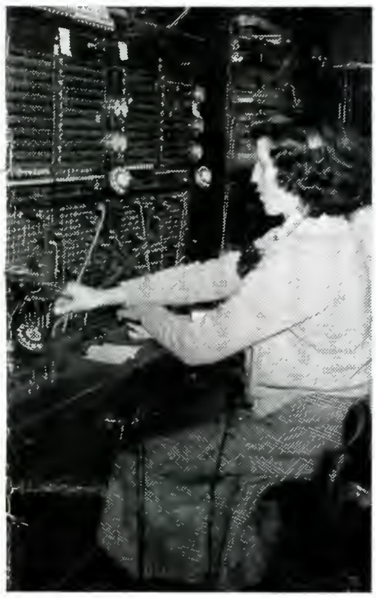
1880 to 1980

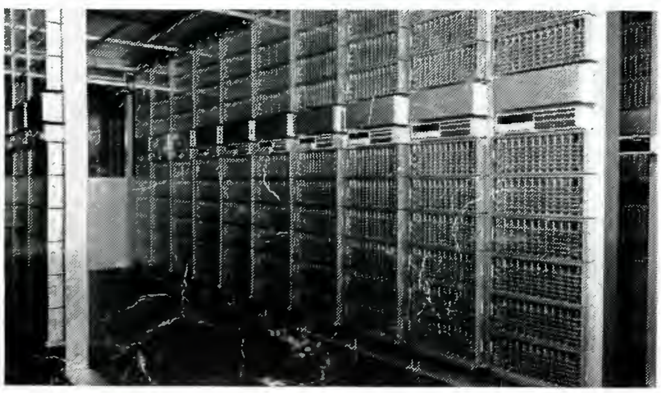
by
A.H. Freeman

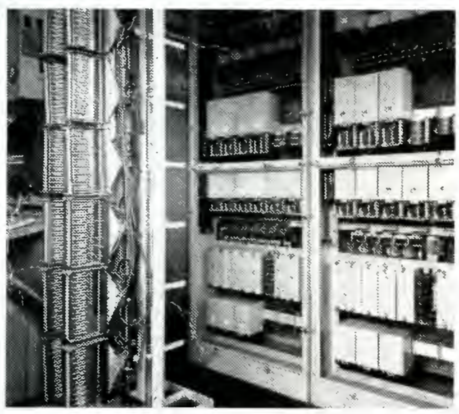












AUSTRALIAN TELECOMMUNICATION MONOGRAPH No. 5

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HISTORY OF TELEPHONE SWITCHING TECHNOLOGY IN AUSTRALIA, 1880 - 1980

BY A.H. FREEMAN

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Australian Telecommunication Monographs are issued from time to time by the Telecommunication Society of Australia. The object of the Society is to promote the diffusion of knowledge of the telecommunications, information transfer, broadcasting and television services of Australia by means of lectures, discussions, publications and other means.

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FOREWORD

The telephone network has been referred to many times as the most complex machine in the world. Many billions of dollars continue to be invested in its development alone, and multi-national companies and telecommunications administrations around the world are competing aggressively to gain or retain a market share in the business it generates.

Australia has won a reputation for having one of the most advanced networks of the developed nations in terms of the sophistication, spread and quality of the services offered and also in terms of the cost of those services as a proportion of average family incomes.

Australia has a low population density and a small customer base (1/20th of the USA market, 1/7th of the Japanese, 1/4 of the United Kingdom's, 1/2 of the Canadian) yet, on a comparison of hours of work required to pay for the annual costs of residential telephone services, Australia ranks better than Germany, United Kingdom, Japan, New Zealand, Norway and France, but worse than United States of America, Canada and Sweden.

In comparison with Canada, it is worth reporting that Telecom Australia has a 54% greater coverage than Bell Canada and that most Canadian States still have greater than 20% of rural services provided by "party" lines, which have disappeared from the Australian scene.

90% of Telecom's equipment needs are sourced in Australia and over 250 firms (mostly indigenous) are involved in supplying equipment, parts, attachment equipment and specialised contract work.

Telecom revenue is presently 2.2% of GDP with a real growth rate of 6-8% p.a. indicating that telecommunications is the "engine" for information technology growth and a catalyst for economic growth and modernisation of primary, manufacturing and tertiary infrastructure.

These statistics are quoted to indicate that, notwithstanding its "tyranny of distance", Australia ranks very highly among developed countries with communications infrastructure. This status has been achieved mainly through the contributions over many years of the APO and Telecom Engineers to the planning, development and design of equipment used in our network, and through the specification of advanced facilities and standards by participation in company designs and world forums such as CCITT.

This reputation is now helping Telecom, through its wholly owned subsidiary company, Telecom Australia International Limited, to establish contracts off-shore in order to help restore Australia's balance of trade. Some 130 contracts have been placed in over 30 countries. To date these have focused on locally developed products (including the digital radio concentrator, the rural digital exchange) and our expertise in optical fibre and network management. These and other products and services are particularly suited to many of the developing countries in South-East Asia and the South Pacific Basin.

How this reputation has been won for Australia in the switching field will unfold for the reader through the chapters of this book.

There would be no one better qualified than Mr A H (Harry) Freeman to write the history.

Mr Freeman's personal contribution to the planning of the Australian network stands alone.

The "History" makes fascinating reading for anyone who has had some involvement in the industy. The one hundred year time span, the technology span from manual to stored-programme control, and the astute references to the big decisions taken on the way though, reflect the depth of understanding of concepts and detail which set the author apart from his contemporaries.

I'm sure the "History" will produce just as much enjoyment for students and casual readers because of the interesting way the evolution of the network is outlined — particularly the local initiatives for signalling logic and signalling facilities which acted as the market pull and influenced greatly the technology drive from the manufacturing companies with whom we were associated.

Many "world-first" milestones are recorded — perhaps this indicates a spirit of adventure appropriate for our colonial background — perhaps it is further testimony to the Harry Freemans who helped shape our network.

Ron McCarthy BE, FIE (Aust)

Telecom Australia, and Chairman,
Telecommunciation Society of Australia.

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PREFACE

The Australian telephone system has many of the attributes of a good servant. It is unobtrusive but always ready when needed. The range of services provided expands continually to match the customers needs. It performs these services efficiently with a minimum of fuss and is easy to control. In modern jargon, it is user friendly. All this at a reasonable cost.

Until recently it has been a self contained entity but with the advent of ISD it has become part of a world wide automatic network. This triumph of technology has been created in stages by the efforts of generations of engineers and technologists from many countries. This Monograph is an attempt to document the Australian contribution to this process.

Development of the Australian telephone system relied heavily on overseas equipment designs and practices but there was always a need to adapt these to meet problems created by Australia's unique demography and geography. In some instances the problems were solved by using standard equipment in network configurations that were not envisaged by the original designers. In other cases the designs were modified to suit Australian conditions. Less frequently suitable equipment was designed locally and occasionally overseas suppliers were asked to build equipment using Australian circuits.

Individually the local initiatives were usually fairly modest but collectively they created a distinctive network with features found nowhere else. Another result of this activity has been the creation of a pool of distinctive skills which is recognised world wide for its excellence. Because the problems faced and solved in Australia are similar to those now being met in developing countries, Australian engineers play a major role in assistance to these countries.

There have always been a few persons in Telecom Australia and earlier in the PMG's Department with an interest in old things and the history of the telephone in Australia. However it is only recently that the uniqueness of Australia's telephone service has been widely recognised. Prior to 1960 only a few Headquarters engineers had contact with their counterparts in other countries. The work leading to the introduction of crossbar changed all that. Australia was invaded by eager sales engineers, determined to demonstrate the superiority of their company's product. To the surprise of many, including myself, some of these products were little if any better for our purposes than the home grown equipment we hoped to replace.

At this time I could see the value of a history of Australian telephone technology and started collecting information as it came to my attention and tapping the memories of older colleagues. My involvement in some bicentennial activities forced me to collate and organise some of this material and led to the production of this monograph.

The sources used in writing it are many and varied. The most valuable source is the Telecommunication Journal of Australia. Since 1936 it has carried many articles describing new equipment and projects and the sample answers to examination questions reveal details of practices which are found nowhere else. Annual reports and internal publications such as STD newsletters, engineering instructions and the "Course of Technical Training" also give many details.

Considerable use has been made of the NSW Historical Officer's collection which has some unique material which has filled in many gaps. Unfortunately some of these records have not been catalogued and access is therefore difficult. They include reminiscences of Sydney's first telephonist and other staff who worked in the early years of the telephony.

The main theme of this monograph is the way that successively more powerful technologies were used in Australian telephone exchanges. This was done in response to pressures of network growth, the need or desire to introduce new facilities or because new technology offered economic advantages. Emphasis has been given to the specifically Australian aspects such as local modifications and improvements and indigenous design work.

Telephone exchanges are only a small part of the telephone system and the same pattern of importing and adapting new technology applies to line plant, transmission equipment, microwave radio and subscriber's equipment. Each of these areas deserves to be recognised and in some ways their history is even more impressive but information about them is scanty. Even such commonplace items as precast jointing boxes and cross connecting cabinets are uniquely Australian.

Writing on historial subjects is a selective and subjective process. It is based on source documents that were produced to answer an immediate need with no conscious thought of their historical value. A decision may be documented, but not the underlying reasons. A new item of equipment may be described for the guidance of installation or maintenance staff but its impact on network structure must be inferred. The survival of these documents is subject to the opinions and policies of archivists who must allow most of them to be destroyed.

An author must interpret the sources and in the process personal views will inevitably intrude. This is particularly true when writing of events in which the author was personally involved. The reader will observe my emphasis on the reasons for the changes and on the impact of non engineering factors on them. I have used my memory of events to help create the thinking of the time but where matters of fact are concerned I have confined myself to matters for which there is documentary evidence.

It is my hope that this monograph will be a useful outline of an important aspect of telecommunication history. However "Of making many books there is no end" and I am acutely aware that this is not the last word on the subject. For this reason the references have been made as comprehensive as possible in the hope that future authors will find this monograph useful as a starting point.

INTRODUCTION

This history is a broad overview of the technological changes in Australian telephone switching over the period from 1880 when the first exchange was opened until the introduction of AXE and digital switching in 1981. It is intended to be both a self contained history and a framework within which more detailed studies may be viewed.

A conscious choice was made to exclude any treatment of AXE or digital switching. These technologies are a complete break with the past and are already having an unprecedented impact on the network. It is already clear that there will be no further significant developments in analogue switching, making this decision almost inevitable.

The account is nominally divided into three periods corresponding to specific technology regimes. The first was dominated by magneto and Strowger step-by-step. It ended with the first 2000 type automatic in 1938, the Melbourne trunk exchange in 1940 and CBM country exchanges from 1950. The outbreak of war in 1939 was a major interruption to the development of the network and has therefore been taken as the nominal transition date. The second period was dominated by step-by-step automatic and 2VF trunk switching. It ended in 1960 with the issue of the Community Telephone Plan. The third period was the crossbar era and the end of this period is taken as 1981 when the first AXE exchange was cutover.

There are two parallel themes in technology. The first is the adoption of a new technology, followed by its adaptation to local needs. The second is the spread of that technology through the network. It was therefore found convenient to have two parallel themes. Chapters 1, 3 and 5 deal with the development of the network and the spread of each new technology, while chapters 2, 4 and 6 deal with the technologies themselves and the way they were adapted to meet local needs.

Some descriptive material which seemed desirable but did not fit comfortably into either group of chapters has been placed in chapter 7 titled 'Technology Principles'. This is a history, not a text book, but some of the older technologies are almost forgotten. The chapter is meant mainly to assist in understanding the earlier equipment but brief details of the principles of crossbar and SPC as well as a treatment of some traffic concepts have also been included. It includes a reading list for those who wish to find out more details.

Several topics have been omitted from this history for various reasons. Subscribers' equipment such as PBXs, PABXs and small business systems form a separate area which has little in common with public exchange equipment, TRESS, TELEX, CUDN and other data oriented equipment have been omitted for similar reasons. The extensive work by Telecom staff in developing installation practices and maintenance aids calls for a writer more familiar with these areas.

It had been intended to include a fairly comprehensive account of local design initiatives but it was found impossible to do justice to this matter. There has been a very large amount of such work but it was often regarded as trivial and unworthy of documentation.

The references include all published historical material dealing with the growth of the Australian network of which the author is aware. There is a lot of unpublished material held by the Historical Officers in Headquarters and the States as well as Australian Archives but no attempt has been made to record it in this book.

NETWORK DEVELOPMENT TO 1939

BEGINNINGS

Before 1901 the telephone systems were under the control of the Electric Telegraph staff in the independent colonies. The first telephone exchange in Australia was opened in Melbourne in 1880, and by 1887 exchanges had been established in every capital city (1),(2),(3),(4),(5). Development was initially concentrated around the city centres but some suburban exchanges had been established by 1901 in all cities except Hobart. By this time each city network had developed its own character which was to influence future growth for decades.

Under the colonial governments a laissez faire attitude to country telephones prevailed. If a specified number of applications were received for service in a town an exchange was opened. This number was 15 in NSW and similar figures applied elsewhere. Development was slow and patchy under these policies.

In 1901 the Postmaster General in the first Australian Parliament set up a committee, chaired by Sir Charles Todd, to report on the colonial telephone and telegraph systems which had been taken over by the Commonwealth. This report (6) summarises world technology of the time as seen by Australian engineers, gives a detailed description of the Australian scene at that time and also contains recommendations for work to be done in the next three years. This makes it a convenient starting point for a history of telephone switching in Australia. Some statistical details are attached and show that there were 22,299 lines of which 79% were in the capital cities. In 1901 the capital city networks fell into two classes with Sydney and Melbourne much larger than the rest.

SYDNEY had 3710 subscribers lines connected to Central exchange in the GPO and a further 4207 connected to 23 branch exchanges, which ranged in size from 432 at Edgecliff to 20 at Liverpool. Comparable cities overseas had a much smaller number of relatively large exchanges to serve their suburbs and in this respect Sydney was an anomaly. It is not known whether this was due to a deliberate policy, nor can it be said whether there was any penalty involved.

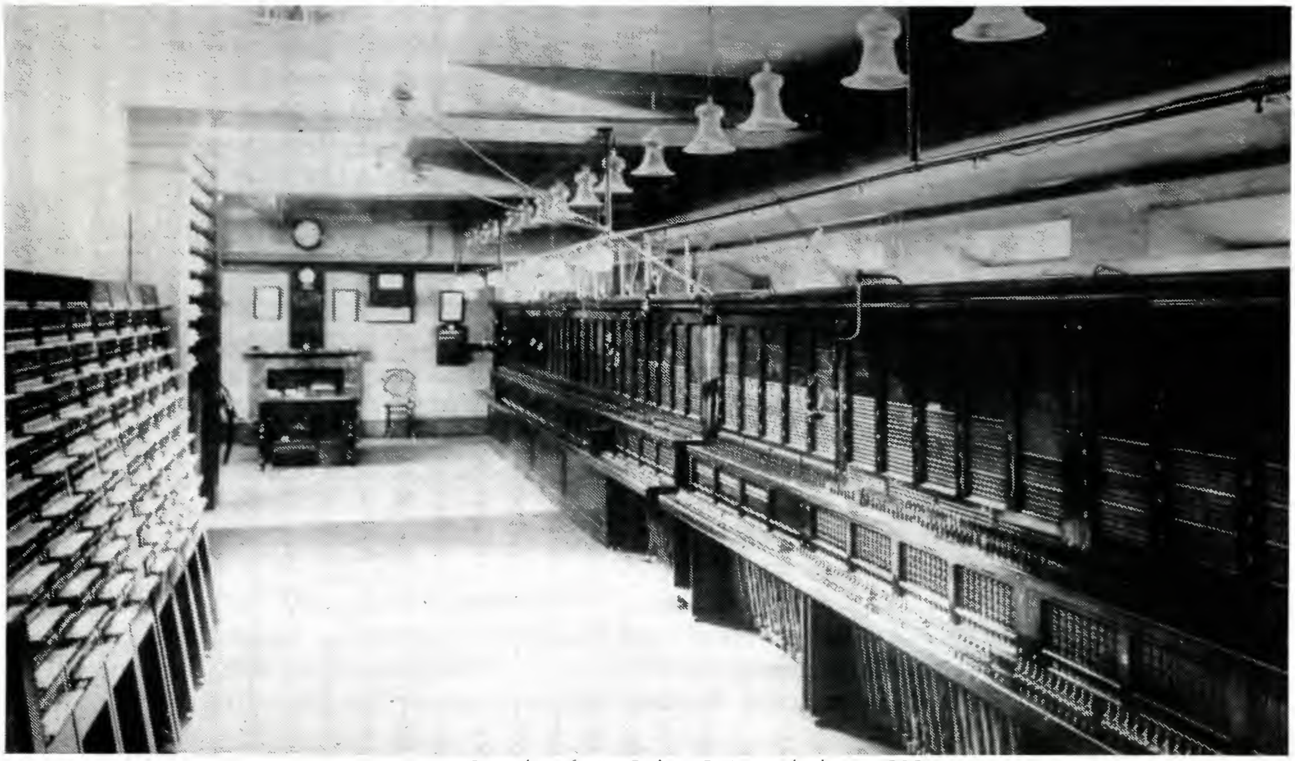


Fig. 1.1 — Central Exchange Sydney Series Multiple ca. 1890

On the credit side, the short lines possible with the closely spaced exchanges gave savings in line plant, while the small, non multiple, suburban exchanges were inexpensive and could be fitted into spare corners of post offices. On the debit side, there were extra operating costs involved in staffing numerous small sites and in switching the large volume of junction traffic caused by the small exchanges. In due course there would be a need for many new buildings as the exchanges grew too large for the available space. Overall the pluses and minuses probably balanced fairly evenly. However, the network of 1901 had a profound effect on the pattern of future development.

Central exchange was a branching multiple type of the latest design and had replaced an obsolescent series multiple exchange 15 months earlier. However, the report expressed some doubts about its reliability. Plugs with a barrel diameter of 3/16" (4.8mm) were used to give a 9000 line multiple capacity and were wearing rapidly. However this seems to have been a teething problem, and the exchange remained in service till 1915.

The suburban exchanges were all non multiple magneto and mostly built for metallic lines. There was a plan, which may have been implemented, to instal series multiple at Edgecliff using rebuilt parts of the old Central exchange. Three or four exchanges must have had some kind of transfer facilities, and these were probably ring down circuits.

MELBOURNE had 3057 subscribers connected to Central, and a further 1747 connected to 12 suburban exchanges. Three exchanges accounted for 1273 of these lines. The network was more conventional than Sydney in respect to exchange areas. Even here, however there were suggestions that with CB exchanges it would be desirable to amalgamate Windsor, Hawthorn and Malvern into a single large exchange.

Central was an old series multiple exchange, badly in need of replacement. It had single wire switching which was unacceptable for an exchange of this size and the cords were hung from the top of the switchboard making operating a task for athletes. (3).

Fig. 1.2 — Melbourne Central Exchange Series Multiple in 1886

The multiple capacity was 3600 lines and it was estimated that this would be exceeded in two years.

The next largest exchange was Windsor, with 623 subscribers and it had recently been equipped with a modern branching multiple board. All other exchanges were non multiple. Malvern and Hawthorn each had four positions and probably had ring down transfers. No other exchange exceeded two positions.

Some suburban exchanges were equipped for metallic lines but the lines were almost entirely single wire and interference from electricity mains was being experienced.

PERTH had the largest network in the second group and, thanks to the prosperity created by the gold rush, had modern exchanges. Perth Central had 973 subscribers on a branching multiple switchboard, Fremantle had 430, also on branching multiple, and three smaller exchanges had a further 204.

ADELAIDE was similar to Perth with 1207 subscribers on Central, 205 on Port Adelaide and two similar exchanges. It had an obsolescent but adequate single wire series multiple exchange at Central and a three position non multiple exchange at Port Adelaide.

BRISBANE had an almost new branching multiple Central exchange with 1207 lines and 108 lines on two suburban exchanges.

Fig. 1.3 — Brisbane Central Exchange Branching Multiple Magneto Ca.1910

HOBART had a single exchange with 494 subscribers connected. The exchange had twelve 50 line non multiple positions and transfers were making life difficult for the operators.

In country areas there were exchanges in 60 towns with a total of 4751 lines connected. The list of locations suggests that mining towns are over represented. Except for the Western Australian goldfields, all the exchanges were non multiple magneto and only seven exchanges exceeded 200 lines. Most of these lines were to commercial or industrial premises in the towns and very few farming or grazing properties had telephones.

The committee made recommendations for meeting growth and upgrading the telephone system where necessary. These recommendations were reasonable and involved replacing Melbourne and Sydney Central exchanges with CB, replacing the single wire board at Adelaide Central with branching multiple, and installing branching multiple at other exchanges as they grew beyond about five positions.

Unfortunately, the telephone service was starved of funds until 1907 and the recommended replacements were not made. The resulting chaos and other matters led to a Royal Commission,(7) and the undertaking of a vigorous upgrading program mainly in the metropolitan networks. This was nearly all completed by 1915, when wartime shortages halted the work. The timing of the various projects involved was based on need and the availability of buildings so that each network was affected in a different way. Up to 1914 the new exchanges were CB or branching multiple but, following the success of automatic at Geelong in 1912 it was decided to use automatic in preference to manual exchanges if more than five positions were needed.

Because of the major changes which followed the introduction of automatic exchanges in the cities it is best to treat the initial upgrading using manual technology as one topic and the later conversion to automatic as a second topic. The dividing line is different for each city, ranging from 1914 in Perth and Sydney to 1925 in Brisbane.

NEW MANUAL EXCHANGES IN THE CITIES

MELBOURNE suffered most in the lean years and had the lions share of the new multiple exchanges after 1907. The biggest problem was Central and in the years to 1908 major surgery was performed to prevent the service collapsing completely. The result was a workable but extremely unusual arrangement.

Evidence to the Royal Commission was that it had:—

A 3600 line series multiple exchange

A 300 line branching multiple junction switchboard

12 x 100 line non multiple switchboards

A 4800 branching multiple switchboard

The effective capacity was 4800 lines made up of the original 3600 line exchange and the 12 x 100 line non multiple positions. The 300 line junction switchboard was apparently a suite of B positions referred to in passing in the 1901 report. It had at least 3600 lines in the multiple and may have been larger. The 4800 line branching multiple switchboard must have been a similar suite with access to both the old switchboard and the non multiple positions. Some clever tricks must have been used to achieve this result. The story is worth researching and would show the abilities of the engineers of the time.

Because of the need for a new site and building for CB this "make do and mend" exchange remained in service until 26 August 1911 and was further extended to a capacity of 5400 lines. It was then replaced by a new CB exchange in Lonsdale Street which grew to over 10,000 lines in a short time.

By 1908 the three largest suburban exchanges were all in trouble. Hawthorn had 10 non multiple positions while Malvern had 11 and both were the subject of severe criticism at the Royal Commission. Incoming junction positions appear to have been provided to give some relief prior to their replacement with CB at Hawthorn in 1911 and magneto multiple at Malvern.

Windsor's magneto multiple exchange installed in 1901 was in a fairly small switchroom and reached its capacity by 1907. Temporary relief was provided by a small non multiple exchange at Yarra. A CB exchange was installed at Windsor in 1910 and Yarra was closed.

The remaining exchanges were much smaller and presented no immediate problems for non multiple magneto. The next conversion was Brighton, cutover to automatic in 1914. This will be discussed in the next section.

Modern junction signalling and operating facilities were a part of this re-equipping of the Melbourne network. Lamp signalling and order wire working were used on most junction routes and in some cases keyless ringing was used. In 1914 it compared favourably with the best overseas networks in this respect and it was the largest and best manual junction network in Australia.

SYDNEY's problems in the seven lean years were different from Melbourne.

Central exchange was satisfactory, in spite of the forebodings about wear in the jacks. Even so, conversion to CB was attractive both as a service improvement and to reduce operating costs. The exchange room was large enough to allow a staged cutover, which was undertaken as soon as money could be found.

A CB exchange with an initial capacity of 500 lines was cutover on 12 August 1908 in the same room as the branching multiple exchange. The new exchange was called "City" to distinguish it from the old Central. Extensions and staged cutovers saw the old exchange gradually replaced but it continued to carry trunk traffic till 1915 when a new trunk exchange allowed it to be closed.

Fig. 1.4 — North Sydney CB Exchange

Sydney's big problems were in suburban exchanges. These rapidly displayed all the bad features of the large non multiple installations, aggravated by the high proportion of junction traffic. With no dedicated junction positions, incoming junction terminations were spread over the A positions and each operator had a mixed load of subscribers, incoming junctions and transfers from other positions. Both subscribers and incoming junction calls often had to be transferred to another operator to complete the connection. Three operators were frequently involved in a single call while four and five were sometimes required. The result was that the operators were overloaded and connection times were excessive.

By 1907 there were 10 non multiple exchanges with five or more A positions and it was clear that it would take some years to replace them all. There were also a further seven which grew to five positions in the next three years.

Faced with this problem, an expedient was tried which was probably based on the Melbourne exchange and turned out to be highly effective. It involved adding multiple B positions for incoming junctions to a non multiple suite (8). These positions were sections of standard series multiple exchanges, with some small changes to them and to the existing A positions to make them compatible. The result seems to have exceeded expectations. Taking the junction traffic from the A positions eliminated the overload, while the B position operators handled this junction traffic more expeditiously. The improvement reflected back to the originating operator whose work load was also reduced.

At least seven exchanges were equipped with these B positions. They were never intended to be permanent and were all replaced by 1916. However they helped the network over a rough spot and fully justified themselves. Five exchanges could be equipped with these positions for the cost of a single branching multiple exchange and the performance was little inferior. Installation was simple and did not require a large amount of labour.

Whether or not the cause was the availability of a satisfactory short term expedient, installation of full multiple exchanges in Sydney was slower and by 1912 only six full multiple exchanges had been installed. By this time automatic exchanges were preferred and details of the automatic exchanges in Sydney will be found later in this account.

Experience with these B positions may have changed some of the attitudes of engineering and operating staff. They found that there was an alternative to a full multiple exchange which was not greatly inferior in performance and far less costly. In part this was because, with many small exchanges, the proportion of local traffic was small and the penalty for eliminating the multiple over A positions was small. There seems to have been considerable experimenting with these B positions. Refinements such as lamp signalling were added to some.

In any case this expedient led to the development of a local design which had a fairly long life. These exchanges combined non multiple A positions and multiple B positions. The design overcame the compatibility problems of the expedients and had some extra features.

Local calls were transferred via the B positions, using the same operating procedures as on calls to other exchanges. This eliminated the numerous small groups of A-A transfers formerly used. Junctions used lamp signalling and order wire working with the same operating efficiency as the best of the full multiple exchanges. The reduced A position load allowed A positions of up to 220 subscribers, but 200 was the normal limit. At least eleven exchanges of this type were installed with the first being at Waverley, Randwick and Manly in about 1911.

Efficient junction operating was even more important for Sydney than for Melbourne and order wires and lamp signalling were used extensively. However there were many small routes for which order wire operating was not appropriate. Automatic tandem working was eventually used to reduce these problems.

The Australian junction networks followed overseas practice but there were some differences and fleeting evidence of local design. These differences take the form of upgrading magneto exchanges using methods developed for CB exchanges, such as the use of lamp signalling for magneto junctions which is not mentioned in contemporary text books. Also, the use of non multiple A positions with multiple Bs were used overseas in large CB exchanges but never in magneto.

PERTH, ADELAIDE and BRISBANE had fewer problems during the seven lean years as each had an adequate Central exchange and no large suburban exchanges.

In the Perth network the only exchanges upgraded with new manual equipment were Fremantle, replaced with CB No.9 (a type designed for medium sized exchanges) in 1911 and Cottesloe where some kind of magneto multiple was installed. The other suburban exchanges were small and remained non multiple while Central retained its branching multiple magneto until it was replaced by automatic in 1914.

In Adelaide the series multiple Central exchange was kept in service (not without difficulty) until 1910 when it was replaced by CB in a new building. Port Adelaide was replaced by CB No.9 in 1908 (9). The rest of the network carried on happily with non multiple magneto.

In Brisbane the branching multiple magneto was replaced by CB in 1912. The only large suburban exchange was Toowong which was converted to magneto multiple at some stage. The remainder continued to be served by non multiple magneto possibly with series multiple B positions.

Hobart remained non multiple till 1908 when it received the first CB exchange in Australia.

CAPITAL CITIES GO AUTOMATIC

Following the successful field trial of Strowger automatic at Geelong in 1912 it was decided to use automatic equipment as the preferred type for new exchanges in multi exchange networks. This decision was adhered to as far as circumstances allowed and only a few new manual exchanges were installed in the cities after 1914.

An important factor in this decision was the high operating costs of manual multi exchange networks. In retrospect it seems a rather bold decision. It was widely believed that available automatic equipment was unsuitable for large networks. There were doubts of the ability of subscribers to remember five and six digit numbers and semi automatic was being actively developed. The same arguments surfaced years later in trunk switching, but with greater validity because of the complexity of trunk networks.

Up to this time most Strowger equipment had been installed in the USA by small independent companies as single exchanges. The only two large networks were in Los Angeles, with 13 exchanges and San Francisco with less than 10. These were main/branch networks with nearly all the lines connected to the main exchanges. Australian cities had different requirements but the concept proved adaptable enough to meet the needs of Sydney, Melbourne and smaller cities for many years.

Because of the upgrading program which had started in 1907 the initial application of automatic was patchy and limited. Each network had different problems and required an individual solution.

It is convenient to start with PERTH where the Central exchange was converted on 26 September 1914 (10). There were only two other significant exchanges in the network, Fremantle and Cottesloe. Both had been recently upgraded and had at least ten years of useful life ahead of them. A five figure numbering scheme was adopted.

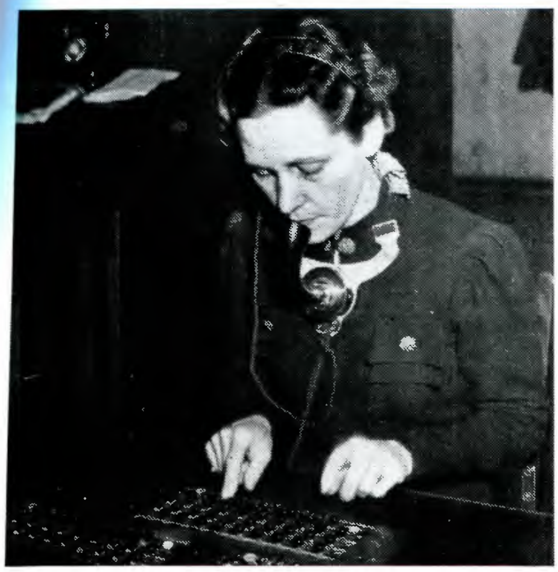


Fig. 1.5 — Keysender auto B position unidentified Sydney Exchange

Keysender Auto-B positions in the automatic exchange were used for calls from manual to automatic. For calls from automatic to manual the subscriber dialled an access code for the desired exchange. Fremantle and Cottesloe were full multiple exchanges and B positions were probably converted to Auto-As. The other exchanges were less than 200 lines and would have had only one position and jack ended junctions.

No change of significance was made to this network until 1930 when Cottesloe was converted. The numbering was completely changed at the same time. Some ingenuity was shown in making the exchange codes easy to remember. In 1933 incoming automatic access was provided to Fremantle with a six digit numbering.

Between 1935 and 1940 four new exchanges were established in a ring around Perth Central. South Perth and Fremantle were both converted in 1941. The network then had a conventional main/branch structure.

SYDNEY had 28 exchanges and by 1914 seven of these, accounting for 55% of the lines, had fairly new multiple switchboards. Plans were made for the conversion of the remaining exchanges to automatic and eleven exchanges, including one on a new site at Vaucluse, were installed by 1915. Tenders were called for a further eight but because of the war the money could not be found and no contracts were let.

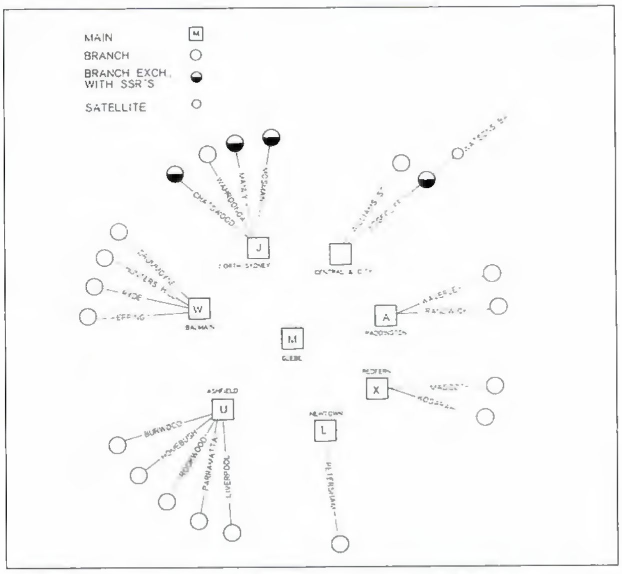


Fig. 1.6 — Switching and Numbering proposed for Sydney 1913

A switching and numbering plan was produced in 1913 with ten main exchanges and five digit numbering. The recently installed multiple exchanges had an adverse influence on these plans as they included some locations, such as North Sydney and William Street which should have been main exchanges. For this reason some of the early main exchanges were regarded as temporary and three were later replaced. Two multiple exchanges (Mosman and Burwood) were replaced by automatic and the switchboards reused elsewhere in the network.

For various reasons the initial plan was modified in the first few years and reference (11) describes these changes. By 1920 the network had stablised to the form it was to retain until 1938.

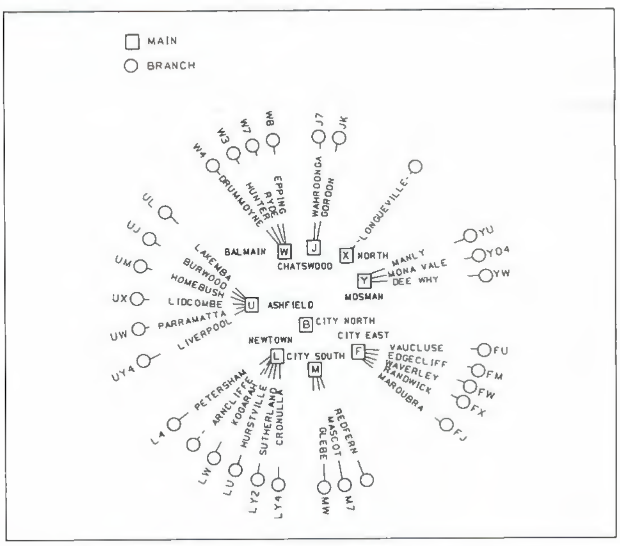


Fig. 1.7 — Switching and Numbering for Sydney 1931

Auto-B positions with keysenders were used at City, North, Edgecliff, Petersham and possibly other exchanges but most manual exchanges had dials on the A positions. Initially automatic subscribers reached all manual numbers by dialling B(2) to reach an operator at City but by late 1915 access codes for all manual exchanges except Liverpool were introduced.

The automatic network was also used to switch traffic between manual exchanges which were not connected by direct junction routes. Manual tandem switching at Central was almost completely eliminated. Sydney may have been the first city in the world to do this. It is known that New York used 'mechanical tandems' for this purpose from about 1920, several years before any local automatic exchanges were installed and that the first automatic installation in London included a mechanical tandem.

Subsequent development of the Sydney network to 1938 followed the plan which had been established. Six digit numbering was introduced exchange by exchange as necessary and manual exchanges were converted as they reached capacity or wore out. Until about 1935 the exchange boundaries remained largely unchanged.

Over this period four new exchanges were established in new suburbs while City, William and Paddington were replaced by City North, City South and East in a rationalisation of boundaries.

In 1925 and 1926 automatic terminating equipment was installed in North, Edgecliff and Kogarah, allowing auto subscribers to dial subscribers in these exchanges. This required special designs of final selectors of which no record has been found.

An early form of Switching Selector Repeater was installed in Burwood, Homebush, Lidcombe and Parramatta when they were cutover in 1915 (13) but these were removed soon after. A better type of SSR was installed in most branch exchanges from about 1927.

In the mid thirties a review of the exchange areas in Sydney was performed, possibly because the greater use of cables was creating transmission problems. A total of 77 exchanges was planned and this was beyond the capacity of a six digit main/branch exchange scheme.

The problem was overcome by a limited use of satellites (1000 line groups detached from a branch exchange), with the result that a few calls were switched over five junctions in tandem. Two major network changes were incorporated in this plan. The 8 level main exchange was moved from Balmain to Drummoyne in 1941 because the Balmain building and site were limited, and the 'temporary' main at Mosman, established in 1915 was eliminated with the conversion of North Sydney from CB to auto in 1938.

By 1914 85% of MELBOURNE subscribers were connected to exchanges that were less than four years old and the only exchange requiring immediate relief was Brighton. This exchange was converted in 1914 followed by Sandringham in 1918 and Malvern in about 1919. A numbering and switching scheme was produced in 1921, presumably a revision of some earlier plan. It was a main/branch scheme with eight main exchanges and mixed five and six digits. Only three more automatic exchanges were established by 1925 but after this slow start more rapid progress was made and by 1939 over 75% of lines were automatic.

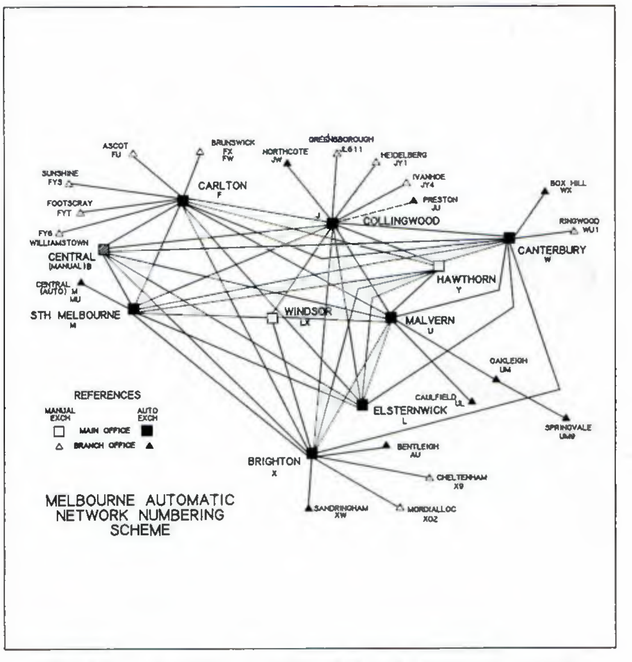


Fig. 1.8 — Switching and Numbering for Melbourne 1936

When Central reached capacity relief was provided by establishing new automatic exchanges in the inner suburbs, while the Central Business District remained manual until 1938 when City West was established in an extension of the Central building and took over some of the city area.

The first plan for ADELAIDE was for semi automatic equipment in which the selector stages were controlled by operators. The conditions favoured this kind of equipment and only three fairly small exchanges were proposed initially.

These were at Port Adelaide, Unley and Norwood. The latter two were new exchanges, giving relief to Central, while Port Adelaide was a CB No.9 exchange which had grown to its limit. The equipment was ordered from England and the Port Adelaide exchange was delivered by Siemens and cutover in 1914/15. The supply of equipment for Unley and Norwood was delayed by the war and these exchanges were cutover on 12 April 1919 and 21 June 1919 using Western Electric equipment.

Fig. 1.9 — Adelaide Central Exchange showing keysender auto B positions

The operators were located at Central except for a daytime staff at Port Adelaide. To the subscriber there was no visible difference between semi automatic and manual systems and the switching and numbering arrangements were an internal matter for the operators.

No further conversions were needed until 1927 by which time the semi auto system had lost favour. The Siemens equipment at Port Adelaide was converted to full automatic and kept in service until 1934 (23) but Norwood and Unley were not compatible and were replaced by standard automatic in 1928.

The numbering and switching for Adelaide was a similar, but smaller version of the Sydney and Melbourne networks. A feature was the provision of a 'tandem' main exchange at Central which provided first and second selectors for four branch exchanges. A similar arrangement had been in use in Sydney from 1914 to 1920, pending the establishing of City North but the Adelaide installation seems to have been meant to be permanent. Five figure numbers sufficed until after 1945.

Between 1927 and 1930 eight exchanges were converted to automatic and two new automatic exchanges were opened. Central CB exchange remained and, because its area had been reduced by opening new exchanges, it had capacity to meet growth for some time. Keysender positions were fitted for traffic to the automatic exchanges. There were also five small manual exchanges in the Adelaide Hills with less than 1000 lines between them.

Semi automatic was proposed for BRISBANE in 1914 on similar lines to Adelaide but was not proceeded with and the network remained fully manual until 1926. A fairly rapid program followed and ten exchanges were established by 1930 to convert over 85% of the network to automatic. The residual manual exchanges were a large magneto exchange at Toowong and two small exchanges at Sandgate and Wynnum.

The equipment used in Brisbane was Siemens No.16 step-by-step. This was similar in principle to the equipment in other cities but there were differences in detail. A five digit main/branch switching scheme was again adopted.

In 1929/30 HOBART CB exchange was replaced by two automatic exchanges at Hobart and Newtown. Only a small number of manual lines were left in the network. Four figure numbers were used for Hobart, with five digits at Newtown.

An automatic exchange was opened in CANBERRA in 1927 to replace an earlier small manual exchange. It was probably justified on political, rather than economic grounds and used three digit numbering, later extended to a mixed three and four digit numbering.

TELEPHONES IN TOWNS

Telephones in country areas fall into two categories, those in towns or large villages and those on farm or station properties. For the purposes of this account the two classes will be called town and rural telephones.

Country telephone development up to 1901 was slow and patchy, a result of the laissez faire attitudes mentioned earlier. By Federation there were exchanges in 60 country towns with a total of 4751 lines connected. The list of locations suggests that mining towns are over represented. Except for the Western Australian goldfields, all the exchanges were non multiple magneto and only seven exchanges exceeded 200 lines.

The same policy was followed after Federation but with a liberalising of the conditions for opening new exchanges. By 1939 nearly every country town and large village had an exchange. Most of these exchanges were small and used non multiple magneto boards. They ranged from 10 line pyramid boards to 200 line floor positions. Only a few exchanges exceeded 200 lines and needed two or more positions.

The upgrading program of 1908 to 1916 included at least five and probably seven country towns, as listed below, but this was followed by a lull. The introduction of 200 line positions and the use of more efficient transfers raised the maximum acceptable size of non multiple magneto to 1000 lines. By 1940 only four more country exchanges were converted to automatic.

TABLE 1.1
Multiple Manual and Standard Automatic Country Exchanges up to 1940

Kalgoorlie	Multiple in 1901
Boulder	Multiple in 1901
Coolgardie	Multiple in 1901
Toowoomba	Branching multiple magneto 1910
Newcastle	Branching multiple magneto 21/3/1910
Broken Hill	Lamp signalling magneto in 1912
Launceston	CBM in 1910 (14)
Ballarat	Probably multiple magneto, details unknown
Bendigo	
Geelong	Auto in 1912
Cairns	Auto in 1932
Rockhampton	Auto in 1938/39
Tamworth	Auto on 25/3/1939
Wagga	Auto on 27/7/1940

RURAL TELEPHONES

High costs and, initially, limited benefits hampered the growth of rural telephones for many years. In time the interaction of political pressures and economic realities produced a framework which gave most rural properties a tolerable service with the costs subsidised by a complicated policy set out in Circular Memoranda, which were updated at intervals.

These provided rules to determine how much line plant would be provided at Departmental expense and for deciding if a new exchange would be opened. These rules were biased in favour of the subscriber rather than the Department.

The Departmental line plant was described as an 'entitlement' which was the length of line which would be provided at Departmental expense. The subscriber had to provide or pay for the remainder and usually erected it himself. Such lines were known as 'part privately erected' or PPE lines. Various cost cutting measures were permitted on these lines including the use of iron wires, earth return circuits, and low ground clearances. Multi party lines were normal but more than six parties on a line were discouraged.

Since the exchange and its connection to the network were a charge on the Department, the subscribers' interests were best served by providing numerous small exchanges and reducing the length of PPE line required. Operating costs of small exchanges however were relatively high. Although these costs were contained by restricting the opening hours and by operating them on an agency basis they still generally exceeded the extra revenue generated by the subscribers.

The subsidies to rural subscribers were paid for by the profits on other parts of the system and there was always a fine balance between encouraging the rural services and maintaining the overall health of the service. The regulations were periodically revised to maintain this balance. (In theory at least, but there was always some political input).

The object as described later was to provide:—
A telephone that worked, or better,
One that worked all the time, or better still,
One that worked well all the time.

By 1939 the effect of these policies was that in farming areas where properties averaged less than about 250 Hectares, there was a network of part time exchanges and the telephone was within the financial reach of most farmers although many did not avail themselves of the service. In the grazing districts where properties were much larger the telephone was still expensive.

In some cases PPE lines were up to a hundred miles long, with ten or more parties, and gave only a marginal service. However, the realities of technology and economics prevented anything better being provided.

The regulations allowed a subscriber to build a line either to the nearest exchange or the nearest continuous service exchange and rich graziers were sometimes prepared to build long lines merely to get the advantage of continuous service.

The end result of all these factors was a disorderly network of privately constructed lines and about the only thing to be said in its favour was that it worked fairly well and was the best that the country could afford at the time.

Even with the agency arrangements the operating costs of small exchanges were a burden, particularly if the exchange justified continuous service. The idea of a small automatic exchange was therefore attractive and the first Rural Automatic Exchange is claimed to have been locally designed and installed at Barep, Victoria in 1925. By 1930 a handful of standard RAXs from English companies had been installed, apparently as field trials (15), (16), (17). They allowed the Department to get an understanding of the capabilities and limitations of such exchanges.

There were various constraints on their use relating to power supply, trunk line signalling and connection of PPE lines. However there were enough cases where RAXs could be used to advantage to justify their adoption as one of the available types of exchange.

After a hiatus in the depression bulk orders were placed with four English companies for RAXs of up to 200 line capacity. Each company had a different approach to the problem of building an economical unit of this size but all provided essentially the same facilities. A total of 38 were installed by 1941 before the war stopped further supplies.

TRUNK SWITCHING DEVELOPMENTS TO 1939

Australian trunk exchanges before about 1930 were designed for physical trunks with magneto signalling and other types of circuit which could not transmit 16Hz. signals were fitted with signalling devices (ringers) to make them compatible with the switchboards. At most locations the volume of trunk traffic was too small to justify a separate trunk exchange and it was combined to some extent with a local exchange. Three different arrangements could be found in this period.

(1) Very small exchanges had one or two combined A and trunk positions and each operator handled all traffic. Sometimes a special group of jacks and indicators was provided for trunks and junctions.

(2) Larger exchanges had one or more special positions for trunk switching forming an integral part of the exchange.

(3) If the trunk traffic was large enough or there was some problem in combining local and trunk switchboards (for example if the local exchange was automatic) a separate trunk exchange was provided.

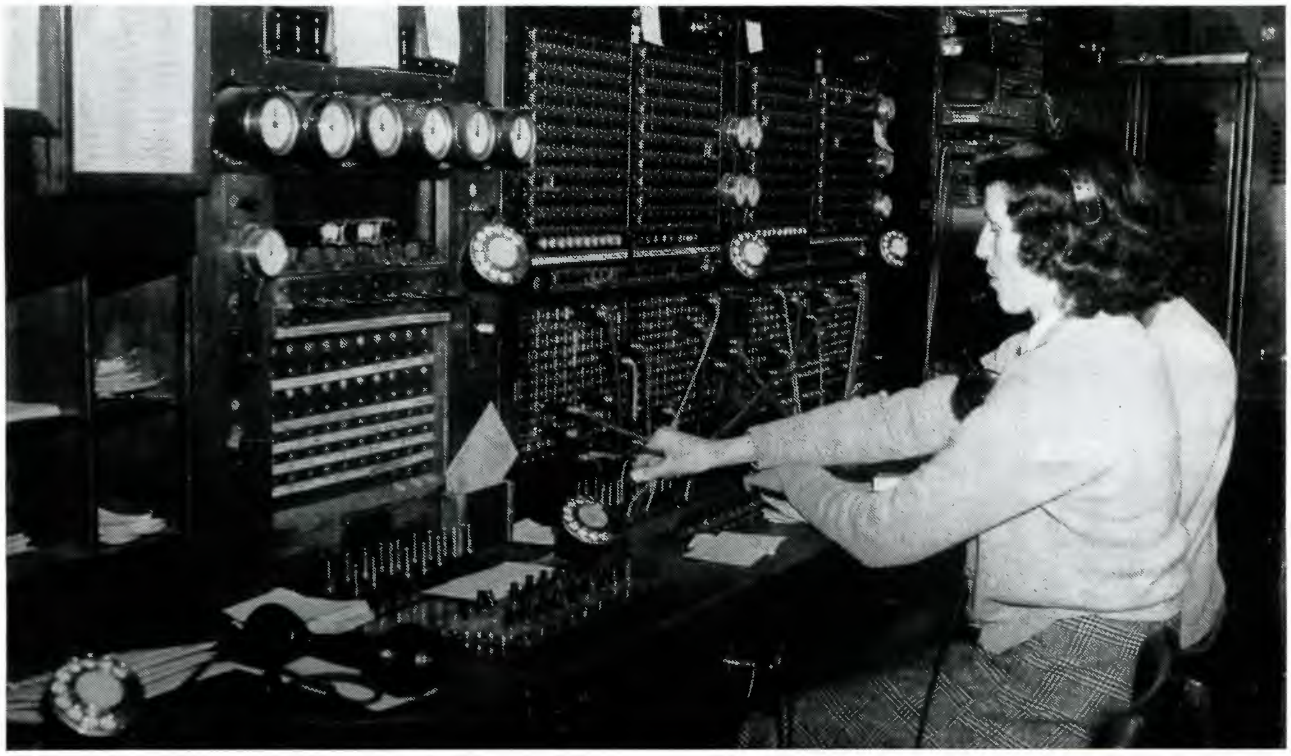


Fig. 1.10 — Queanbeyan Exchange 1950 non multiple magneto A and trunk positions

As trunk traffic grew an exchange would progress from the first to the third of these arrangements. The first two were the most usual and continued in use until the 1980s. As there was no essential difference between trunks and ring down junctions this was both logical and convenient. Timing clocks and pigeon holes for dockets had to be provided and if specialised trunk positions were provided some minor operating aids were included. Some switchboards were made locally and there is a record of two being made in Sydney workshops for Wagga and Wollongong in 1920.

The first stand alone trunk exchanges were needed in the capital city networks. They were imported and were stock items. They were designed for delay working and had separate recording and switching positions. An exchange of this kind was in service in Melbourne in 1908 at Wills Street and was later replaced by one at Central. This reached an ultimate size of 40 switching positions and nine recording positions and was replaced in stages between 1940 and 1942.

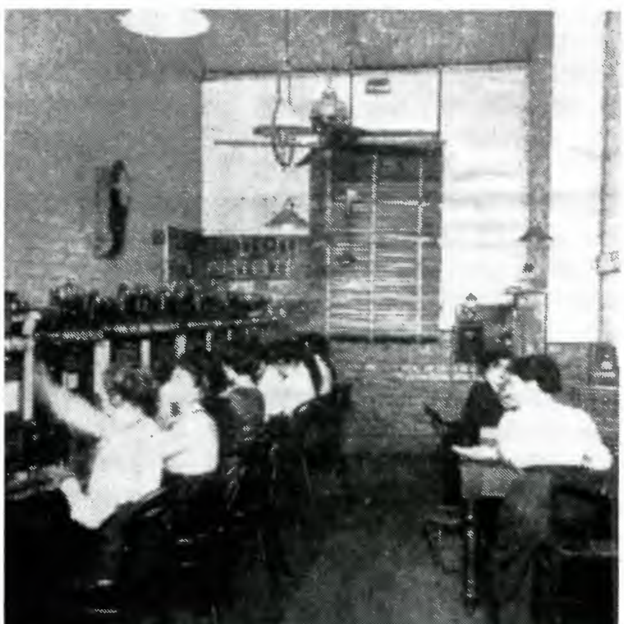


Fig. 1.11 — Melbourne Trunk Exchange Wills Street 1908

Sydney used part of the magneto multiple Central exchange for trunk switching from 1900 to 1915 and the first dedicated trunk exchange was cutover in 1915. The specification of this exchange exists (17) and can be taken as typical of the period although the actual exchange may have departed from the specification. The circuits were essentially the same as a lamp signalling branching multiple magneto local exchange with a few refinements. In particular the cord circuit allowed the operator to speak separately to either party or to both and the operator could ring the local subscriber without the assistance of the B operator. A maximum of six trunks could be connected to each position and two positions had special line and cord circuits for phonophore trunks, an early type of composite system. These used "howlers" for signalling instead of magneto ringing.

Fig. 1.12 — Sydney Trunk Exchange 1934

When Adelaide Central exchange was converted to CB a trunk exchange was installed in the same room. The two switchboards were separate but closely integrated. It grew to 15 positions and in July 1929 it was replaced by a new exchange in a separate room to allow growth of the CB exchange. The new exchange had 24 operating positions (21).

Similar arrangements probably applied at Brisbane and Hobart while Perth's trunk exchange was installed in the new auto exchange building late in 1913. Newcastle is said to have had a trunk exchange installed in 1923 which would have been magneto signalling. In 1950 it had been extended with lamp signalling magneto switchboards. No details are known for Geelong or Canberra, which must have had small trunk switchboards. Other locations were small enough for arrangement described under (1) or (2) above to be adequate and no record exists of other dedicated trunk exchanges.

From 1905 'Phonophore' or condenser telephones were used to allow trunk lines to be superimposed on existing telegraph wires. This allowed the trunk network to be greatly expanded at low cost. They used howler signalling and needed special line and/or cord circuits. Composite systems, working on the same principle, superseded Phonophores and used VF ringers working at a frequency of 135Hz. which gave standard magneto interface conditions at the switchboard.

When carrier telephone systems were introduced in 1925 VF ringers using 500Hz. and later 1000Hz. were used for these systems and became the standard. 135Hz. continued in use in locations where no power was available since it could be powered from dry cells.

As the capital city networks were converted to automatic it became attractive to allow country operators to dial subscribers instead of asking the incoming trunk operator to do it for them. This is first mentioned in the 1923/24 annual report at which time it would have been useful only for Sydney, Perth and perhaps Geelong. The equipment appears to have all been locally made, using a variety of methods. DC signalling over the loop and various derived signalling paths were used initially but these techniques were of limited application. The same problem was being addressed overseas by the development of VF dialling but no equipment was commercially available. Local initiatives in NSW, South Australia and Queensland starting in the 1930s produced workable systems which were fairly widely used.

South Australia was first in the field using a frequency of 2200Hz. and a system providing both way working. 47 trunks were fitted by 1940 and over 100 by 1945. NSW developed a simpler system, limited to one way operation, also using 2200Hz. and had about 30 circuits in service by 1945. Queensland developed a system using modified VF ringers but none was installed before 1945 (19), (20), (21).

Demand working was introduced cautiously from about 1925 on short routes where trunk provision allowed it. In the small country trunk exchanges this presented no problems. It was merely a change in procedures. The larger exchanges, however, could not be used for demand working without fairly extensive modifications.

The problem was avoided in Sydney and Melbourne by supplementing the existing exchange with a new suite suitable for both demand and delay working. Growth in trunk traffic was met by extending this suite and transferring routes to it. Subscribers were instructed to call one of two codes for trunk service depending on the location required. With careful planning it was arranged that all routes on which demand working was possible were on the new exchange, and the old exchange continued to be well loaded.

The introduction of carrier systems and amplifiers in 1925 made it possible for the first time to contemplate an Australia wide trunk network. Achieving this required extra facilities in exchanges, including pad switching and sometimes cord circuit amplifiers. These needs, and the emergence of new signalling systems led to the development of sleeve control switchboards.

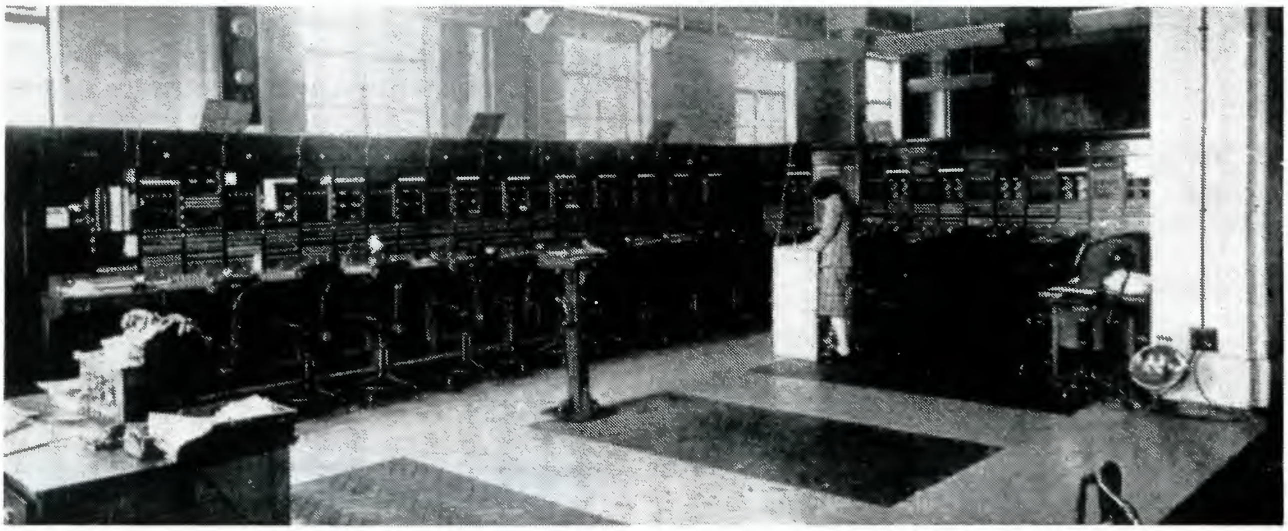


Fig. 1.13 — Hobart sleeve control Trunk Exchange as modified for demand operation

The first such exchange in Australia was installed in Hobart in 1929 as part of the conversion to automatic. The Hobart exchange was designed for delay working but was later modified for demand working. The details of the conversion are given in ref (22). A few other sleeve control switchboards were installed between then and 1942. Two specific cases were at Tamworth in 1939 and Wagga in 1940 when the local exchanges were converted to automatic.

The day to day management of a large exchange with demand working capability was a complex task. It was necessary to decide when a route had to be put in delay, and allocate positions for these routes. This had to be done with hardly any management aids. Operators also had problems. They had to know where every route appeared on the multiple and what destinations the routes could be switched to at the distant end. This difficult task was not helped by the continual changes in routings and periodical rearrangements of the multiple layout to accommodate additional trunks.

In the period under review only two trunk exchanges in Australia were large enough for these problems to be serious. These, of course were Sydney and Melbourne. In 1936 both were due for replacement and tenders were called for semi automatic exchanges in both cities. However a sleeve control switchboard was purchased for Sydney and cutover in August 1938. The reason for doing so is not known, but examination of the tender schedule suggests that the space available for automatic equipment was insufficient. This exchange grew to over 100 positions before it was replaced.

A semi automatic exchange was purchased for Melbourne but its installation properly belongs in the next section.

By 1939 the trunk network had come of age. In 1937/38 a total of 40,000,000 trunk calls were made, increasing to 48,000,000 in 1942/43. Long distance calls were commonplace, although transmission was not always good, especially where several trunks were switched in tandem.

It had always been regarded as a prestige service and in keeping with this attitude various special features had been introduced. These included particular person calls, pre booked calls for a specified time up to a week ahead and reversed charge calls. If requested the cost of a call could be provided immediately after a call was made (ring back pricing). It was even possible to pay for a messenger to call a non subscriber to the exchange to receive a call.

The quality of service varied widely over the country and was greatly dependent on traffic volumes. High volume, short distance routes could economically be given a good demand service. Low volume, long distance routes were forced to accept long delays and often poor transmission. The Adelaide to Perth route in 1939 still had only a single two-wire amplified trunk, and when extended to Melbourne or Sydney the transmission was poor. The long term aim was to give demand service on all routes and satisfactory transmission on any call but it was far from being achieved.

SWITCHING TECHNOLOGY TO 1939

LOCAL MANUAL EXCHANGES

Before 1900 nearly all manual exchanges were imported from Western Electric in USA or England. By 1880 Western Electric was already building switchboards with the brand name 'Standard' which were easily recognisable as prototypes of what became an industry standard. By 1900 this 'Standard' model had taken a form which was not to change significantly for the next 80 years.

There were two significant changes to the electrical design in this 20 year period. The first was a change from low impedance indicators in series with the line to high impedance indicators in shunt. This gave improved transmission and was introduced from about 1890. The second was the change from single-wire earth return to metallic circuit switching. This was a major change involving two-wire cords and new types of plug and jack. The 1/4" (6.3mm) jack and plug was introduced with this change.

Most switchboards installed in Australia before 1890 had series connected indicators but some of these were subsequently changed to a shunt connection. Metallic circuit switchboards were bought from about 1896. Single-wire and metallic switchboards could not work together so a degree of recovery and re-use took place. The single wire boards were gradually relegated to country towns where they could still give satisfactory service.

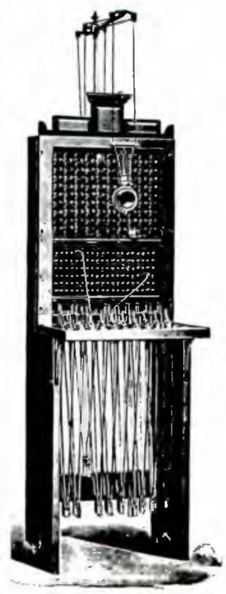


Fig. 2.2 — *Manual Switchboard* 1882

Fig. 2.1 — *Melbourne's first exchange opened* 12 *May* 1880
Compare with later illustration

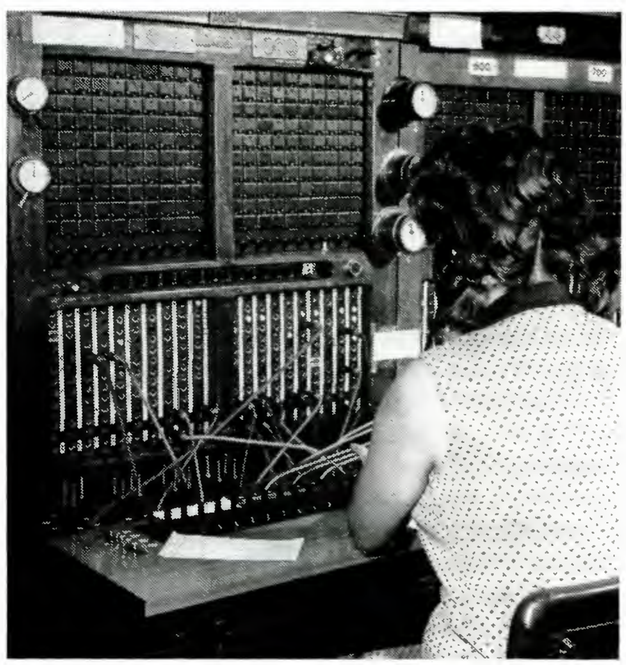


Fig. 2.3 — *Magneto Telephone Exchange Richmond*, NSW 1973

Some unusual switchboards were made in the early years of telephony and at least a couple found their way to Australia. The second Sydney exchange was a cordless design, not unlike a crossbar switch, and the first Adelaide exchange had the plugs and cords above the switchboard.

The first series multiple switchboard in Australia was in Melbourne and was arranged with the plugs and cords above the switchboard in order to allow very long cords to be fitted. It was designed for a multiple capacity of 3600 lines. Three other series multiple exchanges were installed, in Sydney in 1887 and in Adelaide in 1894 and also in Brisbane. These were all of the same type and had the cord shelf above the calling and clearing indicators to allow longer cords. Single-wire switching was used and they were built in self contained sections of two positions and had a multiple capacity of 3000 lines. The Sydney exchange was fitted with double cord B positions at some stage in its life. Adelaide probably had B positions from the start for Port Adelaide junctions and by 1901 was using order wires. Brisbane was replaced before there were any suburban exchanges and no B positions were needed.

A feature of series multiple exchanges which seems remarkable now, is that an exchange of up to 3600 lines could be and usually was, powered entirely from primary batteries.

Branching multiple exchanges were first installed in Australia towards the end of the century and by July 1901 were in service in Sydney, Brisbane, Windsor (Vic), Perth, Fremantle, Kalgoorlie and Boulder. They were all from Western Electric and were almost identical. A feature was self restoring indicators, which could be placed at the top of the switchboard leaving more space for the jackfield. They used more power than earlier switchboards and required secondary batteries. Reticulated power was still rare and sometimes a local gas engine and dynamo set had to be installed to charge the batteries. The exchanges usually had single cord B positions and facilities for order wire working using magneto clearing signals. Later exchanges of this type had subscribers' meters operated from a push button on the A position cord circuit.

Lamp signalling magneto was a development of the above branching multiple exchange and one type was designed to be converted later to CB. The idea was that it could be installed and work with the existing lines and at a later date when the line plant had been upgraded sufficiently to allow CB to be used the equipment would be modified.

The CB multiple exchanges installed before 1940 were fully imported and only two models were used. CB No.1 (BPO designation) was meant for large exchanges with a multiple capacity of about 11,000 lines. Single cord B positions were provided with 20 cords on early exchanges and 34 on later supplies. Lamp signalling order wires were provided for junctions to suitable exchanges as well as facilities for magneto junctions. CB No. 9 was a smaller type.

The only significant local initiative in manual technology in this period was the development of series multiple B positions working with non multiple A positions. Apart from the Melbourne Central Exchange which may have been the first application, most of the development took place in NSW.

Details are scarce but the first installations were made in 1907 using imported 'Incoming Junction Switchboards' which were actually two position sections of a series multiple B suite. A copy of the tender schedule and an indistinct photograph of the installation of Ashfield give the only technical details. They were designed for order wire calling and magneto clearing. They had a multiple capacity of 3000 lines but were fitted for 1000. At least eight exchanges were fitted with these positions. Some alterations would have been needed to both the existing A positions and the new equipment to allow interconnection.

These positions seem to have been used as test beds to try out more efficient signalling methods, based on the CB exchange at City and published information from overseas. It was fairly easy to provide a system of lamp signalling similar in operation and equal in performance to junctions between CB exchanges.

In 1910 and 1911 the experience gained was used to build three new exchanges with the combination of non multiple A and series multiple B positions. These could be described as tidied up versions of the earlier expedient taking advantage of the fact that it was a new installation. One extra feature was that local calls needing transferring were switched by the B positions, giving an increase in efficiency and eliminating the numerous A-A transfers otherwise needed. Because of the reduced work load of the A positions and lower calling rates due to the introduction of metered calls it was possible to increase the size of the A positions to 200 lines.

This design seems to have been regarded as a second grade, but acceptable, option and was used at various times when nothing better was available. In fact, it was probably better in many cases than the conventional full multiple or automatic exchange. One advantage was that the amount of site specific equipment was a minimum. These exchanges could be produced rapidly, and the A positions were reusable when replaced.

One can only speculate as to the degree of local originality in these developments. The overseas view was that CB was the only satisfactory system for large cities and magneto exchange development was neglected. However there were large magneto multiple exchanges in service and lamp signalling junction circuits were developed for them. The economics of non multiple A positions in CB exchanges in large networks was recognised overseas, but no magneto

Fig. 2.4 — Hamilton Exchange, NSW non multiple magneto A *positions series muliple* B *positions*

exchanges seem to have been built in this form. In any case the result of the design effort was the first uniquely Australian type of telephone exchange.

STEP-BY-STEP TECHNOLOGY TO 1939

From 1912 until some years after 1939, practically all automatic equipment was imported, first from AEC Chicago and later, when manufacturing began in the UK, from the five British manufacturers. All design was carried out by the manufacturers and very little was designed to meet specific Australian needs.

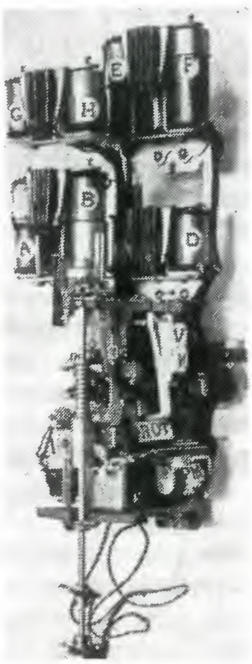


Fig. 2.5 — Strowger Final Selector as installed 1912

The first AEC equipment, supplied from 1912 to 1915 used 'uncovered' switches with relays sprouting out in all directions. Keith line switches were used as preselectors, and there were usually two preselector stages known as primary and secondary line switches. The circuit techniques were rather primitive and most of this equipment was replaced after a fairly short life.

By 1919 when the next exchanges were supplied there had been a large amount of development and change. As well as many circuit improvements, the constructional detail had been reviewed. Relay mountings on selectors had been changed to a style which continued to be used for all future step-by-step switches and which allowed covers to be fitted. Preselectors and finals for 100 lines were mounted as a single unit called a 'primary board' while group selectors and repeaters were mounted on double sided frames called 'trunk boards'. Except for the Siemens No.16 in Brisbane this type of layout remained standard for all equipment supplied until 1938.

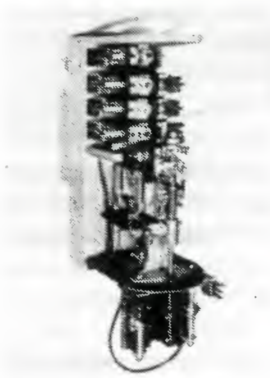


Fig. 2.6 — Strowger Selector Covered Switch

At City North (Sydney) 25 outlet uniselectors were used for the first time as secondary line switches in place of Keith switches. These switches were also used as junction hunters to improve junction occupancy at City North but this may not have been the first such application. In later exchanges 25 outlet uniselectors were used as primary line switches without secondaries.

Manufacture of automatic exchanges began in England about 1925 and this became the main source of equipment. With one exception the English equipment was electrically and mechanically interchangeable with the equipment from AEC Chicago. There were minor differences, particularly in the preselectors, but the whole range was (incorrectly) called Strowger.

The use of SSR's to avoid 'tromboning' local traffic was tried and discarded in 1915 in Sydney. Better designs became available about 1926 and were used fairly extensively.

Interconnection of group selector outlets was performed partly on terminal strips at the end of the selector boards and partly on an IDF. Two types of terminal strip were used. The early type was known as 'fishback'. It gave a primitive type of homogeneous interconnection but was difficult to design and rearrange. This was superseded by an arrangement known as 'piano wires' when sequential gradings were discovered. Sequential gradings were more flexible and efficient and far easier to change.

The equipment used in the Brisbane network was Siemens No.16 manufactured by Siemens Brothers in England. Although the selector mechanism was almost the same as Strowger the circuit arrangements were different and interworking was difficult. For this reason Brisbane used this type of equipment exclusively until 1947. The main differences were the use of interrupted ground from a central source to drive switches when hunting, provision of A party battery feed from the first selector and different junction signalling. Ten point rotary switches were used as primary and secondary subscriber preselectors and all equipment was mounted on single sided racks.

By 1939 the APO had adopted the BPO 2000 type equipment as the standard for new exchanges and a small amount had been installed. Details of this equipment appear in chapter 4.

TRUNK TECHNOLOGY

All early trunk lines used magneto signalling and special switching facilities were seldom provided. They were terminated in the same way and on the same positions as ring down junctions and if there were enough of them they were grouped on one or more special positions, which were not much different from the rest of the exchange.

Dedicated trunk exchanges began to appear in Australia from 1908 and before describing their design a short digression into matters of operating procedures and traffic theory is appropriate. The interaction between these factors and trunk exchange design was always important.

OPERATING PROCEDURES

Two manual trunk operating procedures were generally used, known as delay working and demand working. Delay working was a system of queueing calls to get greater usage from trunk routes without unduly inconveniencing the subscriber. Demand operating gave almost immediate service but was more costly to provide.

The following description of the delay operating procedure at a large exchange is taken from the specification for a new trunk exchange in Sydney printed about 1912.

(a) A local subscriber desirous of using a trunk line calls for the trunk recording telephonist, and is connected to the trunk recording desk.

(b) The trunk recording telephonist enters on a ticket the particulars of the desired connection, informs the subscriber that he will be called when the trunk line is disengaged, and passes the ticket to the trunk telephonist operating the position on which is situated the answering jack of the required trunk line.

(c) When the call is about to mature, that is to say, during the currency of the call preceding it the trunk telephonist communicates by order wire with the proper junction telephonist and has the local subscriber's line connected to the switchboard .

(d) By the time the distant subscriber has been connected to the trunk line, the local subscriber has been signalled by the trunk telephonist, and connected to the trunk line. Conversation then ensues.

(e) Calls inward will be dealt with in substantially the same way particulars of the required connection being entered on a ticket by the trunk telephonist (not the trunk recording telephonist) and the connection made in due course.

This method of operating ensured that all calls were handled in strict order and that both the calling and called parties were waiting before the preceding call had finished. It allowed even small trunk groups to operate at high traffic efficiency. Long delays were not needed to achieve this object and routes were seldom designed for average delays of more than 30 minutes in the busy hour. The longer delays which were so often met were an indication that the trunk provision was inadequate.

With demand working the call was set up by the operator who wrote the docket, usually while the subscriber waited. This was only possible if the subscriber did not have to wait too long and therefore the trunks were used less efficiently. However, the operating costs were less and subscribers preferred demand service. Indeed there was often a large growth in traffic when a route was changed from delay to demand working.

The choice between planning a trunk route for delay or demand working was never simple and involved such intangibles as the customers expectation and the possible stimulus to demand. The two most tangible considerations were the cost of extra trunks and the saving in operating costs. Table 2.1 gives the trunk occupancy which could be achieved with different sized routes under three conditions of average delay. These delays are 15 minutes, which would be regarded as a good service with delay working, 1.5 minutes which is about the longest delay tolerable with demand working and 0.5 minutes which would be a good demand service.

Table 2.1 Occupancy of circuits

Delay in Minutes	**Number of circuits in route**					
	1	2	5	10	20	50
15	0.71	0.84	0.93	0.96	0.98	0.99
1.5	0.2	0.45	0.7	0.82	0.89	0.95
0.5	0.08	0.28	0.55	0.71	0.82	0.9

It can be seen that the traffic advantage of delay working is greatest for small routes and becomes insignificant for a large enough route especially since the practical upper limit of occupancy is about 0.9.

With regard to the relative costs of trunks and operators, in 1910 the cost of a trunk line was of the order of 100 times an operator's annual salary, whereas today the cost of a trunk line is less than the average operator's salary. As an indication of the trunk traffic in early years there were only two trunks in 1910 from Sydney to beyond Penrith. In 1925 there were four trunks from Sydney to Melbourne and one from Sydney to Brisbane.

EXCHANGE DESIGNS

It is hardly surprising that early trunk exchanges were specifically designed for delay working. With delay working, booking and switching of calls were separate functions and in large exchanges specialised positions were provided. The recording positions were merely answering posts where the dockets were prepared. The line positions were electrically not much different from a magneto A position. Jacks and indicators for up to 10 trunks were usually provided. Access to the local network was provided with an outgoing junction multiple, order wires to other exchanges and dials for calling automatic numbers if required. There was sometimes an outgoing trunk multiple for transit switched calls or alternatively a special through switching position with second appearances of all trunks. Pigeon holes for docket storage and switchboard clocks for timing calls occupied much of the switchboard face.

There was a lot of movement of dockets, from the recording operators to the trunk operators, and then to pricing operators and 'docket runners' were continually moving around the exchange. Pneumatic tubes were used in very large exchanges.

With demand working there was no specialisation. Each operator might have to connect a call to any trunk connected to the exchange and special recording positions could not be used. A full trunk multiple was necessary and in order to make it easy to find a free trunk on a route it was highly desirable to provide busy lamps with every appearance of a trunk on the multiple.

Demand working was usually introduced on only a few routes from an exchange while others remained in delay. The demand operators answered all requests for trunk calls but if the call was for a route in delay the docket was placed in a pigeon hole for collection and distribution to a nominated 'delay' operator handling calls to that route. Any position could be used for connecting delayed calls.

Small trunk exchanges with up to three positions were inherently suitable for either delay or demand working. All operators could reach any trunk jack and arrange any docket shuffling between themselves.

SIGNALLING

Some derived trunk circuits could not transmit 16Hz. ring and these circuits signalled with VF ringers using frequencies ranging from 135Hz. to 1000Hz. These provided magneto signalling conditions at the switchboard. Magneto ringing from the switchboard was detected and caused the VF signals to be transmitted to the trunk. At the distant end the VF signal was detected and caused 16Hz. ring to be transmitted to the switchboard at that end. There was also an earlier system in which a VF signal was generated by a buzzer and received on a 'howler', a loud speaker roughly tuned to the buzzer frequency. This required special arrangements such as keys on the switchboard associated with the line or special cord circuits.

With the conversion of local networks to automatic a need was seen for distant trunk operators to dial subscribers in those networks themselves instead of asking the incoming operator to do it. Where the trunk circuit was suitable this was done by DC signalling over the loop or on a derived composite circuit. If DC signalling was impossible, VF signalling was employed. Bursts of tone of varying length were used to represent different conditions such as seizure, release or dialling. Systems using one frequency, known as single frequency or 1VF systems were limited in the range of signals they could provide. Systems using two frequencies (2VF) were more versatile and could provide additional facilities which would produce operating advantages in manual networks.

The need for better signalling facilities was also addressed by the makers of carrier equipment and signalling paths were provided as an integral part of some carrier systems. The first such systems purchased for Australia were installed on the Sydney to Maitland cable in about 1942. On later systems the signalling leads were designated E and M and E and M signalling became the generic name for this arrangement.

TRANSMISSION CONSIDERATIONS

Long distance telephony requires the use of amplifiers and because both way speech is required there are problems with stability. If too much amplification is used there is either singing, a hollow sound or excessive echo. If too little is used the received speech is too weak. Additional facilities were needed in trunk exchanges to solve these problems.

Where amplified trunks were switched together the best arrangement was to provide separate speech paths through the exchange for the two directions of transmission i.e. four wire switching. It was difficult to implement and a compromise known as tail eating which was nearly as good was developed. It still required four wires through the exchange but did not require much change to existing switchboard designs.

It was also necessary to vary the gain of a trunk circuit depending on the type of circuit to which it is switched. This was usually achieved by fitting switched pads (attenuators) in the trunk line relay sets and this needed signals between the relay sets to control the pad switching.

Another way to control transmission was to fit some cord circuits with amplifiers and use these cord circuits when particular trunks were connected together. For example, when the Adelaide-Melbourne and Melbourne-Sydney trunks were both physical circuits, a cord circuit amplifier at Melbourne allowed satisfactory transmission on a call from Adelaide to Sydney.

SLEEVE CONTROL SWITCHBOARDS

Sleeve control trunk exchanges were designed to overcome limitations in magneto trunk exchanges. The principle behind this type was that all trunk line relay sets provided the same interface conditions to the switchboard. This allowed new methods of signalling to be introduced without the need to change the switchboard circuits. The name derives from the fact that most of the signals between the switchboard and the line relay sets were carried on the sleeve wire.

The few sleeve control exchanges installed before 1940 were fully imported company designs. The first one in Hobart had two wire switching and pad switching to control transmission levels. The Sydney exchange was more sophisticated and included provision for tail eating. Standard line relay sets were provided for magneto or 2VF signalling and local designs were developed to connect the home grown VF signalling systems.

NETWORK DEVELOPMENT 1939 to 1963

CAPITAL CITIES

2000 type equipment became the APO standard from 1938 but small quantities of pre 2000 type continued to be bought to fill gaps in existing suites. There was also at least one contract let for supply of Strowger equipment from America early in the war when supplies from the UK were limited.

Between 1939 and 1945 the capital city networks were under considerable pressure and with little new equipment available it was necessary to get the most possible out of what was available. Most of the 'make do and mend' was never documented.

Fig. 3.1 — 2000 Type Equipment racks

The Department was also required to provide assistance to the war effort in many ways and as this was often secret work there are few records. The following notes are merely a few items known personally to the writer.

In Sydney and, presumably, other cities an air raid warning system with sirens over the whole area was set up using PMG lines and equipment designed and built by the Department. This was controlled from a central location. A network was also set up to switch off street lighting during air raids also controlled from that point.

Contingency plans were prepared for use if a telephone exchange was destroyed by enemy action. As well as arrangements to transfer 'emergency' subscribers to a nearby exchange, a network of 'shadow' exchanges was set up. These were small manual exchanges in inconspicuous places close to main cable routes. Later a few portable exchanges were built from available units with the intention of using them to restore service. Towards the end of the war they were put into service as extensions of existing exchanges on the understanding that they might need to be pulled out in the unlikely event of an exchange being bombed or sabotaged.

Although these portables were never needed for their original purpose, they were invaluable in the post war years to solve short term network problems and many more portables were built and used up to about 1970 (1). Years later portables were used to restore service in Canberra after the Civic exchange fire.

For many years after the war there was a chronic shortage of cable pairs and some use was made of line concentrators to give service where there were unusual problems in providing relief cables (2), (3), (4). They never played a large part in the Australian scene.

In the years from 1945 to 1963 the capital city networks were extended in step-by-step and grew to about four times their pre war size. This required major changes in the networks and in the cases of Sydney and Melbourne the limits of six figure numbering were reached. The following accounts of each network give the main developments.

SYDNEY

As mentioned in the previous section, a redesign of exchange areas had been carried out just before the war and a tentative numbering plan produced. This plan would have soon run out of numbers and the first task of the new Planning section headed by E. Sawkins was to review the numbering. Various ways of growing to seven digits were examined and rejected in favour of a rearrangement of main exchange areas to extend the life of six digits. Satellites were used extensively and studies were made of the impulsing performance of the multi link routings involved (5).

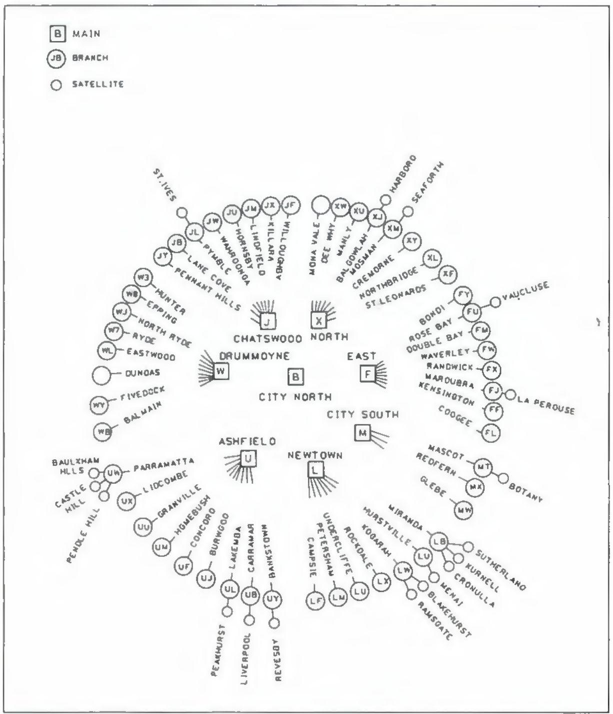


Fig. 3.2 — Switching and Numbering proposed for Sydney 1941

The new numbering and switching plan had nine main exchange areas instead of eight, and required changes in the switching and numbering of about 20 exchanges as well as the setting up of the two new main exchanges at Redfern and Homebush. The CBD was to be served by five exchanges in a co-main configuration. At the time the Cumberland County Plan was intended to hold down the population of Sydney and surround it with a green belt. It was expected that because of this, six digits would suffice for at least 20 and possibly 30 years.

This plan required the use of level 0 for the Homebush main exchange area and it was no longer available for the trunk exchange code. A study was made of the false traffic on level 1 and it was concluded that codes starting with 11 would be usable for trunk exchange codes.

There was a rather ambivalent attitude to this plan. It had the potential of being a long term solution for the Sydney network, and even those who doubted this acknowledged that a more ambitious plan, involving seven digits and almost certainly registers, was beyond the resources of the Department. As it turned out, the decision to stay with six digits and other decisions made at the time created the situation which allowed the APO to embrace crossbar as the standard system for all applications in 1960.

An advantage of this plan was that it could be introduced gradually, whereas the seven digit proposals would have needed large expenditures early in the programme. This plan was the basis of planning for the next 15 years but it was never completely implemented.

The limits of six digits were first breached in 1958 in Sutherland shire, served by three exchanges, Miranda, Sutherland and Cronulla which shared a single 10,000 line number group. A band-aid job fixed this up while the whole question of renumbering was examined.

By then it had been decided to introduce Extended Local Service Area (ELSA) and extend the closed numbering area to about 25 miles radius. This made the early introduction of seven digit numbers essential and it was also necessary to clear level 0 for Subscriber Trunk Dialling. A new numbering and switching plan was produced which allowed orderly progression to seven digit numbering. This plan has been followed to the present, with minor adjustments. It is essentially a step-by-step numbering scheme and must remain so until all step-by-step exchanges have been replaced. The crossbar switching scheme, however does not always follow the step-by-step plan.

MELBOURNE

Up to 1939 the numbering and switching scheme for Melbourne proposed in 1921 was adequate. A revised plan had been produced by 1944 with provision for 57 exchanges (6). It involved replacing three of the earliest main exchanges which had of necessity been placed in less than ideal locations.

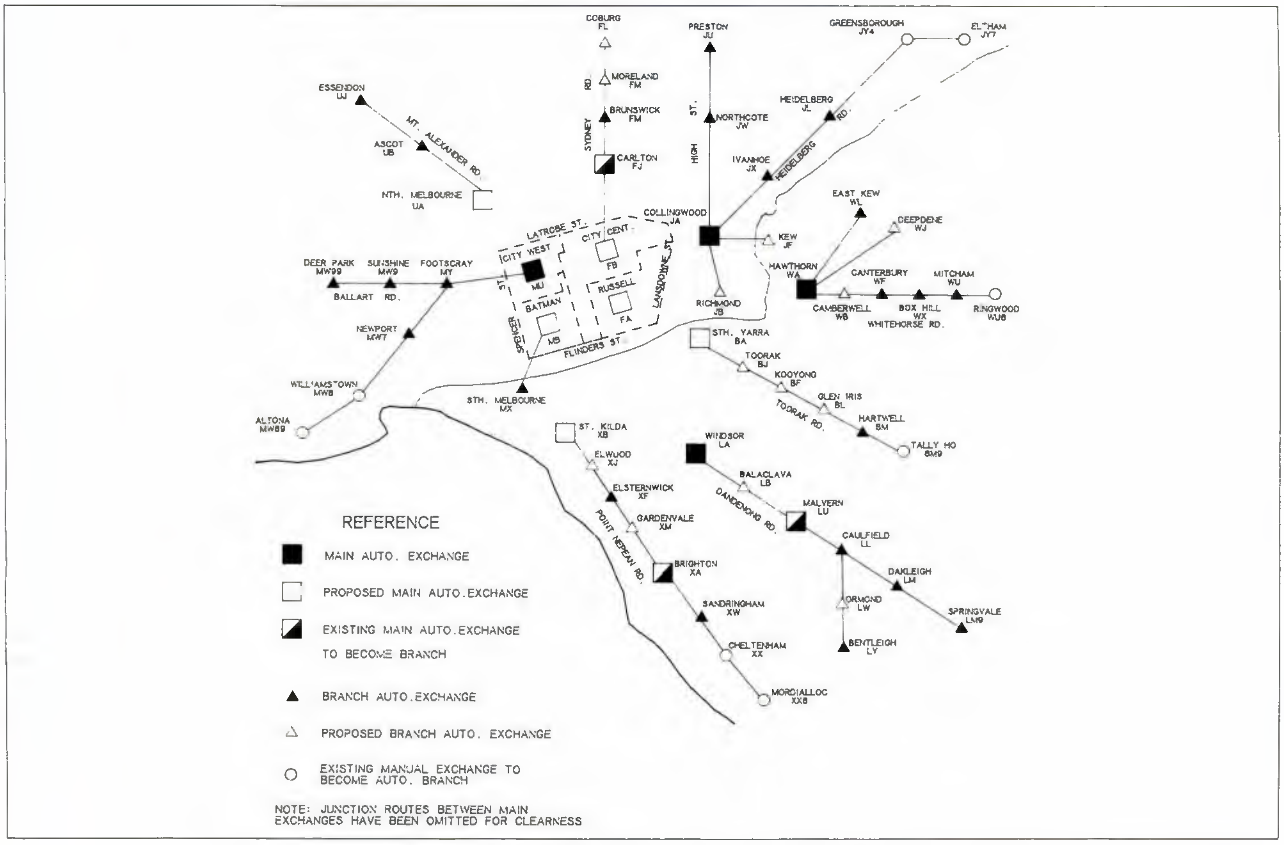


Fig. 3.3 — Switching and Numbering proposed for Melbourne 1944

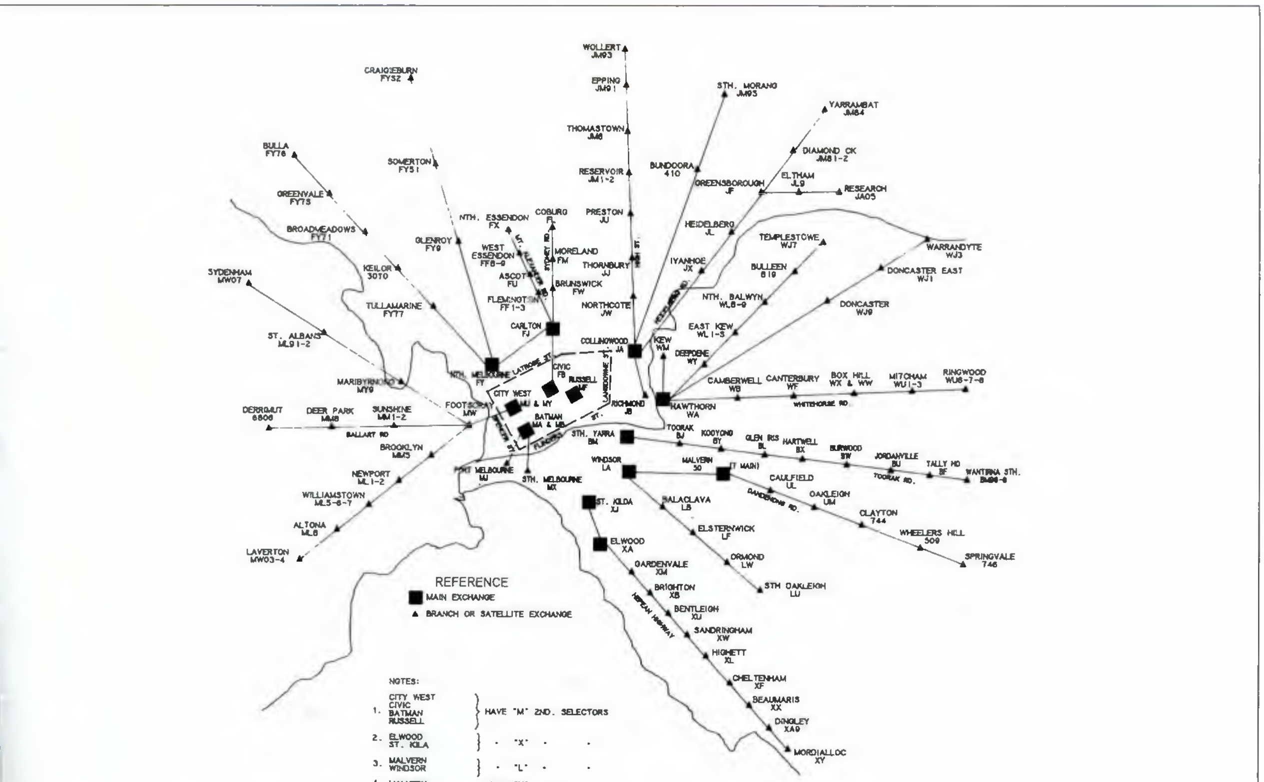


Fig. 3.4 — Switching and Numbering for Melbourne 1959

As with the Sydney scheme it could be implemented gradually as need or opportunity dictated and was still incomplete by 1960. The introduction of ELSA in 1960 was achieved by the use of level 7 which was still very lightly committed. Figures 3.3 and 3.4 show the 1944 plan and the situation in 1959.

Extensive use was made of alternative routing from DSRs in the Melbourne network to get more efficient trunking.

ADELAIDE, PERTH, BRISBANE, HOBART

The only significant change in the Adelaide network was the final replacement of Central CB exchange in 1955 (7). The established five and six digit numbering and switching scheme needed only minor changes to allow for new branch exchanges and the capacity of six digit numbering was adequate.

Perth grew rather slowly in the years to 1963 and no fundamental changes were made to the network.

In Brisbane the Siemens No.16 equipment caused some problems when 2000 type was introduced because of some basic incompatibilities. Interface relay sets had to be designed to solve these problems and the switching plan was modified to reduce their impact. Apart from this, there were no fundamental changes.

HOBART

Hobart grew from a mixed four and five digit scheme to a uniform five digits and by 1963 was approaching the limits of five digits.

CANBERRA

Canberra continued to be served by a single exchange with mixed three and four digit numbers until 1949 when a second exchange was opened at Civic with five digit numbering. The old Central exchange was progressively replaced by new exchanges at Barton and Deakin and a full five digit scheme introduced. A fourth exchange was opened at Yarralumla in 1954 and trunked as a branch of Barton.

On 22 September 1961 the Civic exchange was destroyed by fire and the restoration of service was a massive feat in which many parts of the Department played important roles. A replacement exchange was cutover 51 days after the fire (8).

COUNTRY EXCHANGES AND NETWORKS

By 1939 many country exchanges were reaching the point where conversion to automatic was justified. It seemed that the automation of most large country towns would be a fairly rapid process. However the war interrupted this process after only four exchanges had been converted as listed in the preceding section.

After the war the Australian Post Office faced a large backlog of unsatisfied demand with limited resources and a world shortage of automatic equipment and production capacity. The economic justification for conversion of country exchanges with less than about 2000 lines was marginal, since there was usually a need for a manual trunk exchange and operating staff facilities could be shared.

CB multiple was therefore adopted as the standard equipment for country exchanges of up to 2000 lines with 3000 lines possible by raising the multiple. Automatic was only to be used for larger exchanges or for special cases.

Fig. 3.5 — Queanbeyan Exchange 1954 CBM *Local and Sleeve Control Trunk Positions.*

The peak years for CBM installation were from 1950 to 1956 by which time supplies of automatic equipment were more readily available. A few more were installed in slow growing country towns in 1957 and 1958. Two unusual CBM exchanges in NSW were Bathurst, cutover in 1955 and Dubbo in 1956. These were fitted with terminating automatic access to allow trunk operators to dial subscribers direct. At Toowoomba in Queensland a CBM exchange was installed to supplement the magneto multiple exchange and over 5000 manual subscribers were served by the two exchanges before they were replaced (9). Most CBM exchanges were installed in timber framed or aluminium buildings of standard designs.

A CB non multiple switchboard was also designed for use in smaller exchanges. It was intended to use them whenever a small magneto exchange was replaced but few applications were found. The first was installed in Berry as a field trial. No more than about 30 or 40 were installed and they did not play a significant part in the network.

Except for RAXs automatic conversions in country areas between 1945 and 1956 were limited to cases where there was a compelling economic or other reason. Automatic was usually installed if the exchange would soon exceed 2000 lines but there were exceptions such as Toowoomba detailed above. Another example of the measures taken to minimise expenditure is the use of automatic at Goulburn to meet growth while keeping the magneto exchange in service (10). One major project carried out at this time was the conversion of the Newcastle network which is considered in more detail later.

Magneto exchanges were allowed to grow to the limit of the available switchroom space, in spite of the inefficiency of the transfer working involved. The largest non multiple magneto exchange in NSW was at Cowra. It had been relocated in a new switchroom during the war and was allowed to grow to 2600 lines.

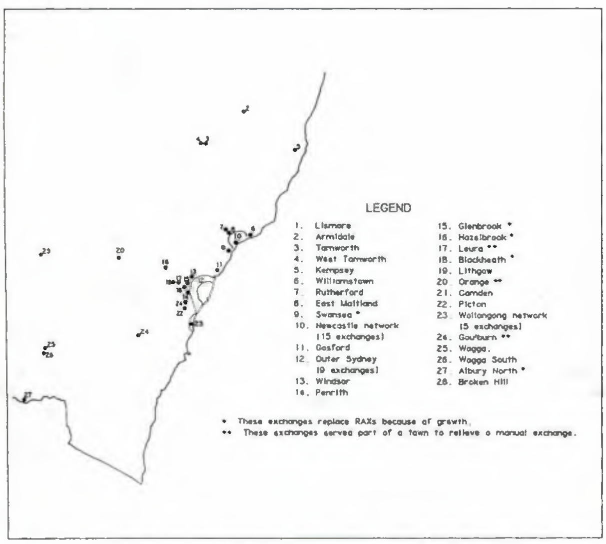


Fig. 3.6 — Country Automatic Exchanges in NSW at 1960

After 1956 the policy was to use automatic whenever an exchange needed replacing and could be justified economically, but not to deliberately convert exchanges that still had reserve capacity. Networks of automatic exchanges began to emerge and plans were developed for the full automation of local calling with at least some short distance trunk dialling by subscribers. These plans assumed step-by-step equipment but it was quickly recognised that something more versatile was going to be needed.

By 1960 there were several distinct types of automatic exchanges and networks in country areas. Most common was a single automatic exchange with three or four digit numbering and with access to an operator on level 0 and sometimes access to nearby manual exchanges on single digit codes. This was the standard arrangement for RAXs and by analogy it became known as RAX trunking.

A few cities developed simple networks of two or three exchanges. At Tamworth, for example, an exchange was established in a new industrial estate at West Tamworth. Another pattern was a ring of RAXs surrounding the town with special dialling instructions. A third was a small automatic exchange in an outlying part of a large town, with the central area still manual. This was done to extend the life of the manual exchange. One case was Toowoomba, referred to in chapter 5.

A different category was an automatic exchange near the periphery of a unit fee area and within unit fee distance of part, but not all of that area. For example, Palm Beach had local call (unit fee) access to Mona Vale exchange but no other part of the Sydney unit fee area. By judicious choice of codes and access barring Palm Beach subscribers called Mona Vale using directory numbers, while Mona Vale subscribers dialled a special prefix for Palm Beach. Other boundary cases were more complex but as far as possible, if two automatic exchanges were within unit fee distance dialling between them was provided.

Larger networks were rare and had individual features. Three examples, all from NSW are Newcastle, Wollongong and Campbelltown and are described below.

Newcastle was a special case, being the largest country city in Australia. It was the only country city large enought to be declared a unit fee network. The network extended five miles from the Newcastle post office and had three large exchanges; Newcastle which was branching multiple magneto installed in 1910, Hamilton and Waratah which had non multiple A positions and series multiple B positions. There were also some smaller non multiple exchanges.

Conversion to automatic had been planned before 1930 but was deferred by the depression. The network plan seems to have been for three main exchanges at Newcastle, Hamilton and Mayfield (replacing Waratah) and five figure numbering. The first actual conversion as Newcastle on 19 March 1941 one of the last of the pre war orders to be supplied. In March 1944 to satisfy the needs of wartime industries a temporary automatic exchange was installed at Hamilton which supplemented the manual exchange. It was built up from recovered equipment and was meant as a stopgap.

After the war the exchanges at Hamilton, Waratah and New Lambton were in urgent need of replacement and the case for automation was very strong. The pre war plans were no longer appropriate and they were revised before any further conversions were carried out. Some details of the revised plans have survived and they show major changes from what seems to have been the pre war plan.

A major consideration was that the network was approaching the point where expansion to a ten mile radius would be justified under the telephone regulations. This would bring nine more exchanges into the network, served by open wire routes which had limited capacity and would be costly to replace with cables. The switching plan had to recognise these limitations at least in the short term.

At the same time, much of the additional area was still rural and new exchanges would probably be needed when the land was developed for residential use. In the older part of the network a review had identified the need for several additional exchanges.

The new switching plan involved two main exchanges, six branches and seven satellites. A mixture of five and six digit numbering was proposed.

The next two automatic exchanges in the network were Mayfield and New Lambton in 1947. They were trunked as branches of Hamilton in accordance with the new plan although the network was not extended until 1950. The 1947 plan was followed initially for this extension but major changes were made as the outer areas were developed and the final form was a main/branch network with four main exchanges. In most respects this network was then a small scale version of Adelaide, Brisbane or Perth.

Most of the branch exchanges had SE50 DSRs which could switch on first or second digits and fortuitously the numbering allowed routes from terminal exchanges to second selectors in foreign mains, particularly Newcastle. The ten mile radius included almost all of the Newcastle suburbs but one notable exception was Swansea in the south. It was given unit fee access to Belmont in a similar way to Palm Beach.

The introduction of ELSA in 1960 and renumbering for STD required the Newcastle unit fee area to be part of a much larger closed numbering area. The renumbering had to allow step-by-step switching to continue while allowing subscribers to dial as many unit fee calls as possible and barring trunk distance access. The objectives were incompatible but a numbering and switching plan was produced which came close to achieving them (11). This was helped by the existence of four spare first digits. All this was done within the constraints of step-by-step trunking and the limitations of individual exchanges. Only much later, when an ARM crossbar trunk exchange was installed at Hamilton was subscriber dialling of all unit fee and trunk traffic achieved.

Wollongong is typical of several major industrial complexes which developed outside the capital cities after the war. Its development actually began before the war with the BHP steel works. By 1945 Wollongong was the commercial centre for a string of mining towns along the coast and the industrial complex at Port Kembla. Rapid growth was predicted and it was apparent that the nearby towns would become commuter suburbs. However the telephone development was not enough to have it declared a unit fee area.

Each exchange therefore had unit fee access to only those exchanges within five miles radius of itself. Three exchanges, Wollongong, Port Kembla and Unanderra were within unit fee distance of each other. In addition, Unanderra could call Dapto and Wollongong could call Corrimal for unit fee. A closed numbering scheme was therefore developed, extending initially from Unanderra to Corrimal and with the potential to extend it to Thirroul.

Dapto was converted to CBM in 1952 and the other four exchanges were converted to automatic between 1952 and 1956. Access barring was arranged at each exchange on codes to trunk distance exchanges. Each exchange still appeared as separate entries in the directory with different dialling instructions. It was expected that multimetering would eventually allow subscribers to dial all calls between these exchanges. When ELSA was introduced the access barring was removed and the numbering plan extended to a larger area.

In 1960 the Campbelltown secondary area was in a state of transition from a rural district to a commuter suburb of Sydney and beginning to acquire light industries. The switching plan was for a secondary centre at Campbelltown and minor centres at Camden and Picton. There were a number of RAXs in the area and both Campbelltown and Camden were in need of replacement. New junction and trunk cables were planned as part of the Sydney — Melbourne coaxial cable project. It therefore seemed a good application for step-by-step multimetering, and plans were produced to convert the three minor centre exchanges to automatic and provide the maximum possible STD both within the area and to Sydney.

By the time planning had commenced the Community Telephone Plan was about to be released with simplification of the charging system and this was allowed for in the design. Indeed, it would have been impossible to produce a satisfactory plan otherwise. The resulting numbering and switching plan was complex with codes chosen to segregate unit fee and multimetering traffic as far as possible as well as segregating certain transmission classes. There was considerable complexity in the trunking, and first selectors at Campbelltown, Camden and Picton were segregated into blocks with different trunking arrangements (23). Campbelltown was a secondary centre so some traffic needed to be four wire switched and step-by-step switches were modified to give two wire or four wire switching on different levels. It was an example of what step-by-step could be made to do, but equally of what it should not have been asked to do. Experience with this and other less complex configurations played some part in the decision to change to a register controlled system.

During this period rural areas continued to be served by small magneto exchanges, RAXs and PPE lines. The regulations were revised in 1950 and published as Circular Memorandum Number 4 of 1950 (CM4/50). This document, with several addenda over the years remained in effect until 1970.

Two standard APO type RAXs were used throughout this period and between 700 and 800 were installed. The overall magnitude of the RAX program was set by Headquarters while the States were responsible for allocating the available units.

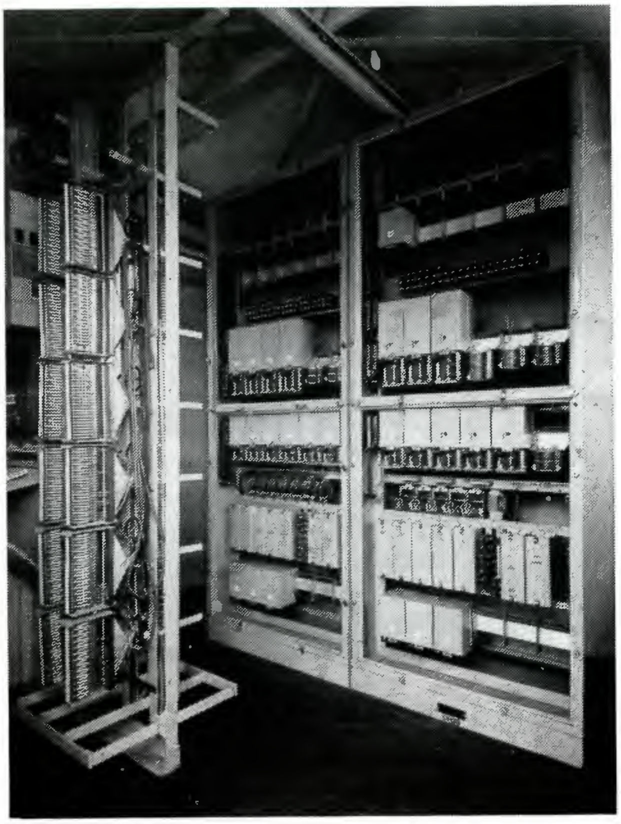


Fig. 3.7 — APO RAX C+ D Units

The decision rules used considered such factors as the economic justification, the effect on the office keeper's income, the suitability of line plant and adequacy of trunk provision. RAXs tended to be installed in closely settled areas and in exchanges of between 25 and 100 lines. At first they were usually one to one replacements of existing manual exchange. Gradually the desirability of defining new exchange areas when RAXs were installed was recognised and later installations often combined two or more exchanges (12).

There were some efforts in this period to find a cost effective substitute for PPE lines but with little success. Starting with war surplus equipment there were trials of VHF radio as exclusive services and as party lines but the stumbling block was provision of reliable power at the subscriber's premises. A high frequency network based on Broken Hill was established in 1948 but its scope was limited. A few similar networks were set up at other bases. Most graziers for whom this would be suitable found the Flying Doctor Radio Network service cheaper and adequate.

Rural carrier systems, designed for subscriber services were introduced from 1958/59. They were successful in suitable cases but CM4/50 was not flexible enough to accommodate them. This problem was overcome by creating a ficticious exchange called a 'remote controlled electronic exchange' abbreviated to RCEE. In 1984 there were 201 RCEE points with 674 services connected.

Remote controlled magneto exchanges were introduced for use where no office keeper was available and the line plant was unsuitable for automatic. A few 'ALL' type units were purchased from LME as a trial and after some experience a local design was produced in Queensland (13). Only a few applications were found but they have given service where nothing else was possible. In 1984 there were 55 of these serving 570 subscribers.

For the really remote subscriber, however, the position in 1960 was still the same as it had always been. Indeed, as late as 1965 the Research Laboratories were investigating methods of improving joints in PPE lines (14).

TRUNK SWITCHING 1945 to 1963

During this period the trunk network developed from almost completely manual to a semi automatic system with usually one operator per call. The dominant signalling system was 2VF but a substantial amount of other types of signalling was used.

The process was gradual, with automation being introduced as and when conditions were favourable. Factors which played major roles were the traffic volumes, the existence of automatic local exchanges and the availability of resources to provide adequate trunks and automatic trunk switching exchanges. The fine details are always difficult and often impossible to discover so this account describes the broad patterns, illuminated by a few specific instances where details are available.

The changes began with the purchase of a semi automatic trunk exchange for Melbourne which was cut over in stages from 1940 to 1942 (15). This exchange was designed to work like a manual exchange with automatic equipment used to provide more versatile operating conditions. The operators and supervisors were able to modify the behaviour of the automatic equipment in various ways.

Operators reached an outgoing trunk by keying a code, allowing the automatic equipment to search for a free trunk. If all trunks were busy, lamp signals specified one of three courses of action. These were:

(1) Storage wait. The subscriber was told to wait and when a trunk became free it was offered to the operator.
(2) Storage clear. As before, but the subscriber was asked to hang up. This was an intermediate step to formal delay working and its use often allowed delay working to be avoided.
(3) Delay. Tell the subscriber to hang up and pass the docket to the delay positions via the pneumatic tube. An indication of the probable delay was given to the operator who could advise the subscriber.

Supervisors had displays showing the number of calls in storage on each route and decided when the status of routes should be changed. There were many other management aids which allowed the supervisors to adjust the staffing and know how the exchange was performing.

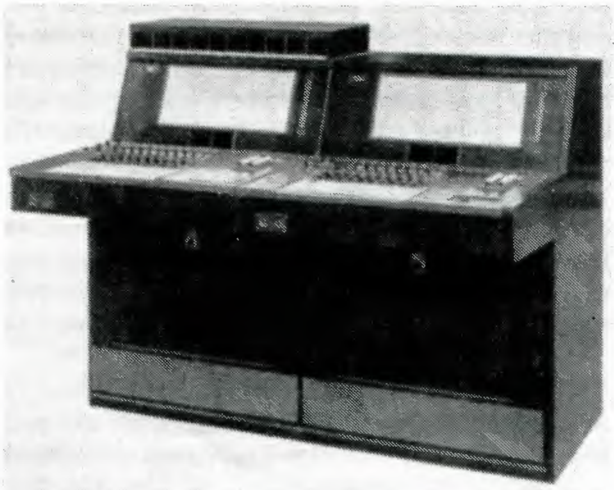


Fig. 3.8 — Melbourne Semi Automatic Trunk Exchange Operating Positions

2VF signalling was an integral part of the exchange and was used on all trunks connected to it except for a few multi office trunks which continued to use magneto signalling. Both the exchange and the 2VF signalling were developed by Siemens Bros. to specifications produced by the APO (16). The signallingspecifications were based on CCITT recommendations with some variations to suit local conditions. Bothway working and unambiguous supervisory signals were features of 2VF and in this respect it was far superior to magneto and better than the local VF signalling systems.

Special positions were provided for interstate traffic designed for 'back to back' working, a method which allowed maximum use to be obtained from the trunks. In fact, since charges were rounded up to the nearest three minutes, it was not unusual to get over 60 minutes of paid time per hour from each trunk. Geelong and Ballarat were not included in the initial cutover but continued to be served from the old demand exchange for a while.

At the country exchanges where 2VF equipment was installed the magneto switchboards were modified to give lamp signalling and positive supervision.

No provision was made for automatic transit switching at that time. Indeed doubts were expressed as to the value of transit switching in Australian conditions of low traffic and long, expensive trunks. The Melbourne trunk exchange could use demand clear operating to heavily load such routes and still give a service which the subscribers regarded as good. Under these conditions the probability of an automatic transit call being successful would be low. Therefore the cost of automatic transit was a significant increase in trunk provision. The size of the problem can be seen from the table of estimated trunk requirements for 1941 in the tender for the Melbourne trunk exchange. There were 72 routes with 10 or fewer trunks and only seven with more than 10. Most of these were designed for delay or demand clear working. However the exchange design allowed for the later addition of transit switching.

Trunk network automation had been the subject of much research in the preceding decade and the Melbourne installation was one of the first to attempt to put the new ideas into practice. It was also the last to be built before war put an end to new installations and therefore received considerable attention around the world. A similar exchange was installed in Adelaide in 1947 (17) and later recovered and reinstalled at Lismore.

In the immediate post war period new trunk network plans were produced with more ambitious objectives. The ultimate objective was fully automatic transit switching with one operator per call and the possibility of a limited amount of subscriber trunk dialling with multimetering. Several factors had led to the new attitudes.

Trunk traffic had increased dramatically during the war years, carrier costs were lower, particularly for long routes with 12 channel systems, and operator salaries were higher. The USA had developed a plan and the equipment for operator trunk dialling which showed how automatic alternative routing could reduce the cost of such a network to an acceptable figure.

The new trunk switching plans were completely different from the pre war plans. In a fully manual network transit switching was avoided like the plague but in an automatic network it was essential. Thus there were more switching centres and more levels in the hierarchy. Switching centres were designated as National (only one at Melbourne), Main, Primary, Secondary and Minor centres. Automatic alternative routing was an integral part of the plan. Transmission requirements made four wire switching essential or at least highly desirable at trunk centres of secondary or higher status.

New equipment was needed to meet the needs of the new network plan and two new types of trunk exchange were designed. Primary and higher level centres were to be equipped with semi automatic exchanges, similar to the Melbourne type but with some changes in features. Some facilities which had proved unnecessary were deleted and automatic transit switching was made an integral part of the design. Once again the APO specified its needs and Siemens Bros. produced the design.

Smaller trunk exchanges were to use a locally designed sleeve control switchboard which could stand alone or be integrated with a CBM exchange in the same switchroom. Automatic transit switching equipment was available as an optional extra. Transmission needs were to be met by provision for pad switching and the use of network cords to give four wire (tail eating) switching.

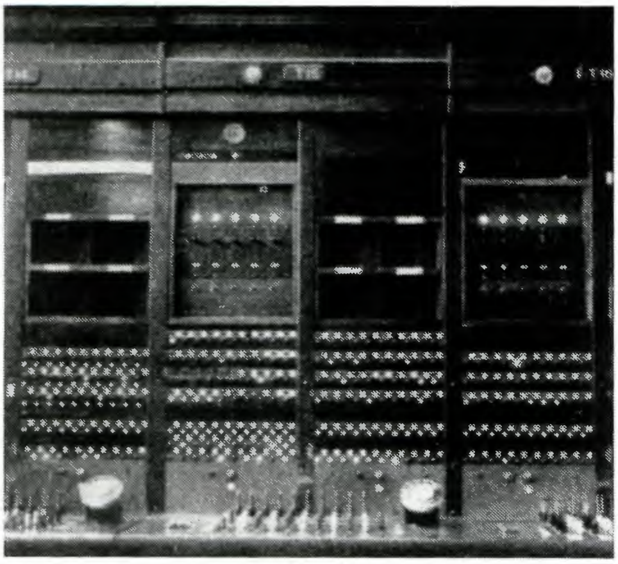


Fig. 3.9 — Hobart Sleeve Control Trunk Exchange detail of Face layout

2VF signalling was adopted as the standard but it was expensive and other systems were used where the full 2VF facilities were not needed. A compound frequency system suitable for both way trunks was designed and used in NSW. Another innovation used on the Sydney to Maitland and Sydney to Orange carrier cables was a carrier signalling system. This was the first use of E and M type signalling in Australia. The use of this type of signalling grew slowly as systems were purchased which had inbuilt signalling channels.

Shortage of resources in the post war period caused delays in the replacement of the sleeve control trunk exchange in Sydney. Several expedients were used to eke out the capacity of this exchange. The first was a simple type of semi automatic trunk exchange which was locally developed and installed in the GPO for interstate traffic. It used 2000 type switches, had minimal facilities, but did what it was intended to do. Later some cordless positions were built which could only be used for "delayed" traffic. Finally a sleeve control relief exchange was installed at Dalley which handled traffic to a smaller number of very high traffic routes.

Records of other expedients at this time are scarce as they usually had a fairly short life. An interstate exchange was designed and built in Adelaide during the war (18). Wollongong had a 2000 type semi automatic exchange similar to the one in the Sydney GPO. Newcastle had transit switching equipment at Hamilton, separated by 3km. from the associated trunk exchange.

Melbourne subscribers were given dialling access to several nearby manual country exchanges, where the operators prepared dockets and connected the call (19). This gave some relief to the Melbourne trunk exchange and reduced the operating costs. It was not applied generally because conditions in other places were unfavourable.

Although the advantages of automatic transit switching were recognised and there was a long term target of 'one operator per call', the shortage of trunks held back its introduction. Transit switching was introduced cautiously at first, starting in Melbourne where transit selectors were installed on 15 Aug. 1953 (19). A big increase in transit switching occurred when the Sydney semi automatic trunk exchange was cutover at Dalley in 1957. This exchange had a maximum capacity of 89 outgoing trunk routes and as there were already many more routes than this out of Sydney some had to be discontinued and the destination reached via a transit switching centre. Instead of increasing the through positions at these centres, it was decided to install automatic transit switching equipment. This was nearly all installed in sleeve control exchanges with a few in magneto exchanges.

A start was made on the installation of semi automatic trunk exchanges at Primary centres towards the end of this period but very few were established. The planned semi automatic operator trunk network was not much more than half completed when it was overtaken by the development of STD.

STEP-BY-STEP MULTIMETERING

The APO attitude to multimetering was rather equivocal in the early post war years. It was thought that its use would be limited for many years to short distance, high traffic routes and that there was no justification for a comprehensive network. It was given a low priority in the immediate post war years although the APO RAX had space for multimetering relay sets.

A multimetering committee was formed soon after 1950 to examine the possibilities and make recommendations. The work of this committee resolved a number of problems about the basis of charging and made it possible to define the facilities needed (21). Amongst other matters it identified the need for simplifying the charging system before widespread multimetering could be introduced.

The use of multimetering was shown to be more economic than manual switching of short distance routes and after an experiment, limited to APO staff (22) was successful two equipment designs were produced, one in APO Headquarters circuit laboratories and one in NSW. Both were installed on a number of short distance routes around Melbourne and Sydney, the first being from St. Marys to Sydney in 1956 (23). Arbitrary access codes were used since work on a national numbering plan had hardly begun. In fact there were senior engineers who doubted the need or practicability of a national numbering plan.

A third series of multimetering relay sets for step-by-step equipment was produced when details of the crossbar metering and charging systems were available. They provided both the necessary interfaces to allow step-by-step exchanges to use crossbar STD and a charging relay set which could provide step-by-step multimetering if crossbar was not available. A crossbar version was produced for fixed rate routes which was widely used in the period before a specifically designed register became available and is still an important component of the STD system.

Most of the first multimetering routes became unit fee with the introduction of ELSA but the charging equipment was then redeployed.

(Footnote: In modern usage multimetering is the method of charging for STD calls but before 1963 the word was used to refer both to the trunk dialling and the charging. For convenience the old usage has been adopted here.)

TECHNOLOGY FROM 1939 to 1963

CB and MAGNETO

The decision to use CB in most large country exchanges was a pragmatic response to post war shortages. It was clearly impossible to undertake large scale conversions to automatic in country towns. Thus there was a case for developing a new manual exchange with a capacity of the order of 2000 lines. For this size of manual exchange CB was clearly the best choice. Existing British designs were not entirely suitable and as it was intended to manufacture the exchanges locally a complete redesign was undertaken.

These exchanges had a few unusual features (1), (2). There was no answering field and calling lamps were fitted in the multiple, eliminating the IDF giving some cost savings. B positions were not normally provided since there was little junction traffic. Either a dial or a simple keysender could be fitted. All relay sets were mounted away from the switchboard in a separate equipment room. The overall height was less than previous switchboards, creating a more open effect.

A sleeve control trunk exchange was designed at the same time and was usually installed in a common suite with a CBM local exchange with the subscribers multiple extending over it. In this situation two types of cord circuit were needed, terminating cords to connect subscribers to trunks, and through cords to connect trunks together.

The first exchanges of this type had separate terminating and through positions. Trunks were answered at the terminating positions and if a through connection was needed the call was transferred to a through position. This arrangement, with two types of position, was not very efficient and an alternative arrangement with both terminating and through cords on each position was soon adopted. At a later stage a composite cord circuit which switched automatically into either the terminating or through mode was designed (3).

These trunk exchanges were also installed in automatic networks where the number of positions was too small to justify semi automatic. In these cases there was no subscribers multiple and all positions had through cords.

The studies into the economics of CB showed that a small non multiple CB exchange could also be justified. This was designed (4) and built in small numbers but the number of applications was less than expected.

Magneto non multiple remained the workhorse in smaller country towns. There were a number of changes to the design of these exchanges mainly to allow them to continue to work with more modern equipment. One change was a gradual shift to three conductor cords, jacks and plugs. The extra (sleeve) conductor provided a busy test on trunk and junction multiples and was also used as a dialling circuit, giving a better arrangement than the earlier method of dial keys on automatic lines.

Lamp signalling on trunks and junctions was introduced in a piecemeal fashion as carrier circuits and 2VF penetrated the network. The older switchboards lent themselves to the fitting of extra lamps, keys and jacks to meet such new requirements and, in the absence of any firm standards, there was a large degree of local initiative.

The final change to magneto exchanges was the fitting of operator controlled metering on incoming trunks. This was provided so that subscribers could call STD to the exchange.

2000 TYPE and SE50

The BPO adopted a new type of selector in 1935 chosen from a number of designs by British manufacturers. This was designated the 2000 type and it was adopted in Australia with the first installations being at North Sydney and City West (Melbourne) in 1938. It was a complete redesign of the bi-motional switch concept to give a more economical and reliable switch. All equipment was mounted on uniform single sided racks and a space saving of about 20% was claimed mainly from the use of 10'6" (3.2 meters) high racks.

Fig. 4.1 — 2000 Type Selector

The switches were normally provided with 200 outlets by means of wiper switching. This gave higher traffic efficiency and allowed juntion preselectors to be eliminated. The new equipment was electrically compatible with earlier equipment to the extent that a mixture of both types in the one exchange created few problems.

Primary and secondary line finders were used instead of subscribers uniselectors except in high calling rate exchanges. These switches had common controls and the circuits were rather complex but there were considerable cost savings. After a few years experience with line finders it was found that the higher maintenance costs and low reliability outweighed any savings in capital costs. Uniselectors were then adopted as standard.

The equivalent switch to an SSR was called DSR and provided extra facilities. These included direct switching to other exchanges in the same main exchange area and direct switching to the trunk exchange on level 0. This switch may have been specifically designed to meet Australian needs, since it was not used in the UK. Apart from this the rest of the 2000 type equipment was to BPO specifications and standards.

From 1912 to 1945 there was little original contribution to automatic exchange technology by Australians, as would be expected since it was all manufactured overseas. There were however some local initiatives. Most of these were small refinements and are not documented. Eight known cases are listed below.

- Some early work on link trunking was done by C.McHenry with application to two stage preselectors (5).
- Release guarding was added to early models of group selector using methods developed for 2000 type switches (6).
- SSRs were modified in one case to give direct switching between branch exchanges and in another to discriminate on the third digit (7).
- A special circuit was developed to meet a special switching problem in Adelaide (8).
- DSRs and SSRs were modified to give alternative routing (9).
- Sutherland RAX was modified to allow it to be included in the Sydney network instead of being parented on the trunk exchange.
- The first RAX in Australia was locally designed and built.
- Automatic back busying of junction circuits (10).

There had been a small telephone circuit laboratory in Headquarters for many years. It was mainly concerned with examining tenders and advising States on unusual problems. Around 1940 it was strengthened and began producing its own designs specifically suited to Australian needs. One of the first such designs was the 'Silvester' PBX. The laboratories also did a great deal of research into impulsing and testing circuits, the two most critical functions in step-by-step systems.

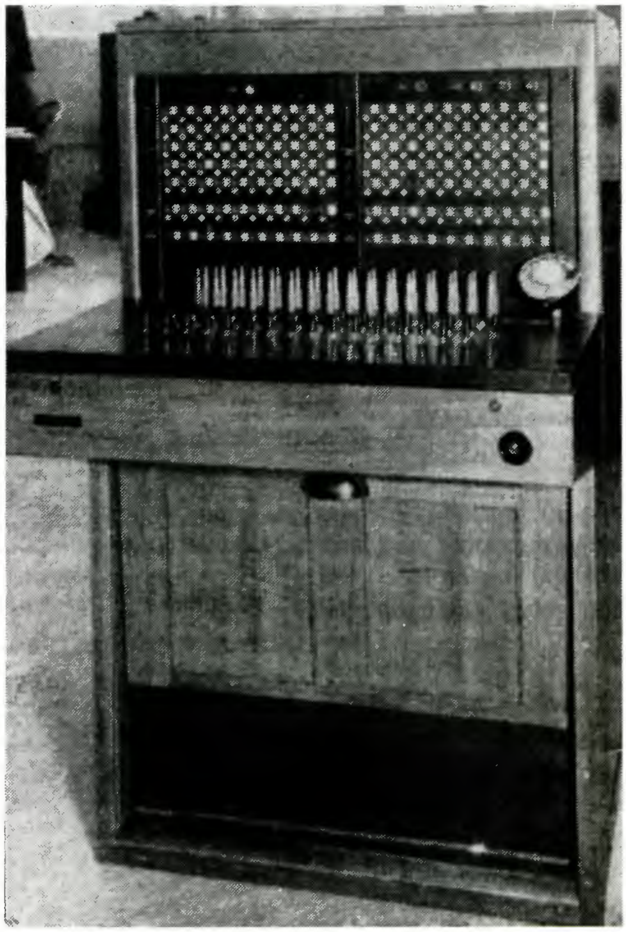


Fig. 4.2 — Silvester PBX

Hardly anything is known about the first few RAXs which were installed before 1930. The first large scale use of RAXs began in 1935 using equipment purchased from four English companies. Each company had its own design with ingenious ways of cutting costs to make a small exchange economically viable. It is not known whether the APO had much say in the range of facilities provided.

These RAXs were not entirely suitable for Australian conditions and some of them were modified to solve a local problem. Experience with these units showed the APO what facilities were needed under Australian conditions.

After the war two RAX designs were produced in the APO circuit laboratories and were manufactured in quantity (11), (12). When the SE50 switch was manufactured in Australia the design was suitably modified. These items appear to be the first automatic exchange equipment totally designed by the APO. The design was an amalgam of the four companies' designs with a strong bias in favour of straight forward methods so that the result was a good workhorse that gave long life.

Because of the problems of equipment supply during the war it was decided to become as self sufficient as possible in the manufacture of telephone equipment. After negotiations STC and TEI set up factories and over a period of years developed their capability until all items of automatic exchange equipment were locally produced. The switch chosen for local manufacture was the SE50 selector which was an improved version of the 2000 type (13).

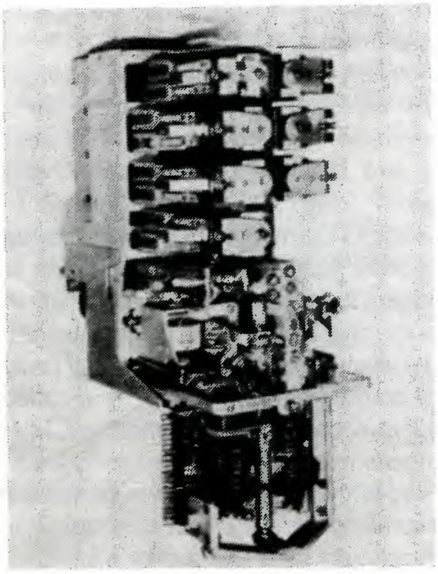


Fig. 4.3 — SE 50 Selector

The APO played a large part in circuit designs for locally produced switches and in particular in the impulsing and testing circuits which incorporated refinements developed in the Circuit Laboratories. In the case of the SE50 DSR the APO seems to have been almost entirely responsible for the design.

The attention given by the APO to impulsing arose from the size and complexity of the Sydney and Melbourne networks in particular. Features of these networks were:—

- The area covered was larger than any other step-by-step network in the world.
- Because of this, junction loop resistances were higher than elsewhere.
- The proportion of calls which used three junctions in tandem was unusually high.
- There was a large amount of old equipment in Sydney.
- Post war plans envisaged a large amount of satellite working with up to five junctions in some calls.

Loop resistance limits for acceptable signalling performance were established for the planned network configurations including satellite working. These allowed the post war network redesigns to be implemented, and were a key factor in stretching the life of step-by-step in these networks to 1963 when crossbar was introduced.

The trunking limitations of step-by-step were a continual irritation in this period and a variety of more flexible and/or economical discriminating switches were suggested and investigated. A few of these found limited use in the networks. The following list may not be complete but it illustrates the variety of methods investigated:

SE50 Type DSR switching on first or second digit.

SE50 Type DSR modified for alternative routing.

SR (Switching repeater) drawing CE61, provided one direct route and all other traffic via backbone.

SDR (Switching dual repeater, designed in NSW) switching on any digits with alternative routing.

RDR (Route determining register, designed in NSW) up to 18 direct routes on any codes. Used an impulse regenerator to store the dialled digits until routing decisions were made.

DR (Discriminating repeater) Used common controls which had the discriminating logic.

SDS (Switching dual selector, designed in NSW) A modification of the SE50 DSR to give similar properties to the SDR.

Discriminating switching repeater. Designed in Adelaide to solve a specific problem.

In similar vein was the development in NSW of two designs of digit absorbing relay sets to replace selectors where the network numbering permitted. The first application was on level 1 where the only second digit used was 1.

After the war carrier systems were used in local networks as short term relief, particularly where there were delays in providing a major conduit route. Special signalling relay sets were designed as required for these systems (14). Most of these systems were recovered and reused in the trunk network after a very short period in service. However a few in country networks were more permanent.

The introduction of negative impedance repeaters resulted in higher loop resistances on junctions and the BPO SCDC signalling system was adapted to Australian needs. Other line signalling relay sets were designed for country networks where phantom circuits were used.

The introduction of STD required modifications to DSRs which had been designed to provide auto-manual conditions on level 0 with no multimetering capability. Other small modifications to step-by-step equipment were needed to provide STD access barring. Details are given elsewhere of work on step-by-step STD which was used in suitable locations while the crossbar STD facilities were being developed.

In 1961 and 1962 there were two trial installations each of Siemens No. 17 and Siemens and Halske EMD (14) step-by-step equipment. These were under consideration as the next type of equipment. Both used motor uniselectors as 200 outlet group selectors and had some advantages over bi-motional systems. However they lacked the versatility of crossbar and no further installations were made. A pentaconta crossbar exchange was also installed at Kew as part of the evaluation process (16).

Since 1961 there have been few changes made to the existing step-by-step equipment and these have been concerned with interfacing to crossbar.

TRUNK EXCHANGE TECHNOLOGY

By 1939 trunk network automation was recognised as a future trend rather than an immediate possibility. Many of the functions of a trunk operator were difficult, if not impossible to automate with available technology.

Some of these functions were:

(1) Managing the queueing needed to get adequate usage out of small, expensive trunk routes.

(2) Providing a written record of each call for accounting purposes.

(3) Providing such personal services as fixed time, person to person and reverse charge calls.

(4) Adapting to changes in the routing pattern as the network grew and new direct routes were provided.

(5) Adopting special routing patterns when breakdowns occurred.

At the same time the growth of trunk traffic was creating operating problems and some large trunk exchanges were almost unmanageable. Faced with the dilemma that manual methods could not cope with the demands and that only some trunk operating functions could be automated, a semi automatic system, with the possibility of ultimate full automation was the best option.

Two functions which could be performed better in a semi automatic exchange than in a large manual trunk exchange were the distribution of calls from subscribers to operators and giving access to a large trunk multiple. These were the main functions provided in the first semi automatic trunk exchanges in Australia. The automatic trunk multiple in the Melbourne trunk exchange was designed to mimic the actions of an operator at a cord type trunk switchboard and at the same time to do it more efficiently. For example, in a cord type exchange if all trunks on a demand route were busy the operator would hold the call and scan the busy lamps of the route to see when one became available. In the Melbourne exchange, if the operator keyed the code for a route and all circuits were busy, the call would be put in 'storage' and a lamp signal indicated when a trunk became free.

The provision of an automatic trunk multiple made it possible in principle for a distant operator to switch a call through the exchange to an outgoing trunk (automatic transit switching). However such calls could not be given the benefit of call storage and with the traffic conditions applying in 1940 automatic transit was at a severe disadvantage. The exchanges were therefore designed so that this facility could be added at a later date.

Semi automatic operation required positive signals from the called exchange when the call was answered and when the distant operator disconnected the call. New signalling systems were needed to provide additional signals and a system using two signalling frequencies (600Hz and 750Hz) and known as 2VF was adopted as an Australian standard. The frequencies and signal durations followed CCITT recommendations but as no detailed system recommendations had by then been produced it was specifically designed to meet APO requirements.

2VF signalling and Siemens semi automatic trunk exchanges were designed to work together but the exchange could in principle work with any type of signalling and 2VF could be used in other types of exchanges.

Later versions of the Siemens semi automatic trunk exchange were basically similar but transit switching was fitted as a normal part of the exchange and some of the operating features were dropped. Automatic alternative routing of transit calls was provided by means of transit registers which were called in if a transit call encountered busy conditions. In response to APO needs relay sets were designed for a number of other types of signalling, and in particular for E & M lead signalling. This was more economic than 2VF for carrier circuits with this facility inbuilt.

Except for a few early installations the post war sleeve control trunk exchanges were designed and built in Australia. They could be co-sited with a CBM exchange, in which case the subscribers multiple extended over the trunk positions. Operating procedures made use of this feature to eliminate the need for transfers between the local and trunk positions. The subscribers multiple had different interface conditions to the trunk multiple and two types of cord circuit were needed, one for terminating and one for through calls. The first exchanges had separate terminating and through positions, but it was found more convenient to provide a mixture of the two types on each position. Later a 'Composite' cord circuit was developed which could be used for either type of call. Provision was made for four wire (tail eating) switching by providing line and net jacks for four wire trunks and a few pairs of net cords for connecting the network jacks on four wire to four wire calls. Pad switching was also provided.

After about 1955 automatic transit switching was added to selected sleeve control trunk exchanges. This used Siemens motor uniselectors, and new 2VF line relay sets were designed for this application. A version was also built for magneto trunk exchanges, using the same switch circuits.

The preceding developments made possible an operator trunk network with a single operator switching and controlling a call. This is the maximum level of automation possible in an operator trunk network and was being approached by 1960. Further automation required the replacement of the trunk operator altogether and a change to STD.

MULTIMETERING

Before subscribers could dial their own trunk calls some method of charging was needed to replace the manually written dockets. Two methods were known by 1955. The USA and a few other countries had adopted automatic toll ticketing with machines which produced punched paper tape. Most countries had adopted the simpler method of multimetering. The main disadvantage of multimetering was that detailed call records could not be provided, but overseas experience showed that, at least for short haul traffic, subscribers would accept this.

By 1955 there were enough short routes on which STD with multimetering could be economically justified to make it worth while developing the concept. There were both commercial and engineering problems to be solved before STD could be introduced and the first field installations were made in 1956. Features of these early installations which set precedents for later developments were:—

(1) Metering incremented by one unit fee at regular intervals, rather than several registrations at the start of each three minute period.

(2) All trunk charges expressed as multiples of the unit fee.

(3) Subscribers could opt out of multimetering but would have to pay for the privilege.

Three designs of step-by-step multimetering were produced, one in NSW and two in Headquarters. In each case there was a family of relay sets involved, capable in principle of providing multimetering on a national scope but in practice fairly limited.

NETWORKS FROM 1963 TO 1980

THE ANSO COMMITTEE

The crossbar age in Australia was ushered in by the work of the ANSO Committee (Automatic Network and Switching Objectives) and the publication of the 'Community Telephone Plan for Australia 1960'.

The Committee was formed in 1957 when it was apparent that several independent studies were in need of a common direction and that the time was right to set the APOs telephone system on a new course. It took control of these studies and initiated the further studies needed to produce a National plan.

The Community Telephone Plan was one of the last products of the Committee and set out in broad terms the conclusions reached and the framework within which future telephone development would be carried out. To a great extent it was a formality; new planning decisions and procedures were implemented progressively during the life of the Committee and, for example, the new charging zones were made public when a white paper was tabled in parliament on 12 August 1959 and had been introduced by the time the report was issued. It was however a key document which formed the basis of planning for the next 20 years.

It was fortuitous that circumstances favoured such a broad ranging review of the total network. Post war expedients had succeeded in allowing the APO to catch up with most of the demand without requiring any commitment to new technology, but they all reached their limits at about the same time. Sydney and Melbourne needed redesigning for seven digits and it was appropriate to consider a break with step-by-step. The CBM exchanges in country cities were reaching capacity and needed replacement with automatic. Networks such as Wollongong had revealed the anomalies of the existing charging system and the limits of step-by-step in such areas. Broadband bearers were being introduced on major trunk routes, including the Sydney to Melbourne coaxial cable. Subscriber trunk dialling was becoming attractive for many routes and operating costs had increased to the point where much short distance trunk traffic was unprofitable.

Other countries had produced plans for large segments of their telephone network but the Community Telephone Plan was the first of such comprehensiveness. The Bell system in the USA had produced the DDD (Direct Distance Dialling) plan for the trunk network, but this, of necessity, ignored the local networks, many of which were owned by independent companies. The BPO had also produced a fairly comprehensive trunk network plan which was independent of local switching. In this case it was assumed that the existing step-by-step and Director systems would continue to serve local switching needs.

It was also fortuitous that most of the large manufacturing companies were developing new equipment lines. The APO had a unique opportunity to choose a new system and have it adapted to its needs. The requirements as outlined in the Community Telephone Plan could only be met with a register controlled system using high speed VF signalling. There were both crossbar and electro mechanical systems available which had these features and the potential to satisfy the APOs needs and all major manufacturers were invited to offer any type of equipment which they thought would meet APO requirements.

In the event the crossbar systems were clearly superior and after much deliberation the L.M.Ericsson crossbar system was chosen (1). The LME proposals included one version of ARF for capital city networks, another for large country exchanges, ARK for smaller country exchanges and ARM for trunk switching. Considerable development was needed to meet APO needs and both LME and the APO played a large part in this process.

In order to gain experience in crossbar equipment while this development was proceeding an order was placed for an ARF101 type crossbar exchange at Toowoomba to replace two manual exchanges with a total of nearly 5000 subscribers connected (2). This location was chosen as one where a non standard exchange would not unduly hamper future planning.

OVERVIEW OF CAPITAL CITIES

Between 1963 and 1980 crossbar became the dominant equipment type in the capital city networks. Unlike earlier equipment changes this took place at a relatively uniform rate and in an essentially similar manner in all networks. For this reason a broad outline of the process is provided, supplemented by details of unusual features of individual cities.

A controlling factor in the process of changing from step-by-step to crossbar was the speed with which the Australian manufacturers could switch over to the new type of equipment. Negotiations between LME, the

Fig. 5.1 — Crossbar Switch Racks

APO, STC and TEI produced a fairly tight and, as it turned out, rather optimistic timetable (3). Implicit in this timetable was the complete cessation of step-by-step manufacture over a period of three years, after which period the only way exchanges could be extended in step-by-step was by replacing other installations with crossbar and recovering the step-by-step for reuse.

In parallel with the change over of manufacturing it was necessary to plan for the installation of crossbar and its integration in the existing networks. For the capital city networks this planning had also to cover their extension to include the ELSA zones. These plans were produced during 1960 and 1961 and provided:—

(1) Numbering capacity for the addition of ELSA zones and growth for at least 20 years with satisfactory strategies for further growth.

(2) A switching network for step-by-step call origins with access to both step-by-step and crossbar destinations.

(3) A switching network for crossbar call origins with access to both step-by-step and crossbar destinations.

The second requirement was the most restrictive as it meant that the network design had to allow step-by-step trunking until all step-by-step first and second selectors had been replaced. In the cases of Sydney and Melbourne this involved a large amount of seven digit numbering and extra switching stages. Depending on how these extra stages were used the resulting network could have more main exchanges, more branch exchanges in one or more main exchange areas or terminal exchanges with more than 10,000 numbers. A mixture of all three was found to be needed.

The use to be made of tandem switching in the crossbar networks was a matter of great concern. After living for half a century with the constraints of step-by-step and the post war efforts to squeeze Sydney and Melbourne into a six digit numbering straight jacket, crossbar was seen as the solution to a multitude of problems. Unfortunately there was no Australian experience of a register controlled local network nor were any overseas networks sufficiently like ours to be useful as models.

The tandem structure finally adopted after much soul searching had elements taken from the hierarchical trunk network and from step-by-step practice. Detailed studies in each State produced individual designs for each city adapted to fit in with local conditions.

It had been thought that step-by-step tandems could be used to carry most tandem switched traffic for some time after the introduction of crossbar but this was soon recognised to be inefficient. Crossbar tandem networks were therefore set up early in the crossbar programme and these initial networks were found to need very little subsequent change and they were the basis of development until the introduction of AXE in 1981.

One of the options offered with ARF was the ability to replace the first switching stage of a step-by-step exchange with crossbar, using SR-B cord circuits with standard registers and crossbar group selector stages. It provided a neat solution to some network problems and was an essential item in country networks. It had been hoped that this arrangement would be an economical method of giving register control to all existing step-by-step exchanges, with the resulting junction economies offsetting most of the cost of conversion. Detailed network studies, however, showed that the savings were insufficient in the majority of cases. A modest amount was installed in the city networks in the first few years but the main application was in country areas.

Two enhancements of the original ARF equipment became available soon after the first exchanges were established and found considerable use in metropolitan networks. The three stage group selector was specifically designed to give the greater availability needed in large exchanges and when it became available in 1967 it was extensively used both in terminal exchanges and terminating (Y) tandems. An important feature was that an existing two stage group selector could be fairly easily upgraded to three stages. REG-LP was not initially meant for metropolitan networks but it offered better facilities at a lower cost and became the preferred register. However existing REG-LM installations were usually extended to the limit of a module (100 Regs) before changing over to REG-LP and this usually took a fairly long time.

By 1968 there was a large amount of very old automatic equipment which was becoming a maintenance problem. Since 1930 hardly any replacements had been made except where it was unavoidable and even then the equipment was frequently reused. A particular problem was the pre 2000 type equipment which had all been installed before 1939. Spares had become difficult to obtain and it could not provide STD. In September 1968 a target was set of replacing all pre 2000 type equipment by 1982. This target was substantially met.

The introduction of STD was initially limited to crossbar and step-by-step main exchanges but it soon became apparent that the desired STD penetration could not be achieved without giving the facility to DSR branch exchanges. DSRs were designed to give access to a manual trunk exchange on level 0 and could neither repeat dialling on this level nor pass multimetering signals. There were two basic types of DSR (2000 and SE50) each with a large number of slightly different circuits. Modifications were developed by the Circuit Design Laboratory and all DSRs in capital city networks were upgraded to give STD capability.

From about 1970 a long series of studies examined the possibility of upgrading registers to give new facilities and rectify some design deficiencies which had been found in service. They culminated in the approval in principle of a register modernisation programme (REMO) in January 1975. The programme was delayed when it was found that the most economical method in the capital city networks was to convert the exchanges to ARE11 (4). It finally began in 1977/78. The main objectives were to provide new facilities, improve network performance and reduce maintenance costs. In the long term ARE 11 allowed future upgrading to be achieved by software changes.

The following sections describe some features of interest about individual networks.

SYDNEY

Sydney had already introduced seven digit numbers and had no spare levels to be used in the ELSA area. Moreover, the Y (0) level which had been used to stretch the life of six digit numbering had to be recovered for STD access. The numbering and step-by-step switching plan used seven digit numbering on level 6 with level '6' second selectors at each main exchange to give additional main exchanges. This allowed the level to be used both to recover the Y level and provide for most of the ELSA exchanges.

At some main exchanges third selectors were fitted for selected codes to eliminate satellite trunking and the impulsing problems it created. In the rest of the network individual exchanges were extended as necessary by seven digit numbering on a spare code. This code was usually reserved for crossbar.

The level 6 numbering was expected to be adequate for about 20 years and no specific plans were prepared for growth beyond that point. One possibility was to convert all equipment to register control and develop a new numbering plan free from step-by-step constraints. If this could not be justified, level 8 could be used in the same way as level 6 and the plan deliberately left this level lightly committed to reduce the cost of doing so.

Large network savings were expected from crossbar because of the independence of numbering and switching and the alternative routing capability. It was an article of faith that a tandem network designed for step-by-step would not be the best for crossbar. The only existing networks using alternative routing were hierarchical trunk networks and these were used as the starting point for the Sydney tandem design. It was thought that the choice of tandem locations could have a large influence on costs. These considerations led to the development of two design aids.

The first was a 'Traffic Dispersion Recorder' which provided details of the destinations and durations of a sample of calls from a step-by-step exchange. It borrowed some techniques from the American automatic toll ticketing equipment and used the SILLIAC electronic computer at Sydney University to process the miles of punched tape produced by the recorder. A suite of programs produced firstly a matrix of existing point to point traffic which was used as the basis for forecasting future traffics. This was the first significant engineering use of electronic computers in Australia. The present traffic forecasting systems in Telecom are directly descended from this work.

This was the first application of electronic computers to telecommunications engineering in Australia and one of the first in the world (the present traffic forecasting systems in Telecom Australia have directly developed from this original). In fact, at that time, similar AMA tapes in America were still being processed by elaborate electro mechanical equipment.

This data was used as the input of a computer program known as 'COMET' (Calculation of Most Economic Tandems) which gave estimated junction quantities and costs for specified tandem configurations. Some simplifications were needed to fit the problem within the capacity of the available computer but the results were a useful guide to network design. Unexpectedly, it showed that an alternative routing system had considerable ability to adapt and make the best use of whatever tandem network was provided. Consequently, for the conditions applying to the model the selection of tandem numbers and locations was not as critical as expected.

The tandem network proposed for Sydney therefore gave most weight to existing and proposed junction routes with tandems located at external plant nodes. Not surprisingly, most of these were existing step-by-step tandems. Figure 5.2 shows the network which was adopted.

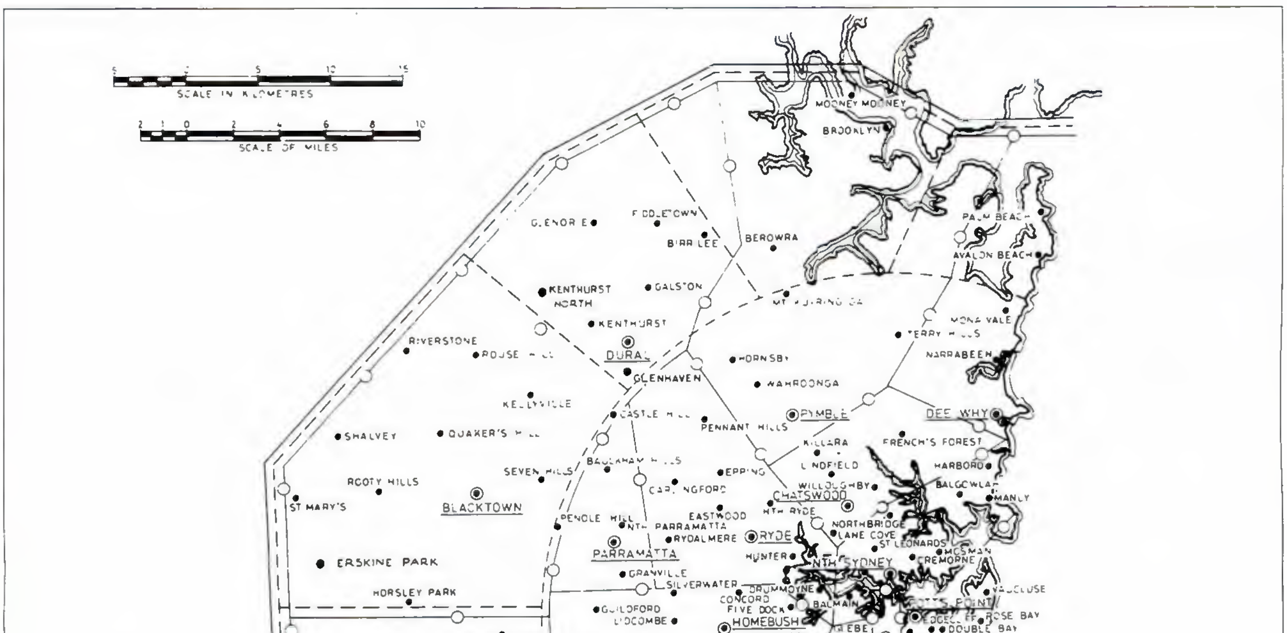


Fig. 5.2 — *Sydney Network Tandem Areas*

The first crossbar exchange in Sydney was at Petersham and was commissioned in May 1963 with 2800 lines installed (5). It was an extension of a step-by-step exchange in a new switchroom and was the pilot model of ARF102 with MFC signalling. This was about a year later than planned, because of the large amount of redesign needed to meet the APO's requirements. By this time several installations in different States were almost complete and waiting for feedback from this cutover about any last minute changes that were needed.

The second exchange in Sydney was in a new building at Haymarket which was cutover late in the same year. This took about 3000 existing subscribers from City South. The predicted calling rate for Haymarket exceeded the design limit of the available LME subscriber stage grouping plans and two new grouping plans were produced for Australian conditions. The call capacity of the subscriber stage markers was also exceeded and a new higher speed marker was produced. This marker eventually became standard for all Australian ARF exchanges.

Within two years crossbar had been installed in most exchanges in the Sydney zone and future growth until 1982 was almost entirely in crossbar. There was a small amount of recovery of step-by-step which was reused where a switchroom was almost full and to meet growth in slow growing areas, particularly in the country.

The early crossbar program in Sydney included SR-B equipment for about 40,000 lines of equipment. This was installed mainly to release step-by-step group selectors needed for seven digit numbering. It also produced junction economies by the use of direct routing but as this was not enough in itself to justify the change little further use of SR-B was made in the network except for the ELSA zones where step-by-step trunking was inadequate.

The tandem network was also established fairly rapidly, but some locations had to wait on buildings, particularly at Lakemba. The tandems had to be established before the tandem line relay sets had been designed and makeshifts using terminal exchange relay sets were used. In due course these relay sets were replaced by tandem relay sets and reused in terminal exchanges.

Three stage group selectors were introduced as soon as they became available and were used extensively in the first switching stage of terminal exchanges and in Y tandems. Even with three stage switches there were practical limits to the size of switching stages due to the complexity of homogeneous interconnections and the policy of providing buildings for ten year periods. Consequently, by 1980 many terminal exchanges and most Y tandems were effectively two or more separate entities.

Early in 1979 the Sydney network had a million services and over 70% were crossbar or register controlled step-by-step. The network had increased to 1,116,971 by June 1981, the last year before AXE was introduced.

MELBOURNE

The plans for crossbar in Melbourne were slightly different from those for Sydney. Fortuitously, level 7 was spare and was used for the ELSA zones, allowing somewhat simpler step-by-step trunking. Seven digit numbering was mainly provided by adding third selectors on some levels at main exchanges, a system which could ultimately provide a hundred separate 10,000 line groups in each main exchange area. Level 9 was nominated for possible ultimate use to supplement level 7 in the ELSA zones as it was lightly used.

Traffic data for designing the crossbar tandem network was produced by a locally developed call dispersion recorder, rather simpler than the Sydney traffic dispersion recorder, but able to get larger samples because holding times were not measured (6).

In designing the tandem network specific categories of traffic were targeted which made up a large proportion of the total traffic. It was considerably different from Sydney with only four tandem locations to serve the old unit fee area. These were located close to the centre of the network and each had three specialised switching stages (7). Transmission factors played a large part in the design and the tandems were chosen to minimise the amount of 20lb (0.9mm) cable required. The outer areas were to be served by five smaller tandems with X and Y stages.

The inner tandems were set up in 1964 followed later by a fifth tandem at Lonsdale. As with Sydney, the original design has needed hardly any change.

A policy of fairly substantial recovery and reuse of step equipment was adopted for the first few years of crossbar introduction. There were short term advantages in deferring the cost of many first in installations and in having fairly large crossbar exchanges from the start. There were also advantages in concentrating step-by-step to a smaller number of sites. This policy produced a more efficient network but the process was rather labour intensive.

About 70,000 step-by-step lines were converted to SR-B including 20,000 in the outer zones where existing step-by-step exchanges had been installed pre ELSA and needed additional switching capability which could most ecomically be provided in this way.

Three stage group selectors and REG-LP were used as extensively in the Melbourne as in the Sydney network. One strategy used in Melbourne was to replace the 1GV stages with new equipment and to reuse the recovered stage to extend GIVs. As a result Melbourne exchanges tended to have tidier trunking arrangements than Sydney. These differences were small and may have been due to a tighter resource position in Sydney than in Melbourne.

The first new ARE11 exchange in Australia was installed at Elsternwick in June 1976 as a field trial (8).

In June 1981 the Melbourne network had 1,019,870 services of which 77% were served by crossbar or register controlled step-by-step.

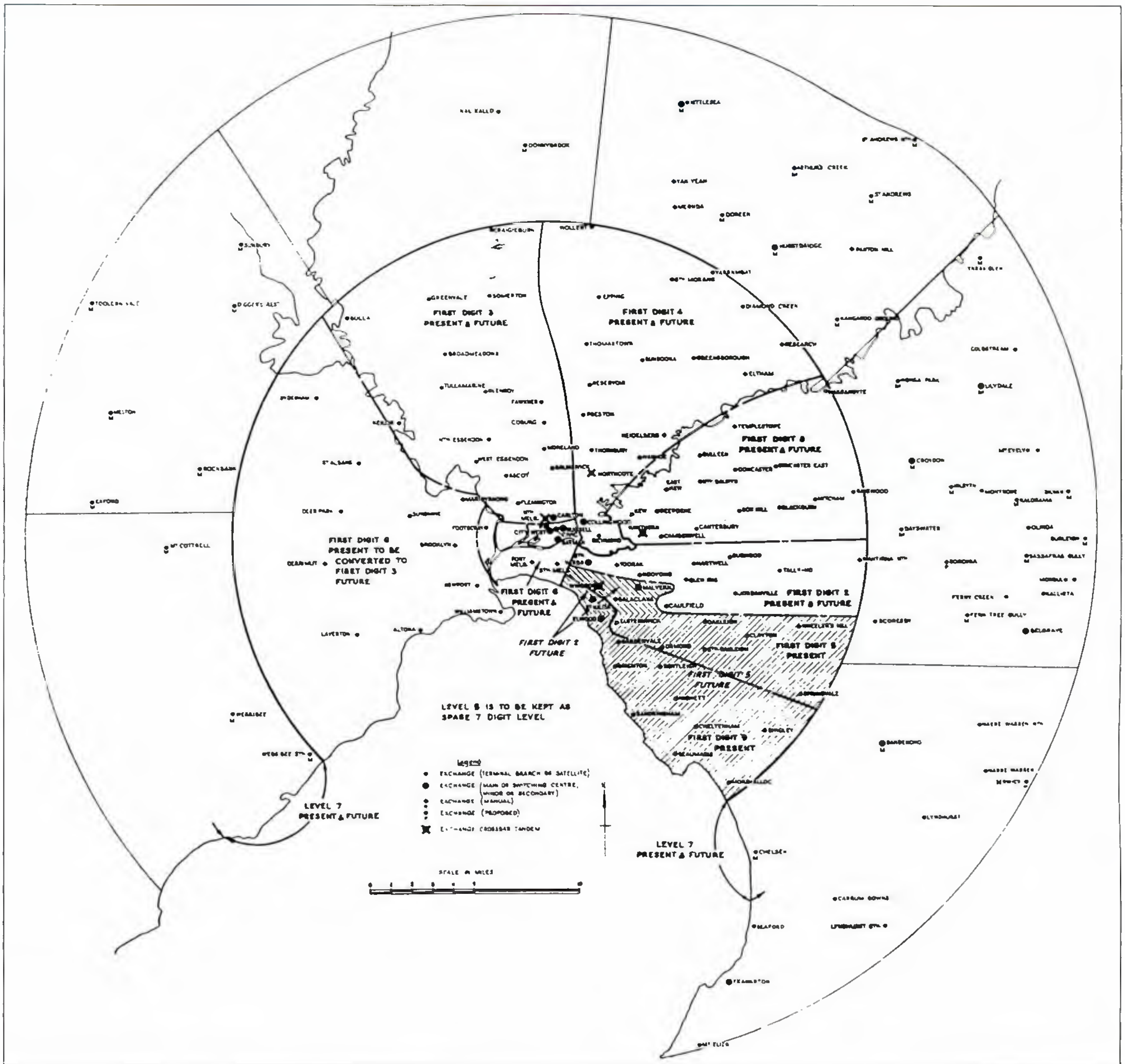


Fig. 5.3 — Switching and Numbering proposed for Melbourne 1964

ADELAIDE

The National numbering plan for Adelaide provided for ultimate seven digit numbering with area code 08 and using B digits 2,3 and 4. Initially however it was to continue with 6 digit numbering using area code 082.

The network plan used spare levels for the ELSA zones. The inner zone was served by three Y tandems and only one X tandem. A feature of the Adelaide network was that exchange areas were rather larger than in other Australian cities and this was a factor in allowing such a simple tandem network to be used. The sub metropolitan area was served by a central tandem.

Seven digit numbering was introduced in the network on 30 September 1973 (9). The area code was changed from 082 to 08 and most numbers became seven digit with first digit 2 or 3. Some six digit numbers were left on levels 5,6,7 and 8 which required some special switching and analysis to distinguish them from country numbers with area codes 085 etc.

When it was decided to introduce ARE11 the Salisbury exchange on the outskirts of Adelaide network was chosen for a field trial of the techniques needed to convert an existing ARF exchange to ARE11 (10).

In June 1981 the network contained 352,513 services of which 87% were crossbar or register controlled step-by-step.

BRISBANE

Cleveland exchange in the Brisbane area was chosen as one of the field trial ARF exchanges and was cut over in 1963.

Like Adelaide, Brisbane was given ultimate seven digit numbering on 07 using B digits 2,3 and 4, but with six digit numbering initially.

A network of four X tandems and six Y tandems was adopted with a seventh being added later. About 20,000 lines of SR-B were installed, mainly in the early stages of crossbar. Seven digit numbering was introduced in 1975.

By June 1981 the network had 357,299 services of which 84% were crossbar or register controlled step-by-step.

PERTH

Perth also had initial six digit numbering and was completely converted to seven digit working on 29 October 1977. The tandem network had two X tandems and seven Y tandems and also had a 'Superior X tandem' to give a further level of hierarchy.

Perth grew more rapidly between 1960 and 1980 than other capital cities and therefore had a smaller proportion of step-by-step equipment. Greater use was made of SR-B with the result that by June 1981 the network had 311,243 services and 98% were crossbar or register controlled step-by-step.

HOBART

The five digit numbering plan for Hobart was inadequate to meet development and a new six digit numbering plan was developed to cover the whole of the Hobart Secondary Area. The city and adjacent ELSA zones were served by a single crossbar tandem.

By June 1981 the network had 58,824 services of which 74% were crossbar or register controlled step-by-step.

CANBERRA

The Australian capital grew at a very rapid rate between 1960 and 1980 and partly as a result of the Civic exchange fire in 1961 the network has the highest penetration of crossbar of any capital city. The remaining two step-by-step exchanges have been equipped with SR-B to create a fully register controlled network.

Initially the Canberra network was part of a larger six digit area but the more remote portion was separated and given a new area code when growth created difficulties. The closed number area for Canberra still includes the whole minor area, but the number of exchanges and services outside the city and suburbs is very small.

A single tandem exchange was provided at Civic and served the network until about 1980 when a second tandem was established at Deakin. This was provided mainly to give greater security.

One feature of the network was a number of large PABXs with 2000 or more lines. These were built with modified ARF equipment which provided access to the network being trunked as terminal exchanges.

COUNTRY NETWORK DEVELOPMENTS

Automatic switching had made a modest and somewhat patchy impact on country areas by 1960. The 1959/60 annual report showed that of 539,718 country services, 63% were magneto and 37% were automatic. The detailed figures for NSW showed that 37% were magneto, 20% CB and 43% automatic. However, the Canberra and Newcastle networks accounted for over a quarter of the automatic lines. There had been hardly any progress with building up networks of country automatic exchanges. Figure 3.6 shows how the standard automatic exchanges were concentrated in a few areas.

Over the next 20 years most medium and large country exchanges were converted to automatic. There was little variety in these installations and any specific cases discussed here can be taken as typical of a class. There were so many that a detailed list of places and dates would be of little value.

The Community Telephone Plan defined new objectives in the automation of country exchanges, with a strong emphasis on building networks. This process got off to a fairly slow start, because of the lack of suitable equipment, but one initiative, the group charging scheme, gave an immediate stimulus to the process by changing many short distance trunk routes to junctions. As far as possible, any two automatic exchanges within unit fee distance were given dial access to each other. The access codes were chosen where possible to fit in with an ultimate network plan.

A switching plan and the outline of a numbering plan, allocating STD codes to closed numbering areas appeared in the Community Telephone Plan. Subsequently the numbering details were extended to individual exchanges and the switching plan revised in the light of economic studies of individual secondary areas.

The systematic design of country networks had never been attempted before on the scale envisaged in the Community Telephone Plan and it took several iterations before the networks took their final form and the necessary equipment designs were finalised.

From the time the main themes of the Community Telephone Plan became known (about 1959) any automatic exchange installed at a minor centre was designed with some consideration of the network implications and the numbering plan for the area. This went at least to the extent of allocating codes to charging zones and to exchanges within those zones. Until 1963 these exchanges were step-by-step and this placed some constraints on the facilities which could be provided.

From 1963 ARF exchanges were installed at minor and secondary centres. Until 1970 these used REG-LM and were designed on the assumption that ARM exchanges would eventually provide higher level switching functions. In order to minimise manual switching, automatic access to exchanges in the minor area was provided on a temporary basis as much as possible. Some STD was also provided using fixed rate equipment.

Three ARM 50 exchanges were installed as minor centres in 1969/70 at Gladstone, Jamestown and Melrose in South Australia in accordance with LME's proposals but even before they were installed it was apparent that they were too costly. As detailed elsewhere studies were begun to develop a two wire minor centre. Meanwhile, of course, the conversion of manual exchanges to automatic could not be put off and the use of metropolitan type ARF as described above continued.

It was also becoming clear that the 'first in' costs of any kind of minor switching centre were higher than previously expected and that many of the smaller minor centres proposed could not be economically justified (11). The switching plans were progressively revised and the results of these revisions impacted on the design of the ARF minor centre.

The first bulk supplies of ARF minor centre equipment with REG-ELP/H4 and full STD facilities were made in 1969/70, by which time a large number of minor centres had been equipped with REG-LM. The new equipment was used mainly at new minor centres but, as resources permitted, was also used to upgrade older centres. First priority for upgrading was given to step-by-step minor centres which were fitted with SR-B and crossbar first stages. Replacement of REG-LM equipment was given a lower priority since there was less to be gained in most cases.

By this time a uniform approach to minor centre design had been established. Most minor centres were in towns with 1000 or more subscribers and used ARF for local and minor area switching. Most terminal exchanges in the area were small and were a mixture of magneto, APO RAXs, ARK-D and ARK-M exchanges. Six digit numbering was standard, with several minor areas being included in a single numbering area. The APO RAXs could not be given closed numbering and retained the old arrangement of two or three digit local numbers with all other numbers prefixed by '0'. There was frequently a manual trunk exchange co-sited with the minor and this was usually sleeve control. Where a step-by-step automatic exchange had been installed before the minor centre, it was converted to register control with SR-B. In some larger towns and cities there were one or two suburban exchanges. These could be ARF, ARK or step-by-step. If step-by-step the exchange would trombone trunk to the minor centre.

Conversion of country terminal exchanges to automatic using ARK was pursued fairly vigorously as soon as the equipment became available. Most of these exchanges were in portable buildings and standard designs for sizes up to 1400 lines were developed. Some ARKs were used in outer suburban areas of capital cities and other large urban networks. Occasionally two such portables were installed side by side to serve over 2000 lines but, although this was more economical than establishing a permanent crossbar exchange, there were environmental objections. In June 1981 there were 2686 ARK exchanges in service in Australia.

There were a few large country areas with populations of the order of 100,000 supported either by industry or tourism and which had networks of several large exchanges. Three typical cases were Wollongong, discussed in chapter 3, Geelong and the Gold Coast. There were also some large country cities with similar but smaller networks. These networks were similar to those in the capital cities but on a smaller scale and usually embedded in a minor area which was partly rural. The minor centres in these networks had to be individually designed to perform as a tandem centre for the built up area as well as a minor centre for the periphery.

These networks usually had some step-by-step exchanges installed before crossbar was available which had to be doctored in some way to fit in with a larger network. The usual solution was to fit SR-Bs. These smaller networks were often more difficult to design than the larger, but more homogeneous, capital city networks. Unfortunately, very few of these have been documented in a form suitable for publication. Details of the intentions can be found in development plans but the implementation often varied from these plans.

A landmark in the replacement of manual exchanges was reached in 1977 when Tasmania became the first State to have fully automatic local services.

During this period it was necessary to come to grips with the problems of long PPE lines. Although mainly an external plant problem some switching equipment changes were also involved. This included providing facilities to connect subscribers in several charge zones to an exchange. Two radio systems were also developed which included concentrators at the repeater sites (12),(13). For the most remote subscribers a satellite system was developed with some integration of switching and transmission but this is beyond the scope of this history.

THE MOVE TO FULL STD

The Community Telephone Plan made three major changes to the trunk network:—

(1) By extending the unit fee areas it immediately halved trunk traffic allowing the existing trunk switchboards to meet growth for about five years without extension.

(2) It made a commitment to extensive use of STD which made it likely that manually switched trunk traffic would not reach the pre ELSA levels for many years (14).

(3) It caused some integration of the local and trunk networks so that the old boundaries became less relevant.

Although the boundaries were blurred there were still parts of the system which were almost exclusively concerned with trunk switching. For the purpose of this section trunk switching equipment is defined as secondary and higher switching centre equipment, manual assistance exchanges and charging equipment.

ELSA was introduced on 1 May 1960 with many short distance trunk calls being reclassified as local. In 1959/60 there were 134,000,000 trunk calls and the number was reduced to 75,000,000 in 1960/61 the first full year of ELSA. This provided a breathing space to allow the development of full STD equipment.

In the meantime the APO designed point to point STD equipment was available and could be used from either step-by-step or crossbar origins where conditions were favourable.

Although the manual trunk network could meet this reduced demand there were strong economic incentives to provide STD as rapidly and extensively as other constraints allowed. Point to point routes were therefore established where trunk provision was adequate and significant traffic streams were involved using the locally designed equipment. By June 1967 19% of all trunk calls were dialled by subscribers over these routes.

A new phase in the provision of STD came with the cutover of ARM exchanges during 1967/68/69 (15),(16). The first were in Sydney, Canberra, Newcastle, Geelong and Launceston between September and December 1967. This gave access from about 250,000 subscribers' lines to a wide range of destinations. The ARM network was rapidly extended to include all capital cities and 18 secondary centres by June 1969. Growth in manually connected trunk calls was virtually halted by June 1968 and the peak year for these calls was 1968/69 with 114,200,000 manual trunk calls.

The ARM installations replaced some of the point to point STD routes but the equipment found new applications on early choice routes, particularly from country minor centres to capital cities, an application which had been envisaged from the start. New routes of this type continued to be provided and extended on a fairly large scale.

Between 1960 and 1967 the trunk switching plan had been changed almost beyond recognition as the result of detailed cost studies. The primary causes were the higher 'first in' costs of crossbar in comparison with step-by-step and a general lowering of transmission costs. The result was a reduction in the number of switching centres and a downgrading of most of those remaining. At first these changes were inhibited by the need to have enough ARM exchanges to provide charging for all trunk calls. The provision of charging at ARF minors removed this constraint and led to a further reduction of the number of four wire switching centres.

The whole process was one of optimising crossbar design to network needs and adapting network structure to suit the nature of crossbar equipment.

By 1967 this process had been largely completed but there were still further reductions up to 1980 as proposals for individual minor centres were reviewed. The following table shows the number of switching centres planned at several dates.

Switching Centre		**Number Proposed**		
Classification	**1960**	**1968**	**1975**	**1978**
Main	**6**	**5**	**5**	**5**
Primary	**43**	**0**	**1**	**1**
Seconary	**196**	**55**	**35**	**35**
Minor	**796**	**300abt.**	**257**	**210**
Total	**1041**	**360abt.**	**298**	**251**

Some of the secondary centres, notably Goulburn and Griffith in NSW were established before the full implications of the network changes had been realised. A few minor centres were also established which could not be justified in the light of later costs.

The other component of the STD network was the ARF minor centre with REG-ELP-H4. The first were installed during the 1969/70 year and details are given in the chapter on country networks.

For several years the operator trunk network was left almost unchanged while efforts were concentrated on STD. It was adequate to meet the demand and there was no point in abandoning such a valuable asset. It was kept as independent as possible from the STD network but some interworking was essential. A policy was adopted that operator switched calls used the operator trunk network to reach the target minor centre and shared only the minor centre switching and the terminal link with subscribers.

Although the level of manually connected trunk calls never again reached the level of 1958/59 some new manual trunk exchanges were still needed. As small country exchanges were converted to automatic their manual trunk traffic was transferred to other centres, so that some trunk exchanges grew rapidly. The 2VF network and associated trunk exchanges were obsolescent and a new type of exchange was needed. LME had offered an AFG type exchange which was integrated with an ARM trunk exchange. After some changes were made to suit Australian requirements the first of these was installed at Wangaratta in 1969/70 followed by a further ten in the next four years. Interworking with the 2VF network was provided, using routes barred to subscribers but operators were also given access to the STD network. From this time the 2VF network steadily declined.

For manual assistance centres where there was no ARM the APO designed two cord type four wire switchboards known as AFM 401 and AFM 402. The AFM 401 was a modified sleeve control switchboard designed in NSW and installed in the Sydney overseas exchange and at Parkes. The AFM 402 was a more ambitious project developed in Queensland under the direction of the Circuit Laboratories and included service assessment, directory information and other ancillary positions.

The rapid growth in STD trunk traffic was outstripping the limits of ARM in the capital cities and tenders were called on 5 April 1968 for a large capacity trunk exchange for Sydney to be commissioned in 1973. The ITT 10C system was selected and adopted as an alternative to crossbar where appropriate (17). It was an SPC system with more flexibility than crossbar and additional facilities, including the potential for call charge record (CCR) which was seen as highly desirable for ISD. It also included a new type of manual assistance position with a visual display of call details replacing dockets. These positions could be sited as much as 400km from the automatic switching equipment.

10C exchanges were installed in all capital cities except Hobart starting with Waymouth in Adelaide (18) and were used both to meet demand for STD and to provide new facilities that were difficult or impossible to provide in ARM exchanges. The manual positions were adopted as standard with the intention of centralising the switching of all manual assistance traffic to the 10C exchanges with decentralised groups of switchboards in suitable country towns. A 10C exchange was also installed at Bendigo, to assess its suitability for smaller centres. However this was the only such installation.

As STD took over from the operators for simple number to number calls, the proportion of person to person, fixed time, reversed charge and similar calls increased and policies were developed to eliminate these. Mostly this was done by administrative changes and subscriber education. Instead of booking person to person calls, subscribers were encouraged to make a short call to find when the wanted person would be present. Fixed time calls faded away when network congestion ceased to be important. Surcharges were added to discourage the use of operators.

Public telephone STD calls required a new type of instrument and these were introduced when the availability of STD was great enough to justify this (19). INWATS (a service providing national unit fee at terminating customers expense on 008 codes) was introduced in 1979 mainly as a new facility for subscribers who could use it to improve service to customers but it also made a slight impact on reverse charge calls. Only 3% of trunk calls were still being dialled by operators in 1985.

ISD was introduced in 1976 using multimetering with charging applied at 10C exchanges (20). Unlike STD it was available only on request. This was followed in 1980 by ISD with call charge record (CCR) from exchanges which had calling line identification. By 1985 78% of international calls were dialled by subscribers.

CROSSBAR TECHNOLOGY

The crossbar switch itself has a long history but until 1935 it was only a solution looking for a problem. Prior to this time it was seen as a robust, reliable but costly alternative to electro mechanical uniselectors. It was used only in Sweden in two applications where the reliability and robustness justified the cost.

Crossbar came into its own only when more was known about link trunking and marker control. This made it possible to build switching stages of any size from small units and the crossbar switch was well suited to such uses. By the time the APO decided to adopt crossbar there were several systems in various stages of development. A major factor in choosing the LME system was that the switching stages had already seen a fair amount of field use and could meet the APO needs with little, if any, redesign. Descriptions of the LME equipment at this time are given in refs. (1) to (5).

In other respects the LME system needed a lot of development to meet APO needs, which were different from those of any other country and more extensive than most (6). This redesign was aided by the modular nature of the equipment which had four fairly independent sub systems:—

(1) Switchblocks with their associated markers.
(2) Line signalling relay sets and cord circuits.
(3) Registers
(4) Information signalling equipment, for communication between registers and markers.

SWITCHBLOCKS

The switchbiocks originally offered by LME met nearly all the APOs needs and only two additional types were developed. There was also some redesign of markers.

Because of the very high calling rates in inner city exchanges two new configurations of SL stages were produced coded 10C and 10D. These were simple extensions of existing groupings, involving no new concepts. However it was also necessary to redesign the subscriber stage marker to reduce its operating time. The new marker, coded SLM/S became the APO standard. This work was completed before the first ARF exchanges were cutover.

The other new switchblock was the three stage group selector, designed by LME in response to the APO's desire for an ARF group selector with greater availability (7),(8). The first two stages used identical switch racks to the standard ARF group selector. Some parts of the marker were also identical to the two stage switch, but a new marker rack was needed. A second version was produced which allowed an existing two stage group selector to be expanded to three stages but lacked some of the facilities of a new three stage installation. Both were available for bulk installations from 1967.

A new group stage marker was needed for the metropolitan version of ARF mainly because of the waiting place function (described below). This was completed before the first ARF102 exchanges were cutover.

All markers required small changes from time to time as new facilities were introduced. Most of these involved changes to the code receiver portion and the analysis of received digits.

CHANGES RELATED TO INFORMATION SIGNALLING

In the following sections each major development is described firstly in terms of the objectives, then the signalling changes needed to achieve them and finally the changes in registers and markers.

The original offer by LME described an MFC system which was a direct translation of the DC signalling used in ARF101. The possibility of using MFC to give additional facilities was hinted at and provision was made for 15 forward signals and six backward signals, with the possibility of increasing the number of backward signals. This compared with 11 and 3 in the ARF101.

The design of the new MFC signalling language which can truly be said to have revolutionised switching system design was the joint work of the APO and LME. The former defined the problems and, in co-operation with LME, worked out suitable signalling protocols and meanings for signals. The actual translation of this into hardware was mainly done by LME.

The basis of the signalling system was two sets of control signals. The first used three signals to control digit sending: send next digit, send first digit and end of selection (i.e. no more digits needed). The second set was used after the end of selection signal to indicate the fate of the call or the type of line reached: line free, line busy, line marked for interception etc. A total of six signals in this series was specified in the original offer.

Other signals were introduced to assist in interworking between step-by-step and crossbar. LME practice (indeed world practice) was to insert a register for the purpose of signal translation wherever there was a change in information signalling methods. A REG-U was to be provided at the interface from crossbar to step-by-step which received MFC digits and transmitted decadic signals. A REG-H was to be provided at the entry to the trunk network and a REG-Y at the exit.

In the detailed design of ARF102 it was soon realised that some of these registers could be eliminated if a register was able to work in two or more signalling modes using control signals to tell it when to change.

The first casualty was the REG-U. In the initial stage of crossbar introduction nearly all outgoing junctions would have decadic signalling and it was established that there would be large initial savings and little or no long term penalties if the REG-L was given decadic signalling capability and REG-U deleted. This involved the provision of control signals to change to decadic and to specify the digits to be sent. This needed more than six different signals in the backward direction and a fifth frequency was added to allow 10 signals.

When the details of interworking between step-by-step and crossbar in the Australian networks were more closely examined two problems were identified. The first was that the REG-LM would need to know the number length on all calls, and with the great variations in existing number lengths this needed much more extensive analysis than had been allowed for in the register design. The second was that post dialling delays would be very long on calls to crossbar destinations which overflowed via step-by-step tandems. It was feared that subscribers who were familiar with step-by-step would conclude that the call was unsuccessful.

The solution adopted to minimise the second problem was the introduction of a 'waiting place' at the first crossbar group selector. Calls to crossbar destinations were switched through the first selector before the calling subscriber had finished dialling. If the call was to be switched crossbar all the way it was held until the calling subscriber finished dialling. If it was to be switched via step-by-step the call was switched immediately. This required the first selector to indicate to the register that a call had to be held, and another control signalling series was needed. Also, since the first selector had an analyser to select routes, it was decided to increase its analysing capacity so that it could do number length analysis for the register. One more series of control signals was needed to pass number length information to the register.

A further change made at that time was to allow some details of the calling subscriber's category to be passed to the distant end of the connection. The end of selection process used a two part signal and the register originally sent a dummy digit in response to the signal calling for the second part. This was changed to a general indication of the calling party category.

The end result of all these decisions was originally called MFC-M. It had five different series of control signals, two of which were used only between the register and the first group selector.

Implementation required a completely new register, the REG-LM and a new group selector marker. The register was nearly twice the size and twice the cost of the register in ARF101 and the increase was basically due to the interworking facilities. The new marker was also fairly complex because of the need for analysis of number length and type of terminating equipment. The marker holding time was also increased and different marker access circuits were designed to reduce the delays in this switching stage. This was done by allowing two markers to work as a team instead of independently. The new group selector stage and marker was called 2/160 and the older was 1/80. More flexible allocation of availability and more versatile alternative routing was also provided.

Soon after the development of this register a need arose to send the zone of origin of an exchange to the charging point, initially an ARM. Through a clever innovation this was also done by MFC using a signal sequence which would not normally occur.

The ARM design was next to be tackled and this required defining the MFC signalling language for the trunk network which was to be called MFC-T. At this stage it was assumed that MFC signalling in the trunk network would be completely separate from that in the local network.

Several types of register would be needed for ARM exchanges:—

REG-H1 for calls from a local crossbar exchange, which would interface between the local and the trunk network and would also determine the charge rate and set it in the line relay set.

REG-H2 with similiar facilities to H1 but for calls from step-by-step exchanges.

REG-Y1 for calls incoming from another ARM trunk exchange

REG-Y2 for calls incoming with decadic signalling from a step-by-step trunk exchange.

REG-E to control ARK-M exchanges.

All of these registers were required to signal to other ARM exchanges using MFC-T signalling and also to terminal networks using MFC-M if it was the last ARM in the connection.

When design of the ARM commenced it was soon realised that the MFC signalling needed for trunk switching was a subset of the MFC-M system except for one addition, related to echo suppressor control. This facility was needed on only a very small proportion of calls, and the need for a register at the trunk network interface to repeat MFC signals was questioned.

It was established that a REG-H1 or REG-Y1 could be dropped off after the call had been switched through the ARM exchange (similarly to markers in ARF exchanges) unless this was the last ARM or the call required echo suppressors. The register was needed at the last ARM to provide terminating end analysis. A few other special cases arose where the register had to be left connected. REGS H2, Y2 and E could not be dropped off since they were decadic on the incoming side.

The savings from dropping off the registers were much greater than the extra costs involved in deciding when to do so and this was incorporated in the ARM design. The number of H2, Y2 and E registers needed in an ARM was small and it was decided to combine them in a single REG-EHY2.

As before, the MFC-M signalling language was developed in a co-operative effort by the APO and LME with most of the detailed implementation by LME. The echo suppressor signalling scheme was unique and had the power to provide them in the optimum transmission configuration, which was not possible in the arrangements used elsewhere.

For the development of the REG-E function it was necessary to design the MFC signalling scheme for ARK exchanges (MFC-K). For terminating calls it was virtually identical with MFC-M but some extra signals had to be provided between it and the REG-E. The design of ARK-M had not been finalised when the first ARM's were installed and neither had the REG-E part of REG-EHY2.

These registers were very large and expensive and made a significant increase in the 'first in' cost of ARM, which in any case was an order of magnitude higher than that assumed in the 1960 network studies based on step-by-step technology. This cost was unacceptable for minor centres, and only three ARM minor centres were installed.

The last major register design item was to have been the REG-LP, seen as a simplified version of the REG-LM suitable for country areas. However new facilities were added during the development which completely changed its function and form.

These changes were the result of feedback from field experience with installations of REG-LM in country areas and the higher than expected 'first in' cost of ARM.

Pending the development of REG-LP several ARF exchanges had been installed at minor centres with temporary trunking to give some local area switching and a few STD routes while waiting for the installation of a minor centre ARM. The intention was to remove the temporary trunking when ARMs were installed.

Experience with these installations made it clear that most of the functions of an ARM could be provided in this way. Switching within the area with closed numbering was provided and fairly simple methods of barring traffic between non adjacent zones were devised. Most of the STD traffic could be carried on routes using step-by-step interim multimetering relay sets and the cost penalty of switching the remainder via the secondary centre was small. It was not possible to control ARK-M exchanges but ARK-D could be used.

Attention now shifted to the possibility of using these interim arrangements as the basis for an ARF minor centre design. Some small enhancements were needed but the cost could be kept down by using the parent secondary centre as a 'too hard basket'. STD routes from the minor centre were limited to fixed rate routes (which could carry most of the traffic) while the difficult charging was to be performed at the secondary centre. The ARF would have to identify the zone of origin of any STD call and pass this to the ARM. It would also have to identify any intra minor calls which were not unit fee and pass these to the ARM for charging. Such calls would be 'tromboned' but the traffic volumes would usually be quite small. It was decided that control of ARK-M would be nice but hardly vital.

This called for a fairly substantial change to the REG-LP but it was still seen as a relatively simple register. However LME had been developing a new register architecture in Sweden. Its main feature was that complex functions with short holding times were performed in peripheral devices, and the register itself was quite simple and inexpensive. It was designed to make the addition of new facilities a relatively simple process.

When the new REG-LP facilities had been specified LME suggested that, rather than further modify the existing partly developed REG-LP, it should be redesigned using the new architecture.

An attractive feature of this proposal was that it was potentially a very powerful register but if some features were not needed the appropriate peripherals could be omitted. It was also possible to use the same register for metropolitan networks where it offered cost advantages over the REG-LM and had the potential of adding such features as touch tone dialling and calling line identification (9).

With the new register the cost of controlling ARK-M was less than previously, since this was performed mainly in peripherals. This facility was therefore added to the design and the register with this facility was called REG-ELP. At the same time it was recognised that ARMs would never be required to control ARK-D and the relevant parts of the REG-EHY2 were never designed.

There was one final change to the design of the ARF minor centre. There had always been some concern about charging intra minor area STD calls at the parent secondary centre. A solution to this was found in re-entrant trunking. These calls were switched by the group selector to a route back to the same stage inlet via a local, fixed rate multimetering relay set. Having established the concept, an obvious development was to use a variable rate multimetering relay set, with the charge determined by an analyser capable of computing the charge for any call originating in the minor area. The analyser was called a REG-H4 and this addition produced an ARF minor centre with full facilities.

This became the standard minor centre with a 'first in' cost about a quarter of that of ARM which was now only used for higher order switching centres. The only

ARM function which the REG-LP did not provide was terminating analysis. A REG-Y1LP was developed for this purpose but arrived too late to have extensive use (10).

There were still many proposed minor centres where the cost of establishing an ARF minor facility was much greater than any savings achieved by its establishment. These savings were mainly, but not exclusively, in transmission equipment, the costs of which were declining rapidly. The possibility of designing a lower cost minor centre, based on the original ARK-503 proposal, was investigated for some years but no effective solution could be found.

ARK EXCHANGES

ARKs had been used in Sweden with a simple register and RAX type numbering for some years. The APO wanted closed numbering and the ability to work with step-by-step or crossbar parents. The step-by-step type was the more urgent need and the specification was straightforward. The design was performed mainly by LME and they were available from 1963 (11). The ARK-M design was tied up with the design of its parents, firstly the ARM and later the ARF minor centre. Its production was therefore delayed and the first bulk deliveries were in 1969/70 (12). A third version ARK-L was produced which worked with a manual parent and could be converted to ARK-M when that parent became automatic.

LINE RELAY SETS

A large amount of effort went into the design of line relay sets. There were numerous types depending on the type of line signalling (13), the type of exchange and the type of register, if any, to which it had to connect. They were being designed continually from 1960 until about 1975 in accordance with a priority set in a design list. The capacity of LME to produce new designs and of the APO to test and approve them was a severe limitation over most of this period.

The delays in producing the full range of line relay set designs compelled the State installation staff to develop interim solutions. These often took the form of slight modifications of an existing design with similar facilities to the one required. Some of the modifications were subsequently adopted as the basis for a standard design and this was a significant type of contribution by APO engineers to the design of crossbar. In other cases a 'conversion' relay set was added to a standard relay set. The conversion relay sets were frequently based on step-by-step line relay sets, since the interface conditions to an ARF exchange were similar to those of step-by-step.

MARK II AND MARK III MFC SIGNALLING SCHEMES

By 1967 consideration was being given to the introduction of new facilities in crossbar including centralised interception and calling line identification. This would require further control signals and opportunity was taken to review the whole signalling scheme. The result was the Mark II MFC signalling scheme which was more logical and had considerable room for subsequent expansion. From this time all new register designs had the capability of changing the meaning of signals by re-strapping. This signalling scheme with small changes was adopted by the CCITT as signalling system R2.

The introduction of this scheme was found to be far more difficult than expected. It was necessary for all registers in a closed numbering area to be modified before any of the new signals could be used. A less ambitious scheme was therefore produced and called Mark III (14). This allowed immediate needs for control signals to be met and required changes only in exchanges where the new facilities were needed. The scheme could be further expanded to ultimately give the same facilities as Mark II.

THE REMO PROJECT AND ARE11

The Mark III signalling scheme was one element in a major register upgrading project required to introduce new facilities. This project involved major changes to REG-LM and although the REG-LP had been built with the addition of these new facilities in mind some changes were needed as well as the installation of additional peripherals.

The major facilities to be added were:—

(1) The Mark III signalling system as a prerequisite for (3) and (4)
(2) Calling line identification as a prerequisite for (3) and (4)
(3) Call Charge Record (CCR) as a standard facility on ISD and as an optional extra on STD
(4) More powerful interception facilities including the possibility of automatically tracing malicious calls
(5) Provision for VF touch tone dialling
(6) A greater number of classes of service
(7) A number of minor improvements resulting from field experience which had been accumulated for inclusion in the next major upgrade.

The necessary design work was completed and a programme of register modernisation (REMO) was approved in January 1975. A short while before LME had offered a new system to the APO initially called ANA-30 which was essentially an SPC replacement for the ARF registers and some of the markers. Field trials of this went ahead in parallel with planning for REMO. It offered better facilities than existing relay type registers and in reasonably large installations it was much lower in cost. In fact in most cases the replacement of existing REGs-L with ANA30 instead of upgrading them could be economically justified. The volume of this type of equipment if used in this way was sufficient to justify the development and introduction costs.

It was therefore decided to replace all REG-LM and most REG-LP in metropolitan networks with the new equipment. Exchanges using the electronic register were given a new designation of ARE11. The REMO programme commenced in 1977/78 and was scheduled to be completed in metropolitan areas in five years.

MANUAL TRUNK EXCHANGES

Between 1960 and 1970 the combined effects of ELSA and STD postponed the need for new manual trunk exchanges and the production of a new design was given a low priority. Two specific needs (in Newcastle and Brisbane) triggered the development of a new cordless board. This was designated AFG and used ARM as the switching element (16),(17(,(18). The design was based on the existing LME exchange with circuit changes to meet APO needs, including a formal queueing system for calls. Since the APO had recently designed a cordless console for a different application this was used as the basis of the cordless positions.

The operator had different registers to subscribers and this allowed different facilities to be provided. These included 'operator only' routes, mainly for access to the 2VF network, and methods of handling traffic to overloaded routes without unduly handicapping subscribers seeking the same route.

A development which began before the AFG design was a cord type four wire switchboard. The need for this arose with the opening of the SEACOM cable to Canada. The international circuits provided on this cable needed four wire switching in Sydney and a suite of sleeve control switchboards was modified for this purpose. The main change was the fitting of carrier type double jacks and plugs and making the operators speech circuit four wire. This was adopted as a standard design for small country trunk exchanges needing four wire switching and was called AFM401. However only one more was installed at Parkes.

When it was recognised that this type of switchboard had fairly wide application it was decided to produce a more modern design. The design was carried out in Queensland under the general direction of the Headquarters Circuit Laboratory (19). This was the last cord type trunk switchboard developed for Australia and was called AFM402.

SPC TRUNK EXCHANGES

The ARM design had limitations in the maximum possible size and it was rather difficult to extend it or to add new facilities. For these reasons the APO kept abreast of developments in SPC exchanges and in 1968 tenders were called for a large trunk exchange for Sydney. The 10C system offered by I.T.&T. was considered to meet requirements and to be superior to ARM for very large installations (20). In 1970 the use of 10C was approved as an alternative to ARM where economically justified.

10C was to be used as far as possible as the vehicle for new facilities such as centralised interception and call charge recording. Software development to meet the special needs of the APO was a fairly long process and the first 10C exchange was cutover in 1975.

A component of the 10C system was a new type of operating position with attractive features (21). In particular, the operating positions could be located up to 400km. from the switching equipment. This allowed a completely new approach to provision of operator assistance.

Various new facilities were added from time to time, including ISD multimetering, ISD call charge recording and INWATS.

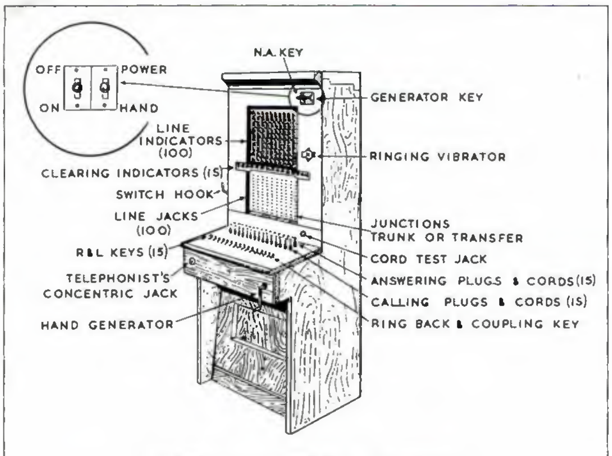
TECHNOLOGY PRINCIPLES

This appendix contains information which supplements the main text by describing the principles underlying the various switching technologies and explains some of the reasons behind the development of systems. The material has been placed here because it would have interrupted the flow of the main text. A reading list has been included as a guide to the most easily accessible sources of more detailed information.

MANUAL EXCHANGES

A manual exchange contains a switching mechanism which is designed to be manipulated by operators to set up calls between subscribers. It also has facilities to allow the subscribers to make their demands known. Larger exchanges and networks must be so built that a number of operators can share the work without conflict.

Manual switching in Australia has always been dominated by magneto exchanges. In these exchanges the telephones have a hand generator (formerly called a magneto) with an output of about 75 volts at 16Hz which can be used to signal the exchange or ring the bell of another telephone. To make a call the subscriber 'rings' the exchange by turning the generator handle. An operator answers, receives a request and established the connection. At the end of the call the subscriber 'rings' again to let the operator know that the connection is no longer required.



(a) Face Layout (100 line switchboard).

Fig. 7.1 — 100 Line Magneto Switchboard

Many magneto exchanges used floor pattern non multiple cord switchboards and this type illustrates many features which are common to other manual systems. Figure 7.1 shows a typical switchboard of this type. The equipment can be divided into three main groupings, i.e. subscribers equipment, cord circuits and the operator circuit.

Each subscribers line is fitted with an indicator and a jack. The indicator has a shutter held by a latch and

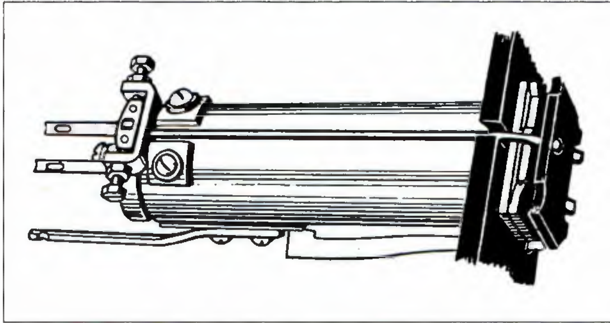


Fig. 7.2 — Subscriber's Indicator

the AC signal from the generator lifts the latch, allowing the shutter to fall alerting the operator. The jack is electrically and mechanically similar to the headphone sockets found on domestic sound equipment. Indicators and jacks are arranged on a vertical panel which is usually called a jack field.

Cord circuits provide the means of connecting subscribers lines together and allowing operators to talk to subscribers. Each cord circuit can provide one connection and enough are fitted to allow for the maximum number of simultaneous calls expected. A cord circuit is made up of:—

(1) Two plugs at the end of flexible cords. Subscribers' lines are connected together by inserting the two plugs of one cord circuit into two subscribers' jacks. This action also disconnects the subscriber indicators.

(2) A three position key switch. In one position it connects the operator's speaking circuit to the cord circuit to allow the operator to speak to subscribers. Another position connects a generator to allow the called subscriber's bell to be rung. In the third (normal) position the operator's circuit is disconnected from the cord circuit.

(3) A 'clearing' indicator which responds to the ring off signal from the subscriber.

The operator's circuit contains the speech components of a magneto telephone and a hand generator. In larger exchanges a generator driven from the mains or by batteries is provided instead of a hand generator.

When a subscriber calls and the indicator drops, the operator plugs the cord nearest to the jack field (the answering cord) in the calling number's jack, restores the shutter, puts the key into the speaking position and talks to the subscriber. The operator then plugs the other (calling) cord into the called number's jack, puts the key in the ringing position and turns the generator to ring the wanted number. The key is then restored to normal which connects the two lines together. At the end of the call the clearing indicator drops and the operator restores the indicator and pulls out the plugs.

Exchanges of this type have been built in sizes from 25 to 200 lines. The upper limit of size is set by the maximum allowable work load for an operator. Smaller sized exchanges of the same type are usually designed to be mounted on a wall and have been made in sizes between 10 and 30 lines.

Two floor mounted switchboards can be installed side by side to make a larger exchange with two operators. Each operator can reach jacks on both switchboards and can therefore handle any call request. The normal procedure is for each operator to answer calls on his or her own switchboard as this reduces the criss crossing of cords. At slack times one operator can handle the whole exchange.

SOME DEFINITIONS

To describe larger exchanges it is necessary to introduce some extra terms.

AN EXCHANGE is a complete switching entity at a single site. It usually comprises all the equipment at that site but sometimes two or more exchanges are co-sited.

A POSITION is a portion of an exchange which includes the operating facilities for one operator.

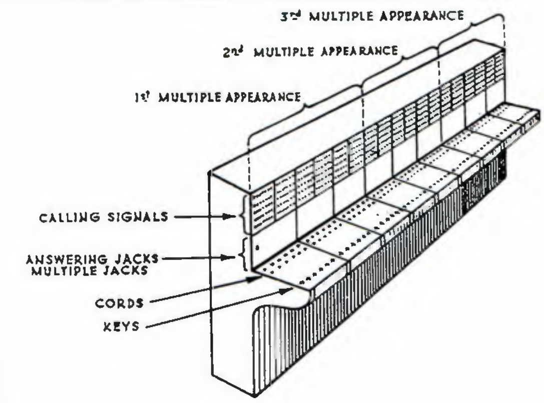
A SECTION is a group of two or three positions which form a logical equipment unit.

A SWITCHBOARD may be a simple position built as a self contained unit, a group of positions forming a logical unit or a complete exchange.

LARGER MANUAL EXCHANGES

A three position exchange can be built by placing three non multiple switchboards side by side but there are some problems. The operators at the end positions have difficulty in reaching over the full extent of the jack fields and interfere with the work of the operator on the middle position. If more positions are added the situation rapidly gets out of hand. Two solutions to the problem of building large exchanges were developed very early in the history of manual switching.

The preferred solution was the multiple exchange. In such exchanges each subscriber's line was connected to several jacks arranged so that every operator could reach at least one of them. The concept is illustrated in Figure 7.3 which shows the layout of the jack field on a typical exchange with nine positions. The lower portion labelled local or answering field is similar to the jack field of a non multiple position and has 200 jacks. Indicators for these lines are located at the top of the position and the operator for that position answers calls for these lines.



Typical Assembly of Multipla Switchboard.

Fig. 7.3 — Magneto Multiple Switchboard

The upper portion of the jack field has additional (multiple) jacks for every subscribers line arranged so that every operator can reach one of the jacks for every line and connect a call to any other subscriber in the exchange. Before connecting a subscriber the operator has to make sure that there is no existing connection to that subscriber. A 'busy test' is provided for this purpose.

The other method of building large exchanges was by the use of transfers. The simplest form of transfer was a connection between two jacks on non adjacent positions. In a three position exchange several such transfers would be provided between positions 1 and 3. A call between a subscriber on position 1 and one on position 3 would be connected via one of these transfer circuits. For a larger exchange more groups of transfers are needed to give every operator access to the rest of the exchange. Transfer working is an effective technique for exchanges up to about five positions but rapidly gets out of hand in larger exchanges. Signalling on transfer circuits uses much the same techniques as junctions and will not be discussed here.

CENTRAL BATTERY

The other type of manual system is Central Battery (CB) in which the subscriber calls the exchange by lifting the receiver or handset from the telephone. Relays at the exchange test the state of the subscribers switchhook and calling and clearing signals are usually displayed by small lamps and less frequently by 'eyeball' indicators. The main advantages of CB are that the supervisory signals are more positive and the subscribers' telephones do not have generators or local batteries. Both multiple and non multiple CB exchanges have been used in Australia but the majority were multiple.

A variation was to use a central battery for signalling and a local battery to provide power to the transmitter. This arrangement was called Common Battery Signalling or CBS and the claimed advantage was that it gave the positive signalling features of a full CB exchange but did not require the same high standard of line construction. An exchange of this type is believed to have been installed at Petersham (NSW).

JUNCTIONS

A junction is a link between two exchanges within a local call network and the earliest junctions between manual exchanges used magneto signalling and were provided by simply connecting the lines to subscriber line circuits at each end. An early refinement was to provide a separate group of jacks and indicators for junctions.

Magneto signalling on junctions caused difficulties because there was only one signal available and it would usually operate more than one indicator or bell. For example, the operator at the originating exchange could not ring the called subscriber's bell without also dropping the clearing indicator at the terminating exchange and calling in that operator. This could be avoided by making the incoming operator responsible for supervising the call and ringing the B party but such a division of responsibility was not favoured.

In theory, both parties rang off at the end of a call, the two indicators fell and both operators challenged the call before disconnecting. The process took some time, particularly at busy times when the operators gave priority to new connections. If a subscriber attempted to make a new call before the call had been cleared he might be answered by either operator and confusion was only too likely. Connections involving three or four operators were possible in some networks and in such cases the problems were compounded.

These problems first became serious in about 1895 when the CBD of large cities in Europe and America became too large for a single exchange. A period of rapid change in junction signalling techniques followed which dramatically increased the efficiency of junction operating. Most of the improvement came from four major changes.

The first change, and the one which made the others possible was the provision of special positions to switch incoming junction calls. These became known as B positions while positions where operators answered subscribers were called A positions. The first B positions were identical to A positions and were mainly provided as a management aid. However, the segregation made further changes possible.

A simple change was to terminate each junction on a cord instead of a jack. Because each junction was in use for most of the busy hour this required less equipment and, more importantly, the operator now had to manipulate only one cord for each incoming call instead of two.

The next innovation was the use of order wires. An order wire is a speaking circuit between the two operators involved in switching the call, arranged so that the A operator can talk to the B operator at any time. In use, the A operator (say at Malvern) presses an order wire key which connects her to the required B operator (say at Central) and if no one else is speaking, orders up the call by saying 'Malvern 2134'. This indicates that a Malvern operator wants Central 2134. The B operator selects a free junction from Malvern (say No.17) and replies '2134 on 17'. The A operator plugs the call to Central junction 17 while the B operator plugs that junction to subscriber 2134 and rings.

Another improvement was the use of battery signalling and lamp supervision at the B position. A supervisory lamp was provided for each junction cord and was controlled by the state of the junction circuit at the two exchanges. The lamp would light if:—

* A plug was inserted in a jack at the outgoing end while the cord at the incoming end was resting on the keyshelf, or if:—
* The cord at the incoming end was plugged into a line but there was no plug inserted at the calling end.

Lamp signalling could be used either with or without order wires. Without order wires the first condition is a calling signal, while the second is a clearing signal. With order wire working only the second condition is of significance and is a clearing signal. In either case the incoming junction circuit does not have a magneto indicator and the A operator can ring the called subscriber without causing any disturbance to the B operator.

A further refinement was keyless ringing. Ringing was initiated automatically when the B operator plugged up a call and continued until the subscriber answered. It was necessary to detect when the subscriber answered and initially this was only provided for CB exchanges. It could be provided at a magneto exchange by fitting capacitors in the telephones and this was sometimes done.

All the above developments were used in some Australian exchanges and an indication of the improvement in efficiency is that the standard load for a B operator at a double cord position was 200 calls per hour, while with order wire working and keyless ringing the load could be as much as 540 calls per hour. There was also some reduction in the A operator's workload.

The B position operator might be accessible to over 100 A operators and at busy times there could be much fighting for an operator's attention. This was only serious if there was a shortage of junctions and several operators were hanging on waiting for the next free junction. The work was sometimes stressful and an inexperienced operator could lose control. Indeed, whenever a new operator was put on a B position for the first time the others would usually gang up and try to break the new chum down.

In Europe and America where there was a large investment in CB exchanges there were further developments involving the use of techniques borrowed from automatic telephony. Because of the early introduction of automatic exchanges, these improvements were never used in Australia.

All the above relates to calls over a single junction. No really satisfactory switching system was ever developed for manually switched tandem calls. A tandem B position was installed in Sydney with double cords and order wires. The operator would receive a request in the form 'Drummoyne 123 for Waverley'. The operator had to nominate a junction from Waverley and reply 'Drummoyne 123 on 17', re-order the call on Drummoyne as 'Tandem 123' and connect Waverley junction 17 to the nominated junction to Drummoyne.

A consequence of the improvements in junction switching was a revival of transfer working in a new form. In multi exchange networks the multiple over the A positions got very little use because up to 85% of all calls were to other exchanges. In some cases it was found to be more economic to switch the local traffic via B positions as if it was to another exchange. The extra operating costs were less than the cost of providing and maintaining the multiple over A positions.

STEP-BY-STEP AUTOMATIC

The first few automatic exchanges in Australia used Strowger equipment supplied by AEC Chicago and nearly all subsequent step-by-step equipment was basically similar.

Strowger's first patent for an automatic exchange was granted in 1891 and by 1912, after many changes, it was becoming accepted as a proven system. The switch mechanism had reached its final form but the circuit details were still rather fluid and frequent improvements were being made.

The heart of the system was the bi-motional switch. This switched a three wire circuit to one of 100 outlets. It had three moving contacts or wipers mounted on a shaft and held in front of an array of fixed contacts arranged in a cylindrical pattern. The wipers were moved to a particular outlet by first stepping the wipers vertically to sit outside one of the horizontal rows (called levels) and then rotating the shaft and wipers to the desired horizontal position.

Usually ten such switches were mounted in a horizontal row and their outlets wired in parallel, so that each switch had access to the same 100 outlets. This unit was called a 'shelf', the outlets of one switch were called a bank and the paralleled outlets of a shelf of switches was called a bank multiple.

A block of selectors all performing the same switching function was called a 'stage' with various descriptive adjectives used to identify a particular stage. A stage was usually made up of a number of shelves with the outlets of each shelf connected together in various ways.

Each time a digit is dialled in a step-by-step system the wiper mechanism of a switch is operated to build up a further part of the connection to the wanted line. Two different types of selector are needed, both using the same switch mechanism but with different control circuitry. These are called final selectors and group selectors.

In a final selector both the vertical and horizontal movement is controlled by the subscriber's dial and two digits are needed to control it. The first digit steps the wipers vertically and the second rotates the wipers across the bank. In this way the switch can reach 100 different subscribers' lines.

An exchange of 100 lines can be built using 100 final selectors (one for each subscriber) with their banks multipled. Each subscriber's line is connected both to a final selector inlet and to one of the bank outlets. In such an exchange only a few of the selectors will be in use at any one time and economies are possible if the 100 subscribers can share the use of a smaller number of selectors.

This is done with comparatively small and inexpensive switches called preselectors. The first preselector was the Keith line switch first used in 1904 which allowed 100, 50 or 25 subscribers to share 10 selectors.

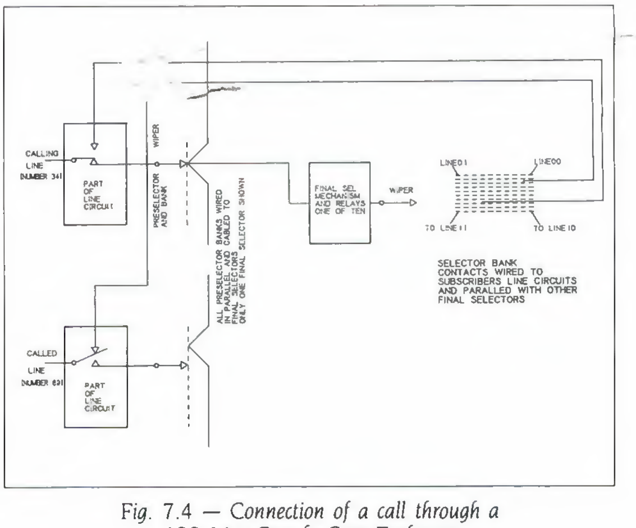


Fig. 7.4 — Connection of a call through a 100 Line Step-by-Step Exchange

Fig. 7.4 shows those parts of a 100 line exchange with preselectors needed to set up one call and indicates the relationship of these elements to the rest of this exchange. Fig. 7.5 shows the same thing in a more compact form known as a trunking diagram. The symbol for a final selector consists of a rectangle to represent the relays and switch mechanism and ten horizontal lines to represent the ten levels of bank outlets. Each symbol represents all the devices in a particular category. The connection between final selector banks and preselector inlets has been shown on this diagram but usually this detail is omitted. The same method can also be used to show the path of a single call with each symbol representing a single switch.

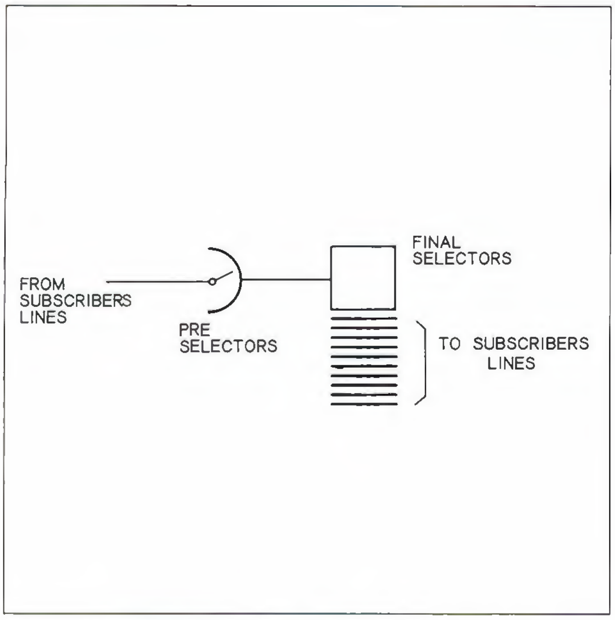


Fig. 7.5 — Trunking Diagram 100 Line Exchange

In exchanges larger than 100 lines an additional type of selector stage is needed and this is known as a group selector. It has the same bi-motional mechanism as the final selector but the associated relays cause it to operate differently. Only the vertical movement of the wipers is controlled by the subscriber's dial. The rotary movement is automatic and the switch tests each outlet on the level to which it has been stepped, stopping at the first idle outlet.

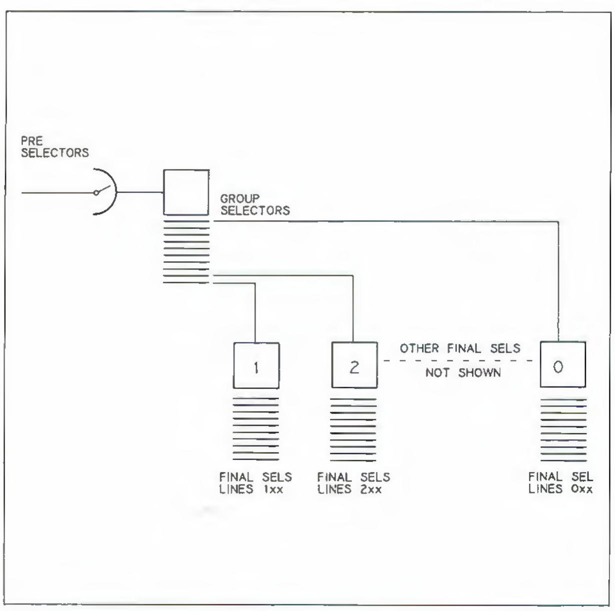


Fig. 7.6 — 1000 Line Exchange Trunking Diagram

Fig. 7.6 shows the equipment needed for an exchange with three digit numbering and a potential capacity of 1000 lines.

The exchange is made up of:

(1) Ten separate sets of final selectors, each giving access to 100 lines with numbers beginning with the same digit. Note that each set of final selectors is shown separately since, although identical switches, they handle different calls.

(2) A group selector stage arranged so that the outlets from each level are connected to final selectors reaching numbers whose first digits correspond to that level.

(3) Preselectors arranged to connect subscribers to group selectors.

When a call is made through this exchange the calling line is first connected via a preselector to an idle group selector. The first digit dialled (say 3) steps the group selector to level 3 and a free final selector on that level is selected. As stated before all these final selectors have access to numbers beginning with 3. The two remaining digits (say 2 and 6) step the final selector to the final selector outlet to which line 326 is connected.

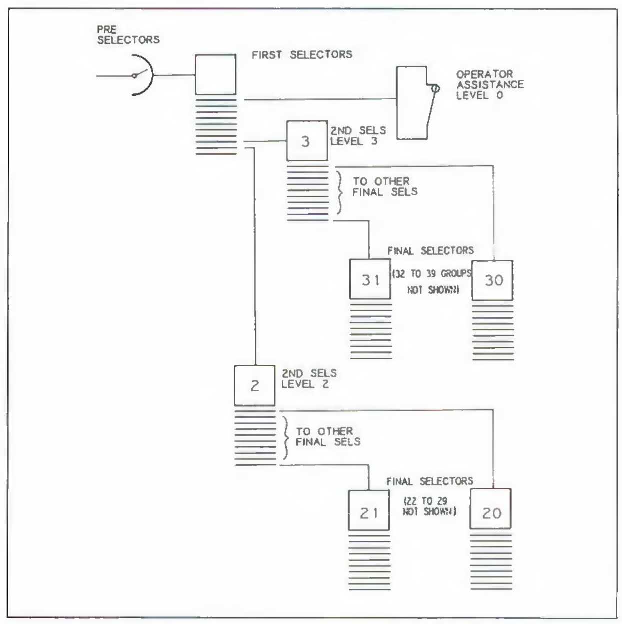


Fig. 7.7 — 2000 Line Exchange Trunking Diagram

Larger exchanges and networks are built up in a similar manner but require additional group selector stages. Fig. 7.7 shows how the trunking diagram for Geelong would have appeared when it had 2000 lines. There are now three different group selector stages and subscribers' numbers have four digits. The first dialled digit operates a 'first selector' which switches the call to a 'second selector' serving a particular 1000 line group. The second digit causes the second selector to switch the call to a final selector serving the required 100 line group and the last two digits complete the selection process.

The diagram also shows the tenth level of the first selectors giving access to a manual switchboard for calls to other exchanges. This was the usual arrangement for automatic exchanges which were not part of a network.

Each call through this exchange requires one first selector, one second selector for the appropriate thousand line group and one final selector in the appropriate hundred line group. The number of group and final selectors must be sufficient to ensure that calls failing because a free switch is not available are infrequent. There might be 200 first selectors, 100 second selectors in each 1000 and 10 final selectors for each hundred. Group selector racks had arrangements which allowed the number of outlets reached on any level to be adjusted to suit the traffic by wiring changes.

When step-by-step equipment is used in a multi exchange network the first one or two digits are used to select the desired exchange. In such networks the numbering, the location of selector stages and the junction network are closely related and the switching and numbering influence the efficiency of the network.

Most networks in Australia used main/branch exchange trunking and a typical example is Newcastle. Fig. 7.8 shows the numbering of the Newcastle network in 1960 with a few simplifications and Fig 7.9 shows how a typical call is switched through the network.

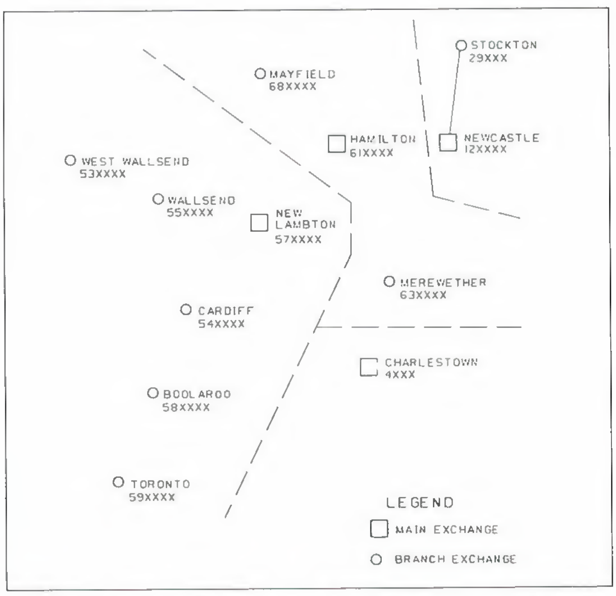


Fig. 7.8 — Newcastle Network Numbering and Switching

The exchanges in the network are divided into four 'main exchange areas' as shown and all exchanges in the same main exchange area have the same first digit. One exchange in each area is a main exchange and all other exchanges in the area are called 'branch exchanges'. For example, the six exchanges whose numbers start with 5 form the level 5 main exchange area and in this area New Lambton is the main exchange while Wallsend, Cardiff etc. are branch exchanges.

First and second selectors are only found in the main exchanges. New Lambton, for example, provides first selectors for all exchanges in its area and second selectors for calls from the whole network to level 5.

The way these selectors are used is illustrated by Fig. 7.9 showing part of a connection from Wallsend (55) to a number in Mayfield (68). When the call is originated the subscriber's line is switched via a preselector to a junction from Wallsend to a first selector at New Lambton. The first digit operates the first selector and the call is switched to a junction from New Lambton to a second selector at Hamilton. This selector receives the second digit and switches the call to a junction from Hamilton to a third selector at Mayfield. The remaining four digits operate selectors at Mayfield to switch the call to the wanted number.

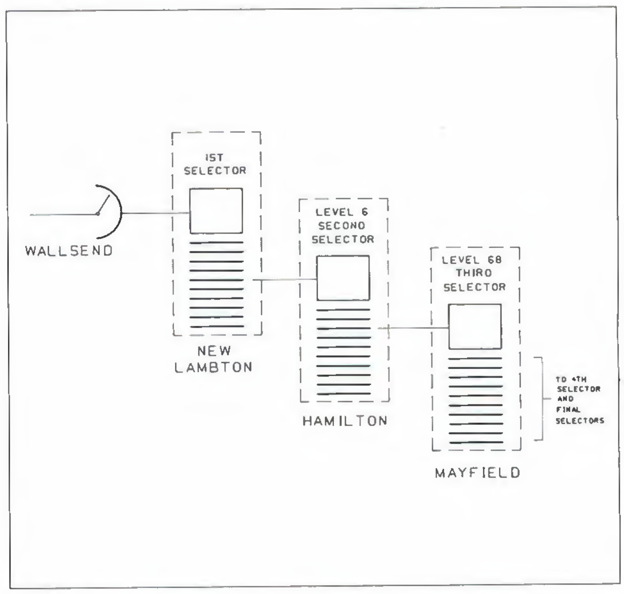


Fig. 7.9 — Path of a call from Wallsend (55) to Mayfield (68)

The biggest disadvantage of this arrangement is that a local call e.g. from Mayfield to Mayfield must be switched via first and second selectors at the parent (Hamilton). Discriminating switches were developed to avoid this 'tromboning'. Some of these switches can also switch calls direct to other nearby exchanges if this is justified by traffic and cost.

Large step-by-step networks often have special arrangements designed to overcome some of the handicaps. One which has seen much use in Australia is the use of satellite exchanges. These are small exchanges using part of the numbering of a branch exchange and usually trombone trunked from that exchange. When step-by-step equipment is used in a multi exchange network the first one or two digits are used to select the exchange. Of necessity the junction network is forced to comply with the numbering and switching arrangement adopted and the numbering and switching scheme adopted affects network costs.

In large networks it was necessary to allow for a long period during which a large part of the network was still manual and interworking between manual and automatic was needed. Fairly simple arrangements, as described in the next paragraphs were adequate for Australian networks.

For calls from automatic to manual the subscriber dialled a short code which gave access to a manual operator. This operator could be at a tandem point or at the destination exchange. Usually these calls were answered on positions similar to B positions and called 'Auto-A' positions. In many cases they were in fact old B positions which had been modified for this purpose. In small exchanges the junctions were answered by A operators.

Two different arrangements were possible on calls from manual to automatic. In large exchanges a group of special positions called 'Auto-B' was provided and equipped with keysenders. The A operator used an order wire to request a call and the Auto-B operator nominated a junction and keyed the number.

The Auto-B positions were cordless and the operator had only to press a key to connect the keysender to the nominated line and key the number. The normal workload was 450 calls per hour or 8 seconds per call.

In smaller exchanges the A positions were fitted with dials and outgoing junctions to automtic exchanges to allow the operators to dial their own calls.

A few manual exchanges were later provided with incoming automatic switches to allow calls from automatic to be completed without an operator.

SEMI AUTOMATIC EXCHANGES

A semi automatic system used automatic switches but they were controlled by telephonists instead of the subscribers. The subscriber had a CB telephone without a dial and made calls in the same way as if the system was manual.

The advantages claimed for semi automatic systems were:—

- Automatic switching was more economical than manual in large exchanges and networks. The main savings were in tandem switching and in the elimination of large multiples.
- There was more freedom in the routing of junction traffic than in step-by-step automatic because only the operators had to know the dialling codes. Therefore a different network numbering and switching arrangement could be used for each exchange.
- It was easier for the subscriber to use than automatic, particularly in a part automatic network where the subscriber had to call manual numbers in a different way to automatic.
- Costly and delicate dials did not have to be fitted to telephones.

The equipment was similar to a fully automatic system with the addition of a circuit interposed between the preselectors and the first group selectors known as a cord circuit. This circuit provided a temporary connection to:—

- A register which stored and transmitted the called subscriber's number
- An operator who keyed in the called number and was then disconnected from the cord circuit.

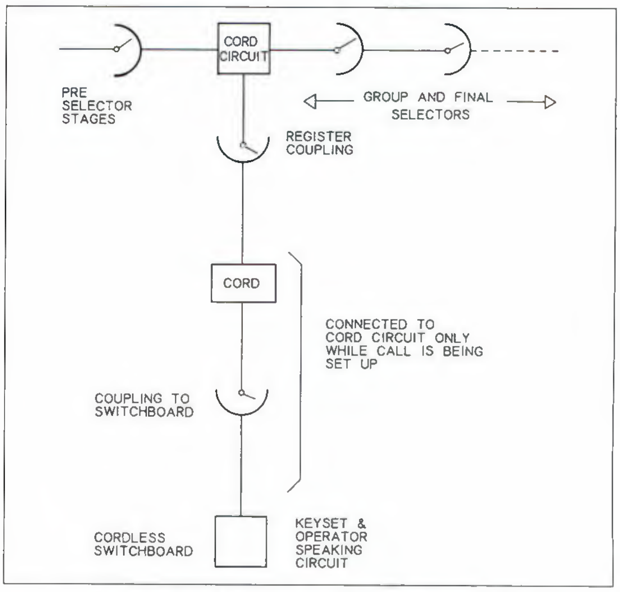


Fig. 7.10 — Semi Automatic Exchange Trunking Diagram

As a local system it had only a limited life, being displaced by register controlled automatic systems. These systems were structurally similar to semi automatic but the registers were more versatile. They stored the number dialled by the subscriber and translated the exchange prefix to the code appropriate to that exchange. In effect the register was provided with sufficient intelligence to allow the operator to be dispensed with. No systems of this kind were ever installed in Australia.

Semi automatic trunk exchanges which came into use from about 1940 were similar in concept and were a response to a similar problem. In this case the operator performed many functions which were beyond the capability of electromechanical logic.

CROSSBAR EXCHANGES

A crossbar selector uses relay type springsets to perform switching operations and has a mechanism which allows MxN springsets to be controlled by M+N magnets. In the LME crossbar switch there are 120 springsets controlled by 10+12 or 22 magnets. The selector can be wired to provide switches of different sizes and in nearly all cases it is used as ten switches of 20 outlets each.

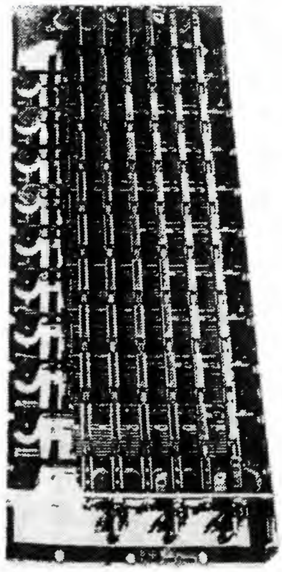


Fig. 7.11 — *Crossbar Switch*

In order to allow an exchange to be built from such comparatively small switches, a technique known as link trunking is used. This involves creating a large selector stage from two or more ranks of switches (known as partial stages). In choosing an outlet from the first partial stage the control mechanism looks ahead at the consequences in subsequent partial stages of the selector. In some ways the increased efficiency achieved by this is comparable to the gains made by a chess player in looking ahead at the subsequent moves.

Two main switching stages were used in ARF crossbar. The subscriber or SL stage connected 1000 subscribers to cord circuits (SR's) for originating calls and connected terminating calls to the same 1000 subscribers. It was equivalent to the preselectors, final selectors and the last group selector stage of a step-by-step exchange. The group selector or GV stage provided access to between 400 and 1600 outlets, depending on the configuration and these could be allocated to up to 80 routes to following stages.

The controls for link trunked selectors are called markers. They are very large and complex and in the interests of economy as many as 200 group selector inlets may be controlled by each marker. The actual number is determined by traffic calculations.

Crossbar switches cannot be efficiently controlled from a subscriber's dial and a register is always used to receive the dialled digits and to signal to the switching stages by a higher speed method. In Australia a tone signalling system known as MFC is used. A digit is represented by a combination of two out of a set of six audio frequencies and control signals from markers are sent using two frequencies out of a different set of five.

The use of a register and the provision of more intelligence in the markers than is possible in a step-by-step group selector means that the switching pattern is almost independent of the numbering scheme and this allows more efficient trunk and junction networks to be designed. Alternative routing is frequently employed in crossbar networks to increase efficiency.

SPC EXCHANGES

The logic elements of digital computers are functionally similar to relays and the possibility of using electronic logic in telephone exchanges was recognised as early as 1950. However at this time electronics could not compete in terms of cost or reliability with relay circuits. There were also problems in matching the high power low speed switches with the low power high speed electronics. In broad terms, solid state logic (transistors and integrated circuits) overcame the reliability problems while low cost memory devices available from about 1977 made SPC economically competitive. The third problem was minimised by the development of new types of relay and finally eliminated by the use of digital switches.

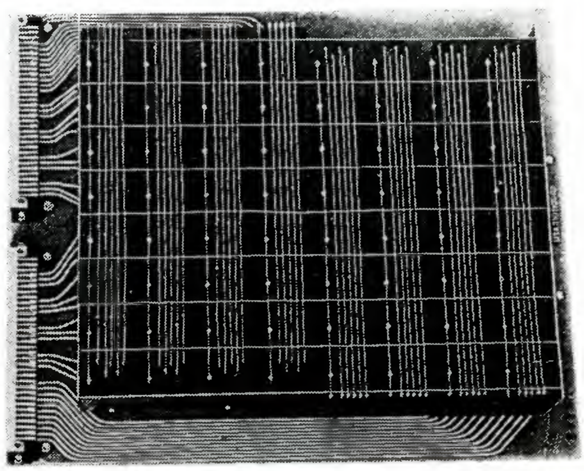


Fig. 7.12 — *Crosspoint Array*

Three main types of SPC exchange have been used in Australia, STC's 10C system, ARE and AXE. The latter falls outside the scope of this history. Each represents a different generation of computer technology and a different approach to design.

When the 10C system was being developed economic considerations favoured the concentration of all logic in a large central processing unit.

Reliability was achieved by making this from up to five large computers sharing the load and with arrangements to transfer the work of a faulty computer to the remaining ones. A consequence was that a large part of the capacity of the CPUs was tied up in performing simple tasks but at that time was more economical than building special devices for these tasks.

Line relay sets used reed relays, specifically designed to interface with solid state equipment. The switching elements were arrays of such reed relays (see illustration) usually with eight inlets and eight outlets or 16 inlets and 16 outlets. Link trunking was used and the greater power of the computer logic allowed up to six partial stages to be controlled as a unit. The system included a manual trunk exchange with facilities that could not be provided with electro mechanical technology.

The monolithic nature of the 10C system made the 'first in' cost very high and it was only suited to very large exchanges. All SPC exchange systems of the time suffered from the same handicap.

ARE was intended as a means of upgrading ARF crossbar and its objectives were limited. It replaced only the registers and markers of the ARF exchange, two problem areas for relay logic which were particularly suited to stored program control. The total processor capacity needed was much less than for a full SPC exchange and developments in minicomputers had made it economic to purchase computing power in smaller units. ARE therefore used up to seven independent processors, each replacing a number of crossbar registers or markers. The interface with the crossbar equipment used reed relays.

AXE was designed when the microprocessor was beginning to show its potential. The design distributes the logic between a large number of peripheral microprocessors and a pair of central processors. All the 'donkey work' is performed by the peripherals. The central processors are left with a comparatively small load of higher level functions. Digital switching overcomes the compatability problems of earlier SPC systems.

NETWORK DESIGN

The design of the junction and trunk network linking exchanges is of equal importance to the design of switching equipment. Indeed many equipment design changes have been the response to network studies which showed the need or desirability of a particular type of network configuration.

The central problem of network design is the choice between direct routes and tandem switching and arises because of the random nature of telephone traffic. Because of this, routes carrying small volumes of traffic are not very efficient. This can be seen from Figure 7.13 showing the usage obtained from trunks in the busy hour in routes of sizes up to 20 circuits when designed to a current standard.

In a network the traffic between two exchanges may either be carried on a direct route between them or passed with other traffic to a 'tandem' switching point. The cost per circuit of a direct junction is lower than the cost of a connection via the tandem (which may be longer and has additional switching equipment at

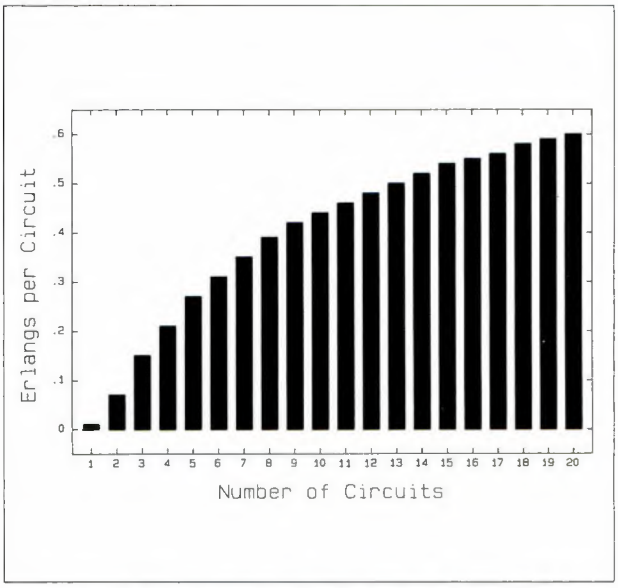


Fig. 7.13 — Traffic Per Circuit Grade of Service .01

the tandem), but the tandem routes are usually fairly large and carry more traffic per circuit.

The decision whether to switch traffic between two exchanges directly or via a tandem depends on the costs of circuits on the routes involved and their efficiency. As a general rule, direct routes tend to be chosen if the traffic is high and/or the tandem routing is circuitous.

More than one tandem may be provided in a network and a call may be switched via two or more tandems. The trunk network has four categories of tandem switching centre and a call may be switched at up to eight points.

A third option in network design is the use of alternative routing. This involves providing a direct route with fewer circuits than are needed to carry all the traffic. Calls which arrive when all circuits on the route are in use are switched via a tandem centre. Overflowing peaks of traffic in this way allows the direct routes to work at high efficiency.

Mathematical models of considerable complexity have been developed to allow decisions to be made between direct and tandem routing and to establish the number, location and organisation of the tandem centres.

The efficiency of a trunk route can be increased if calls are queued and subscribers are required to wait until a free trunk is available. This was a normal procedure in the manual trunk service but was discontinued when STD was introduced. It still has applications for short holding time common equipment.

FURTHER READING

More details of the various types of equipment used in Australia can be found in the sources listed below.

Many copies of most of them exist in Australia. All are held by the Telecom Historical Officer in NSW.

(1) The PMG 'Course of Technical Instruction', Volumes Telephony 1 to Telephony 5 was issued to every technician in training between about 1950 and 1965. Although there were several different issues there is no indication of the issue dates on the books. They describe nearly all the equipment in current use at the time the book was printed. Crossbar 1 and Crossbar 2 in the same series deal with some parts of the crossbar system.

(2) Technical Training Publications (PMG's Department). These were issued in loose leaf form from about 1965 and replaced the earlier books. They give detailed circuit descriptions of most crossbar equipment and some details of 10C. The only complete sets are probably held by Telecom's training establishments.

(3) The Telecommunication Journal of Australia, published two to three times per year from 1935 contains descriptions of many items of equipment. The level of treatment varies but is not usually over technical. A few articles on equipment which is not described in any other easily accessible source are:—
Kline J.A. The Development of the Automatic Selector Vol.6 No.4 p.223
Moynihan, J.F. Early Automatic Telephony in Australia Vol.35 No.2 p.45
Close, W. ARE11 System appreciation Vol.27 No.1 p.3

(4) Freeman, A.H. Automatic telephony in the Australian Post Office (Australian Telecommunication Mongraph No.4, Telecommunication Society of Australia, 1973)

(5) Poole, Joseph, 'A Practical Telephone Handbook' Seventh edition, London, 1930. This describes most of the earlier types of manual exchange. It was the most widely used text book in the Department in the 1930s and many copies still exist.

(6) Atkinson, J. Telephony, London, 1948. Describes British practice in the post war years and includes a good chapter on the Melbourne Trunk Exchange.

(7) Berkely, G.S. Traffic and Trunking Principles in Automatic Telephony. Although dated, this book in either edition gives a very readable description of traffic engineering and network design principles.

(8) O'Dell, G.F. An Outline of the Trunking Aspect of Automatic Telephony, Institution of Electrical Engineers Journal Vol.65 1927 No 362, 364 p185 ff. An excellent account of fundamental principles and early developments in Traffic Engineering.

APPENDIX
Tables and Charts

This appendix contains statistical summaries of the telephone system at 1901 and 1981 and details of some capital city networks at various times.

Table A1

LINES IN SERVICE IN NEW SOUTH WALES AT JULY 1901

Sydney		Country	
Central	3710	Albury	48
		Ballina	28
Ashfield	251	Bathurst	131
Balmain	233	Broken Hill	313
Burwood	350	Casino	28
Chatswood	142	Cobar	22
Epping	35	Coraki	13
Edgecliff	432	Dubbo	46
Glebe	177	Forbes	31
Hunter's Hill	79	Goulburn	21
Kogarah	80	Katoomba	33
Liverpool	20	Lismore	118
Manly	116	Lithgow	19
Mosman	158	Mudgee	42
Newtown	312	Newcastle	222
North Sydney	356	Orange	51
Paddington	153	Singleton	26
Parramatta	184	Tamworth	68
Petersham	286	Wagga	33
Randwick	189	Waratah	24
Rookwood	35	West Maitland	27
Ryde	31	West Wyalong	27
Wahroonga	147		
Waverley	175		
William Street	266		
Total Suburbs	4207	Total Country	1371
Total Sydney	7917		
Total NSW	9288		

Table A2

LINES IN SERVICE IN VICTORIA AT JULY 1901

Melbourne		Country	
Central	3057	Ballarat	259
		Bendigo	146
Ascot Vale	69	Echuca	36
Brighton	146	Geelong	280
Brunswick	53	Hamilton	30
Canterbury	43	Queenscliffe	2
Cheltenham	40	Warrnambool	63
Footscray	37		
Hawthorn	334		
Heidelberg	17		
Malvern	316		
Oakleigh	19		
Williamstown	50		
Windsor	623		
Total Suburbs	1747	Total Country	816
Total Melbourne	4804		
Total Victoria	5620		

Table A3 LINES IN SERVICE IN QUEENSLAND AT JULY 1901

Brisbane		Country	
Central	1182	Bundaberg	77
		Cairns	56
Albion	64	Charters Twrs.	244
Toowong	36	Ipswich	59
		Mackay	49
		Maryborough	71
		Mount Morgan	27
		Rockhampton	156
		Toowoomba	140
		Townsville	166
		Warwick	40
Total Brisbane	1282	Total Country	1085
Total Queensland	2367		

Table A4 LINES IN SERVICE IN SOUTH AUSTRALIA AT JULY 1901

Adelaide		Country	
Central	1207	Gawler	7
		Kapunda	12
Glenelg	8	Mount Gambier	36
Port Adelaide	205	Port Pirie	66
Stirling West	24		
Total Suburbs	237	Total Country	121
Total Adelaide	1444		
Total South Australia	1565		

Table A5 LINES IN SERVICE IN WESTERN AUSTRALIA AT JULY 1901

Perth		Country	
Central	973	Albany	112
		Boulder	144
Cottesloe	118	Coolgardie	150
Fremantle	430	Geraldton	54
Guildford	52	Kalgoorlie	345
North Fremantle	34	Northam	33
Total Suburbs	634	Total Country	838
Total Perth	1607		
Total W.A.	2445		

Table A6 LINES IN SERVICE IN TASMANIA AT JULY 1901

Hobart		Country	
Hobart	494	Franklin	12
		Gormanstown	31
		Huonville	9
		Launceston	247
		Longford	8
		New Norfolk	24
		Queenstown	61
		Strahan	18
		Zeehan	110
		Total Country	520
Total Tasmania	1014		

Table A7

LINES IN SERVICE IN AUSTRALIA AT JULY 1901

State	City	Country	Total
NSW	7917	1371	9288
Victoria	4804	816	5620
South Australia	1444	121	1565
Queensland	1282	1085	2367
Westn. Australia	1607	838	2445
Tasmania	494	520	1014
Australia	17548	4751	22299

Table A8

MULTIPLE EXCHANGES IN CAPITAL CITY NETWORKS

SYDNEY

EXCHANGE	CUTOVER DATE	TYPE
Central	21.6.1887	Series multiple magneto
Central	26.3.1900	Branching multiple magneto
Edgecliff	ca.1905	Branching multiple magneto
City	3.8.1908	CB
Mosman	7.8.1910	Branching multiple magneto
William Street	19.3.1911	Branching multiple magneto
Edgecliff	20.8.1911	Lamp signalling magneto
Petersham	3.9.1911	CBS
North Sydney	30.3.1912	CB
Burwood	ca.1912	Removed from Edgecliff
Wahroonga	ca.1916	Removed from Burwood

Information from card index compiled 1912 to 1920 and held by NSW Historical section. There is some evidence that the Central and Mosman branching multiple magneto exchanges were reused elsewhere after replacement.

MELBOURNE

EXCHANGE	CUTOVER DATE	TYPE
Central	c 1885	Series multiple
Central	26 Aug. 1911	CBM
Windsor	1910	CBM
Hawthorn	1911	CBM
Malvern	1911	Branching multiple magneto

BRISBANE

EXCHANGE	CUTOVER DATE	TYPE
Central	Pre 1900	Series multiple magneto
Central	Pre 1900	Branching multiple magneto
Central	1912	CBM

A multiple exchange may also have been installed at Toowong

ADELAIDE

EXCHANGE	CUTOVER DATE	TYPE
Central	Pre 1900	Series multiple magneto
Central	1910	CBM
Port Adelaide	1908	CB No.9

PERTH

EXCHANGE	CUTOVER DATE	TYPE
Central	Pre 1900	Branching multiple magneto
Fremantle	Pre 1900	Branching multiple magneto
Fremantle	1911	CB No.9

HOBART

EXCHANGE	CUTOVER DATE	TYPE
Central	1908	CBM

Table A9

NUMBERING AND SWITCHING PERTH NETWORK

Exchange	Auto in	Numbering 1914	1930	1933	Notes 1945	
Central	1914	Axxxx	Bxxxx	Bxxxx	Bxxxx	(1), (2)
Fremantle	1941/2	B(m)	FM(m)	FMxxxx	Lxxxx	(3)
Cottesloe	1930	F(m)	Fxxxx	Fxxxx	Fxxxx	(1)
Midland Junct.		J(m)	MJ(m)	MJ(m)	UJ(m)	
Guildford		M(m)	MU(m)	MU(m)	UL(m)	
South Perth	1940	U(m)	ML(m)	ML(m)	MLxxxx	
Cannington		W(m)	MW(m)	MW(m)	MW(m)	
North Beach (opened 1932)				BY9(m)	BY9(m)	
Scarborough (opened 1934)					BY2(m)	
Maylands	1936				Uxxxx	(1)
Victoria Park	1936				Mxxxx	(1)
Nedlands	1937				WMxxxx	
Subiaco	1940				Wxxxx	(1)

Notes

(1) Main exchange
(2) Accommodated level M second selectors from 1930 to 1936
(3) Indialling from 1933 as branch of Cottesloe. Main exchange in 1940
(4) The Australian dial originally had a letter and a number in each finger hole. Long telephone numbers were printed with the corresponding letter instead of the number for the first one or two digits. Thus the number 28-6543 was printed as BW6543. It was believed that this made the numbers easier to remember.
After 1960 the letters were eliminated from the telephone directories and the dials. The letters used and the corresponding numbers are:—

1	2	3	4	5	6	7	8	9	0
A	B	F	J	L	M	U	W	X	Y

(5) Compiled from telephone directories.

Table A10

NUMBERING AND SWITCHING FOR ADELAIDE IN 1935

Exchange	Code	Type	Exchange	Code	Type
Central	B(m)	CBM			
Tandem	L&M	Main			
Blackwood	Ux(m)	Mag	Prospect	Mxxxx	Branch
Brighton	Xxxxx	Branch	Semaphore	Yxxxx	Branch
Glenelg	Xxxxx	Main	Stirling	F9(m)	Mag.
Henley	L8xxx	Branch	Unley	Uxxxx	Main
Norwood	Fxxxx	Main	West Adelaide	Lxxxx	Branch
Port Adelaide	Yxxxx	Main	Woodville	Mxxxx	Branch

Notes

(1) From 1930 to 1933 the Siemens equipment (formerly semi automatic) at Port Adelaide was numbered Jxxxx while the new BGE equipment was numbered Yxxxx. The Siemens equipment was replaced in 1933. Subsequently the Port Adelaide and Semaphore exchanges were renumbered as Jxxxx to free level Y for trunks.
(2) Tandem was installed at Central and had first selectors or Central, and F and M group branch exchanges as well as L and M second selectors.
(3) Some small exchanges in the Adelaide Hills have been omitted
(4) See also note 4 for Perth
(5) Compiled from telephone directories

GLOSSARY

AEC Automatic Electric Company, Chicago
ALL A remotely controlled magneto exchange
alternative routing A switching technique in which a direct route between two exchanges overflows traffic to a route via tandem exchanges.
AMA Automatic Machine Accounting. A method of recording and charging trunk calls. See also CCR.
analogue transmission Transmission of signals in the form of varying voltages corresponding to the speech information being transmitted.
A position An operating position in a manual exchange with facilities for answering calls from and connecting calls to subscribers.
APO Australian Post Office
ARE A crossbar exchange with stored program controlled registers. Developed from ARF.
ARF An LME type crossbar exchange for local area switching.
ARK An LME type of crossbar exchange for small exchanges. Maximum size is 2000 lines.
ARK-D An ARK exchange designed to switch via a step-by-step parent.
ARK-M An ARK exchange designed to be controlled from a crossbar minor centre.
ARK503 A version of ARK provided with minor centre functions.
ARM An LME type of crossbar exchange equipped with four wire switching for secondary and higher switching centres.
ARM 50 A small type of ARM exchange.
AXE An LME exchange with stored program control and digital switching and transmission facilities.
bearer A transmission path for a carrier system.
B position A manual exchange operating position handling incoming junction traffic only.
BPO British Post Office.
broadband bearer A bearer with a large capacity, usually more than 60 voice circuits.
carrier system A system which combines a number of telephone channels for transmission over a single bearer.
CAX Country Automatic Exchange. Superseded the term RAX c. 1965.
CB Central Battery or Common Battery. Manual telephone systems where the power to operate the telephones is supplied from the exchange.
CBD Central business district.
CBS Common Battery signalling. A manual system where signalling uses a battery in the exchange and the telephones have their own battery to power the transmitter.
CCITT International Consultative Committee for Telephony and Telegraphy.
CCR Call Charge Records. A system of trunk charging which records details of each trunk call and has the ability to provide detailed accounts.
cord circuit (1) Part of a manual exchange consisting of a pair of cords and plugs and associated components used to make connections.
(2) A part of an automatic exchange which provides similar facilities.
crossbar switch A switch which uses relay like mechanisms to connect circuits together.
delay working A method of manual trunk switching where the call is booked and connected later when a circuit is available.
demand working A method of manual trunk switching where the call is connected on request.
DRCS Digital radio concentrator system. A system developed to serve remote subscribers using digital radio.
DSR Discriminating selector repeater. A step by step selector which can switch traffic to its own exchanges and some nearby exchanges via direct routes and switches remaining traffic via its parent main exchange.
ELSA Extended local service area. A simplified charging arrangement introduced in 1959 giving unit fee calls over a larger area than previously.
ERF Exchange reference file. A data base of exchange statistics.
FDM Frequency division multiplex. An analogue type of carrier system multiplexing.
group selector An automatic selector with outlets arranged in groups to various destinations including other group selectors.
howler A signalling device used with phonophores which gives an audible signal.
ISD International subscriber dialling.
INWATS Incoming wide area telephone service. The "008" service allowing trunk calls to be made to specified numbers for the cost of a local call. The appropriate trunk charges are met by the called number.
LME L.M. Ericsson
main exchange A step-by-step exchange which provides tandem functions.
magneto exchange A manual exchange where the subscriber uses a hand generator (magneto) to call the operator.
manual exchange A telephone exchange in which operators perform the switching.
MFC Multi frequency code signalling. Used in crossbar exchanges.
multimetering A charging system for trunk calls in

which the meter is operated at intervals during the call.

multiple exchange A manual exchange where an operator can connect a call to any subscriber without the assistance of a second operator.

negative impedance repeaters An amplifying device for two wire junctions.

order wire A speech circuit between two operators to allow them to cooperate in setting up calls.

party line A telephone line shared by two or more subscribers.

PBX Private branch exchange.

PCM Pulse code modulation. A digital type of carrier multiplexing.

Pentaconta A type of crossbar manufactured by ITT.

post dialling delay The interval between the end of dialling and the return of ringing tone to the calling telephone.

PMG Postmaster General's Department.

PPE Part privately erected, a subscriber's line, part of which is constructed by the subscriber.

preselector A switch which connects a calling subscriber or switching stage to a group selector.

RAX Rural automatic exchange. Usually less than 200 lines.

REG-ELP/H4 An ARF register which sets the charge rate for calls.

REG-EHY2 An ARM register used on calls from step-by-step sources.

REG-H1 An ARM register which charges calls from crossbar sources.

REG-LM An ARF register for metropolitan exchanges.

REG-LP An ARF register for metropolitan and country exchanges.

REG-Y1 An ARM register with no charging facilities.

REG-Y1LP An ARF register used on some terminating calls.

ringer A signalling device for trunk circuits which allows magneto signalling to be used.

SCDC Single communication double current signalling. A technique used for DC signalling on high resistance circuits.

SE50 A type of step-by-step bi-motional switch built in Australia.

semi automatic Telephone systems in which automatic switches are controlled by operators.

sleeve control A type of manual trunk exchange.

SPC Stored program control. Used to describe exchange systems controlled by computers.

SSR Switching selector repeater. A step-by-step selector which can switch traffic to its own exchange and some nearby exchanges via direct routes and switches remaining traffic via its parent main exchange. An earlier form of DSR.

STD Subscriber trunk dialling.

step-by-step automatic systems where the switches are directly controlled by the impulses from the subscriber's dial.

tandem An exchange which switches traffic between other exchanges.

TDM Time division multiplexing, where each multiplexed signal occupies the bearer at different times.

10C An SPC switching system used in Australia for large trunk exchanges.

transit exchange A trunk exchange which switches traffic between other exchanges. Usually applied to manual exchanges.

trombone trunking A trunking situation where local calls must be connected via a parent exchange.

2VF A trunk signalling system using two voice frequency tones for signalling.

2000 type A type of step-by-step switch used in Australia from 1938 to about 1950.

X tandem A crossbar tandem carrying traffic outgoing from terminal exchanges to all destinations.

Y tandem A crossbar tandem carrying traffic terminating in a specific area.

About the Author

A. H. (Harry) FREEMAN, who is a member of the Institution of Engineers, Australia, joined the A.P.O. in 1938 as a cadet draftsman in Sydney and was promoted to engineer in 1946. Until 1956 he was employed in the Radio Section, mainly on the installation and operation of broadcasting transmitters.

He then transferred to the Transmission Planning Section at the time when the basic plans for introducing common control systems and for a fully automatic trunk network were evolving and participated extensively in the work which produced the "Community Telephone Plan 1960". During this period he was in charge of the "COMET" project which was the first application of electronic computers to telephone network design in Australia. He was chosen as an APO representative at the fourth International Teletraffic Congress in London in 1964 where he presented a paper on the results of this study.

From 1966 to 1972 he was Supervising Engineer, Trunk Service and Telegraphs, responsible for oversight of equipment maintenance in country areas of New South Wales and for installation and maintenance of telegraph and data facilities. From 1972 until retirement in 1981 he was a Supervising Engineer in the Planning Branch.

In retirement Harry has been active in the Historical Sub-Committee of the NSW Branch of the Telecommunication Society through which he has maintained a link with Telecom. He has kept in touch with current technological development as evidenced by comments in the book.

In addition he has helped his wife in her hobby of pottery and is a member of the Society of Australian Genealogists where he works in a voluntary capacity assisting people to use the facilities of the library in tracing their family ancestry.