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IN THIS ISSUE

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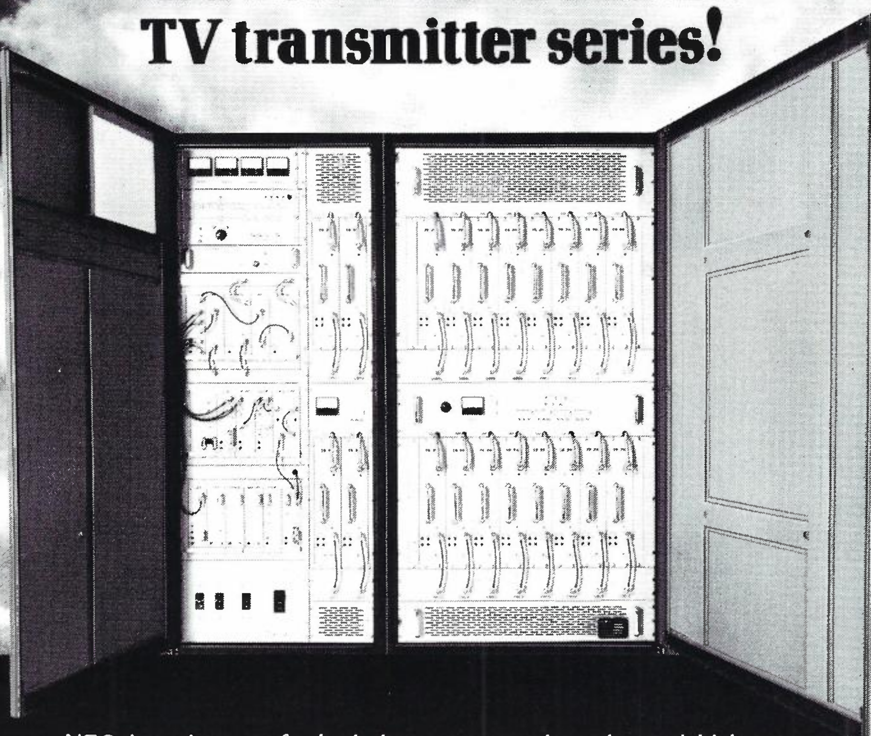

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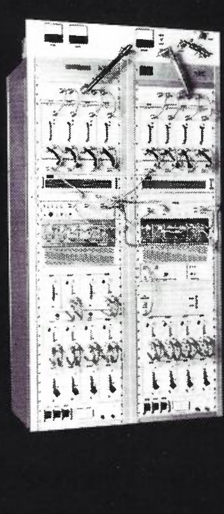

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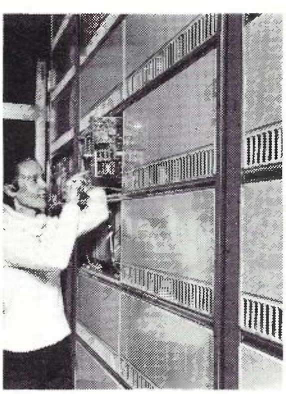

COVER
AXE LOCAL — SWITCHING EQUIPMENT

The Telecommunication Journal of Australia

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History of Local Telephone Switching in Australia and Background to the AXE Decision

K. W. POWER M.I.E. Aust.

Telecom Australia's decision to adopt L. M. Ericsson's AXE system as a new local switching standard for the 1980's and beyond is an important step in the development of the Australian telephone network. The availability of this new stored program controlled (SPC) electronic switching system for urban application will offer great economic advantages in future network expansion and operation. AXE will considerably help Telecom in its objective of containing prices to the Australian telephone customer in the years ahead.

This article gives an outline of the history of local telephone switching in Australia and the background to the decision to buy AXE. The major impacts of this decision are also discussed.

INTRODUCTION

In September 1977, the Government endorsed a recommendation by Telecom Australia that a new stored program controlled (SPC) switching system be adopted as a standard for urban telephone networks. The system, called AXE, was designed by L. M. Ericsson Sweden and offered by its Australian subsidiary, L. M. Ericsson Pty. Ltd. The AXE offer was one of seven proposals to Telecom in response to a world wide call for tenders.

This article outlines the historical background of local switching in Australia and examines the factors behind the recent decision. It highlights the investigation carried out by Telecom over a number of years to determine the best type of switching system for the economic and efficient expansion of the local telephone networks in the 1980s and beyond. Some of the criteria used in the intensive evaluation of the various system offers are also described. Other articles in this journal discuss the AXE system in terms of its technical characteristics, manufacture and installation aspects, and facilities for maintenance and operation in the Australian environment.

GROWTH OF LOCAL TELEPHONE SWITCHING IN AUSTRALIA

Local telephone switching networks came into being in Australia with the opening of the first, manually operated, telephone exchanges in the cities of Sydney, Melbourne and Brisbane in 1880 — just two years after the world's first. Melbourne's first telephone exchange, shown in the photograph, served 44 customers.

From these beginnings, the Australian telephone network has maintained steady growth so that it currently provides a total of just over 4 million services. On the average, each service originates approximately 1100

First Telephone Exchange in Melbourne

calls per year (90% within local networks) — an overall average of some 7,500 local calls for every minute of each day.

In the almost 100 years since the first manual telephone exchange installations, Australian local networks have progressively been modernised and automated by the introduction of a sequence of new switching equipment types, see **Fig. 1.** Key events in this development of the local network were:-

- 1911 : total number of telephone services reached 100,000 with all calls manually switched. Installation of first public automatic exchange at Geelong in Victoria using Strowger step-by-step equipment.
- 1937 : just prior to the second world war, 440,000 services, the first 2000-type step-by-step equipment installation in Melbourne.
- 1957 : Manual services reached their all-time peak. Just under 0.4 million of the subscribers were manually served in a network serving a total of approximately 1.3 million subscribers.
- 1959 : 1½ million services, adoption of L. M. Ericsson, ARF and ARK crossbar switching systems as local network standards.
- 1962 : first crossbar exchange installations — no further step-by-step orders.
- 1964 : number of step-by-step equipped ends 'peaked' at 1.8 million.
- 1976 : 3.7 million services, adoption of L. M. Ericsson, ARE 11 equipment type in selected locations for the upgrading of existing crossbar equipment.
- 1977 : following extensive evaluation of world wide tenders, adoption of L. M. Ericsson's AXE system as a new local equipment standard.

Changes in equipment type have occurred at about 25-30 year intervals, but individual installations of equipment generally remain in service for more than 40 years.

At June 1978 there were 4.1 million services in the Australian telephone network, comprising 100,000 manual and 4 million automatic. Of the automatic services, 68% were connected to crossbar equipment and the remainder (1.2 million services) were connected to step-by-step equipment. The network contained 1425 manual exchanges (mostly serving small rural towns) and 4350 automatic exchanges.

NETWORK DEVELOPMENTS SINCE THE COMMUNITY TELEPHONE PLAN

It is now almost 20 years since the publication of the Community Telephone Plan which set the course of development of the telephone network in the 1960s and the 1970s. This Plan proposed as a long term national objective, a fully automatic service for all Australian customers, with nationwide subscriber trunk dialling (the STD service). From a customer's viewpoint, a fully automatic service is faster and better and, for a telephone administration, it is cheaper to provide and operate. The key features of the Community Telephone Plan were outlined in a White Paper "Progress — Policy — Plans" presented to Government in August 1959.

At the time of preparation of the Community Telephone Plan automation of the Australian local telephone service was well on the way. Telephone services in metropolitan and larger provincial areas were predominantly automatic, using bi-motional step-by-step equipment, but most country services were still manual at that time. Apart from one or two fixed-fee STD routes, national trunk calls had to be connected via a manual operator and call charges were recorded using hand written dockets.

The structure of the Community Telephone Plan was built around the decision to adopt electromechanical crossbar switching as a new standard for local and trunk switching. The crossbar system chosen was that of L. M. Ericsson Pty. Ltd., and included trunk, local and transit applications. The main reasons for changing to crossbar from the step-by-step local switching and semi automatic trunk switching systems were:

- the need to increase the length of subscribers numbers in the larger cities from 6 to 7 digits to meet growth demands,
- the need to introduce nationwide STD (using multimetering technique) to contain spiralling costs of the manual connection of trunk calls,

KEN POWER commenced as an engineer with Telecom Australia in 1955, following the successful completion of an engineering cadetship. In the early years he worked on equipment installation in the country areas of Victoria and later as a planning engineer in Victoria and Tasmania. He also spent a year as a traffic engineering consultant with the telecommunication administration in Malaysia, under the Columbo Plan aid scheme. He has been in Telecom Headquarters since 1972 and was appointed as Superintending Engineer, Telephone Switching Planning in 1975.

Mr Power was chairman of the specialist team chosen to evaluate the world-wide tenders received by Telecom for a new electronic local switching system, which resulted in the decision to buy AXE. He will continue to be closely associated with the AXE project in his current position as Branch head in Engineering Planning Headquarters, where his duties include responsibility for the planning aspects of switching system implementation.

• the need to provide a national linked closed numbering system.
• to enable call routing to be divorced from numbering.

It would not have been economically feasible to modify the existing system types to provide these capabilities. The 'common control' feature of the crossbar system enabled them to be achieved economically.

The crossbar system has since been incrementally developed and evolved for the Australian network by Telecom and L. M. Ericsson to provide improved system features. For example, new features introduced into the ARF system include:—
• a new MFC signalling system,
• a larger group selector,
• an ARF trunk switching exchange,
• an improved register design,

These and other features have been added to the ARF system in Australia to improve its economic effectiveness as a telephone switching machine in our particular network environment. A number of them have become integral parts of the crossbar system family offered by L. M. Ericsson to the world telecommunications markets.

In recent years however, Telecom identified an emerging need for improved switching techniques and facilities which would help contain the increasing costs of network expansion and operation. These studies led to the application of electronic switching techniques for the large trunk switching applications, the modernisation of crossbar through ARE 11, and to the decision to adopt AXE as an alternative local switching standard.

TELECOM'S MODERNISATION PROGRAMME FOR LOCAL CROSSBAR EXCHANGES

Telecom has recently embarked on a programme of modernisation of the Australian crossbar local telephone exchange network. As with all previous modernisation strategies, the aim of the programme is to provide the customer with an overall better service. From a customer's viewpoint, a better service could be described as:—
• the availability of modern facilities which provide for quicker and more reliable calling, and ready access to necessary service information,
• the containment of tariff increases,

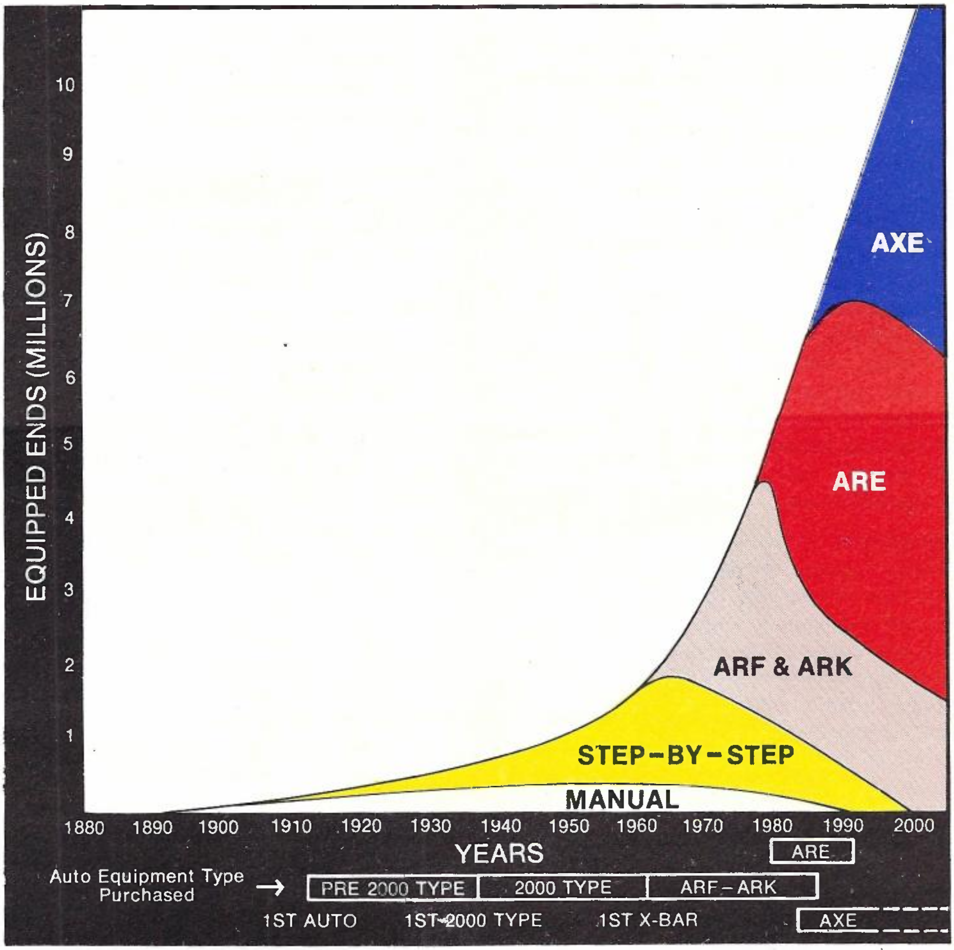


Fig. 1 — Growth of Local Telephone Switching in Australia.

- the maintenance of proper standards of service, with the security and privacy of calls ensured at all times.

To achieve this aim, Telecom must develop the network in such a way that ongoing expansion and operation can be achieved efficiently and economically, and new facilities can be added at reasonable cost.

In the current modernisation programme Telecom will, over the next few years, upgrade crossbar local exchanges to provide features which will help contain capital and operating costs in the already complex telephone network. The upgraded crossbar system will increase call switching efficiency, provide for maintenance and operating savings, and enable several important new services and facilities to be made available for the telephone customer, including:—

- Automatic Message Accounting (AMA) for International Subscriber Dialling (ISD),
- A more efficient centralised service to provide changed numbers, advice, etc.,
- Faster push button telephones using tone signalling,
- An increased range of access options available to the customer when choosing his telephone service.

AMA for international calls direct-dialled is a service much in demand amongst Telecom's customers. It has been recognised for some time that, if ISD is to receive general acceptance, customers must be able to ascertain from an automatically produced record, full details of each call made, as they are now able to do under the manual system. The existing ISD service, which employs multimetering (or bulk billing), was introduced with minimum alteration to existing plant to meet immediate demands, but with the planned intention of introducing the more generally acceptable ISD/AMA service at the earliest practicable date. This marketing strategy was recognised by the Vernon Commission of Enquiry and has been endorsed at Government level. ISD/AMA will employ the Metaconta 10C exchanges at the large trunk switching centres for application of the automatic charging and requires signals from the local telephone exchanges to identify each calling party's number (Calling Line Identification).

Centralised Interception: In certain instances, eg., for a changed directory number, a telephone call requires interception by Telecom so that re-direction information can be made available to the calling party. This type of service is becoming more important each year with the increasing mobility of people. If calls such as this can be automatically diverted to a central location, an improved service can be provided using extensive facilities available at the centre. Telecom's strategy is to electrically 'mark' terminating numbers which require the interception service, and by means of inter-exchange signals, arrange for the call to be automatically re-routed from the originating exchange to the appropriate interception centre. Facilities to be available at the interception centre include:

- A wide range of recorded messages,
- Automatic call re-direction,
- Manual operators who can provide special information or re-direct the call for the customer,
- Quick and accurate tracing of malicious or obscene calls,
- A telephone answering service.

The modernisation programme will provide the special inter-exchange MFC signalling facilities at terminal exchanges to initiate the automatic diversion of the particular calls to the central location.

Push button telephones which employ VF tone signals (Touchfone 12) are much quicker in operation than the decadic instruments currently being marketed (Touchfone 10). Special tone receiving equipment is required at the local exchanges concerned to enable them to function.

The number of options or service categories available to the customer when choosing his telephone service is relatively limited with existing equipment types. The provision of more flexibility in the category markings in the local exchange equipment will enable Telecom to make available to the customer features such as:

- an increased range of trunk access — barring options,
- capability for changing allowable trunk access by key-operation or by dialling a special 'pass' code,
- automatic ring-back price.

The inter-relationship of these various new facilities and the technical capabilities required at the local telephone exchanges is shown diagramatically in **Fig 2.** The Metaconta 10C trunk switching machines in the major capital cities play a very important role in the modernisation programme as they will be the automatic control centres for AMA charging and the centralised interception service.

The initial phase of the modernisation programme is the upgrading of existing crossbar exchanges in metropolitan and larger urban areas. (Country crossbar exchanges will be upgraded later in the programme.) Upgrading will be by means of physical modification of the control registers or by replacement of these registers with the ANA 30 computer control system (ARE 11). Economics are dictating which of these alternative strategies is to be adopted at individual crossbar exchanges, but it is expected that the use of computer control will be chosen at about 90% of locations in metroplitan areas.

Telecom has no plans at this stage to make the new facilities available at step-by-step exchanges. However, progressive replacement of this obsolete equipment, as it reaches the end of its useful service life, will be continued. In the meantime, particular subscribers connected to these old exchanges could be given the new facilities from an adjacent modern exchange, provided they are willing to accept the costs and the necessary number changes.

As described above, a strategic part of Telecom's modernisation programme is the choice of the ARE 11 system as the prime means of upgrading existing crossbar local exchanges. ARE 11 will also be used for all new local exchange installations pending the availability of the recently adopted SPC local system (AXE) as an alternative standard in the early 1980's. The AXE system incorporates all the necessary exchange features as an inherent part of the design and will be cheaper to provide and run than ARE 11

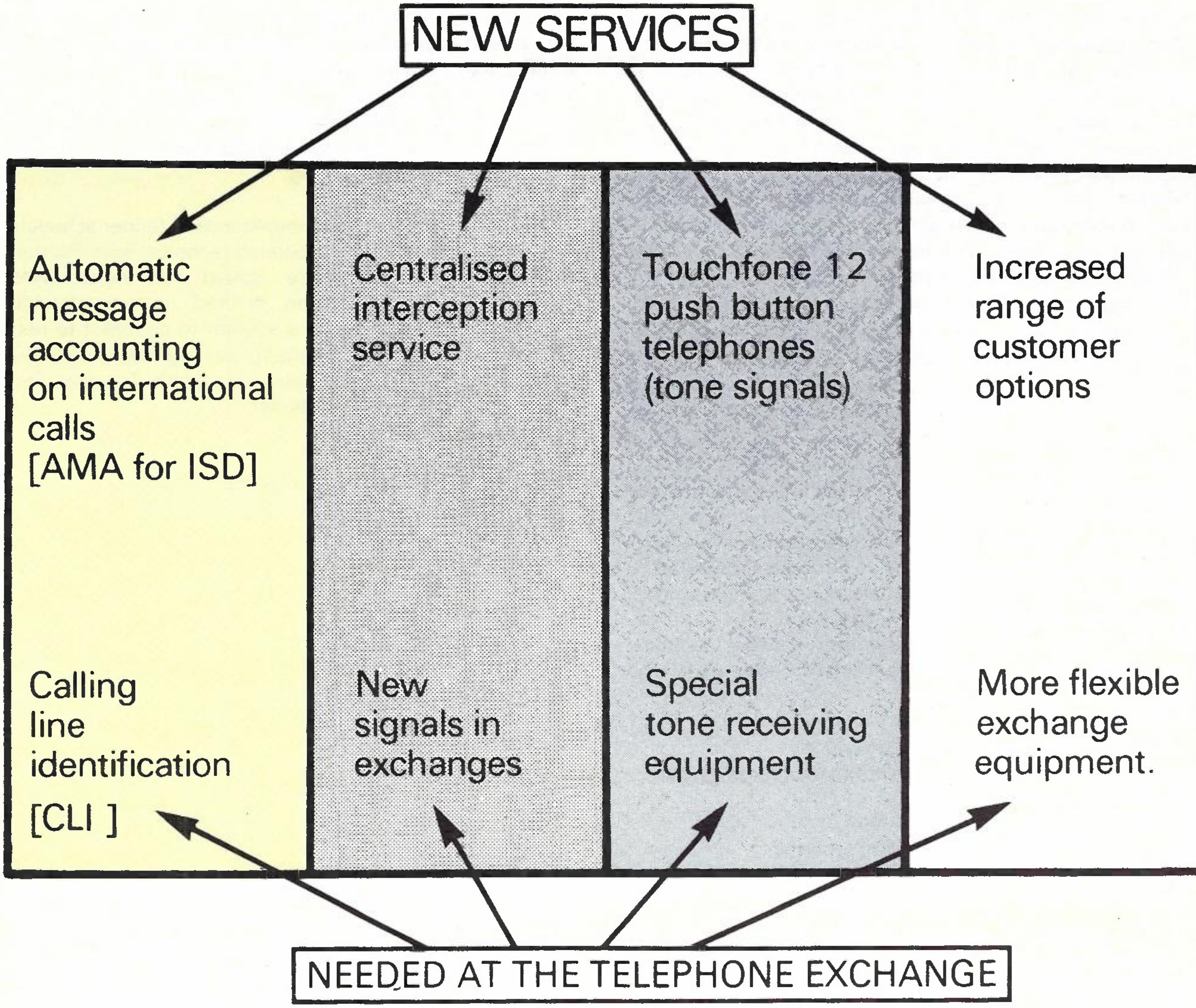


Fig. 2 — Modernisation of Local Crossbar Exchanges.

SPC LOCAL SYSTEM FEASIBILITY STUDIES

The decision by Telecom Australia to test the world market for an SPC local system for application in the Australian urban networks followed many years of study of electronic switching systems. This included monitoring of the world switching scene through all the various phases of advanced research, system development and network studies by both manufacturing companies and operating administrations. In addition, selected Telecom Australia's engineers participated in overseas postgraduate studies in electronic switching, or in system development, within the telecommunications industry. The aims of the studies were to evaluate the progress towards achievement of the various benefits claimed for the SPC system and assess the expected trends in system application costs.

In parallel with these investigations, studies of the Australian switching networks had clearly established that the continued expansion of the electromechanical crossbar system for an indefinite period would result in:—

- rapidly escalating building costs,
- a disproportionate growth at tandem exchanges resulting from the inherent limitations in addressing and outlet availabilities of the crossbar switching system,
- a proliferation of exchange entities as maximum switching capacities are reached,
- increasing expenditure on outside plant because of the limited sizes and traffic carrying efficiency of inter-exchange routes.

In 1969, Telecom Australia had selected the

Metaconta 10C system, developed by Bell Telephone Manufacturing Company in Belgium and offered by STC Australia, for a large trunk switching application in Sydney. The 10C trunk system was adopted as an alternative equipment standard to ARM crossbar for automatic trunk switching and control of trunk manual assistance positions. In the major trunk switching centres, the larger capacity and expanded facilities available with the 10C machines provided for substantial network economies. The first 10C trunk exchange was brought into service in Sydney in 1974 and since that time three more of these exchanges have been cutover.

By 1973, as a result of the evaluations of the world local switching scene and close analyses of the 10C system family, it was clear to Telecom that the time was opportune to call tenders for a new local system. Almost all advanced administrations overseas had adopted, or were adopting, one design or another of SPC local exchanges for ongoing application, and were proposing to install the equipment in their telephone networks in large quantities. SPC local equipment had been in use in North America, Japan and a number of European countries for several years. The economic benefits of its new system technology had been clearly established.

The general benefits Telecom had identified as being achievable with a new SPC local system in the Australian environment were:-

- lower capital costs,
- lower requirements for building space.
- improved operations and maintenance productivity,
- increased installation productivity,
- simplified network administration,
- modernised charging and billing systems,
- improved network utilisation,
- increased range of customer facilities.

In addition, a number of new facilities for the customer have been included in the designs of many overseas SPC local systems. Some of these could potentially be made available to the Australian customers, if justified by market surveys and engineering studies. New customer facilities possible with SPC local systems include:-

- 'absent subscribers' service,
- 'do not disturb' service,
- automatic wake-up,
- customer control of access barring,
- malicious call trace,
- abbreviated dialling for frequently called numbers,
- 'follow me' service
- call waiting,
- third party enquiry,
- direct calling or hot line,
- customer control of interception
- essential service priority

A number of improved network facilities are also potentially available with SPC local systems. These provide for economic exploitation of the system in the telephone switching network and help a telephone administration contain the costs of network expansion and operation. They include:-

- improved maintenance, supervision, and testing aids,
- remote controlled switching stages
- electronic call charging,
- improved adaptability to meet changing needs
- subscriber number flexibility,
- larger maximum sizes,
- more effective traffic switching,
- flexible routing translation and analysis,
- common channel signalling.

CALL FOR TENDERS

In December 1974, a comprehensive tender schedule (Schedule C.8200) and associated technical specification (Specification 1221) were issued for world wide response. The specification defined, in considerable depth, the requirements of a system to enable it to respond to the switching, charging and signalling environment of the Australian telephone network. The specified technical requirements included:-

- traffic carrying capacities,
- transmission limits,
- signalling conditions and systems,
- operational and maintenance requirements,
- documentation standards,
- maximum sizes,
- customer facilities,
- routing capabilities,
- network numbering capabilities,
- charge recording requirement,
- requirements for system support and evolution.

The closing date for tenders was July 1, 1975 and seven offers were received. Exhaustive analysis of the tenders was then commenced by a full time evaluation team, supported by specialists selected from the various disciplines within Telecom Headquarters and State administrations. By mid 1976, Telecom was in a position to announce that it had narrowed the equipment selection down to two tenders, one from L. M. Ericsson (Australia) Pty. Ltd. for the AXE system and the other from STC (Australia) for the 10C medium local system.

After further extensive technical evaluation of the two systems, which included an overseas visit by a specialist team led by Telecom's Managing Director, Mr J. H. Curtis, the AXE system was selected as the more suitable for introduction into the Australian network in the 1980's. Telecom had concluded that, for ongoing urban application, AXE would be cheaper to buy, install, operate and maintain than the existing crossbar system, either in its present form or upgraded with ARE 11. The Government's decision to accept the Australian Telecommunications Commission's recommendation was announced by the Minister for Post and Telecommunications in September, 1977.

CRITERIA AGAINST WHICH THE TENDERS WERE EVALUATED

The aim of the evaluation process was to identify the SPC local system which best met the requirements of the Australian urban network environment. The system chosen had to:-

- conform with the technical specification and performance standards
- provide the necessary customer and network facilities
- be suitable for economic manufacture in Australia
- be more economic to install, operate and maintain than the crossbar system

- be adaptable to future customer and network needs and technological developments.

In order to assess the potential economic effectiveness of the various systems if installed in quantity in the Australian network, each of them was compared against a set of evaluation criteria embracing:-

Purchase Costs

These include the costs of the initial equipment supplies, the costs of future bulk purchases as order volumes increase and any penalties that may be involved in Australian production of the system.

System Adaptation Costs

Any system purchased requires adaptation to meet the particular facility and interface requirements of the network into which it will be installed. This adaptive design was required to be clearly identified by the tenderer and the costs included in the proposal.

Ongoing System Support Costs

The chosen system must be supported by the tenderer in the future to effect any necessary design improvements, to incorporate new customer or network demands not now foreseen and to embrace technological improvements. The extent of this support, and proposed recovery of costs, was required to be quantified in the system offer.

Accommodation Needs

The different systems have slightly different requirements for building space, environmental control and power plant. A particular system's accommodation needs can impact heavily on total network costs.

Conformance with Technical Specification and Performance Standards

The technical specification against which the various systems were offered, prescribed in detail the particular needs of the Australian urban networks. The degree of conformance of each offered system was evaluated in depth.

Facilities which impact on the Customer

This criteria includes the proposed method of operation of the various customer facilities which either come as part of the system, or are potentially available for later introduction.

In addition, there are a number of system features which provide for a more streamlined response to customer demands e.g. remotely changing a subscriber's number and enabling a new service. The particular mode of operation of these features in a system can greatly influence the effectiveness of this important customer interface.

Equipment Design Features

The prime concern in evaluating equipment design features is to determine how effective each system would be if installed, operated and maintained in large quantities in the Australian network. To assess a system's potential effectiveness, its design was evaluated under a number of general headings:

- Installation requirements and techniques: including the suitability of any support aids available for exchange dimensioning and provisioning, the efficiency of procedures for exchange installation under Australian conditions and for the preparation of exchange documentation.
- Maintainability: including the facilities and procedures for the detection, isolation and diagnosis of hardware and software faults that may occur within the system, the proposed techniques for operation and interconnection of exchange maintenance centres and the general suitability of the exchange maintenance systems for meeting the Australian requirements.
- Service Availability: this includes an evaluation of the impact on the customers of the various types of faults that can occur within the system and the expected duration before automatic or manual processes would be able to restore normal service.
- Comprehensibility: under this heading an assessment was made of the relative ease and speed with which Telecom Australia would be able to build up all essential skills for planning, design, installation and operational activities in the ongoing situation.
- Extendability: the extendability of a system includes the facilities, procedures and documentation for the extension of working exchanges under various field conditions. It includes also the introduction of new or amended functions into a working exchange. These design features were evaluated in terms of their general efficiency and possible impact on customer service availability.
- Operability: this includes the system features which are available for day-to-day operation of an exchange network, e.g. the extraction of customer billing data, call and traffic statistics, performance statistics etc.
- Exploitability: this is the ability of a system to economically accommodate future new requirements of the Australian customers and/or the telephone network, and the effect of any system constraints which may limit this ability. It also includes the inherent flexibility of a system for evolution in the future to incorporate new hardware or software technologies as they become available for economic application.
- Ease of System Testing: Under this heading an evaluation was made of the facilities offered by a system to allow for efficient laboratory testing of modifications or additions to system hardware or software, and for any subsequent on-line testing of these changes in a working field exchange.
- Software Support — Program and Data: Under this heading, an assessment was made of the facilities, methods and procedures used to produce all project software for an exchange, and their compatability with Telecom's policies for support operations.

In summary, when the systems were evaluated against the above criteria, AXE was judged by Telecom to be the system most suitable for economic application in Australian urban networks. Compared with other systems offered, AXE best capitalises on recent advances in computer and electronics technology and has features which make it ideal for application in the Australian environment. Moreover, it was considered that the inherent flexibility of AXE's modular design will enable the system to effectively evolve into the future to meet new customer demands, to incorporate new technologies such as digital switching and to generally contain costs.

The evaluation studies also clearly established that

AXE will be cheaper to buy, install and maintain than the existing urban crossbar switching system, either in its present form (ARF) or when upgraded with processor control (ARE 11).

IMPACT OF THE AXE DECISION ON NATIONAL NETWORK DEVELOPMENT

Telecom's decision to adopt a new SPC local system (AXE) will have a significant impact on the development of the Australian urban telephone networks in the 1980s and beyond. The major network effects which will result from using AXE, as compared to continuing with upgraded crossbar as the only urban local system standard, are summarised in **Table 1.**

Impact on Buildings

An AXE exchange occupies only about half the floor space required for an equivalent ARE or ARF crossbar exchange and even a third in a large, inner city exchange. The adoption of AXE will therefore have a substantial impact on Telecom's future building programmes, and the effect is immediate. For some time now, new proposals for large telecommunications buildings, for which a lead-time of about 10 years must be allowed, have been designed assuming the future availability of SPC local equipment. From hereon, all new exchange buildings in urban areas will be designed to accommodate the new technology.

Where practicable, AXE will also be strategically employed in accommodation already available, to avoid major building constructions. This can be achieved by installing AXE in accommodation previously designed for crossbar equipment but not yet occupied, or by re-using accommodation which currently houses step-by-step equipment that has reached the end of its useful working life. However, in these cases, because of the higher heat loads generated by the SPC local equipment, additional air handling capability will normally be required. (Heat load per line of AXE is about the same as crossbar but the equipment is more compact). It is possible that extensive use could be made of packaged air-conditioning units located in the equipment rooms. This topic is at present being investigated by Telecom.

The potential space saving capability of AXE will save Telecom many millions of dollars on building expenditure in years to come, especially in the high cost city areas.

More Effective Use of Telecom Plant

AXE exchanges will operate much more efficiently as traffic switching machines in a complex telecommunications network than can the existing crossbar exchanges. This results from the extensive analysis and call routing capabilities of AXE and the switching Matrix structure which provides for full availability trunking. Some of the switching characteristics of AXE, and how they compare with crossbar, are shown in **Table 2.**

The improved switching capability of AXE will enable urban networks to be economically developed with:-

- larger exchange entities, particularly in the inner suburban and central city areas.
- less junction plant in the inter-exchange network and greater use of large, efficient traffic streams.
- more effective use of tandem switching entities and possibly a reduction in number.

Moreover, once the AXE implementation programme is underway, several new developments of the system are expected to be available, and these could offer further potential economic benefits in urban network applications. They include:-

- digital switchblocks: for use at tandems for the through connection of PCM transmission systems, without the need to decode. This digital switchblock could also be used in terminal exchanges.
- detached exchanges, whose switching is controlled remotely from processors at established AXE exchanges nearby: for use either as expedients to meet sudden growth pockets or as a planned network growth strategy.
- STD charging packages at AXE tandems: to enable trunk traffic to be directly routed to remote destinations.

TABLE 1

Use of AXE in National Telephone Network (Compared with Crossbar)

AXE Feature	Major Impact
Equipment more compact	Reduced expenditures on Future Building Programmes
Improved switching capability	More effective use of Telecom Plant
Comprehensive diagnostic and support aids	Reduced capital and operating costs
Flexible system structure	Potential for new Customer and Network Facilities

TABLE 2 Exchange Capacities

	ARF	ARE	AXE
Average calling-rate Subscribers (0.08 E/Sub)	10,000 or 20,000	40,000	65,000
High calling-rate Subscribers (0.2 E/Sub)	10,000	16,000	25,000
Tandem inlets	1,600	N/A	12,000
Outgoing routes	80	256	1,000
Grading of Routes	Yes	Yes	No

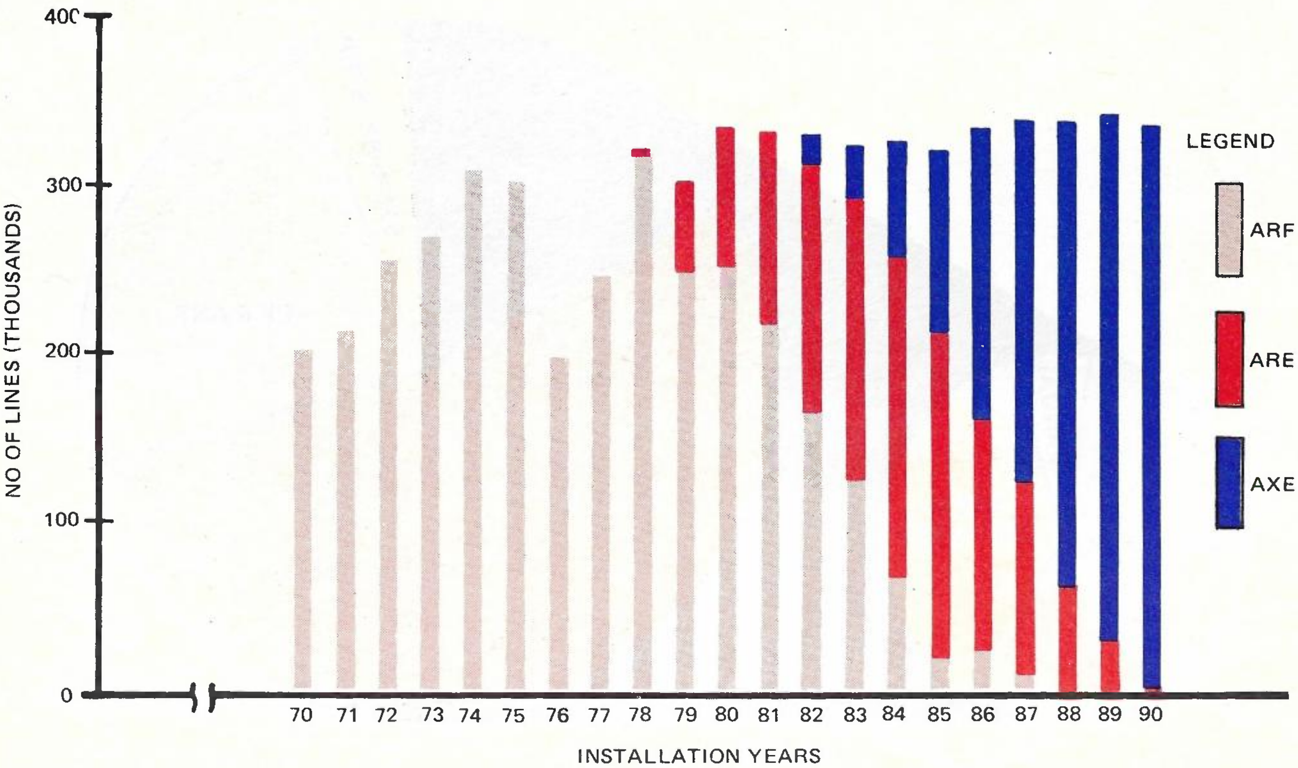


Fig. 3 — Local Exchange Equipment: Annual Nett Installations.

A specialist Telecom Australia team, comprising staff selected from Headquarters and State administrations, is at present studying alternative urban network configurations to determine the optimum use of AXE in the next 20 years and beyond. The aim of the studies is to provide State administrations with guidelines for the strategic application of AXE switching and PCM transmission in their urban networks of the future. The target date for completion of the studies is March, 1979.

Capital and Operating Costs with AXE

Compared with the continued use of crossbar alone, AXE will provide for reduced capital and operating costs in the telephone network of the future. AXE will be cheaper to buy, easier to install and cheaper to operate and maintain. These features result from the extensive use of miniaturised components and modular packaging in the AXE system, and the availability of comprehensive diagnostic and support aids for installation, operation and maintenance.

New Customer Facilities

AXE will also enable Telecom in the future to progressively make available to the customers, selected new facilities for which a demand has been recognised through market surveys. The flexible, modular structure of AXE means that such new facilities can be introduced into the system relatively easily and cheaply. Telecom is then in a position to market these facilities at tariffs which ensure an adequate demand and return on capital invested.

EXPECTED PENETRATION OF AXE INTO THE AUSTRALIAN TELEPHONE NETWORK

The first field AXE exchange is planned to be brought into service in Endeavour Hills, Victoria, in 1980. In that year also, it is expected that the first bulk orders for AXE equipment will be placed with L. M. Ericsson. In the early years however, there are a number of factors which are likely to place some constraint on the extensive use of the AXE system. These include:-

- The need to adequately prove the system as adapted for the Australian network conditions.
- The need to build up Australian expertise and management structures for the installation, maintenance, operation and ongoing support of the system.
- The need for L. M. Ericsson to build up capability and expertise in their Australian factories for local manufacture of a high proportion of the equipment.

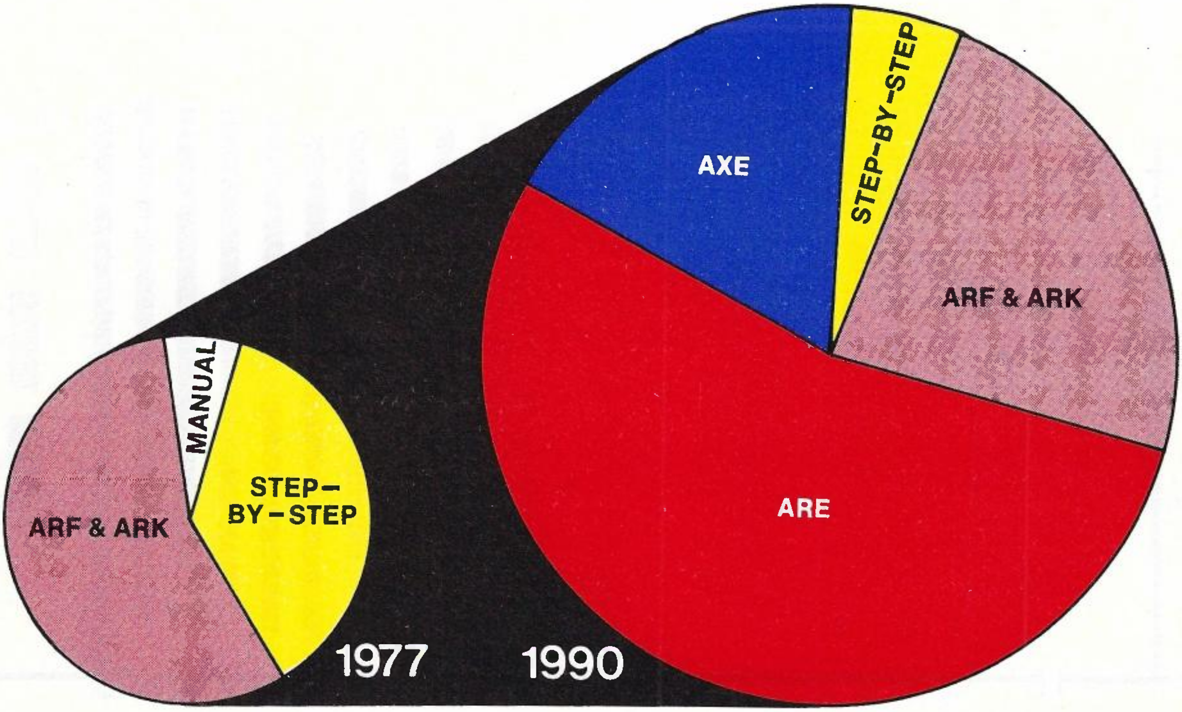


Fig. 4 — Equipment Types in Local Switching Networks : 1977 and 1990

The expected annual installation rate of local switching equipment in the 1980's is shown diagramatically in **Fig. 3**, including both the AXE and ARE 11 equipment types.

Fig. 4 shows the impact of this expected AXE installation programme on the total local exchange lines installed in the network. It can be seen that by 1990, about two thirds of the Australian local switched network is expected to be under some form of processor control.

CONCLUSION

Telecom Australia's decision to adopt the AXE electronic computer controlled local switching system for urban application will result in great economic advantages in the future expansion and operation of the Australian telephone network. It will be an important factor in containing cost increases, and hence prices to the customer, in the years ahead.

AXE/AOM — Some Design Aspects

M. K. WARD B. E. (Hons), M. Eng. Sc. and W. R. CRAIG B. E. (Hons).

The relatively unique development history of AXE by the Ellemtel Company which was established specifically for the development is discussed; followed by an outline of the basic design principles underlying both the AXE and AOM systems. The functional structure of both systems is described and the sub system functions are presented. Descriptive material on AOM has been covered in greater detail than for AXE because information on AXE is already available in published articles (Ref. 1). Finally, software support for both systems is discussed together with an outline of the facilities available for the management of software.

INTRODUCTION

The AXE local switching system and the AOM system for network operation and maintenance have been selected by Telecom as standard systems to be employed in the Australian telecommunications network during the next decade. This paper deals with specific aspects of these two systems which are particularly important from a design viewpoint. Other aspects of the two systems are covered in accompanying articles in this journal.

DEVELOPMENT HISTORY

The basic system concepts of the AXE system originated in the late 1960's from experience of earlier systems. L. M. Ericsson had at that time the AKE 13 trunk switching system and also had experimented with the AKE 12 local SPC switching system with a prototype installation at Tumba in Sweden. A considerable store of information was also available from the experience of other companies and administrations around the world.

In 1970 the Ellemtel Company was established as a jointly owned venture by L. M. Ericsson and the Swedish telephone administration, Televerket. A development team of about 150 people was drawn from both L. M. Ericsson and Televerket with the prime objective of producing an SPC local switching system. In 1970/71 this team developed detailed system requirement specifications and conducted preliminary system design studies to establish the feasibility of the project. During this time a high level programming language called PLEX (Programming Language for Exchanges) was defined and a computer hardware structure developed to match the language.

As a result of the initial studies, L. M. Ericsson and Televerket gave agreement for Ellemtel to proceed with full scale development in 1972. The development objective was to have a pilot installation carrying live public traffic in October 1976. As shown in **Fig. 1**, the development then proceeded in three distinct phases. In the period 1972 to 1974 the initial phase of system design was completed. This was followed in 1973 to 1975 with the design and verficiation of hardware items. The final phase of program realisation did not commence until 1974 but built up rapidly in 1975. By December 1975 a system test plant was in existence at the Ellemtel centre and was performing call switching and normal exchange functions. At the same time installation was proceeding at the selected pilot exchange site at Sodertalje, a suburb to the south of Stockholm. Software was introduced into Sodertalje in three major packages during 1976 and was finally cutover to public traffic with 3000 subscribers connected on 1 March 1977.

In the thirteen months since the cutover, the performance of the Sodertalje exchange has confirmed the design expectations of the system. Difficulties due to unforeseen interworking problems and to live traffic anomalies have been few. Software changes have been made to overcome these problems and remove residual logic errors. In the first six months of operation, the exchange suffered three major automatic re-starts resulting in a total exchange downtime of 21 minutes. In a review period between August 1977 and April 1978 there has been no exchange downtime.

AXE DESIGN PHILOSOPHY

A basic requirement of the AXE project was the development of a two wire switching system which could be used in a local, tandem, or combined local/tandem environment. However, there were other significant constraints which were placed on the system design and which have had a major impact on the end product.

Firstly, the system was required to be totally cost effective — not just on an equipment cost basis but as a total system which is to be installed, maintained, and supported for at least a thirty year period.

Secondly, software security and ease of software management were set as major objectives. This requirement arose from one of the major lessons learnt from early SPC systems. While it is evident that computer control allowed a greater degree of sophistication than had previously been possible, the ability to easily make changes to software logic was not a natural attribute but required careful and basic design consideration of the software structure.

Thirdly, future development trends were required to be accommodated by the system. Thus, new subscribers services or network trends towards digital operation or remote switching units should be able to be added into the system without the major dislocation of the current structure. Of a similar nature, the system was required to be flexible to exploit new technology as and when it became available.

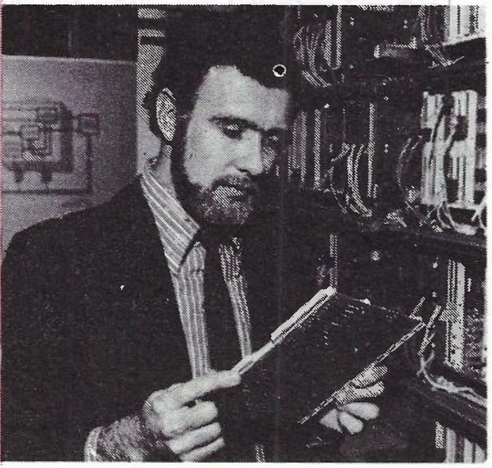
Finally, the system was required to interwork efficiently with operating centres and systems as used by Administrations around the world.

The need to achieve a system which would not just switch calls but which would be flexible and manageable has led to the adoption of a specific design philosophy. Some of the key principles included in this philosophy were:

- The system was to be **highly modular** in both its hardware and its software. The AXE system can be considered as a number of "black box" modules which communicate with each other but which operate relatively independently of each other. Each module may be a mixture of hardware and software or may be only software. Each performs a strictly defined function and communicates with other modules by the transfer of either hardware or software signals over well defined interfaces. The system design phase of the AXE development was concerned with the rigid definition of these modules and their interfaces. Modularity of the AXE system is evident not only in its design but is also reflected consistently throughout its documentation, construction and provisioning practices, and maintenance procedures.
- The basic system design was to incorporate **procedures** required for installation, extension, operation or maintenance. In many earlier systems these procedures were added at a late stage of the development cycle leading to inefficient techniques and lower overall system security. To avoid this, a series of working groups using both Company and Administration experience were established to define the required procedures. Hardware and software techniques to implement these were then developed which were consistent with the methods used to realise the normal call handling functions.
- **Computerised support aids** were to be developed as a

MEL WARD joined Telecom Australia as a cadet engineer in 1960. After graduation from the University of Queensland he transferred to the Research Laboratories, working first on the computer design of filters and equalisers and later on the development of a stored program controlled digital switching system (IST). In 1970 he was appointed as Senior Engineer in Switching Design and joined the 10C Liaison Team in Antwerp, Belgium for a period of three years. On return to Australia, he established the 10C National Support Centre and participated in the initial introduction of the first 10C exchange at Pitt Street in Sydney. At the formation of the Commission, Mr Ward was appointed Group Manager, Logic Design within Switching Design. During 1977 he was involved in special duties on the selection of an SPC Local switching system for Australia and is now Superintending Engineer of the Switching Design Branch.

BILL CRAIG joined Telecom Australia as a cadet engineer in 1960 and graduated from the University of Queensland in 1964. After a short period in Radio in Queensland, he transferred to the Research Laboratories in Melbourne where he carried out technical investigations on electronic switching systems and on stored program control techniques. In 1969 he joined Switching Design to work on design aspects of ARF Crossbar and in 1970 moved to Antwerp, Belgium for nearly three years as a member of the 10C Liaison Team. After returning to Australia, Mr Craig worked on 10C maintenance and in 1973 moved to Switching Planning where he was involved with planning of ISD. In 1975, he re-joined Switching Design Branch as the Section Manager of the SPC Local Design Section and was involved full time as a member of the team evaluating SPC Local tenders. Mr Craig has recently been promoted to Engineer Class 5 in charge of the Systems Design Group of Switching Design Branch at Telecom Headquarters.



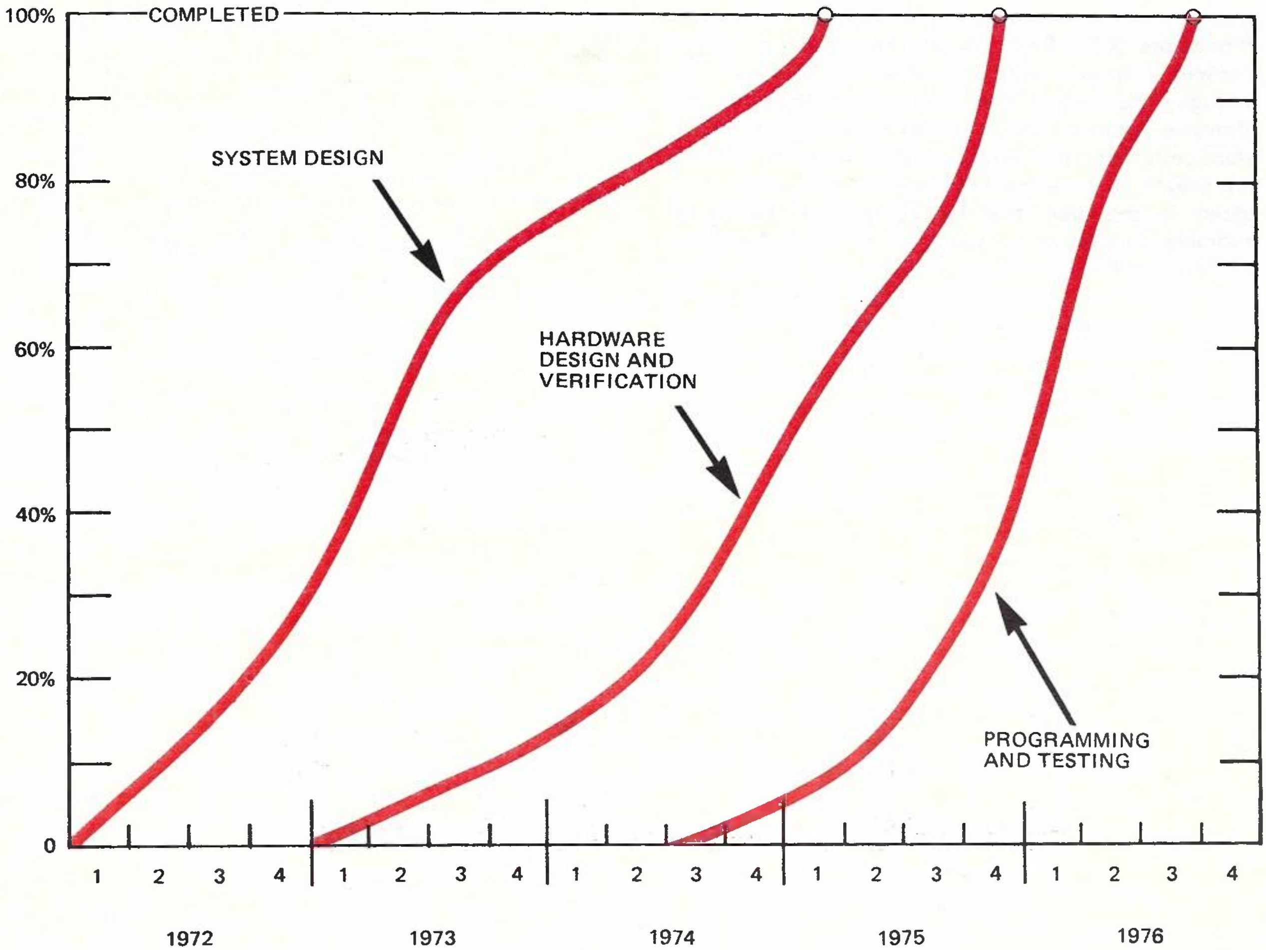


Fig. 1 — AXE Development

first priority to assist in the design and testing of the AXE system. These support aids have contributed significantly to the achievement of the development schedule and to the confidence which can be placed on the system testing. As a by product, these support aids will be used not only during the initial system development but will be used for adaptive engineering support during the entire system lifetime. Early and extensive use of these support aids therefore ensures that a secure product will be available for ongoing system management.

- **Memory would be traded off for system manageability.** This decision recognised that memory costs were rapidly and consistently decreasing as technology developed in the 1970's so that previous design constraints to minimise memory usage were no longer valid. By removing this constraint, many additional features could be added to the on-line system which would increase its security and ease of use in normal operation and which would allow modifications for physical or facility extensions to be safely undertaken.
- **A distributed processing system** would be used, taking advantage of technological advances and decreasing costs in computer hardware design. A distributed processing system reflects the fact that two distinct categories of processing work exist in a real time control situation. On the one hand there are simple repetitive functions to be performed which do not involve any great analysis capability. Examples of these functions would be the scanning of test points to detect changes in line conditions, or the collection of subscribers dialled digits. In the AXE system these functions are realised in Regional Processors (RP) which are small simple computers. The controlling software programs, which are small and should be subject to very infrequent change, are produced on Programmable Read Only Memories (PROM's). An AXE exchange may have up to 256 Regional Processor pairs. On the other hand, other functions may be performed much less frequently (for example, once per call) but require quite complex analytical treatment. Examples of these functions would be the analysis of routing and barring information or the diagnosis of a system fault condition. This

type of function is realised in a single pair of Central Processors (CP). Each Central Processor is a large capacity computer with extensive program and data storage. The Central Processor pair operates in synchronous parallel mode, meaning that each is at any instant performing the identical task to the other and that the results of these tasks are being continuously compared. In the event that the comparison detects an anomoly, checks can be performed to determine which processor of the pair is faulty and the other assumes full control of the exchange. Since the program for a Central Processor is large, complex, and subject to evolutionary change, Random Access Memories (RAM) are used to hold both the program instructions and the associated network and exchange data. These memories are loaded from magnetic cassette tapes.

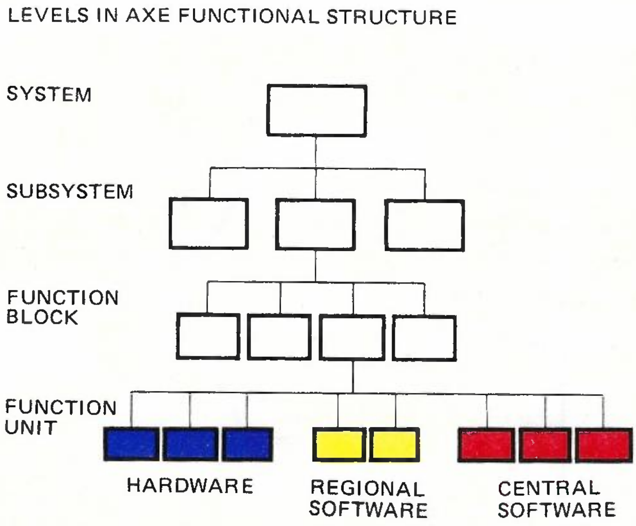


Fig. 2— Levels in AXE 10 Functional Structure

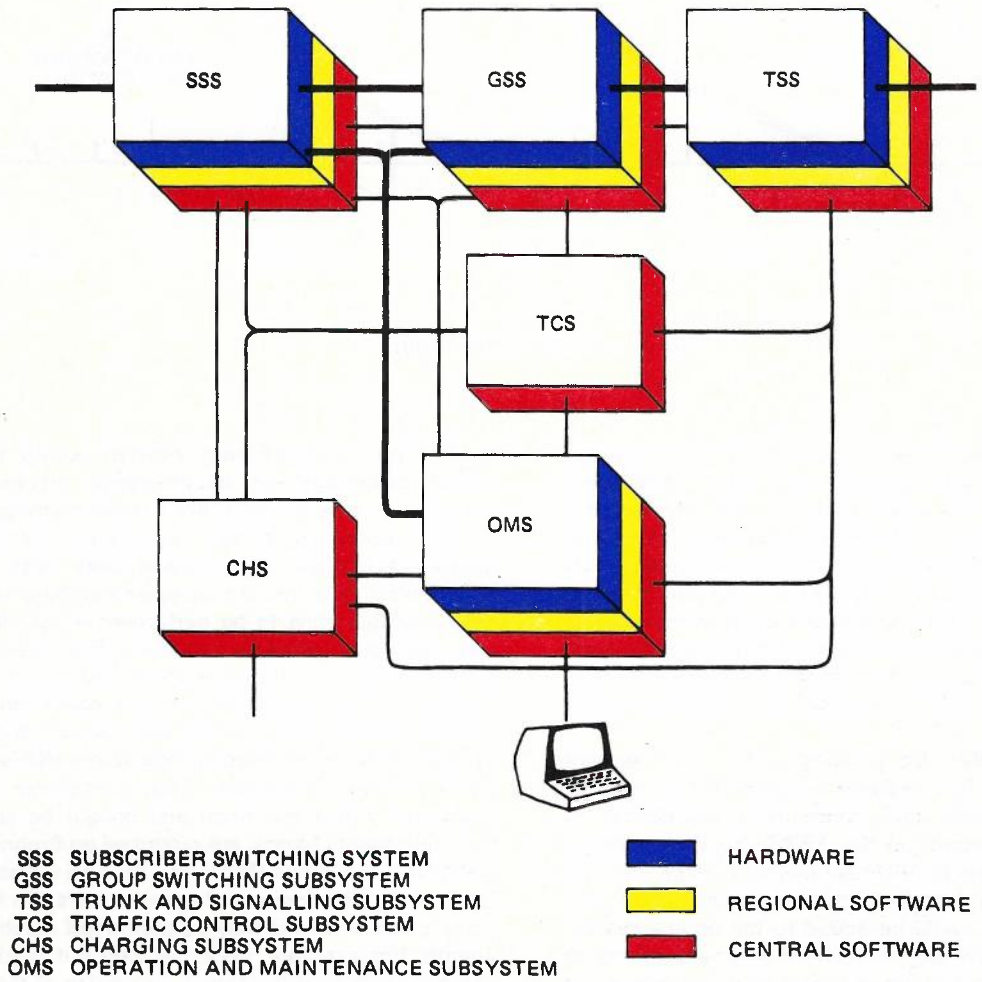


Fig. 3 — AXE: APT 210 Sub Systems

AXE FUNCTIONAL STRUCTURE

Realisation of the AXE system to the above design philosophy has resulted in a four level hierarchical structure of system, subsystem, function block, and function unit as shown in **Fig. 2.** At the systems level AXE comprises two modules known as the switching system APT210 and the data processing system APZ210. At the lowest level, the function units comprise either hardware circuits or software programs which are executed in the central processor pair or in a regional processor. The function block may be considered as the basic module of the system and normal activities in an exchange should require documentation only to this level.

As shown in **Fig. 3,** the switching system APT210 comprises six sub-systems.

The **Subscribers Switching Subsystem** (SSS) provides the line interface to the subscribers service, concentrates subscribers traffic, and collects dialled information which may be in decadic pulsed form or multifrequency tones. The subscribers switch is a three stage concentration network in which the two wire switching matrices use reed relays with thyristor latching. Four versions of the subscribers switch are available to cater for different exchange applications. These range from 0.09 Erlang/subscriber to 0.3 Erlang/subscriber (originating plus terminating) and are adequate for normal suburban usage or heavy inner-city application. A subscribers switch module of 2048 inlets is controlled by one regional processor pair.

The **Group Switching Subsystem** (GSS) performs the switching of concentrated subscribers traffic (local or outgoing) and of traffic incoming from other exchanges. In addition it provides connections, when required, between MFC code senders or receivers and junctions terminating on the exchange. The group switch, in its analogue form, also employs reed relay matrices but is a six stage full availability network. The basic module, which is controlled by a regional processor pair, has 512 inlets and 512 outlets and two traffic versions are available. No DC signals or ringing current are carried in the group switch. This feature allows either an analogue or a digital version of the group switch to be used without disturbing the interfaces between subsystems.

The **Trunk and Signalling Subsystem** (TSS) performs incoming and outgoing trunk or junction functions together with information signalling reception or sending. The implementation of this subsystem is subject to considerable market adaptation because of the variation in line and information signalling systems in use by different Administrations.

The **Operation and Maintenance Subsystem** (OMS) performs automatic supervision of the switching system with the generation of alarm reports when significant faults are detected. These functions are described in greater detail in an accompanying article in this journal.

Each of the above four subsystems comprise both hardware and software function units. System APT210 also contains, however, two subsystems which are realised solely in central processor software.

The first of these is the **Traffic Routing and Control Subsystem** (TCS). This subsystem performs many of the analysis functions which would normally be associated with a register or a marker in a crossbar exchange. Thus, for example, it analyses subscribers' categories, stores and analyses received digits to determine destination, selects suitable free circuits, reserves switching stage paths, controls line and information signalling, supervises calls in progress, and initiates cleardown.

The second all-software subsystem is the **Charging Subsystem** (CHS). In this subsystem, charging analysis is performed and meter registrations are maintained. In AXE system all metering information is held in memory, there being no provision for physical meters. Each subscriber has associated with his service two 24 bit words of memory which are incremented once for an originating local call or at each reception of a multimetering pulse. The duplication of metering accummulators provides a security against loss of information in the event of a memory block failure and also against any transient disturbance providing a false accounts record. Meter reading is initiated by man-machine command but is controlled by CHS. Meter values can be requested singly or in blocks, but in either case the accummulators are not reset at readout. Since commands can be delivered to the system over secure data links, the facility exists to have the computer system which performs the telephone accounting application directly interrogate AXE exchanges on a regular basis to gather meter information.

Each of the APT210 subsystems can be further broken down to their component function blocks. In total, approximately 100 function blocks will be employed in the Australian AXE application. The APZ210 data processing system also follows the same hierarchical structure as APT210. However in this case there are only four subsystems, as shown in **Fig. 4.**

The **Central Processor Subsystem** (CPS) includes the pair of central processors and the associated memory to store programs and data. The programs included in CPS form the operating system which controls the ordered execution and sequencing of APT210 programs which perform exchange tasks. The operating system also administers the loading of memory stores.

The **Regional Processor Subsystem** (RPS) comprises the pairs of regional processors which control the switching hardware of system APT210. The central processors communicate with the set of regional processors via a duplicated Regional Processor Bus (RPB) while each pair of regional processor communicates with the switching system it controls via a duplicated Extension Module Bus (EMB).

The **Maintenance Subsystem** (MAS) provides fault detection and isolation for the processor subsystems. An important part of this subsystem is the maintenance unit (MAU) which continuously monitors the action of the two central processors to determine if one side becomes faulty.

The **Input/Output Subsystem** (IOS) provides the means for communication between the AXE exchange and the outside world. It allows the connection of standard terminals to which may be directed automatic alarm or information outputs or through which commands may be issued to the exchange control. The terminal devices may be located either locally at the exchange itself or at remote centres.

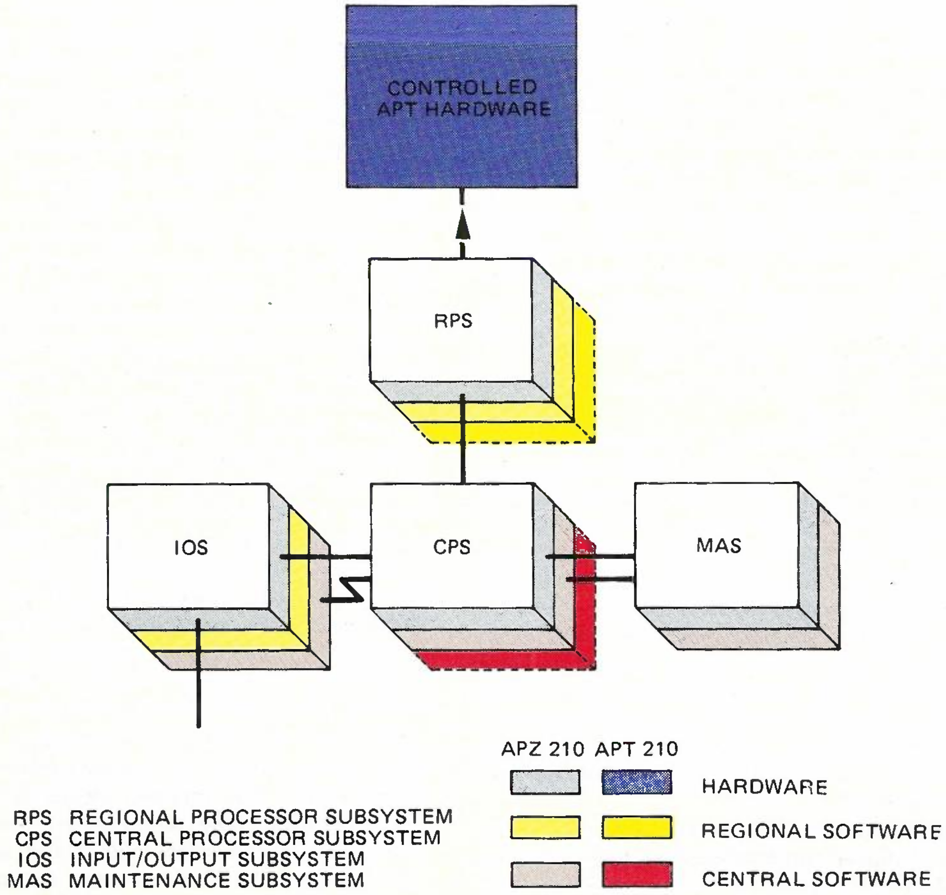


Fig. 4 — AXE: APZ 210 Sub Systems

AXE SOFTWARE STRUCTURE

The majority of function blocks in both APT and APZ involve software function units in either a regional processor or in the central processor. The implementation of this software shows the same modularity as is apparent in the system and hardware structure. Regional processor software is written in an assembly language ASA210R. Most central processor software is written in the high level language PLEX but some critical time dependent functions are written in assembly language ASA210C.

The software of a function block can to a large degree be considered as independent from that of any other function block. Thus, a function block's software may be separately produced and loaded into an exchange system for execution. However, the software of one function block must, of course, interwork with the software of other function blocks. This is only permitted by the transfer of **software signals** between the blocks. These transfers are under microprocessor control and the signals are strictly defined in respect to form and content. The software of a function block consists of both the program and the data which pertain to the function being realised. A program may directly access its own data but is not permitted to access directly the data in any other function block. If information is required from another function block it must be requested by a formal software signal transfer.

The software structure adopted in AXE is a major factor in achieving the basic design aim of software security. It allows software logic faults to be largely contained to the originating function block and to be detected quickly before the fault propagates throughout the system.

AOM101 — A SYSTEM FOR NETWORK OPERATION AND MAINTENANCE

The administration, operation and maintenance of a modern telecommunications network requires the operating administration to continuously monitor the performance of the network, to collect information on various facets of the network, and to analyse or process this information to determine actions required to ensure

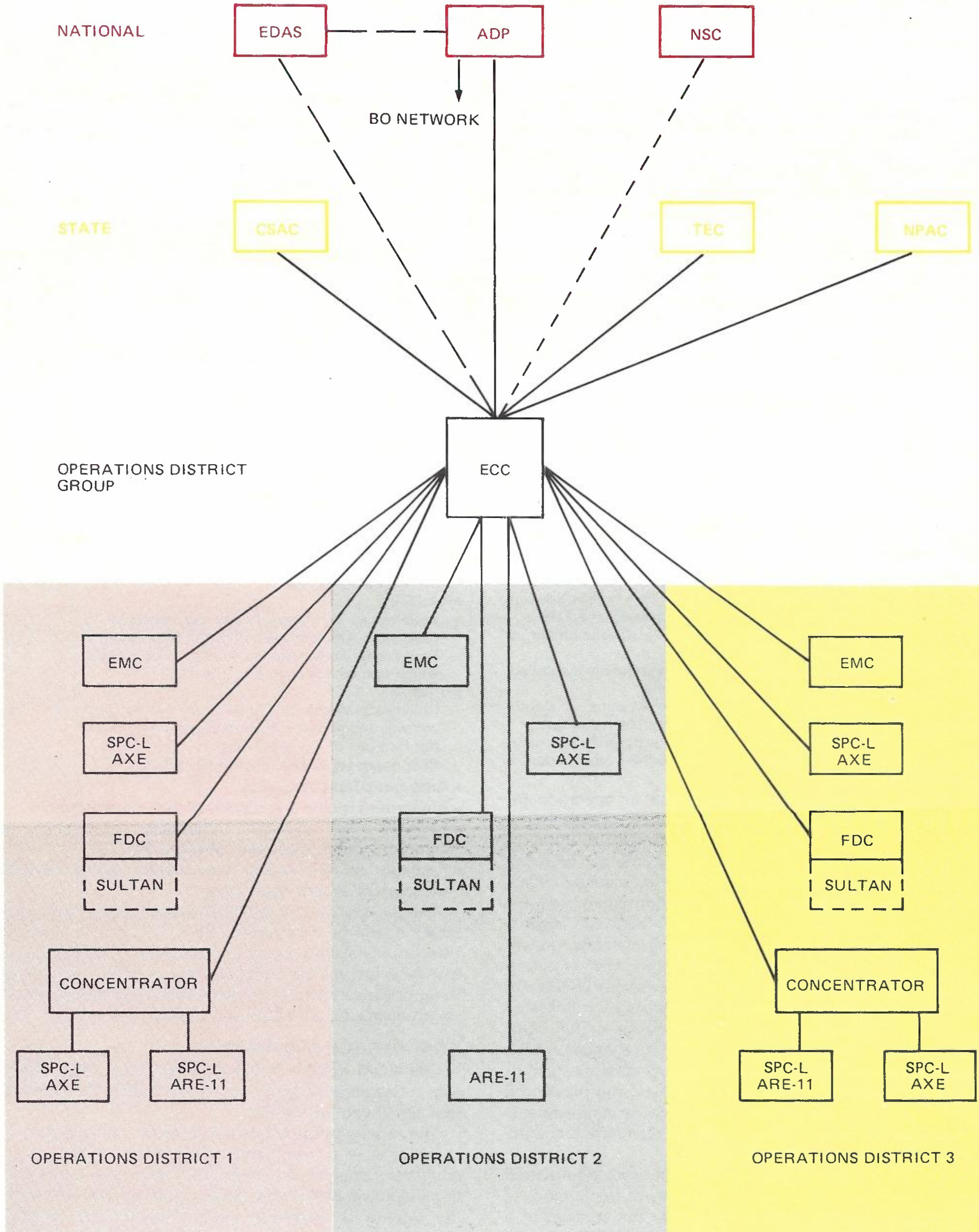


Fig. 5— NOC Network Hierarchical Structure

the continued successful operation of the network.

Traffic statistics are obtained to monitor network traffic handling capability, charging information is required for billing purposes, alarm and fault information is obtained for maintenance, and information in the form of subscriber's records is used for the administration of services to the customer. These are but a few examples of the types of information used by an administration responsible for a telecommunications network.

Generally, the personnel responsible for various aspects of network administration and operation are located in organisationally and geographically separate parts of the operating authority. Within Telecom Australia these functional groups have been identified as "Network Operations Centres" (NOC's) with functions outlined below:

EMC — Exchange Maintenance Centre — Maintenance of switching system, power and transmission plant.

NPAC — Network Performance and Analysis Centre — Analysis of telephone network performance data to reveal trouble spots.

FDC — Fault Despatch Centre — Maintenance of subscribers services, supervision of line plant.

BO — Business Office — Issuing orders for connection and disconnection of subscribers services and facilities.

DO — District Office — One per Operations district with responsibility for the collection of Individual Call Record data and call and revenue statistics.

CSAC — Centralised Service Assessment Centre — Obtain a sample of live telephone traffic and evaluate it on a user's basis. The results are used to produce a quality of service indicator.

SULTAN — Subscribers Universal Line Test Access Network — Intended to perform subscribers line testing and FDC.

TEC — Traffic Engineering Centre — Measurement of telephone traffic and its dispersion.

NSC — National Support Centre — Investigation of software faults, updating and validating of programs.

EDAS — Exchange Data Acquisition System — Centre responsible for the collection of data for meter readings.

AHC — After Hours Centre — Centre responsible for supervision and control of urgent alarms outside the working hours of the EMC and FDC.

Some of these centres have been in operation for some years, others are in the process of establishment, and undoubtedly, the list will be extended in future. In the broadest sense, all these centres interact with the physical telecommunications network by means of information flow. In the past this flow of information has been somewhat indirect and normally involved manual procedures; for example, in Crossbar exchanges, meters are read manually and the recorded information is sent to the billing centre for processing. The various NOC's are now making increasing use of computers for processing the information they obtain from the network. This, combined with the introduction of SPC exchanges which have facilities for internal switching and network supervision and the capability of being controlled and supervised from a remote centre allows the possibility of direct communication and information flow between NOC's and the network by means of data links.

The connection of exchanges direct to all their related NOC's would be uneconomic in terms of the number of data links required. This gives rise to the concept of a network for carrying information between NOC's and exchanges with a data switching capability for switching the information to/from NOC's to/from their related exchanges. In the Australian context, this data switching system is called the Exchange Communication Controller or ECC. **Fig. 5** shows the relationship between the ECC, the various NOC's, and SPC exchanges.

AOM101 DEVELOPMENT

AOM101 is the product name for the LME system which is currently being developed in Sweden and which will meet Telecom's facility requirements both for the Exchange Communications Controller (EMC) and for the Exchange Maintenance Centre (EMC). The system is being developed in three phases, the major features of each phase being:

PHASE 1

- Standardised data link connections between NOC's, ECC and AXE exchanges.
- Message switch facilities for all NOC's to communicate with AXE exchanges using standard AXE commands and outputs.
- Reception and logging of alarm indications from AXE exchanges and updating of alarm displays at the EMC and FDC.
- Logging of all man machine communications made via the ECC or made locally at exchanges.
- Command authorisation facilities to restrict functions which can be performed by remote terminals in the NOC's.
- Facilities for recording and displaying statistical data in the EMC responsible for the ECC.
- Facilities for search of the man machine transaction file (per time period, on command type and on command group).

PHASE 2

- Facilities as for Phase 1 with the capability to cover both AXE and ARE 11 types of exchanges.
- Facilities for increasing the number of exchanges which can be connected to the ECC.

PHASE 3

- Facilities provided by Phase 3 are not yet firm but will undoubtedly incorporate refinements to the facilities of Phases 1 and 2.

Proposed additional facilities include:

- Automatic fault diagnosis.
- Computer storage and display of documentation.
- Facilities for limited message switching of communications between selected NOC's.
- Facilities for file search and display using selected parameters as the search key.

The timing of the AOM development is such that Phase 1 will be completed late in 1979 with the first Telecom installation being a model early in 1980. Phase two facilities will be complete late in 1980 and Phase three is expected to be implemented over several years commencing about 1983 and extending beyond 1990.

AOM DESIGN PHILOSOPHY

The AOM system is being developed in accordance with a design philosophy which is basically the same as that employed with AXE.

The requirements for overall system manageability in terms of ease of installation, extensibility, software support, maintainability and reliability were major considerations injected early in the design process. As with AXE, the system is organised with a functionally modular structure with modules that can be flexibly combined into small and simple stand alone units as well as large and complex systems to satisfy the requirements of different markets. A four level functional hierarchy is employed consisting of system, subsystem, function block and function unit.

OVERVIEW OF THE AOM101 SYSTEM

At the highest hierarchical level, AOM consists of two modules which are the application system APT and the control system APZ. Each of these systems comprises a number of subsystems as shown in **Fig. 6**.

APT SUBSYSTEMS

The AOM APT system consists of seven subsystems with the following functions:

OCS Operator's Communication Subsystem. This subsystem incorporates the facilities for handling operator terminal equipment which is directly connected to the AOM or remotely connected to AOM at NOC's. Types of terminal equipment include video display units and teletypewriters. The basic language for operator communications is English. Command communication with AXE exchanges is effected with standard AXE commands; with ARE, standard ARE commands will be used. However, the possibility exists in future for OCS to perform command language translation to allow for a common command language to be used for similar functions in different types of exchanges.

OCS establishes and supervises the connection between an operator's terminal and an exchange or the AOM itself. It also steers printouts from exchanges or from AOM to the appropriate operator terminal. Result printouts are normally directed to the terminal from which they are initiated but an operator can redirect an answer printout to another terminal or to a line printer. OCS automatically redirects printouts to a standby device when a terminal device is tested as unserviceable by functional checks within OCS.

All command communication via OCS is checked for authorisation in order to prevent unauthorised persons from obtaining access to functions at exchanges or at the AOM. Authorisation checks are done on the basis of the exchange identity, command type, terminal identity and operator signature identity.

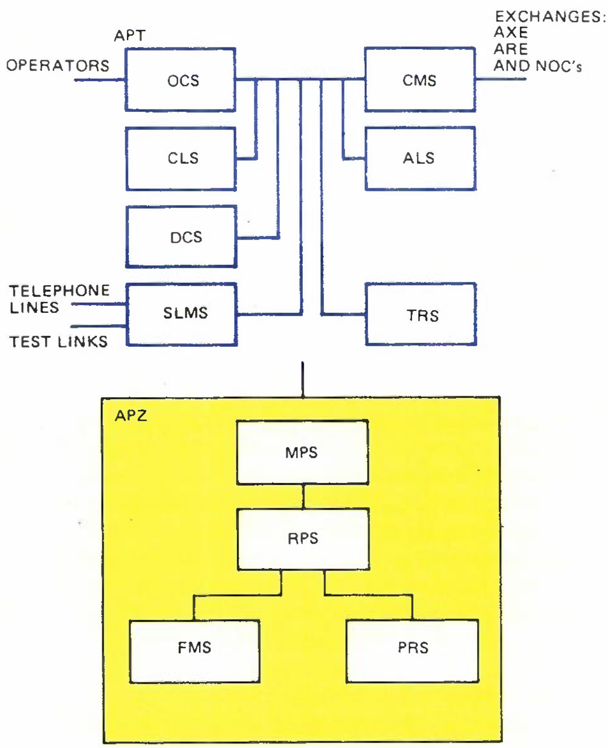


Fig. 6 — AOM: APT and APZ Sub Systems

CLS. Command Logging Subsystem

This subsystem contains functions for logging of all operator communication originating from a terminal in an NOC, from a local terminal in an AXE exchange, or from a local terminal in the ECC. The logged information is stored in two main groups depending on the age of the information. Information younger than X days is stored on disc and older information on magnetic tape where X is a system parameter which may be varied to suit different Administration's requirements.

After receipt of a transaction (command plus response), CLS analyses and sorts the transaction on one of two main principles, viz by function (command code or group) or by exchange identity (exchange name). Sorting by a combination of these two principles is also possible.

CLS also contains facilities which enable a terminal operator to search transaction files using any one of the following search keys which is specified in the search command:

- All transactions during a given period for a given exchange.
- All transactions with a particular command code.
- All transactions associated with a given group of commands, and
- All transactions from a given NOC for a given command group.

CMS. Communication Subsystem

The CMS subsystem includes the functions for communications over the data links connecting the ECC to exchanges and NOC's as shown in **Fig. 7.** The system of communication on synchronous links is based on the X25 principle specified by CCITT. The physical link protocol is HDLC specified by ISO. Operating speeds available for synchronous links are 1200, 2400, 4800 and 9600 bits/sec.

CMS also contains facilities for the checking and location of faults on the data links. Facilities for automatic changeover to a standby link will be available with the Phase 2 development.

The Phase 2 version of AOM will include the development of a concentrator device to which a number of exchanges can be connected and which will be connected to the ECC via a data link. This concentrator will increase the number of exchanges controllable via the ECC and reduce the cost of the data link network.

ALS. Alarm Subsystem

The ALS subsystem contains facilities for the reception, analysis, and presentation of alarm conditions within the connected exchanges and within the AOM system itself. A general presentation of alarm conditions is given on semigraphic colour displays, while detailed alarm information is presented on terminals and line printers. ALS also contains functions for audible indications of alarms.

All alarms are displayed at either the EMC or FDC appropriate to the operations district except after hours when urgent alarms are forwarded to the AHC. ALS contains facilities for assembling the alarms into 5 different classes depending on the urgency with which maintenance action should be taken. The various classes of alarm are distinguished by means of form and colour on the display panel.

ALS performs sorting of alarms into different files which can be accessed by operator command. For example, all alarm messages for a particular exchange are organised into a file. Facilities to allow selective searching of alarm files using different search keys, for example, alarm class, are provided in ALS.

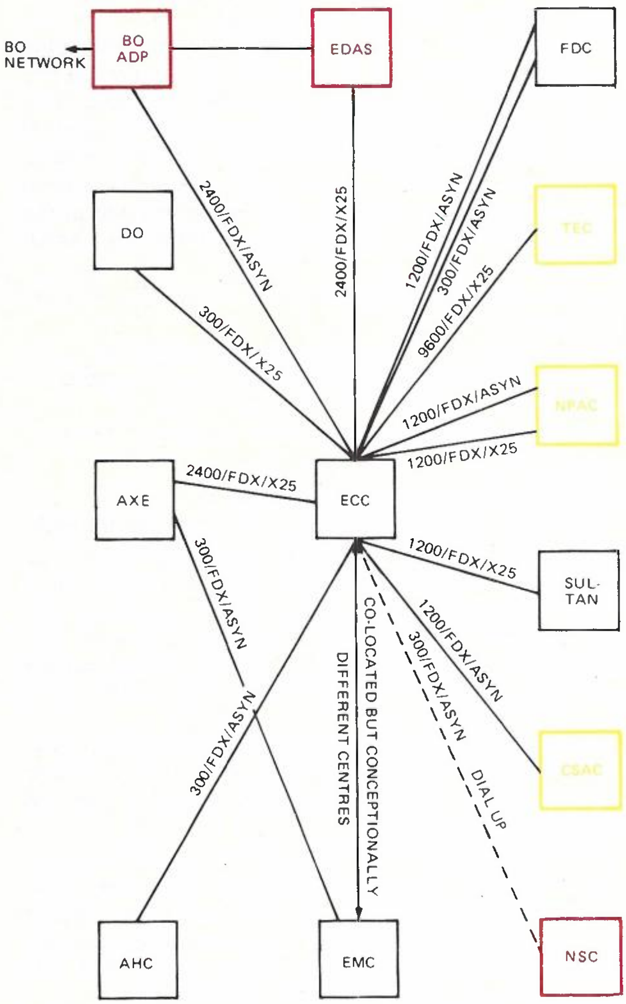


Fig. 7 — NOC Network Data Links

DCS. Data Collection Subsystem

This subsystem includes functions for initiating measurements and statistical functions in exchanges and for the reception, analysis, storage and distribution of different types of data on files.

The remaining two subsystems in the standard AOM APT system, namely SLMS (Subscriber Line Maintenance Subsystem) and TRS (Traffic Route Testing Subsystem) are not required in the ECC because Telecom provides alternative methods of achieving the functions performed by these subsystems.

APZ SUBSYSTEMS

The AOM APZ system is made up of four subsystems with functions as follows:

MPS. Main Processing Subsystem

MPS is the functional name of the VAC1610/P computer which is employed as the main processor in AOM. It consists of the central processing unit, storage and storage control facilities and executive software which includes functions for loading, input/output control, program priority administration, test, software dumping and program tracing.

RPS. Regional Processing Subsystem

RPS is the functional name of the APN163 computer which is used as the regional processor in AOM. It consists of a two board central processing unit, storage facilities and executive software.

INS. Internal Network Subsystem

INS contains facilities for the control, distribution, and supervision of communication between MPS and RPS. The transfer of information between MPS and RPS is effected using control logic similar to HDLC.

FMS. File Management Subsystem

FMS includes facilities for the administration of data files stored on magnetic discs or magnetic tapes. Files may be organised for serial access, index access, or direct access and access protection facilities are provided in FMS for security purposes.

PRS. Printout Subsystem

PRS contains facilities for handling of printouts on line printers.

A summary of the overall characteristics and limits of the AOM 101 system is shown in **Table 1.**

SOFTWARE SUPPORT

A major requirement of any SPC system introduced into the Telecom network is that the software of the system may be simply managed and administered. Software support encompasses facilities, methods and procedures used to produce and maintain all project software for an exchange. Both program logic and data are included in this category. The quality of software support systems has a major bearing on the operating reliability of the system in the field and on the risk involved in making ongoing facility and data changes which become necessary during the life of an exchange.

Telecom has developed a policy for SPC systems that program software shall be centrally administered and controlled at a National Support Centre (NSC) and that data software shall be prepared and controlled at State Support Centres (SSC). This policy aims at maintaining a standard nationwide generic program with identical logic in all field exchanges. It allows data preparation, however, to be controlled by each local administration since the information concerned is of a regional nature.

The AXE system allows the Telecom support policy to be fully realised due to the fact that program logic and data software are completely separate in their production processes. Other major features of the AXE system related to its software support are:

- The comprehensive and proven support aids.
- The program fault detection techniques.
- The administration of program logic modifications.

SUPPORT AIDS

The NSC will have two major tools provided for the preparation of tested program logic. Firstly, a model AXE exchange will be installed in the Headquarters Switching Design Laboratories. This model exchange will be identical to a normal field exchange except that the size of the switchblock will be reduced and only a small number of subscribers services and junction circuits will be connected. The model exchange will operate as a captive office, interworking with other model exchanges installed in this laboratory, to give altogether a national simulated network in which any type of call connection can be established. Program logic will be loaded and tested on the AXE model exchange before being cleared for field exchange use.

The second major tool available to the NSC is the APS 210 software support system. APS is a sophisticated data base management system which has been designed for operation on an IBM 370 computer centre. The APS system was developed very early in the AXE project life

Table 1 — AOM: Technical Characteristics.

General characteristics	
No. of exchanges that can be connected	32-48
No. of subscribers	300,000-500,000
No. of datalinks	48
No. of operator terminals	64
No. of alarm displays	8
No. of magnetic tape drives	8
No. of disk drives	8
No. of line printers	8
Main processing subsystem	
Central processing unit	
Number of instructions	163
Instruction length	1 or 2 words
Units of information	double word 32 bits word 16 bits halfword 8 bits quarter word 4 bits bit 1 bit
Priority system	256 hardware levels 8 external interrupts per level
Main storage	
Type	semiconductor
Capacity	4K words expandable in 4K modules to 512 K words
Word length	16 bits plus parity bits
Cycle time	950 ns
Storage protection	hardware feature
Regional processing subsystem	
Central processing unit	
Number of instructions	54
Instruction length	1-4 words
Units of information	word 16 bits bit field 1-16 bits bit 1 bit
Priority system	one level with chained vectorized interrupts
Main storage	
Type	semiconductor
Capacity	4K words expandable in 4K modules to 64K words
Word length	16 bits plus parity bit
Cycle time	800 ns
Mangnetic tape drive unit	
Type	HP 7970E-151
No. of tracks	9
Recording technique	phase encoded
Packing density	1600 bpi
Disk drive unit	
Type	HP 7920A
Capacity	50M bytes
Visual display unit	
Type	HP 2640
Screen capacity	24 lines x 80 columns
Data rate	110-9600 baud
Alarm display unit	
Type	Semigraf 240
Screen	19″
No. of colours	7
No. of lines	48
No. of characters per line	80
Line printer	
Type	Terminet 340
Max print speed	340 lines per minute
Print line length	132 positions

and was used extensively by L. M. Ericsson in the switching system development. This is of significance since it has resulted in a stable system being offered to Telecom in which procedures and methods are well established and proven.

Large amounts of program information must be held and manipulated for an SPC system. The APS system provides efficient administration of this information by means of programs which operate on files of information identified as "documents". These documents may hold program source information, macro or procedure information, software signal information, or program libraries.

Standard programs operate in APS to check document information, to test or alter information or programs, and to generate the final object code which is to be loaded into field exchanges. After testing and production at the NSC, the final programs in object code will be produced on a cassette magnetic tape. This program logic is completely independent of exchange data so that a single version only need be produced for all exchanges which have the same facilities. Copies of this cassette tape may be made simply at either the NSC or at the SSC for distribution to field exchanges.

The State Support Centres will also use software support aids. The SSC's will have access to an IBM370 centre for the execution of support programs which will generate the exchange dependent data. At the SSC's, exchange data must be prepared for each individual exchange. The support programs translate the telephony oriented information (circuit information, analysis information, subscribers' classifications, etc.) into a form which is suitable for loading at the field exchange. The final product is again produced on a cassette magnetic tape. Programs and data are linked together automatically by the AXE system at the time the separate cassettes are loaded into the AXE central processor memories.

A clear division exists therefore between the responsibilities of the National and State Support Centres, which will allow efficient system management.

REGIONAL PROCESSOR PROGRAM SUPPORT

The program logic in a Regional Processor (RP) is required to realise functions which are of low analytic complexity but which are executed at a high repetition rate. It is necessary therefore that an efficient process be used to convert the functional requirements to the object code which is executed in the processors. This is achieved through the use of an assembly language ASA210R for the preparation of RP programs. The assembly program to convert source code to object code is provided for operation on an IBM370 computer. This program is not currently integrated into the APS210 support system but steps are being taken to include it.

RP programs are not subject to frequent change and are implemented in an exchange on Programmable Read Only Memories (PROMs). The PROMs will be produced by standard manufacturing techniques from tapes, produced and controlled by Telecom, which define the final object code. PROMs produced to a new program version must themselves be fully tested before a clearance for fullscale manufacture and clearance to the field can be given. Testing will be conducted on the model exchange.

AOM SOFTWARE SUPPORT

The decision to adopt AOM101, as a computer controlled data switching system to interconnect the AXE exchanges with Telecom's Network Operating Centres, will add a significant ongoing software support workload. The program logic within AOM101 may be expected to undergo considerable change throughout the system lifetime since it will form a major interface to so many of Telecom's operations. Even as initially planned, AOM101 will proceed in three major phases of development which are compatible with Telecom's plans for its network development. The National Support Centre must therefore be able to test new program developments and to produce object tapes for distribution to each AOM101 centre. It is also likely that Telecom will itself undertake application program development in this area where requirements are specific to Australian procedures and operating centres.

In order to be able to test new or modified AOM101 programs, the model exchange will include a full facility AOM system with all Network Operating Centre interfaces. The AOM101 system employs two computer types which are different from those used in the AXE system. These are the UAC1610 (central processor) and the APN163 (regional processors). Both machines are programmed using a high level language which is different from that used in AXE. A dedicated set of support programs are therefore provided to allow file administration, updating of source tapes, program compilation, etc. These programs do not operate within the APS210 environment but are executed on an IBM370 computer system.

PROGRAM FAULT DETECTION AND CORRECTION

The major features of the AXE system in relation to program fault detection and correction are:

- The modular program structure and the software signal concept allow easier isolation of faults.
- The trace facility in AXE gives program status information in a form which is easy to interpret and analyse.
- Fault location and testing is simplified by working in a high level language.
- The facilities available for the secure introduction and administration of program corrections.
- Individual program modules (function blocks) can be separately recompiled and introduced into field exchanges without disruption to non-effected blocks.

PROGRAM FAULT DETECTION

Program errors can be detected during normal execution of the AXE operational programs as an attempt to perform an illegal sequence. Each fault results in an output giving a fault code together with two words of information related to the fault. The normal situation is that these give the function block and instruction address at which the fault was detected. If the fault occurred in a central processor (CP) program, a minor restart will be initiated. This will always cause the output of a standard dump which gives the contents of the Jump Address Memory (JAM). This dump identifies the preceding sequence of program actions by giving the block members and instruction addresses at which program branches have occurred. The dump can also include the values of particular variables which have been defined by investigating staff.

Further information on the cause of a program fault can be obtained by use of the program trace facility. A trace is initiated by the occurrence of a nominated event during the normal execution of the operational programs. The information output from the trace is matched to the modular structure of the operational software, being a listing of the software signals sent between function blocks together with the values of the data transferred. The trace facility can be used in either static or dynamic tests. Static tests will be of particular value in the model exchange where the AXE system operation can be interrupted during tests. The dynamic trace mode in a field exchange ensures that normal exchange functions are not disturbed.

PROGRAM CORRECTIONS

A process for the introduction of program corrections is essential in any SPC system. In the AXE system, this process has been given considerable design attention in order that the probability of handling errors is reduced and to give controlled correction administration. The following design features assist in providing secure correction administration.

- The wide limits on **memory capacity** allow the system to contain many features to increase manageability and reliability.
- AXE corrections are introduced into the system by man-machine command codes and are written in **symbolic assembly language** source code. The conversion of this code to machine language code is performed on-line. Printout of system corrections is also in symbolic source code. This feature greatly assists comprehension of the program logic state and reduces the probability of human errors.
- The code replaced by a correction is saved in memory. Thus, in the event of a system recovery, the pre-change program status can be immediately restored.
- **Additional information** such as correction identification number and related fault report number can be stored in memory. This assists in orderly administration.
- Corrections are located in **correction zones** directly related to the function blocks concerned. A full list of corrections per function block may be requested by man-machine command.
- Corrections can exist in three states. A **passive** (or inactive) correction is one which has been loaded into a correction zone but no jump linkage has been written. The old program logic is therefore executed. When a correction is made **active**, the program jump is inserted so that the new program logic is executed. In the event of a system restart such corrections revert automatically to the passive state. An active correction may be converted to **approved** status by man-machine command. Approved corrections are not made passive when a system restart occurs.

The use of program patches is, of course, not the only method available for introducing program modifications. Normally the urgency of a program change will not warrant the direct introduction of patches. Function blocks which are affected by a change will be recompiled separately and distributed to field exchanges. A minor system restart is initiated to activate the new function blocks.

CONCLUSION

The AXE system is well suited to meet Telecom's local switching needs of the future both because of its advanced design concepts and because of the emphasis which has been placed in its development on manageability and security. AXE has benefited from the earlier worldwide experience of SPC systems and provides a design which can evolve into the future. The need for adequate support systems to allow secure system management and ongoing enhancement has been recognised in the basic design, and a wide range of facilities are provided.

As a joint development, the AOM system reflects the trends of Administrations to integrate the telecommunications network with their operating and administrative centres.

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Construction Aspects of the AXE System

R. MARSHALL MIE Aust.

The adoption by Telecom Australia of the L. M. Ericsson AXE and AOM systems will involve the introduction of new switching equipment construction practices. This paper provides an overview of the techniques used in the construction of these systems.

INTRODUCTION

The AXE system recently adopted by Telecom includes both AXE exchanges and related exchange maintenance centres using the L. M. Ericsson AOM system. This article outlines some of the construction aspects of the AXE and AOM systems. In particular it discusses the structural, installation and testing techniques, and installation support systems used by these systems.

AXE SYSTEM

As discussed in other articles in this journal the AXE system has been designed on a modular basis. This modular design principle extends to the system hardware and thereby facilitates the introduction of efficient on-site installation and testing procedures.

The installation of SPC systems requires the preparation of a considerable amount of site-dependent installation documentation and data. For the AXE system L. M. Ericsson have developed a number of separate computer-based support programs to enable this documentation to be produced in an efficient manner. The following paragraphs outline the packaging structure, installation, testing and engineering support systems of AXE.

AXE PACKAGING STRUCTURE

The mechanical module in the AXE system is the magazine which contains the hardware for a given function block. The magazines are "box-like" frames of various sizes in which printed circuit assemblies and other units of equipment are mounted and internally connected as shown in **Fig. 1**.

The magazines are mounted on shelf units which provide for flexible mounting and the medium for external cabling via plug ended cables. The shelf units are assembled in suites and can be either 6 (2500mm) or 8 (2900mm) shelves high. This mechanical structure replaces the traditional rack with its associated wiring, testing and documentation.

Vertical cable sections are provided as required for cabling between shelves and to provide access to the overhead cabling structure. The overhead cabling structure consists of three metal troughs to enable the separation of power, signalling and equipment cables. **Fig. 2** shows details of AXE mechanical structure.

AXE INSTALLATION TECHNIQUES

AXE shelf sections and overhead structure are assembled on-site with minimum on-site modification.

The shelf structure contains no cabling as used in a normal rack structure. Instead all cabling between magazines in the AXE system is plug-ended and a large percentage of the cables can be delivered pre-fabricated and labelled ready for placement in the cabling shelves or sections and connection to the magazines. The pre-fabricated cables are either plugged into the front of the printed circuit assemblies or directly into the magazine back plane wiring as shown in **Fig. 3**. Some cabling such as cables to MDF may be fabricated on-site. The extent to which cable can be pre-fabricated depends on the extent to which magazine layouts are standardised.

The number of different cable types has been restricted to simplify cable handling. The cables are always terminated on the plugs using the "pin-to-pin" interconnection method, that is pin 01 at one end is connected to pin 01 at the other end, etc. The cables are terminated on the pins using the wire-wrapping technique.

The printed circuit assemblies are delivered mounted and tested in their magazines and the magazines are placed on the equipment shelves and connected to the cable plugs.

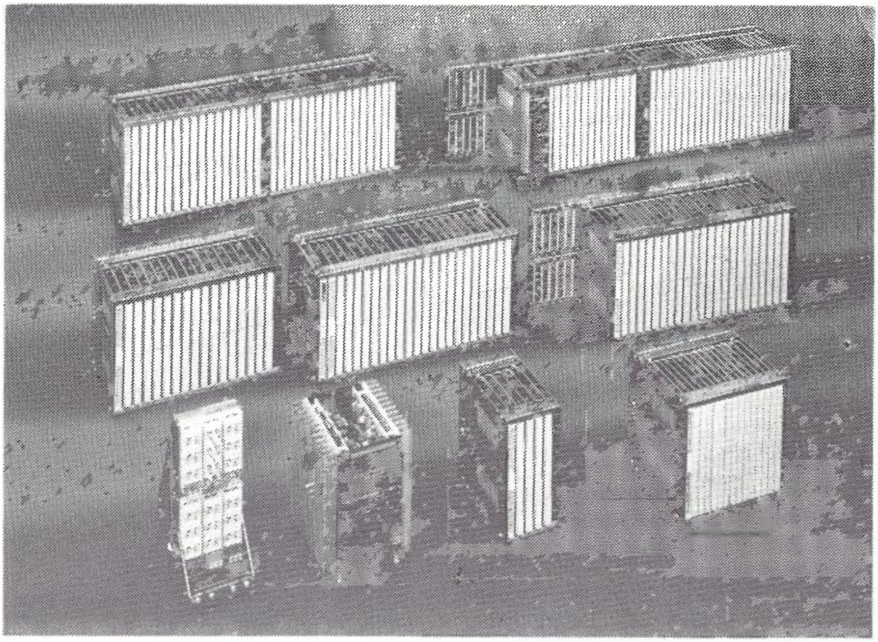

Fig. 1 — Different Magazine Types

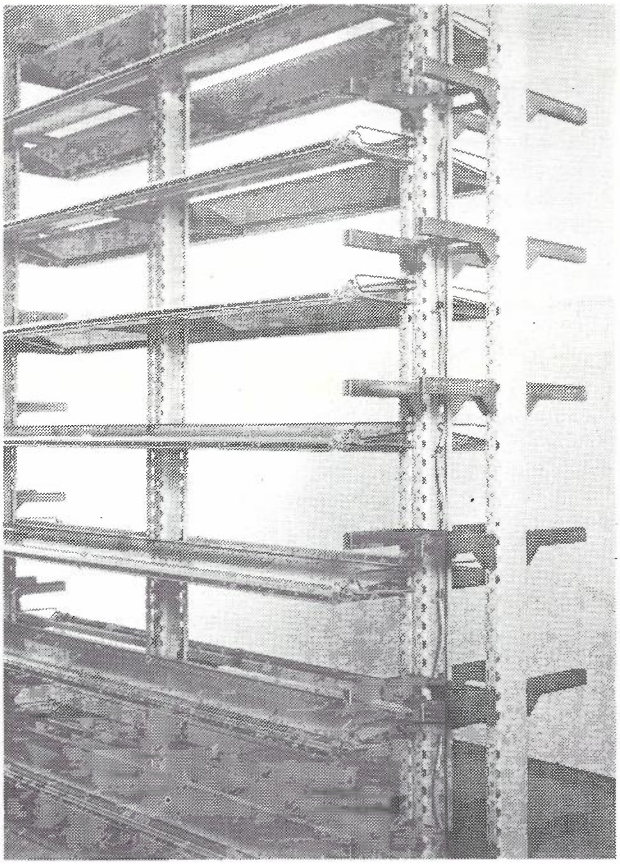

Fig. 2 — AXE Mechanical Structure

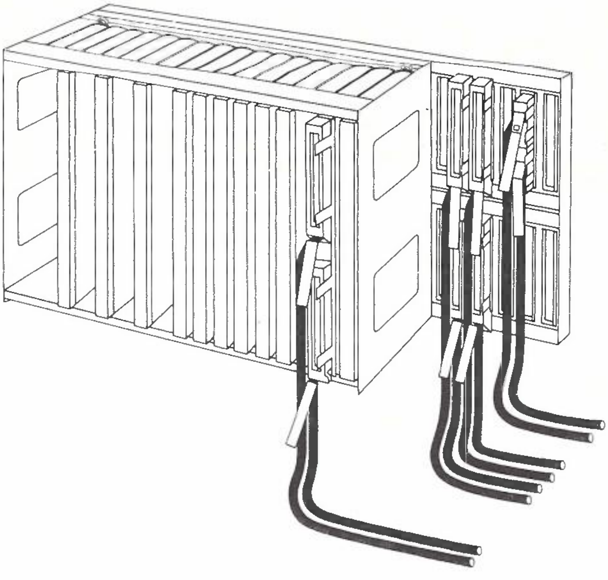

Fig. 3 — Cable Connection to Magazines

AXE TESTING TECHNIQUES

The AXE factory testing procedures are very extensive and are discussed in detail in an associated article in this Journal. Factory testing procedures are designed to ensure efficient subsequent testing of the equipment during the on-site construction phase. In production, magazines are equipped with their printed circuit assemblies and delivered to the installation site with the printed circuit assemblies in position, arriving as fully tested functional units. This procedure is expected to considerably reduce on-site installation handling and testing.

The processor system APZ is tested in the factory as a complete working processor prior to delivery and the on-site testing system used is similar to the factory testing system.

The main activities involved in on-site testing are:

1. Hardware test of power equipment
2. Hardware test of processor system APZ
3. Functional test of APZ
4. Hardware Test of switching system APT
5. Functional test of APT
6. Final overall test

Brief details on each of these tests are set out below:

1) Hardware testing of the power equipment consists of checking fusing, output voltages and other characteristics of the power distribution system.
2) On-site hardware testing of the processor system APZ is performed by the sub-system AVS (APZ Verification Sub-system) which consists of extensive test programmes on equipment of the type used in the factory test. Any faults reported by this system are normally removed by the substitution of one or more boards which, by diagnosis, are considered faulty. At completion of testing, it should be possible to load and execute the operating system in APZ.
3) Functional testing of the APZ system is executed with the regular operating system loaded and with APZ in parallel working mode. This tests the loading and initial start of APZ, the Central Processor sub-system (CPS), the regional processor sub-system (RPS), the input output sub-system (IOS) and the Maintenance sub-system (MAS). The tests are mainly command initiated and verified by system printouts.
4) The hardware test of the Switching Equipment APT tests the following hardware units:
   SSN — Subscriber Switching Network
   GSN — Group Switching Network
   AJC — A Junctor Circuit
   BJC — B Junctor Circuit
   KRD — Keyset Code Reception Device (Touch Phone)
   CRD — Code Receiver Device
   CSD — Code Sending Device

   Testing of the SSN and GSN networks is performed using SOLS (Switch Operation and Link Tester for SSN) and SOLG (Switch Operation and Link Tester for GSN). SOLS and SOLG are on-line installation test programs which automatically carry out systematic testing of all switch matrices and links in the SSN and GSN networks.

   The test of the AJC and BJC circuits uses a special test device called CIRTI (Circuit Tester for Installation) which consists of hardware and software and works on-line. CIRTI is connected to the SSN and to the incoming and outgoing sides in GSN and performs systematic tests on all AJCs and BJCs.

   KRD and CRD code devices are tested by use of a multi-frequency code tester to ensure the correct digits are received or sent.
5) Functional testing of the Switching Equipment (APT) covers the operation and maintenance and the traffic handling functions.

   The test of the operation and maintenance functions covers changes in subscribers, exchange analysis and charging data, together with alarm and blocking functions and supervision functions. These tests are activated by command or from supervision circuits in the

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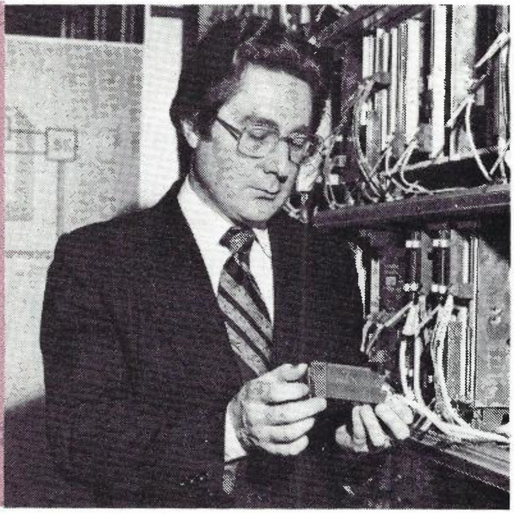
He joined Telecom Australia as a Cadet Engineer in 1961. After qualifying in 1963 he worked for four years on the installation of telephone switching equipment in metropolitan centres in Victoria.

In 1967 he transferred to the Telephone Exchange Equipment Section Headquarters and was involved in the provisioning and installation standards for new switching systems. From June 1975 until July 1977 he was a member of the SPC Local Evaluation Team which recommended the purchase of the AXE system.



APT system and the result is checked against the operational procedures.

The functional test of traffic handling covers the interworking of hardware, software and data to switch traffic. All traffic cases, routing, digit and charging analysis and each trunk circuit and line connection are tested. Test traffic is generated from a Subscriber Traffic Generator (STG).

6) The final overall test is designed to test the entire exchange under operating conditions. The test consists of two parts:

- Generation of test traffic
- Combined Test

Generation of test traffic is performed by means of the Subscribers Traffic Generator (STG) which is connected to a number of subscribers inlets. STG is an autonomous test device controlled by a minicomputer and can be connected to 128 subscriber lines and initiate up to 10,000 connections per hour over the 128 lines.

The combined test is performed while the exchange is carrying test traffic and includes checks of various operational functions such as restart, change of function and change of data under load conditions prior to commissioning the exchange.

A completed AXE exchange with some of the equipment covers removed is shown in **Fig. 4**.

AXE INSTALLATION ENGINEERING SUPPORT AIDS

Installation of any SPC system requires the preparation of a considerable amount of site-dependent installation documentation and data. The preparation of this documentation can be a very time-consuming and tedious process.

To overcome this problem L. M. Ericsson have developed an extensive range of computer based installation engineering support systems to enable efficient handling of the AXE system. These systems have been designed to run on an IBM 370 computer and are used for the development of material lists and site-dependent installation documentation and data.

The AXE system has also been designed with completely separate production processes for program logic and site dependent data. The site-dependent data tapes are produced by the EXDATA and TRAFDATA systems whilst the program logic tape is produced by the APS system which is discussed in detail in an associated article in this journal. Program and data are linked together automatically by the AXE system at the time the separate tapes are loaded on-site. The separate preparation of program and data is an important design feature which enables efficient handling of site-dependent data.

Installation support aids can be grouped as follows:

1) Exchange Data System (EXDATA)
2) Traffic and Network Data System (TRAFDATA)
3) Material Explosion and Dimensioning Systems

1) The Exchange Data System (EXDATA) is a software system which can produce the following documentation for a given AXE project:
   - Exchange Dispositioning Data — the allocation of devices to various inlets and outlets.
   - Cabling Tables — cable running lists including cable lengths.

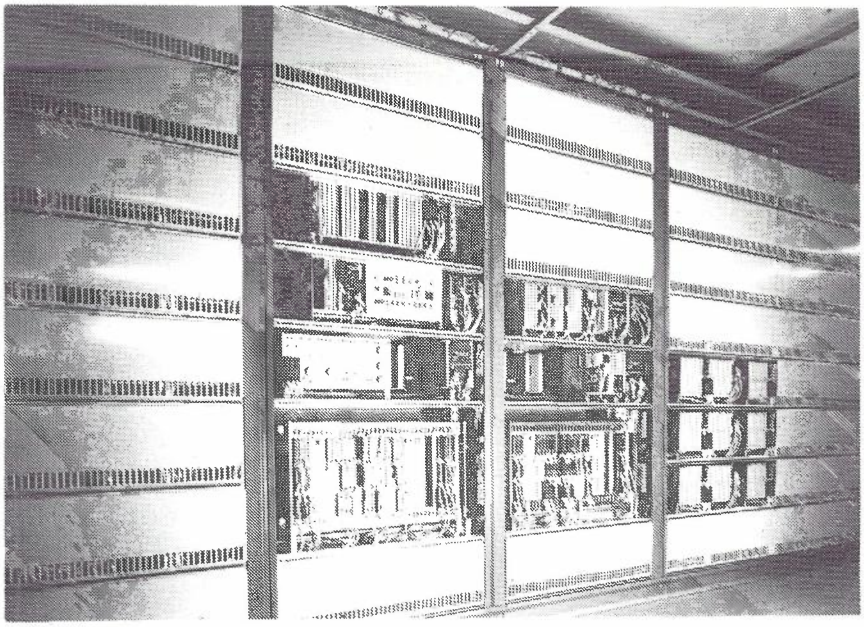


Fig. 4 — Typical AXE Exchange

- Cable Labels — production of labels for all cables which are pre-fabricated in the factory.
- Exchange Data Commands — production of a tape to enable the hardware configuration of the exchange to be represented in data.

2) The Traffic and Network Data System (TRAFDATA) is a software system which can produce the following information for a given AXE project:
   - Traffic Data Commands — production of a tape to enable all network routing and charging information to be represented in data.
   - Subscriber Data Commands — production of a tape to enable all subscribers information (i.e. categories) to be represented in data.
3) Material dimensioning and explosion for a given AXE exchange can be performed by using a group of software systems together with various data bases. These systems perform the following functions:
   - Memory Store Dimensioning (STOREDIM) — the calculation of memory requirements for a given AXE facility level.
   - Processor Load Dimensioning (PRODIM) — the calculation of processor load for different traffic applications.
   - Power Dimensioning (POWDIM) — the calculation of power requirements for a given exchange.
   - Spare Part Requirements (RESEX) — the calculation of spare part requirements for a given exchange or group of exchanges.
   - Traffic Dimensioning (TRAFDIM) — the calculation of device quantities which are traffic dependent.
   - Material Explosion (BDM) — the calculation of material quantities for a given project.

AOM SYSTEM

The AOM system is a system developed by L. M. Ericsson for the remote control of maintenance of exchanges. It consists of an Exchange Communication Controller (ECC) and an Exchange Maintenance Centre (EMC).

The Exchange Communication Controller (ECC) is a computer system used for storing and directing messages between AXE exchanges and various network operating centres. The functions and interconnection of these centres are discussed in detail in associated articles in this Journal.

The packaging and installation techniques used for the ECC are similar to the techniques used for a normal commercial computer installation. The total installation time is relatively short with a minimum of physical installation work, the majority of the time being required for system testing.

The following paragraphs outline the structural, installation and testing techniques used for the Exchange Communication Controller (ECC).

ECC PACKING STRUCTURE

The ECC consists of a relatively small number of computer type cabinets which are delivered fully assembled. The basic magazine structure and cabling techniques adopted for AXE are used within these computer cabinets. The ECC cabinets are 1800mm high and a typical cabinet is shown in **Fig. 5**.

ECC INSTALLATION TECHNIQUES

ECC cabinets are delivered fully assembled including the magazines and printed circuit assemblies. All cables between cabinets are plug-ended and supplied prefabricated from the factory. The cable and terminating techniques are the same as those used for the AXE system.

The cabinets are free standing and the minimum amount of cable between cabinets can be run either under a false floor or overhead.

The on-site installation effort involves installing the cabinets, plugging in the cables, and arranging of the external connection to the various modems.

ECC TESTING TECHNIQUES

The ECC system is fully assembled in the factory and tested as a complete system before delivery.

The main activities involved in on-site testing are:

- The test of system hardware which involves the testing of each unit using hardware test programmes.
- The test of the various sub-systems which is executed using test programmes running on the main processor.
- The hardware structure test which checks that the system is correctly inter-connected and can operate in

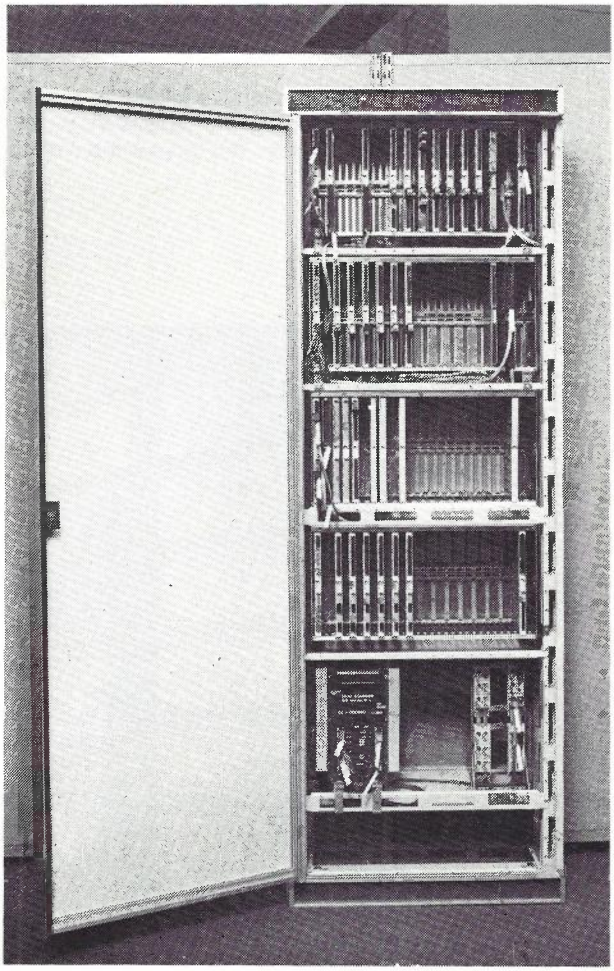


Fig. 5 — Typical ECC Cabinet

the particular network environment.

- The test of the application system which is an overall test to ensure correct functioning of the system. The tests are initiated by command and the results compared against a testing instruction.

CONCLUSION

The AXE system offers considerable installation advantages compared with the current crossbar system. These advantages include:

- Reduced floor space requirements
- Simplified mechanical structure
- A large proportion of cabling by standard plug ended cables
- The magazine structure for easy handling
- Automated testing procedures
- Extensive software installation engineering support systems.

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THE WINSTON CHURCHILL MEMORIAL TRUST CHURCHILL FELLOWSHIPS TO UNDERTAKE OVERSEAS STUDY PROJECTS

Objects of the Churchill Trust

THE WINSTON CHURCHILL MEMORIAL TRUST was established in Australia in 1965, the year in which Sir Winston Churchill died. The principal object of the Trust is to perpetuate and honour the memory of Sir Winston Churchill by the award of Memorial Fellowships known as "Churchill Fellowships".

Function of the Churchill Trust

The aim of the Churchill Trust is to give opportunity, by the provision of financial support, to enable Australians from all walks of life to undertake overseas study, or an investigative project of a kind that is not fully available in Australia. This opportunity is provided in furtherance of Sir Winston Churchill's maxim that: "with opportunity comes responsibility".

There are no prescribed qualifications, academic or otherwise, for the award of a Churchill Fellowship. Merit is the primary test, whether based on past achievements or demonstrated ability for future achievement in all walks of life. The value of an applicant's work to the community and the extent to which it will be enhanced by the applicant's overseas study project are important criteria taken into account in selecting Churchill Fellows.

To enable it to provide this opportunity the Churchill Trust administers funds which now stand at over $5.7M. The original capital of $4.2M was subscribed, or pledged, in 1965 by all sections of the Australian community to enable the Churchill Trust to be established as a perpetual memorial to Sir Winston Churchill.

Scope of Churchill Fellowships

Churchill Fellows are awarded a return economy-class overseas air-ticket and an Overseas Living Allowance to enable them to undertake their approved overseas study project. In special cases they may also be awarded supplementary allowances including Dependants' Allowance. 59 Churchill Fellowships were awarded for 1979 at a total cost of $300,000.

All Churchill Fellows are presented, at an appropriate ceremony, with a certificate identifying them as such. This certificate bestows upon the recipient the prestige of being a Churchill Fellow and, while a Fellow is overseas, serves to open many doors that would not otherwise be opened to a private individual.

Applications for Churchill Fellowships

The Churchill Trust is now calling for applications from Australians, of 18 years and over, from all walks of life who wish to be considered for Churchill Fellowships tenable in 1980.

Completed application forms and reports from three referees must reach the Churchill Trust by the 28th February 1979.

People wishing to be considered for a Churchill Fellowship should send their name and address NOW with the request for a copy of the Churchill Trust's Information Brochure and application forms to:-

The Winston Churchill Memorial Trust (M),
P.O. Box 478,
CANBERRA CITY, A.C.T., 2601.

or, for residents in South Australia, Western Australia, Tasmania and the Northern Territory, the approriate address below:-

G.P.O. Box 498, Adelaide, South Australia, 5001.
P.O. Box 6209, Hay Street East, Perth, Western Australia, 6000.
G.P.O. Box 1260N, Hobart, Tasmania, 7001.
P.O. Box 2147, Darwin, Northern Territory, 5794.

Operation and Maintenance of AXE in the Australian Telephone Network

W. K. BATE, ARMIT

This paper, one of a series on the AXE System, provides a general description of the operations and maintenance facilities of the AXE system and outlines an organisation for control of the maintenance of the AXE exchanges.

INTRODUCTION

Telecom Australia has introduced stored program controlled (SPC) switching systems into the trunk network, with the Metaconta 10C system, and into the metropolitan terminal telephone network by conversion of ARF crossbar exchanges to processor controlled ARE exchanges. The introduction of the AXE system is a further step by Telecom to ensure that the telephone network can continue to be economically expanded, operated and maintained. By 1990 90% of the metropolitan terminal telephone networks in Australia will be processor controlled — either AXE or ARE.

This paper provides a general description of the operations and maintenance facilities of the AXE system and outlines an organisation for control of the maintenance of AXE exchanges.

OPERATIONS AND MAINTENANCE FACILITIES

Exchange Equipment Supervision and Maintenance

The main means of supervising the AXE exchange equipment is by the use of on-line supervisory functions. These functions, contained in both hardware and software, continuously and automatically monitor the performance of the various sub-systems, devices, routes and circuits during normal traffic handling. AXE maintenance sub-systems internally process the performance data from the supervisory functions and provide an alarm message when equipment performance has deteriorated to the extent that maintenance attention is needed. Staff respond to the alarm message by interrogating the maintenance sub-systems, using an input-output terminal, to obtain whatever additional data are required for fault location. The internal processing of performance data ensures that minor disturbances and temporary faults are not needlessly notified to staff.

Switching System (APT) Supervision

The Operation and Maintenance Sub-system (OMS) has a number of function blocks for continuous and automatic supervision of the switching system of the AXE exchange. The major functions are described below and their application is shown in **Fig. 1**.

- Disturbance Supervision. For individual devices and routes a counter is decremented for each seizure and incremented by a preset number for each disturbance (e.g. signal failure, time release). If an upper limit is reached an alarm is given, if zero is reached the counter is reset to its initial value and any alarm previously generated is reset.
- Switching Network Supervision. On every connection through the switching stages continuity and leakage tests are performed on the speech path. When a fault is detected a counter is stepped for each of the matrices on the path of the connection. When a particular matrix counter reaches a preset limit, the last link used from this matrix is blocked and an alarm given. Switching faults, such as failed reed crosspoints, can be isolated by analysing the contents of the counters.
- The number of blocked links is also supervised and an alarm given when a preset number is exceeded else the counters are automatically reset after a certain interval.
- Call Quality Supervision. For individual devices the ratio of the total number of seizures to the number of seizures of a minimum duration, is compared to the same ratio for all similar devices in a group. For example for an individual outgoing trunk its ratio is compared to that of the route for which the trunk is part. Faults causing short holding times of devices are detected.
- Seizure Supervision. For trunk and junction devices, and subscribers lines (usually high calling rate lines), a count is recorded to ensure all devices are seized at least once during a supervisory period.

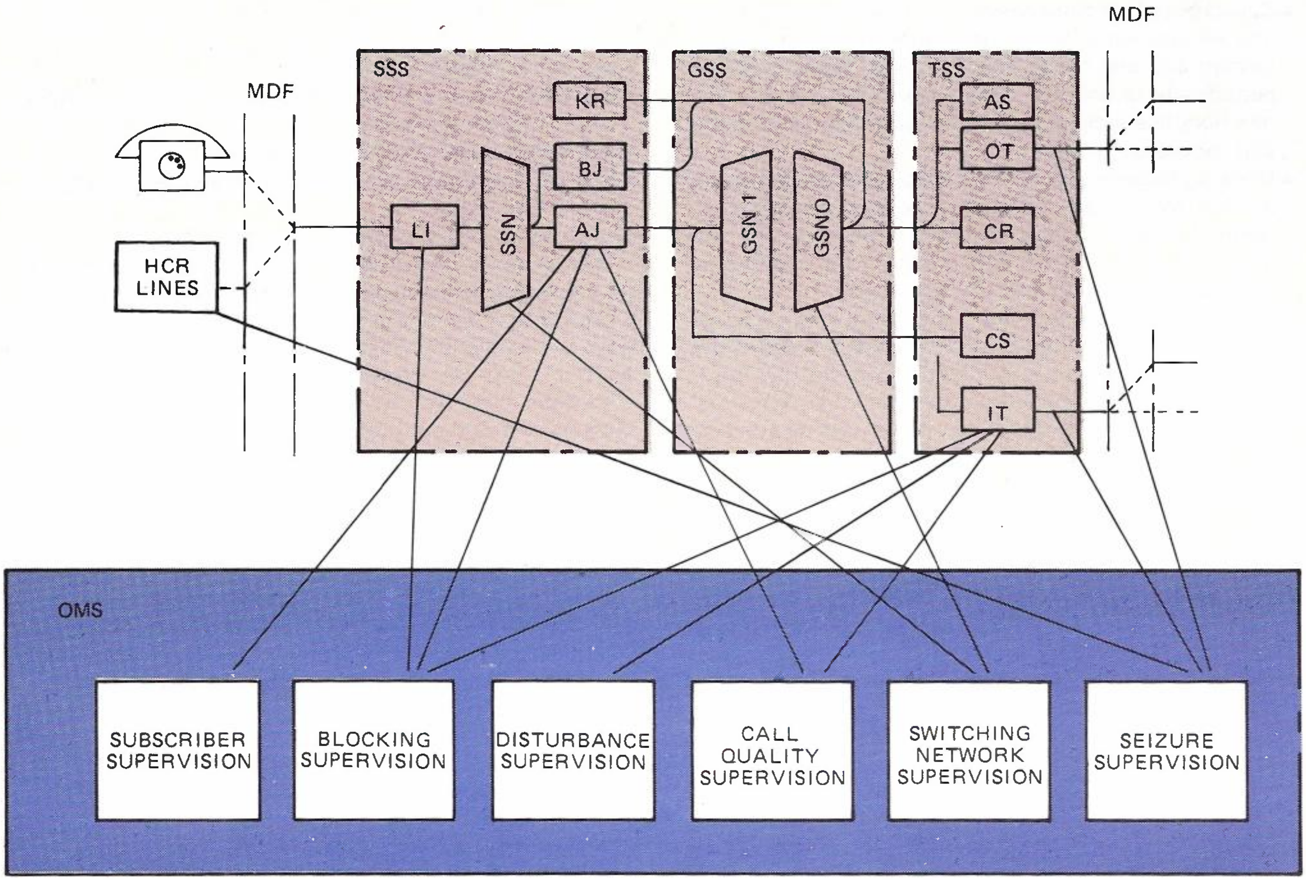


Fig. 1 Switching System Supervision Facilities

WALLY BATE joined Telecom in 1951 as a Technician in training. In 1962 he was appointed a Trainee Engineer. As an Engineer, from 1964 to 1977, he was engaged in technical service aspects of subscribers and telephone switching equipment. This Engineering experience was gained as a Field Engineer in the Victorian Administration, and as an Engineer at Headquarters in the Network Performance and Operations Branch.

When he participated in the selection of the AXE Telephone Switching System, he was an Engineer Class 4, in the Network Performance and Operations Branch. His current position is District Telecom Manager — Melbourne City.

- Subscribers Line Supervision. On calls to and from each line an automatic test of insulation resistance is performed and any faulty line identified. Faulty lines are periodically re-checked. This supervisory function also monitors line-lockout conditions and records all faulty and locked-out lines.
- Blocking Supervision. For individual devices an alarm is given if the number of blocked devices per group exceeds a preset number. There is a provision for two levels of alarm urgency depending on the number of blockages per group and the group size.

These supervisory functions check both the exchange equipment and the external connections (subscribers lines and inter-exchange circuits) to the exchange. Alarm messages are spontaneously presented, on an input/output terminal and a visual display, when service affecting fault levels have been reached.

Data Processing System (APZ) Supervision

The Maintenance Subsystem (MAS) comprises a number of functions for on-line supervision of the central and regional processors. In addition, MAS contains programs for fault diagnoses, system reconfiguration and software recovery.

The central processor consists of two identical sides working in parallel on the same programs and data. There are individual supervisory circuits for each CP side and in addition, there are common circuits for comparing processor sides. The supervisory circuits are divided into three classes:-

- Side Indicating. With these circuits voltage, parity check, and time supervision faults are detected by the central processor side.
- Side Comparing. With these circuits the two central processor sides are continually compared to detect faults. For example, a hardware fault in one side will cause data mutilation in that side and can be detected and isolated by these side comparing circuits.
- Total Supervision. A circuit checks program handling time. The circuit is periodically set and must be reset in a certain time by program execution.

For temporary system disturbance there is a function in MAS which records data relevant to the disturbance. For example, time, origin of signal and address of store word. After the receipt of a certain number of temporary disturbances automatic diagnosis is performed on the data and an alarm message initiated.

Regional processors are supervised by internal circuits and programs which check parity, program execution time and routinely check specific internal functions. In addition, the central processors routinely checks all regional processors by sending signals and checking the received responses.

Maintainability

Maintainability encompasses the facilities provided by the system to detect, indicate and isolate faults and the procedures to restore the system to full operating condition after fault rectification.

The AXE system has the following design features which assist in achieving system maintainability:-

- equipment redundancy,
- modular software structure,
- separation of programs and data,
- automatic recovery and reconfiguration for certain central processor faults,
- automatic blocking of faulty equipment,
- internal supervision of performance and processing of supervision data,
- a user oriented Fault Trace and Repair Manual.

The majority of exchange faults are detected by the AXE supervisory functions. Fault isolation for many faults will be able to be determined direct from the alarm message generated by the supervisory function. For other faults it will be necessary to use test traffic and diagnostic programs to assist in fault isolation. Some diagnostic programs provide a list of all suspect faulty boards with a weighting factor for each board.

The use of the Fault Trace and Repair Manual is necessary for all but the most common faults. The manual provides a logical guide to assist staff in fault isolation.

There are a number of special facilities available in the AXE system to assist in fault isolation. The facilities are generally initiated directly from an input-output terminal, by maintenance staff. Some of these facilities are:-

For the APT System:

- test calls directed via selected devices or paths,
- reading of fault counters and selected test points,
- listing of devices, routes and circuits used on failed test calls or normal traffic,
- reading of live traffic signals and data.

For the APZ System:

- place a central processor side in various working states (e.g. stand-by, working in parallel),
- data temporarily reserved with print-out on an input-output terminal,
- execute programs step by step and display and modify register contents,
- tracing of signals to and from function blocks.

Subscribers, Exchange and Network Operations

The correct interpretation, switching and charging of subscribers' calls are dependent on the information (subscribers' data, route data, exchange data, charging data etc.) resident in the exchange data stores. These data stores, which are entirely independent of the call processing program stores, are continually undergoing change to match network dimensioning changes and subscribers classification changes.

The data changes are performed from an input-output terminal via the OMS subsystem. The steps involved are shown in **Fig. 2.** The changes are made using strict data formats described in the operations Manual. The need for strict adherence to the formats is essential to minimise service disruption to one or all subscribers.

EXCHANGE MAINTENANCE ORGANISATION

To achieve efficiency in operation and maintenance it is necessary that a maintenance organisation be developed to meet the characteristics of the SPC switching system and to make full use of the facilities of the system. Use of an existing maintenance organisation, developed for older electromechanical systems, will not enable the operations and maintenance potential of the AXE system to be realised.

For the AXE system the following characteristics, which are common to all SPC systems, must be considered in development of a maintenance organisation:-

- a low number of faults per plant unit — high reliability,
- design features which minimise the service impact of faults and reduce the need for immediate attention to certain faults,
- only minor and infrequent scheduled testing required,
- very little manipulative work needed on the switching equipment,
- a strict, disciplined approach is required in performing all data changes,
- the ability to perform practically all O & M activities from an input/output terminal.

Furthermore, the maintenance organisation must also be developed to:

- ensure service standards are achieved at an acceptable cost,
- make efficient use of trained staff,
- ensure the development and retention of O & M skills.

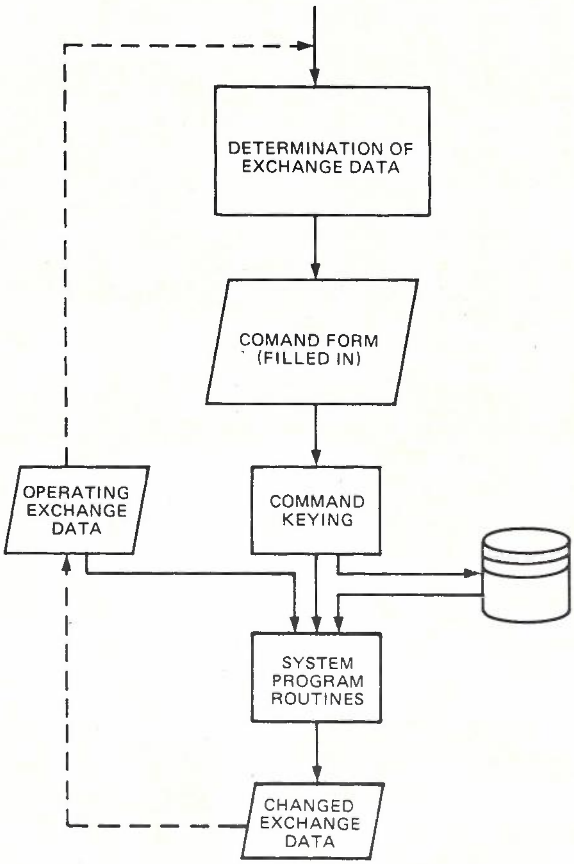


Fig. 2 Steps in Data Changing

Exchange Maintenance Centre — EMC

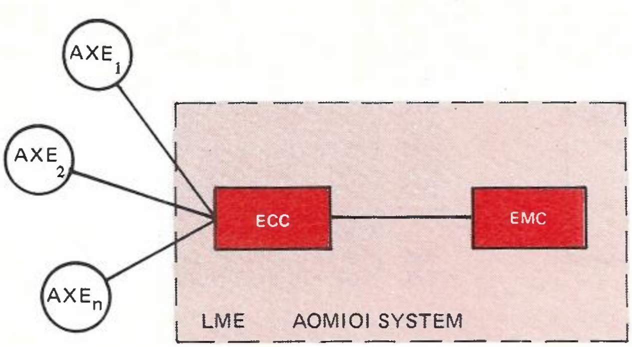
The above factors suggest a maintenance organisation, based on maintenance centres, which controls a number of AXE exchanges. These centres, called Exchange Maintenance Centres (EMCs) are linked to the exchanges via an Exchange Communications Controller (ECC). The EMC plus the ECC, shown in **Fig. 3**, are equivalent to the LM Ericsson Network Operations and Maintenance System, AOM 101. The design, development and method of installation of the ECC and EMC are detailed in associated articles in this Journal.

The EMC staff will be responsible for the performance, operations and maintenance of the AXE exchange equipment. They will perform the various tasks required at the exchanges from input-output terminals at the EMC. These tasks include fault analysis, performance assessment, call tracing, equipment blocking and deblocking and changes to site dependent data.

The work at each EMC is proposed to be organised into five functional cells where each cell will be responsible for its particular function at all exchanges. These functions are:-

- data and software control
- fault analysis and repairs
- performance supervision and scheduled testing
- construction liaison and acceptance testing
- activity co-ordination.

Each centre will have a work layout designed to suit the flow of work between each of these five functional cells. In addition, there will be extensive documentation, visual display units, printers and coloured video alarm displays to provide the necessary communications between EMC staff and the exchanges.



ECC=EXCHANGE COMMUNICATIONS CONTROLLER
EMC=EXCHANGE MAINTENANCE CENTRE

Fig. 3. Trunking of Exchanges to EMC

Exchange Communications Controller —ECC

The ECC is a central data switching system to provide for data transfer between the EMC and the exchanges. The ECC, while primarily for data switching, also provides the following common facilities for the EMCs:-

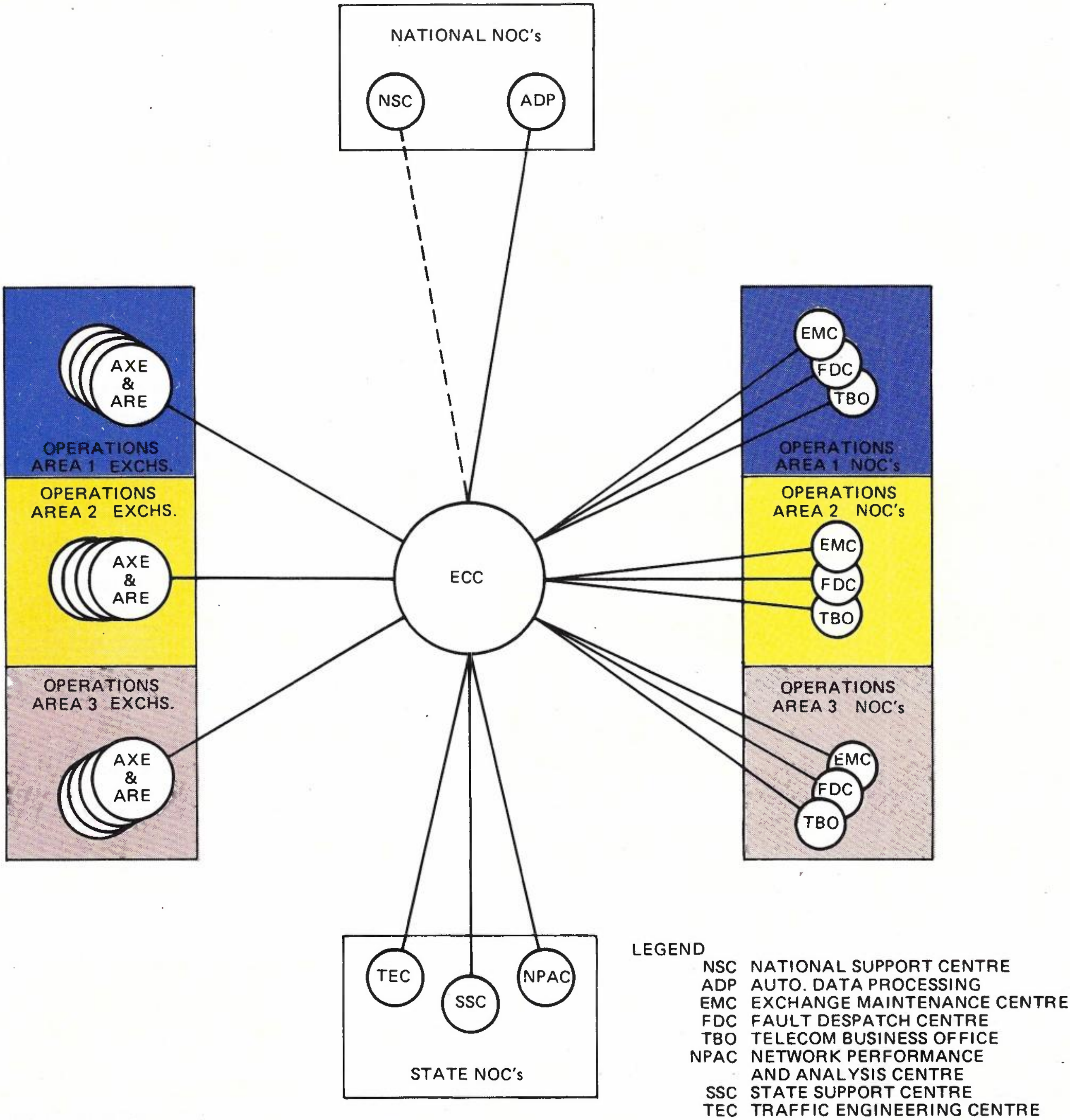


Fig. 4. Integration of Network Operations Centres

- data storage and logging,
- data sorting and retrieval,
- alarm display formats,
- command authorisation.

By providing these common facilities at the ECC, the EMCs can be kept simple, with only input-output terminals being required. It is also proposed to develop the ECCs for the following additional facilities:-

- storage and display of documentation,
- time dependent routine task performance,
- automatic display of processed data
- selective sorting of data under various parameters.

The ECC, by the functions it performs and its physical location with respect to the data network, is a critical part in Telecom's management of the total telephone network. Because of this, considerable design emphasis has been given to security aspects. Features are provided to ensure system failures are minimised, un-authorised access to data is prevented and that a practical contingency plan is available in the event of a failure. This contingency plan will ensure that communications between exchanges and the EMC are maintained in the event of ECC failure. A service availability of 99.995% has been set for the communication and alarm display functions of the ECC equipment. For maintenance and security requirements, the ECC will generally be co-located with one of the EMCs that it serves.

INTEGRATION OF NETWORK OPERATIONS CENTRES

In the management and administration of a dynamic telephone network there is a continuing need for access to data at telephone exchanges. Access to data ranging from that concerning individual subscribers to that concerning the overall network is required. The data are used in assessing performance, dimensioning of equipment and routes, management of the network and the administration of subscribers facilities. The data are required by the "Network Operations Centres" (NOCs) within Telecom Australia. These NOCs are located in various organisational groups within Telecom and each has specific responsibilities which require access to data at the AXE exchange. Examples of these NOCs are:-

- Network Performance and Analysis Centres (NPAC)
- Subscribers' Fault Despatch Centre (FDC)
- Telecom Business Office (TBO)
- Traffic Engineering Centre (TEC)

These NOCs have typically obtained information from electro-mechanical telephone exchanges for performing their functions by direct contact with exchange staff or by the use of special circuits to each individual exchange. With the AXE system it is possible to use the ECC as the central access point for all NOCs, which includes the EMCs, to gather specific data from the exchanges. This arrangement is shown in **Fig. 4.** The ECC will log all transactions between the NOCs and each exchange, which will enable maintenance staff at the EMC to oversight all transactions. In addition, the ECC will perform command authorisation and restrict access to sensitive data and program areas in the exchanges.

The introduction of SPC telephone exchanges has created the demand for the development of two new NOCs. Those are:-

- A National Support Centre
- A State Support Centre.

The National Support Centre (NSC) is concerned with the control and administration of AXE call processing and support programs. One function of the NSC is to assist field staff with complex program faults. For this assistance the NSC can gain access to an individual exchange via a datel link to the ECC. Such access is "read-only" and available only on request of the particular EMC staff.

The State Support Centre (SSC) is concerned with the exchange data which is site-dependent or subscriber dependent. The SSC provides a service for the EMC staff, concerned with on-going subscriber operations, and for construction staff at equipment installations, with data assemblies and corrections.

Details of all NOCs with access to the ECC, and the requirements of the various data links interconnecting exchanges, ECC and NOCs are given in an associated article in this Journal.

CONCLUSION

Operations and maintenance practices and procedures for the stored program controlled systems vary greatly from those for the older switching systems. A new maintenance organisation which provides a disciplined approach for all O & M activities is required to ensure service disruptions are minimised and the potential maintenance benefits available with SPC systems are realised.

Manufacturing Aspects of AXE

J.S. BRANDON and B.J. McMAHON

The characteristics of AXE related to its manufacture are reviewed, the manufacturing processes and test methods described and objectives for integrating AXE manufacture with the existing electronic equipment production at L.M. Ericsson's Australian plant are summarised.

INTRODUCTION

This article reviews the characteristics of AXE related to manufacture. This is done first by considering these characteristics in relation to the manufacture of crossbar equipment, and then by analysing the elements of the AXE system which are used in the hardware production.

The article then describes the manufacturing processes, test methods, and general control procedures which are required to produce this system to the desired quality requirements.

Finally, there is a summary of the general objectives for introduction of this manufacture at the L M Ericsson plant and the relationship of AXE manufacture with the existing electronic production of L M Ericsson in Australia.

MANUFACTURING COST STRUCTURES FOR AXE AND CROSSBAR

The manufacturing cost structures for crossbar and AXE equipment are shown in **Fig. 1**. It is seen that the value added in the manufacturing process is about 54% of the total manufactured cost for AXE compared with 65% for crossbar.

This difference is brought about, firstly, by the replacement of the mechanical movements of relay technique with logic elements derived from integrated circuit packages and other electronic components. Secondly, the highly labour intensive crossbar operations of cable forming, relay assembly and relay set wiring, which have proven uneconomial to automate, do not exist in AXE production.

The components and raw material used in the production of AXE equipment represent about 46% of the total cost compared to 35% with crossbar. The most significant parts of the AXE raw material costs are for mechanical piece parts and printed circuit boards; for the components, a breakdown as shown in Fig. 1 indicates that the electronic component costs are about evenly divided between integrated circuits (ICs) and other electronic devices, with the reed switches and connectors being the most significant other items among these components.

The consequent investment in production equipment for AXE is compared with crossbar investment in **Fig. 2.** It can be seen that the investment in tooling for AXE primary piece parts is only one eighth of that for crossbar. Crossbar production demanded expensive precision tooling and associated machine tools for the primary production of relay and crossbar switch piece parts. This requirement is very much less in AXE but a large investment is required to equip a facility for the manufacture of high quality plated-through-hole printed circuit boards.

AXE investment in secondary production (i.e. assembly) is about 30% greater than crossbar but the equipment is automated.

Testing is a considerably more significant part of AXE production. The testing methods and equipment are more sophisticated, more extensive throughout the production process and more expensive. The investment in test equipment is three times that of crossbar.

It should be noted that in this comparison it is assumed that, for both AXE and crossbar, the electronic components such as integrated circuits, transistors and resistors are not produced 'in-house'. The investment in equipment and technology for production of these components at viable levels and competitive prices is itself very large.

CHARACTERISTICS OF AXE RELATED TO MANUFACTURE

The equipment practice which was developed for use in electronic systems of this type is called the BYB-system and is described in some detail in References 1 and 2. For manufacture, BYB consists of the following elements as shown in **Fig. 3**:

- standardised sections forming a mechanical framework for magazines and cable housing.
- the magazines, consisting of wired backplanes and printed board assemblies.
- the cables for inter-connection of magazines.

It should be noted that there is no equivalent to the 'manufactured rack' in this system. The magazines are the only part of the BYB system which have a functional design. The cables and mechanical framework are simply selected to suit the layout of magazines required to provide a complete AXE switching system.

Since the hardware sub-systems of AXE are often used in the same way in all applications, a standard association of magazines has been identified in many cases. These are called magazine groups and provide a higher level than the magazine for the exchange engineering activities, possibly flowing on to the ordering, supply, and installation processes at the same magazine group level. For production purposes, however, the magazines remain as a basic element.

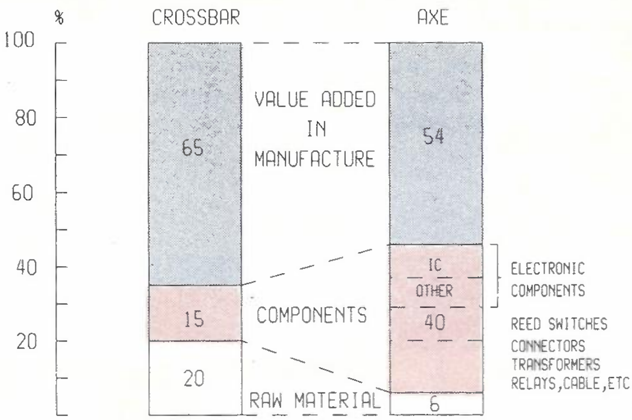


Fig. 1 — Structure of Manufacturing Costs.

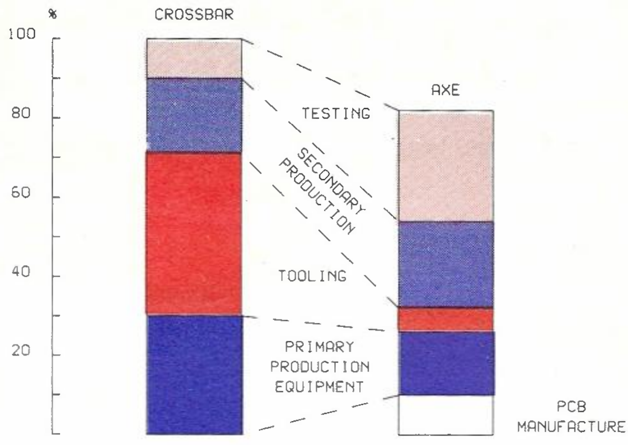


Fig. 2 — Relative Investment in Production Equipment

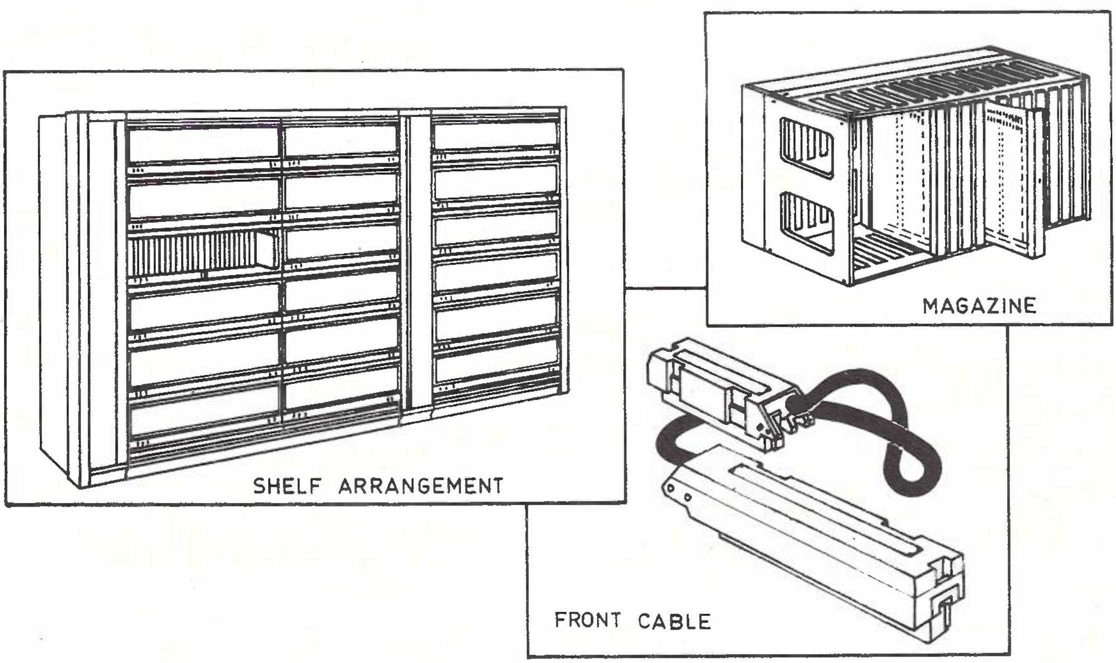


Fig. 3— Manufacturing elements of the BYB-system

AXE COMPONENTS

A general presentation of the manufacturing processes is shown in the flowsheet of **Fig. 4.**

The upper level of this diagram represents the primary production process to form mechanical piece parts and provide other basic materials. If we then consider the components generated from this primary production process together with the purchased electronic components, the breakdown of AXE for the component level contains the following major items:

- Passive electronic components: capacitors, resistors, transformers, thick-film devices.
- Discrete semi-conductor devices: diodes, transistors, light emitting diodes.
- Micro circuits: TTL 74 series for logic, Programmable Read Only Memories and Random Access Memories, and Custom Integrated Circuits for reed switch control.
- Miniature relays: RAV 12 series for printed board mounting and logic voltage operation.
- Printed boards (PBAs): single sided phenolic, double sided phenolic with C-links, single sided epoxy, and double sided epoxy with plated through holes.
- Reed relays: miniature 2-pole reed relay used as the cross-point in the analogue switch matrixes.
- Connectors: An IEC Standard 32-pin male connector is used in the wiring units of the magazine, with the female unit used for signal cables as 32, 16, 12, 8 or 4 pair cables.
- Wiring units and board frames: the mechanical elements which are provided in a range of standard sizes and with two standard PBA spacings to make up the required range of magazines.
- Cables: a range of signal cable sizes and power distribution cables for the 48V and logic voltage cables.
- Shelf sections, vertical irons and covers: the standard mechanical products which are delivered direct to site for the initial installation activity.

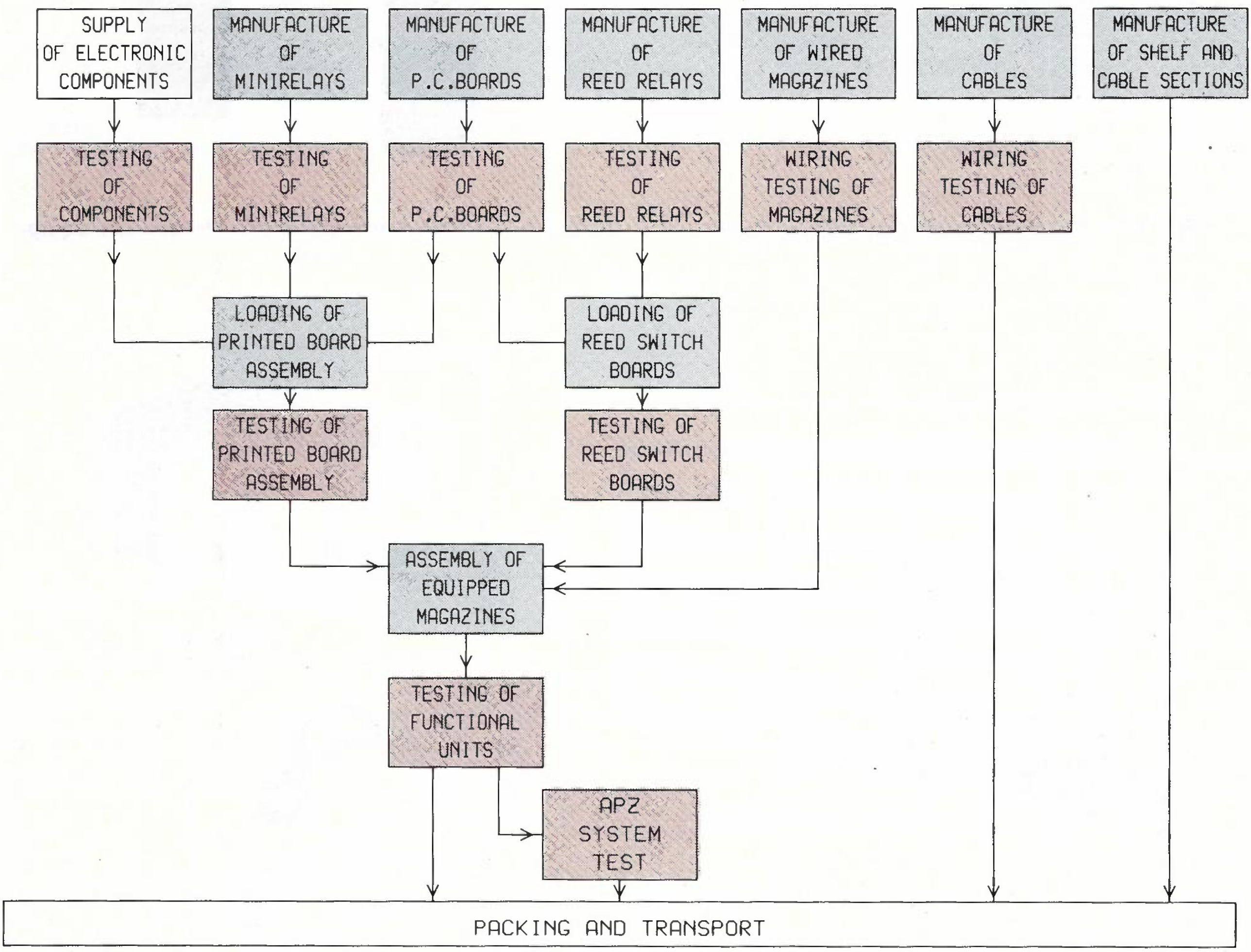


Fig. 4 — General Flowchart of AXE Manufacture

PRODUCTION TECHNOLOGY FOR AXE MANUFACTURE

Component Testing

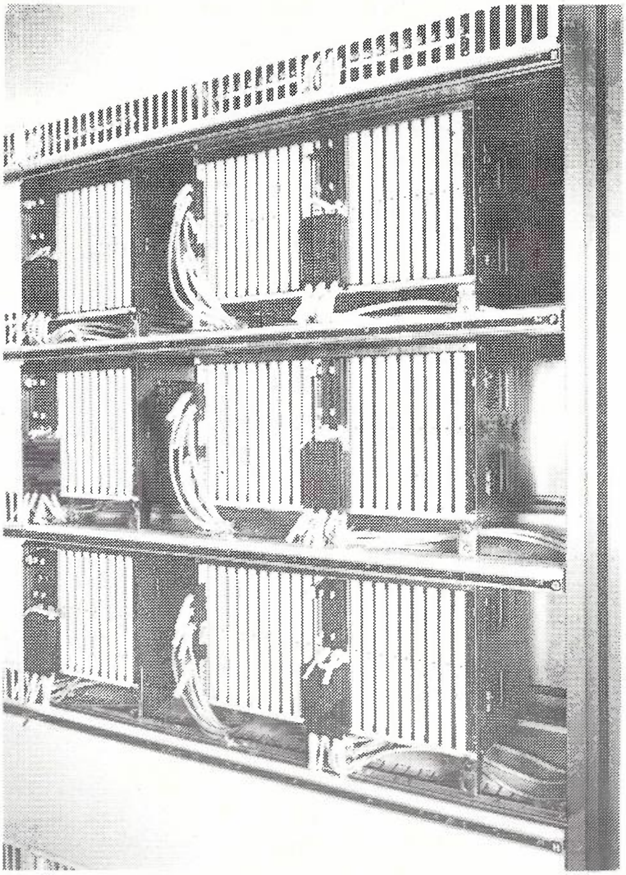
The second level of **Fig. 4** shows a range of component testing activities, indicating the extent to which testing is applied to these components before they enter the next phase of production.

The testing of electronic components, in particular the micro-circuits, represents a significant part of the test equipment investment shown in **Fig. 2.** A general description of these testing procedures is given in Ref 3. The objective with these tests is to ensure that the majority of those components which are faulty on arrival, or which through environment stressing become faulty, are discarded before they become part of an assembly.

A component which has a significant role in fulfilling the requirements of interfacing the AXE-system with its environment is the board-mounted miniature relay. These relays are tested at marginal voltage and current driving conditions, with a check being made of the contact output operation.

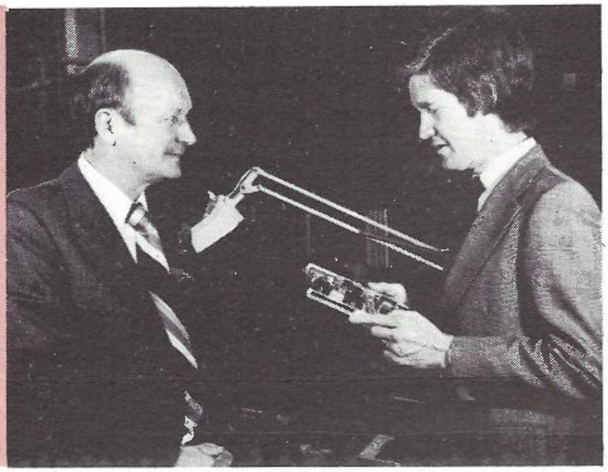
Perhaps the most important component of all is the printed board itself, as it incorporates a large part of the design and production criteria on which the quality of the AXE system is based. Accordingly, when treating the printed board as a component to be checked before any further use is made of it, the precision of the component from the electrical, mechanical, chemical, and production viewpoints must be verified.

The quality of the printed board is a function of every single layout and manufacturing operation. At this stage the checking is made on a sampling basis for a wide range of mechanical and electrical characteristics including size tolerances, solderability, thickness of plating in holes, quality of solder and insulation resist coatings.



Memory Magazines in AXE

JOHN BRANDON joined L M Ericsson in 1963 with experience in industry as a production and inventory control officer, and introduced production control methods in the manufacturing build-up of LME. From 1967 he was in charge of the Data Processing Department, and was subsequently appointed as Director of Manufacturing of L M Ericsson, a position he has held since December 1974.
Bryan McMahon is Systems Engineering Manager with L. M. Ericsson. See Vol. 28, No. 2, page 175.



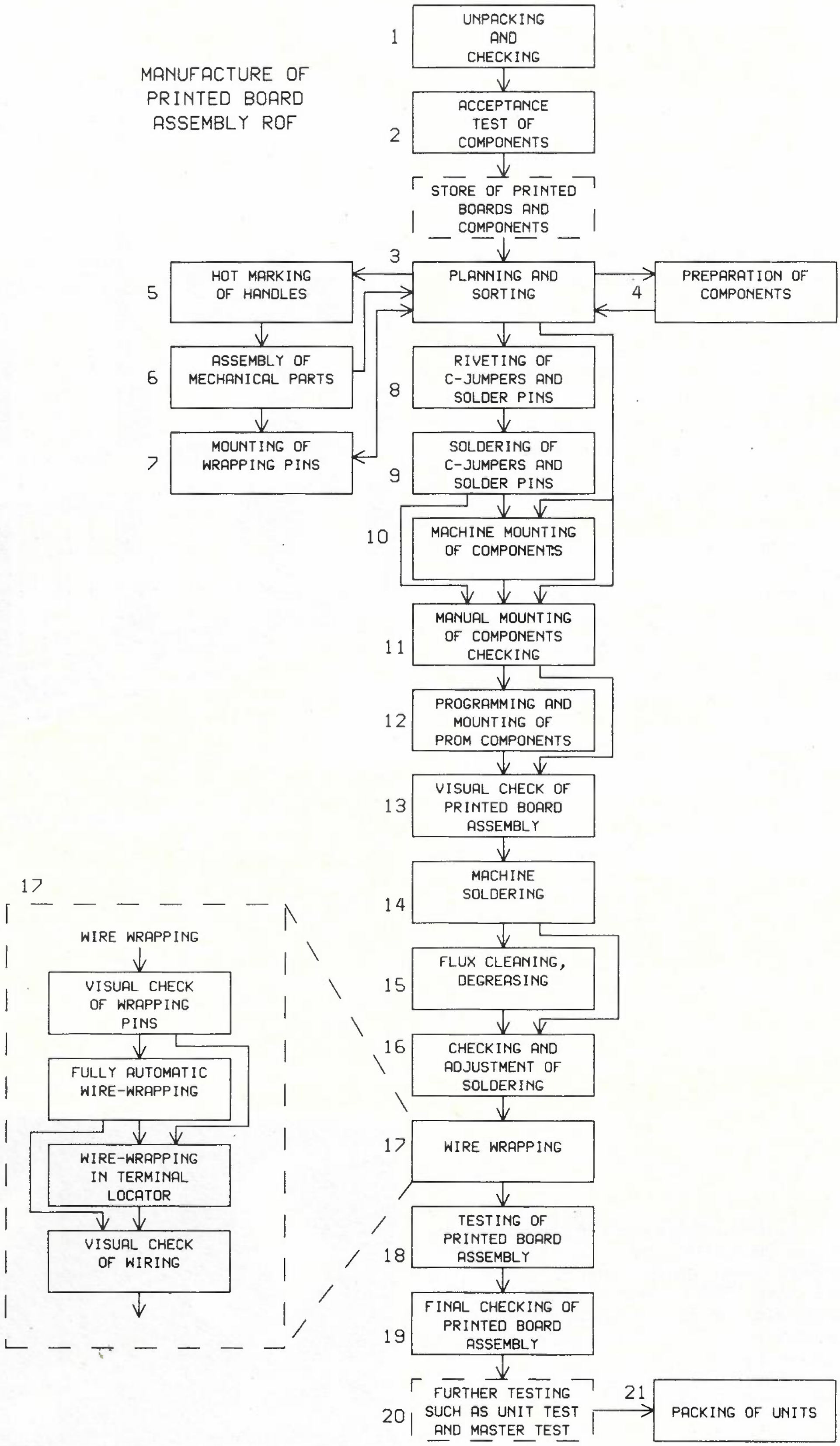


Fig. 5 — Manufacture of Printed Board Assembly ROF

Another component type shown in **Fig. 4** is the crosspoint reed relay. These are tested at various stages of manufacture, but the particular testing of the 2-pole reed relay as a component, and the switch boards are of main interest here. Details of the testing procedures and equipment used can be found in Ref 3.

Manufacture of the Printed Board Assembly

A large part of the manufacturing process, as summarised in the general flow chart of **Fig. 4,** and seen clearly from the photographs of typical AXE equipment, is concerned with the PBAs. In the AXE/BYB system these are designated ROF with the majority having the dimensions of approximately 220 x 180 mm.

If we expand the flow-chart to see the detail for PBA manufacture in **Fig. 5,** we obtain the general procedure for the different types of ROF-boards used in AXE. In this figure, the following items are of particular interest:

Item Description

5 Hot marking of handles. The handles are marked with the article number, revision state, etc, by stamping them with a hot steel die.

6 Assembly of mechanical parts. The board fronts, the connectors, stiffening bars, etc. are mounted on the printed board.

7 If the board is to be wire wrapped, the wrapping pins are inserted into the board with an automatic machine. The boards used have a general printed pattern with positions for dual in-line package (DIP)-holders for ICs and printed tracks for earth and voltage planes.

8,9 If needed, links between connectors, known as C-jumpers, and solder pins are riveted, and soldered manually immediately after the riveting operation.

10 The various axial lead components required in a particular PBA are sorted into the correct sequence in a sequencing machine (with typically 60-100 feed magazines), taped together then mounted on the board, cut and clinched in a Variable Centre Distance (VCD) insertion machine. The ICs are inserted in a multi-magazine dip insertion machine. The sequencing, VCD and DIP machines are all computer-controlled.

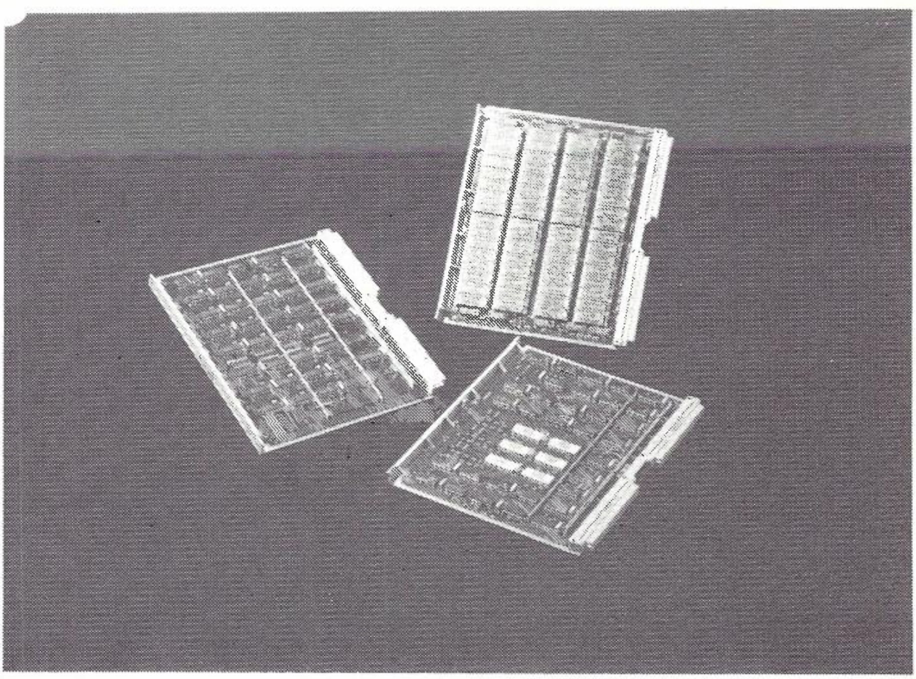
11 All components that are not machine-mounted are mounted manually or semi-automatically on to the printed board. The worker then checks that the mounting is correct and includes all indicated components.

12 Programming and mounting of PROM-components. Certain ICs are programmable and the programming is performed in PROM burn-in equipment. They are then manually mounted on to the printed board.

14 Machine soldering. Automatic operation with 3 stations: Flux bath, heating section and wave or drag soldering bath. Connected via rollers to the flux cleaning equipment. Special fixtures are used.

15 Flux removal and degreasing is performed on all PBAs except those with components sensitive to the cleaning fluid. The cleaning is performed automatically with brushing on the solder side of the board.

17 Wire wrapping. After a visual check of the pins, the board is wired in a fully automatic wrapping machine or in a terminal-locator (semi-automatic) machine. Both machines are punched tape controlled and certain manual wrapping operations may be used to complement the automatic wrapping. A visual check of the wires is made before the board goes to test.



Typical Printed Board Assemblies in AXE

Testing of Printed Board Assemblies

The major part of the printed board assembly articles of AXE are digital but they also contain some analogue functions such as timing circuits. In addition, there are a number of analogue printed board assembly articles containing circuits for speech transmission and telephony system interworking.

Most of the AXE articles are tested in the computer-controlled testing system LPA 101, in which the logical function is tested statistically. The logical data pattern has been made up by means of a simulation program.

For analogue printed board assemblies LPE 201 is used; this system has standardised instruments and is currently available in two models, one for testing of speech transmission circuits, the other for testing of power control boards. Testing is program-controlled and uses generators and measuring instruments controlled from a standard bus.

Printed board assemblies with dynamic memories are tested in two stages, static testing and dynamic testing. Static testing is carried out in LPA 101. Dynamic testing is currently carried out in a special memory test machine, but an accessory device, Dynamic Test Unit (DTU) will be introduced in LPA 101 in order to make the programming uniform.

To see the distribution of these test methods, Table 1 shows a breakdown of the types of PBA used in AXE with either an analogue or digital group selector. It should be noted that this table does not reflect the quantities of each article type required for an installation. Obviously, the reed switch, analogue, and hybrid articles will have a large quantity proportional to the size of the exchange, whereas the ROF 16 digital articles used in the CPU will be required in the same quantity for any size of installation.

Manufacture and Test of Unequipped Magazines

The wiring unit or backplane of an AXE magazine consists essentially of a metal pressing in which the connectors are accurately located at the correct spacing. The design allows for provision of an earth plane which is soldered to the earth pins before wire-wrapping commences.

The wire-wrapping can be performed in a fully automatic or semi-automatic wrapping machine. It is then tested to ensure that the continuity and leakage requirements are fulfilled. This testing is performed in a cable test robot controlled by a paper tape test program.

After this test, the rear cover of the wiring unit is put on, the parts for the board frame are screwed together, and the magazine assembly completed ready for equipping with PBAs.

Functional Unit Testing

The tested PBAs are now assembled into the tested magazines to make up the modules of the AXE hardware — the function units which the magazines represent.

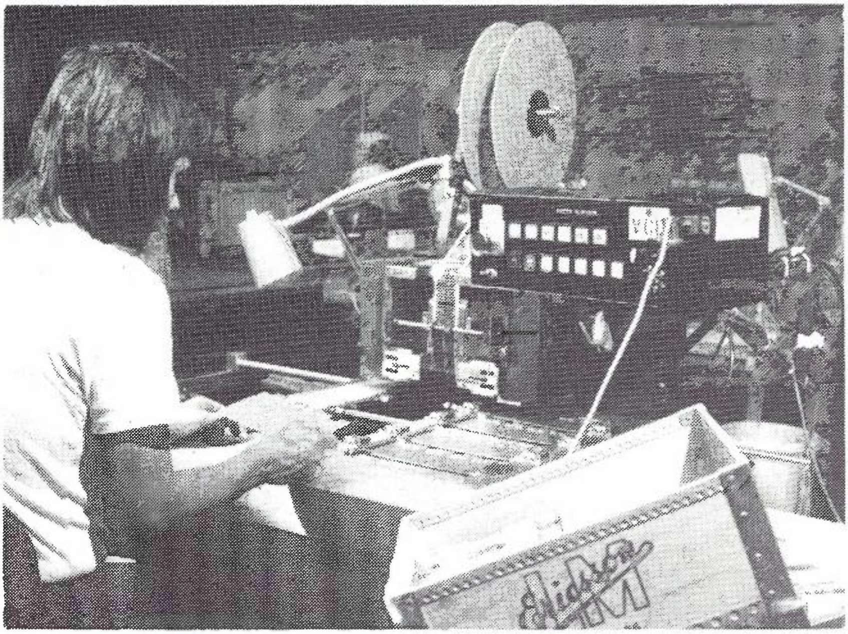
Most of the magazines belonging to the control system APZ of the AXE are tested by means of the special Automatic Verification System (AVS). This is a PDP-11 based test system with a specially developed test language which enables the operation to verify and diagnose the central and regional processors and associated magazines. The memory magazines are first run in an exerciser for a 4-day period and then tested at system level using AVS.

For most of the APT-system magazines, and for the alarm interface magazine of APZ, the functional unit testing is done on the LPA 101 tester equipped with a unit test position.

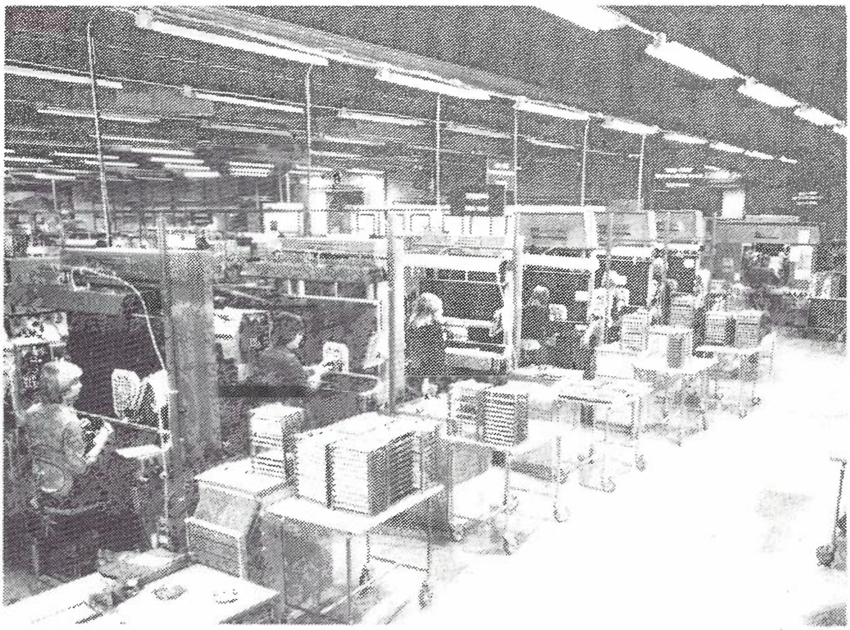
In all of this unit testing, the procedure is aimed at

AXE ARTICLE TYPE	PERCENTAGE OF ARTICLES OF THIS TYPE		TEST EQUIPMENT
	ANALOG GS	DIGITAL GS	
DIGITAL (ROF 13)	47.6	52.0	LPA 101
DIGITAL (ROF 16)	19.7	17.5	LPA 101
POWER	5.0	4.4	LPE 201
MEMORY	0.7	0.5	LPA 101
REED SWITCH	2.3	1.1	LTM 295800
HYBRID (DIGITAL/ANALOG)	5.0	6.2	LPA 101/BENCH
ANALOG	19.7	18.3	LPE 201/BENCH

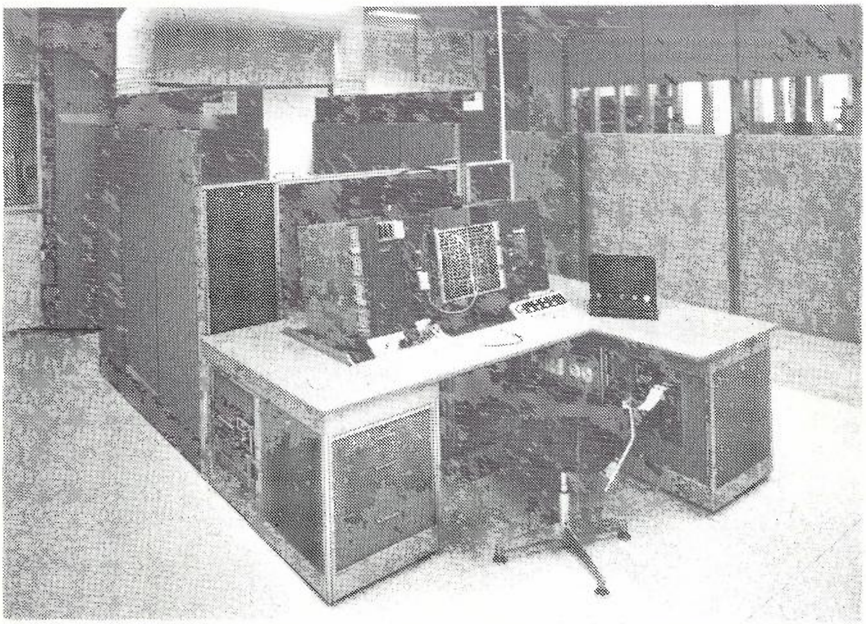
Table 1 — Survey of AXE Article Types and Test Equipment.



Automatic Component Inserting Machine



Wire-Wrap Equipment with Terminal Locator



LPA 101 for Printed Board Assemblies

replacement of faulty PBAs or determination and repair of a fault in the wiring unit. The end result is a fully functioning unit which can be transported to site; the PBAs which have been found faulty are returned to the printed board test/repair centre for analysis and correction of the fault or the program which allowed the faulty board to pass the previous test.

SYSTEM TESTING

Before delivery of the functional units of APZ, a subsystem testing of the magazine group for I/O functions, IOG, and the magazine group for the CPU, CPG, is performed. In this test phase a close simulation of the functional, electrical and climatic environment that will be encountered during real operation is pursued.

The test aims at eliminating those errors which become apparent only when the complete processor is put into operation.

The system interwork test is performed by means of test programs written in a micro-program language and in an assembler program language. These programs are all executed in the CPU. The micro-programs perform a hardware test while the assembler test programs are aimed at a more functional test. To obtain an easy program handling, the programs are stored on a minicomputer disc and loaded in the CPU by the minicomputer. An APZ-side is built up step by step by adding tested magazines. For each new magazine that enters the system, a number of specific test programs are executed.

When the two processor sides are able to work separately, the test of the interwork between the sides takes place. This test is also performed by micro and assembler test programs in the CPU.

As the last phase in the interwork test the now tested hardware is verified against the operating and maintenance systems. When performing this test, the facilities in the maintenance system are used (system restart, fault handling and detection, etc).

The final phase of this system testing is then a burn-in test which can take a number of weeks, and is used to ensure that early hardware failures are taken out of the equipment before delivery to installation.

As a result of this activity, the original set of equipped magazines and cables and the correct function as a working processor have been assured by a comprehensive sequence of functional tests.

AXE MANUFACTURE IN AUSTRALIA

At present, the Broadmeadows plant of L M Ericsson is manufacturing a range of electronic equipment including the ARE-11 system, Ref 5, the ASDP 162 automatic call distribution system, signalling control equipment for both road and railway signals, and other devices for power, transmission, and switching equipment.

From this variety of current production, there is a considerable part of the AXE component range which is already part of the production environment. In particular, the passive, discrete, and integrated circuit range of electronic components in AXE are to a large extent used in the other systems. The Automatic Call Distribution System (ASDP162) uses the BYB-mechanics so that production methods in this type of equipment are already being introduced to the factory.

The most significant new components which are introduced to production for AXE are the reed relays, the custom ICs used in the reed switches, and a number of ICs and passive components not used in the other systems.

Of utmost significance, however, is the major increase in quantity required for production of the BYB-magazines, the ROF printed boards, the cables and connectors required to support the planned introduction of AXE into the Australian network. It is for this increased volume of production that investment in equipment for inspection, assembly, wiring, and testing has now started, to cope with the future manufacturing requirements of AXE.

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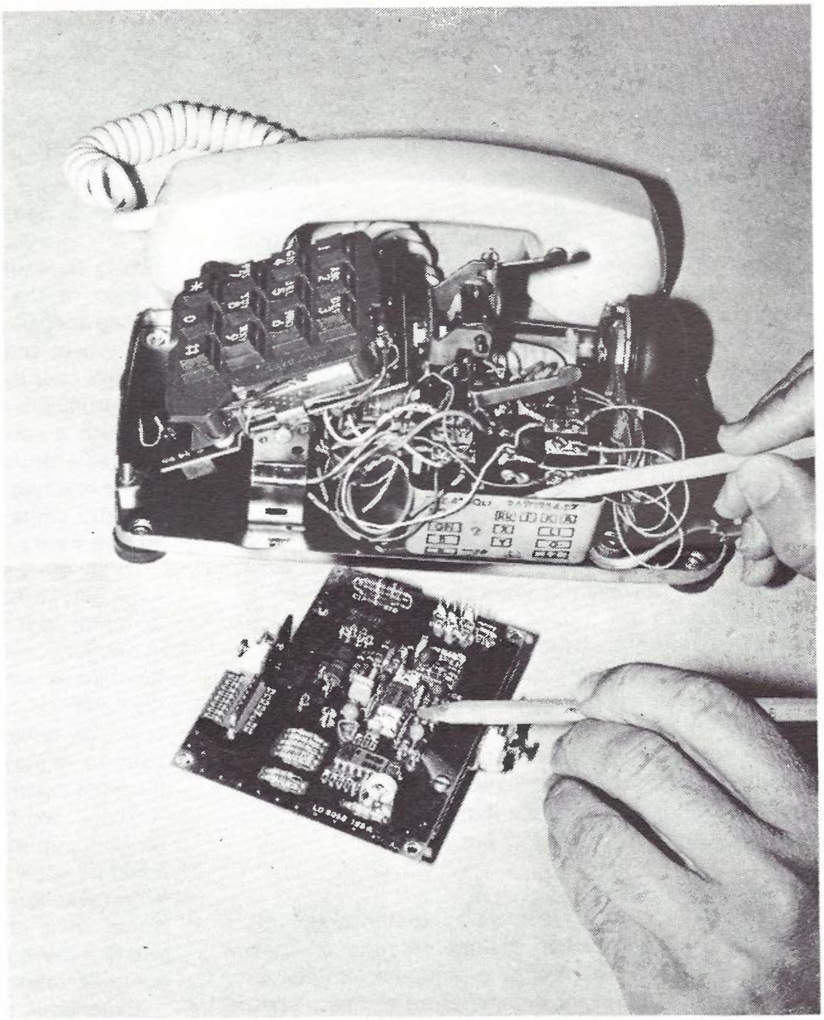
In Brief

Electronic Push Button Telephone.

Components of a traditional Bell Canada push-button telephone dwarf the dial and network assembly of one of the company's new electronic "E" phones, soon to be field tested in Ontario. Reduction in size of the new phone system is made possible partly by the use of miniaturized electronic circuits printed on silicon chips. For example, the network component alone of the conventional telephone beneath the above pencil point, has been replaced by the tiny chip below, hardly bigger than a finger nail. In future, addition of memory chips of similar size will make possible special features such as automatic dialing of pre-stored numbers at the touch of a button. Miniaturization will also permit more imaginative design of telephone housings in future.



Recent Developments in Cable Ploughing Techniques

TERENCE S CODY B Tech., Grad. I.E. Aust.

In the planning stages and during the first twelve months of the coaxial cable project linking Cobar in New South Wales to Ceduna in South Australia, considerable design and practical effort was directed towards developing a reliable ploughing tractor capable of laying hundreds of kilometres of coaxial cable virtually fault free and at minimal cost.

Some of the factors investigated included a reliable cable drum drive, a low co-efficient of friction plough box, a reliable ploughing tyne and a communications system on and to the ploughing tractor.

INTRODUCTION

When ploughing coaxial cables to a depth of 1.2 metres using a Caterpillar D9 or equivalent tractor, a number of factors must be considered if the cable is to be installed fault free over hundreds of kilometres of country with ploughing conditions varying from sand to rock. These factors are:

- Tension in the cable as it is unwound from the drum;
- Co-efficient of friction between the cable sheath and the sliding surfaces on the chute over the canopy and in the plough box;
- Ability to influence the cable ploughing operation from the plough position;
- A satisfactory ploughing tyne;
- Ability for key personnel to communicate immediately and freely during the course of the ploughing operation.

In the planning stage of the Ceduna to Cobar coaxial cable project, these factors were considered in depth and the solutions initially applied have been further developed during the progress of the project.

The end result of these developments is an increase in productivity from the ploughing operation by reducing the men on the tractor required for ploughing the cable from four to two and in addition, there is a productivity gain due to the very low fault incidence during ploughing; that is, repair work is reduced to a minimum. A profile of the ploughing tractor is shown in **Fig. 1.**

CABLE DRUM DRIVE

During 1974, two projects were initiated to provide a reliable drum drive system for the rotation of coaxial cable drums when mounted on a ploughing tractor. One design (South Australian) depended on rotating a drum using the spindle on which the drum was mounted, while a Headquarter's design relied on rotating the drum using a small wheel in contact with its flange.

Following a number of trials, the Headquarter's system was adopted, a particular point favouring that system being that the initial design incorporated fully automatic features, whereas the South Australian system required manual control. The in-service version of the drum drive installation is shown in **Fig. 2.**

Initial Concept

The initial concept of the Headquarter's design comprised two solid rubber tyred wheels, one to drive each flange of the drum. The wheels were mounted on a spring loaded stand to ensure positive contact between the wheel and the flange. A hydraulic valve with linear control over its working range controlled the operation of the drum drive. To operate the valve, the cable passed through a counter-weighted enclosed chute (very much akin to a throat) mounted on the tractor cabin, with the chute reacting to the slack in the cable between the drum and the chute and thereby operating the valve.

Refinements

With the position of the drum drive wheels fixed, it was only possible to drive cable drums of specified diameter, and with cable drums varying up to 0.6 metre in diameter, this was not a very practicable arrangement. In addition, with two wheels driving the drum, their spacing had to be changed for different drum widths. If drums could be driven with one wheel, the drive wheel could then be mounted so as to cover the full range of drum diameters without regard to drum widths.

Tests on the drum drive indicated that a drum weighing up to seven tonnes and 2.4 metres in diameter could be spun easily by a single wheel. Accordingly, one wheel was removed and the hydraulic motor and driving wheel were mounted on a portable hand pump (commonly referred to as a 'Porta Power' unit) and ram operated telescopic assembly.

Experience showed that the spindle holes of wooden drums were not always at the exact drum centre. Some type of shock absorber was required in the mounting system to handle the slight eccentricity of the wooden drums as the 'Porta Power' combination had no built in elasticity. This was provided by replacing the solid rubber tyre with a pneumatic tyre.

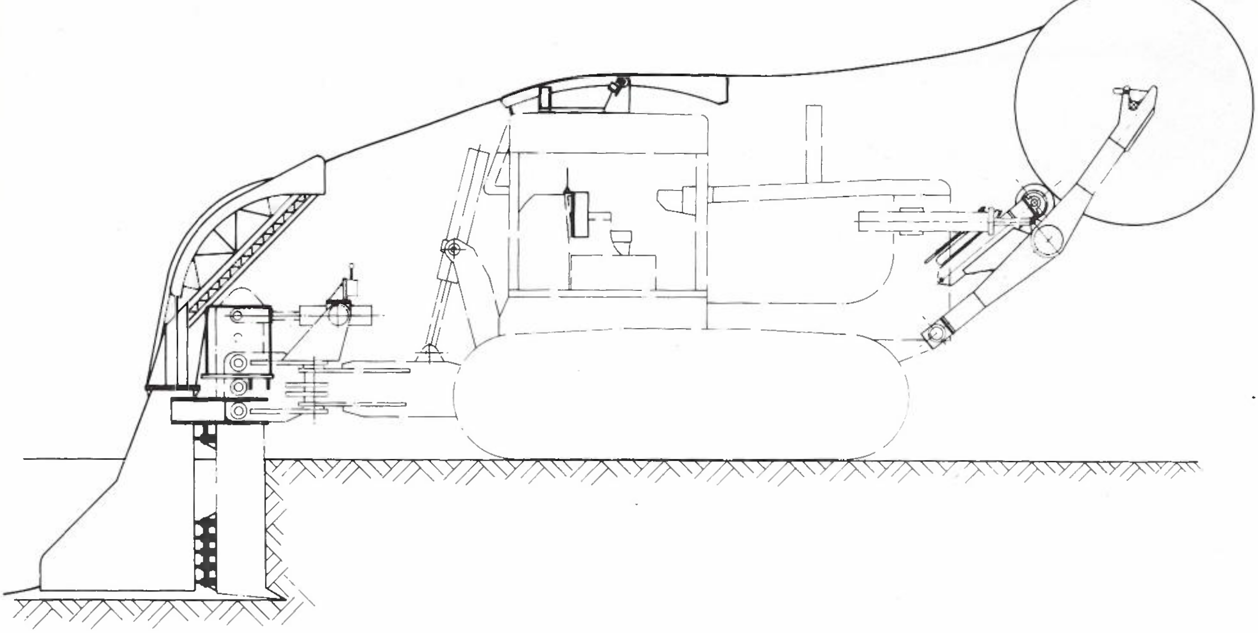


Fig. 1 — Profile of Ploughing Tractor

The operation of the counter-weighted chute on top of the tractor added some small increase in tension to the cable. This was considered undesirable due to a multiplication of this tension through the plough box. (The reason for this will be covered under 'Operation'). To overcome this drawback, the design was altered to a pivoted chute mounted on the cabin of the tractor. The operation of the chute is now dependent only on the amount of slack in the cable between the drum and the chute with the angle of the chute responding to the slack and thus operating the control valve.

Two manually operated valves are used to control the drive system. One, a hand operated valve has three positions for 'unwind — off — reverse' control, while the other is a rotary valve (by pass) speed control for the driving motor. The hydraulic circuit is completely independent of the tractor hydraulics having its own pump and hydraulic storage tank. The hydraulic circuit is shown in **Fig. 3.** In the 'unwind' mode of operation, the control valve on the pivoted chute is included in the hydraulic circuit. In the 'reverse' condition this valve is made inoperative.

Operation

When beginning to plough, the drum drive control lever is operated to the 'unwind' position and the speed control is adjusted until the drum just begins to turn. At this point, the pivoted chute operates, switching off the drum drive once the slack in the cable reaches a predetermined limit. As the tractor moves forward, the slack is taken up and the resulting movement of the chute causes the drum drive to operate. This hunting continues for a few minutes until the ploughing operation settles down.

TERENCE CODY joined the APO in 1960 as a Technician-in-Training. In 1968 he became a Trainee Engineer and graduated from the University of Adelaide with a Bachelor of Technology degree in electronic engineering in 1971. His first appointment as an Engineer Class 1 was in Building Engineering Services where he spent two years. In 1973 he transferred to the Primary Works Section as project engineer for the Ceduna to Cobar coaxial cable project.

In 1977 he was appointed Class 2 Engineer and since late 1977 has been acting Senior Engineer Primary Works (Country).

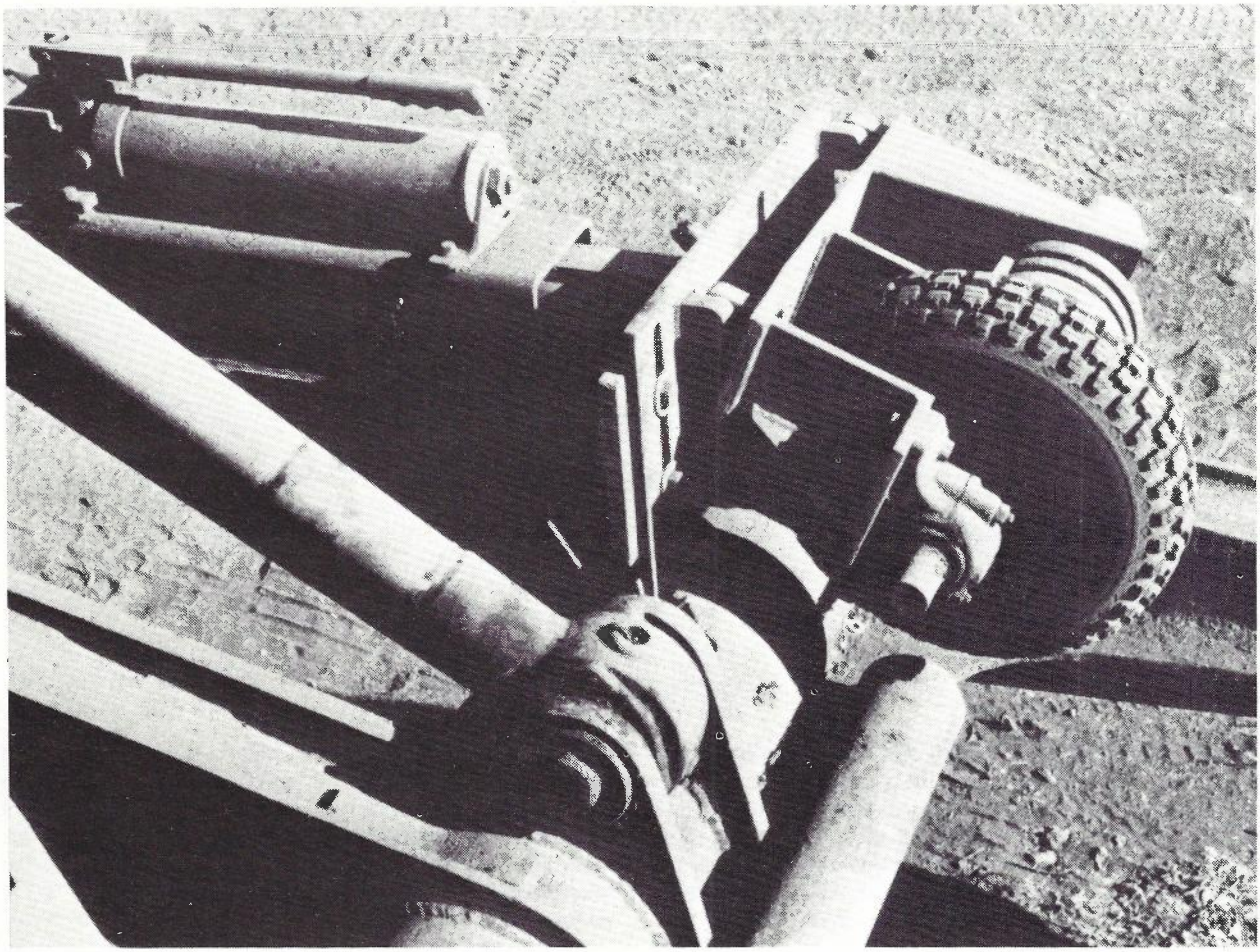


Fig. 2 — Drum Drive Wheel

Due to the construction and the action of the pivoted chute on the control valve, its operation is generally not linear, but rather imparts a 'chopper' action to the drum drive. However, once the ploughing operation has settled down, the speed control can be adjusted to a position where critical damping of the drum drive system occurs; that is, once the tractor has started ploughing, the drum would easily turn and when the tractor stops, the drum would cease revolving: This gives a smooth ploughing action and removes the under damped drive action to the motor due to the operation of the chute.

This method also provides some automatic compensation to the drum drive, for as each layer unwinds the rotational speed of the drum must increase for a given ploughing speed. With less cable on the drum less torque is required to turn the drum and the speed control requires less adjustment.

Overall, the drive with minor modification has worked especially well. Only one fault has occurred to the drum drive systems installed on the tractor in ploughing some 800 km of cable. This was damage to a drive motor because of a faulty seal. The use of the drum drive in its under-driven mode has tended to diminish the impact of a faulty control valve on the overall operation.

LOW FRICTION PLOUGH BOXES

On previous coaxial cable projects, the cables were subjected to very high tensions during ploughing to the extent that if a cable had to be cut for a fault, the cable ends would be drawn apart by up to 0.1 metre over a period of some 12 hours as the tension in the cable 'relaxed'. Small amounts of slack were required either side of a joint to prevent the joint being pulled apart as the cable eased its tension after jointing was completed.

During early trials of the cable drum drive, very high tensions (in excess of 9 KN) at the beginning of a plough were measured. Following these trials, a further project was initiated by Headquarters to design a low co-efficient of friction plough box and control chute.

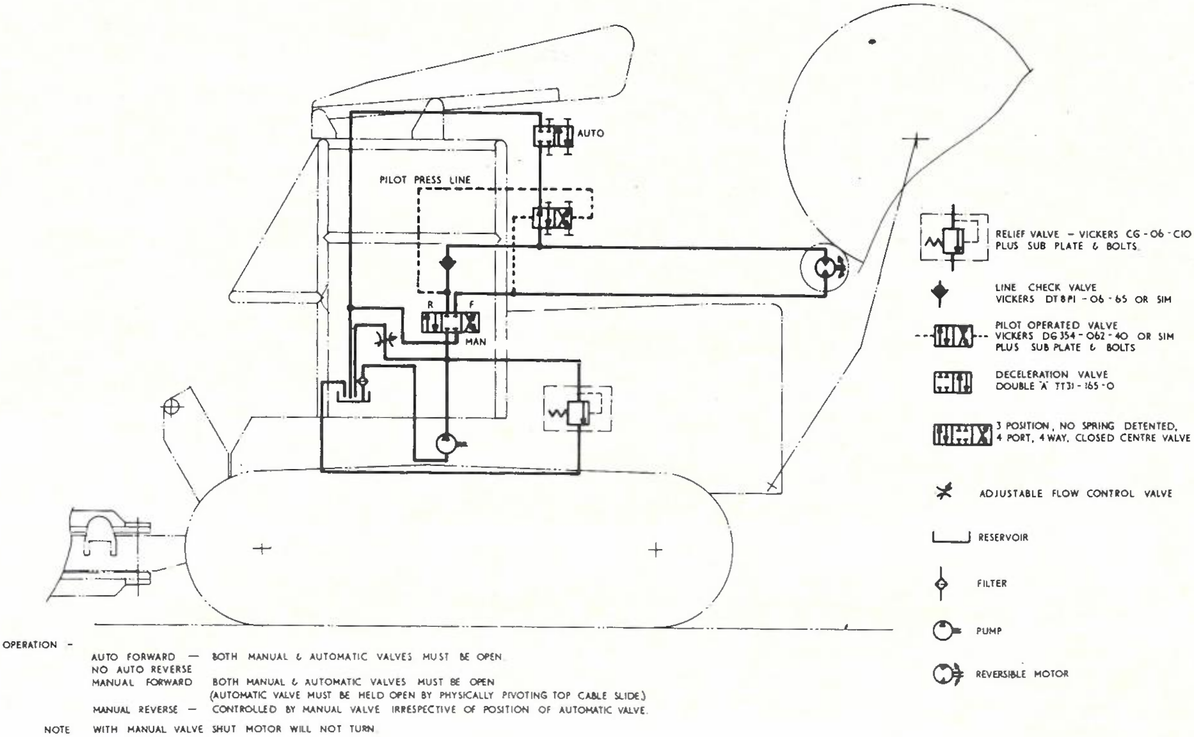


Fig. 3 — Drum Drive Hydraulic Circuit

In considering the design of the plough box the expression

$$\frac{T2}{T1} = e^{\mu\theta} \text{ ———————— } (1)$$

is relevant

T2 is the tension in the cable as it exits from the plough box;
T1 is the tension in the cable as it enters the plough box;
μ is the co-efficient of friction between the cable sheath and sliding surfaces;
θ is the angle in radians through which the cable bends.

The angle θ is fixed at π radians as the cable has to bend through this angle and this cannot be changed. T1 has been reduced to a minimum by the introduction of the drum drive and by the change in the design of the cable slack sensing system on the tractor cabin. The only factor controlling T2 is the co-efficient of friction within the plough box itself.

Initial Concept

The original investigation concentrated on finding a combination of materials that, when rubbed over one another, achieved a low co-efficient of friction enabling the cable to flow easily through the plough box. After a number of tests, a combination of a conveyor belt and a plastic material was found to provide a co-efficient of friction of 0.22.

Using these materials, a complete plough box and control chute were built and the overall system tested. The plough box had three quarters of the sliding surface replaced by a conveyor belt, while the other parts of the system had their total sliding surface replaced by conveyor belts as illustrated in **Fig. 4**.

After the completion of ploughing three kilometres of 4-tube coaxial cable, the plastic material was found to have worn very badly and to an extent that required replacement. Also, the pulleys over which the conveyor belts moved tended to jam because of the high level of dust. The system, as built, required considerable maintenance, and this was unacceptable for the type of country through which the plough was required to operate. However, the overall combination of the drum drive and low co-efficient of friction plough box reduced the tension in the cable from 9 KN to 0.67 KN at the start of a plough; a considerable improvement.

Refinements

Following this trial, the South Australian administration of Telecom Australia took over the development of the plough box design. A curve of 0.3 metre radius at the top of the plough box was one of the contributing factors causing the high tension in the cable in the plough box used in the first trials of the drum drive. Coaxial cable is not designed to be bent through such a small radius and in doing so this increased tension T1 in (1), causing a very high T2. Consequently all bend radii are in excess of 1.2 metres in the new design.

To remove the maintenance-prone aspects of the plough box, a sliding surface of comparable co-efficient of friction with a nylon cable was required. A stainless

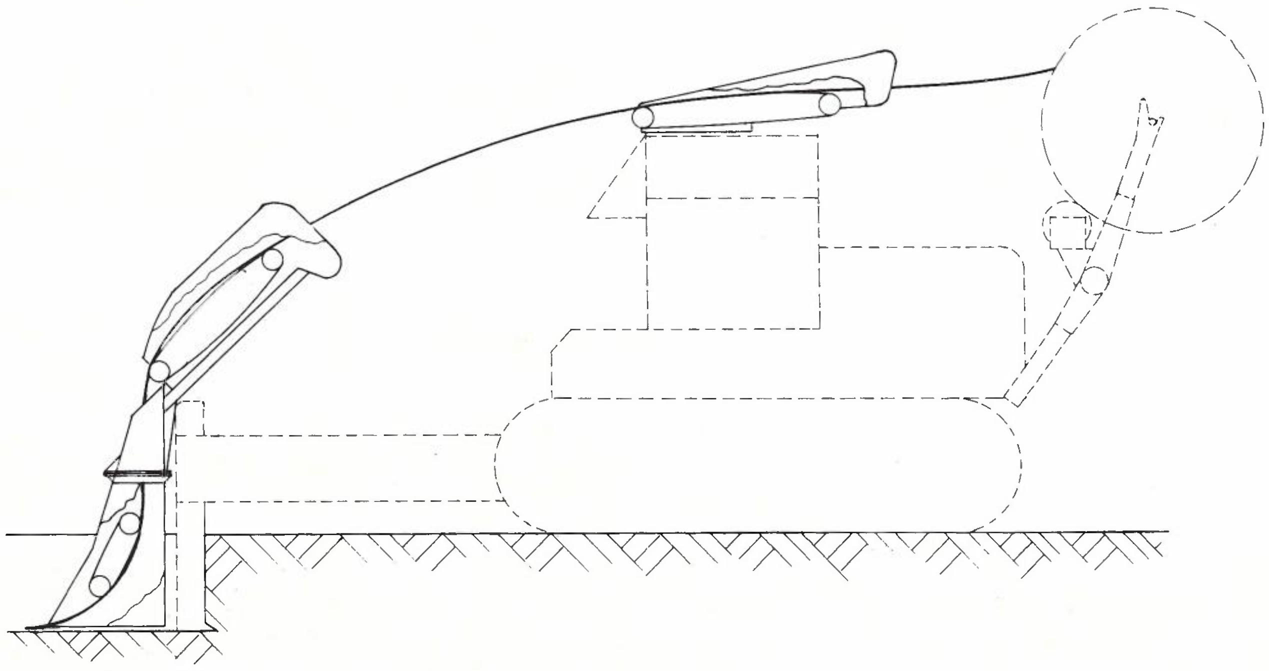


Fig. 4 — Original Concept of the Plough Boxes with Conveyor Belts

steel slide was found to meet this criterion and stainless steel was then used for the plough boxes and the cabin mounted control chute. However, after ploughing 300 km of cable, the stainless steel slides were found to be badly worn, and to overcome this wear problem subsequent boxes had mild steel slides fitted with replaceable stainless steel linings. Once the stainless steel lining has worn sufficiently it is easily replaced without major work required on the plough box.

Operation

The low co-efficient of friction plough box has performed very well, and during the ploughing of 800 km of cable, no faults due to the stretching of the cable have occurred. The tension in the cable has been reduced to such an extent that one man can easily hold the end of the cable at the start of a plough. In previous projects, Back-Hoes or Landrovers had to be used to hold cable ends.

PLOUGH BOX CONTROL

Two double offset ploughs with tilt ram facilities were initially supplied by the Kelly Company for use on the project with a four position hydraulic valve bank being required to control all the functions of the plough. These control functions were:

- Depth of plough;
- Plough box tilt;
- Steering rams (two controls).

The hydraulic valve bank was fitted to a swivel stand mounted on the tilt ram enabling the valve to be operated from either side of the plough.

Function Control

Early in the project, it was realised that steering by using both sets of rams was very difficult. It was found much better to allow one set to 'free wheel' and to steer with the second set. The set of rams nearer to the tractor was, therefore, disconnected from the valve bank and connected instead to a gate valve. This served the purpose of locking this set of rams before the plough was lifted out of the ground preventing it swinging out to one side; but when open, allowing the plough to 'free-wheel' in the ground.

The depth control enabled the plough operator to maintain the cable at the correct depth removing this responsibility from the tractor operator although he does have an over-riding control if required.

The tilt ram control enables the plough box to be maintained in a vertical position relative to the ground no matter at what angle the tractor is working. This has the advantage of maintaining the cable at a nearly constant depth as the tractor moves over very rough ground and through creek beds by preventing the back of the plough from kicking up if the tractor tilts forward.

With the ploughing tyne pivoted only one quarter of the distance from the top of the tyne and the tilt ram connected to the top of the tyne, very high pressures were developed in the ram during ploughing. The only item maintaining the plough box in a vertical position was the flexible hose connection to the tilt ram. On three occasions, due to these very high pressures, the flexible hose pulled out of the coupling and the plough box tilted forward. Only one cable fault occurred on the three occasions the hose pulled out. However, with the box tilting forward, a danger existed of injury to the hands of the plough operator. To prevent this happening again, a pilot operated stop valve has been installed with a rigid coupling between the ram and the valve. This valve is designed to shut off the hydraulic oil if the flexible hose breaks, thus preventing the plough box from tilting forward.

The only faults that have occurred on the ploughing rig have been on the four way hydraulic valve where a number of 'O' rings have given way. Upon investigation it was found that the tie bolts holding the valve bank together had stretched under the hydraulic pressures involved. This fault condition was removed once these were replaced with high tensile bolts.

PLOUGHING TYNE

The ploughing tynes supplied with each cable ploughing rig were a straight shank mild steel tyne with a small toe for fitting a shoe to assist in the passage of the plough. The leading face of the tyne was triangular in shape with no shin guard fitted.

It was found that heavy abrasion above the toe occurred to the tyne, requiring it to be continually built up with hard facing. In addition, the toe of the tyne eventually broke off. As these tynes appeared to require a high level of maintenance, the consideration of possible modifications was attractive.

An old ripping tyne had been supplied with one of the tractors on the project, and as it had been welded a number of times, was unsuitable for ripping purposes. Examination of this tyne indicated that it was of the same overall shape as a ploughing tyne and, therefore possibly suitable for conversion to a ploughing tyne. This adaption was effected and the tyne was fitted to the tractor in time for the ploughing of 34 km of cable through almost continuously rocky ground. The tyne has since been used to plough an additional 500 km of cable without further maintenance requirements.

To overcome the problem of the breaking toes on the mild steel tynes, a modification consisting of a large backhoe bucket socket and tooth was fitted to the tynes. The modification then places the weakest portion of the tyne onto an easily replaceable part, where as previously, when broken, it required re-welding of the tyne. The modification is illustrated in **Fig. 5.** Due to the reliability of the ripping tyne conversion, this modified tyne has not been fully tested operationally.

Advantages

There are a number of advantages in the use of the ripping tyne. They are:-

- The steel of a tyne is very much higher in its wear resistance properties;
- The steel is much tougher with a reduced likelihood of breaking off the toe;
- The tyne can be fitted with a standard ripping shoe more resistant to wear in rock;
- A replaceable shin guard is fitted to the tyne in the position where maximum wear occurred on the original two mild steel ploughing tynes.

COMMUNICATION

Communications on the ploughing tractor are vitally important if misunderstandings resulting in faults to the cable are to be avoided. The communications required were investigated in depth, with the main issue being the obtaining of a microphone capable of rejecting very high ambient noise while accepting normal voice levels. This problem was overcome by using an American Roamwell carbon transmitter. Communications were required between three points on the tractor and to a supervisor on the ground. **Fig. 6** outlines the overall communications circuit.

The operator headsets consist of a standard set of ear protectors fitted with telephone receivers and a boom holding the microphone. The link to the ground uses a vehicle VHF mobile radio mounted in a vibration resistant case on the tractor and a 'Walkie Talkie' held by the controlling supervisor. This radio is fitted with a high noise rejection dynamic microphone.

On the tractor, both stations can hear transmissions from the ground and each is supplied with a 'press-to-talk' facility for the radio link.

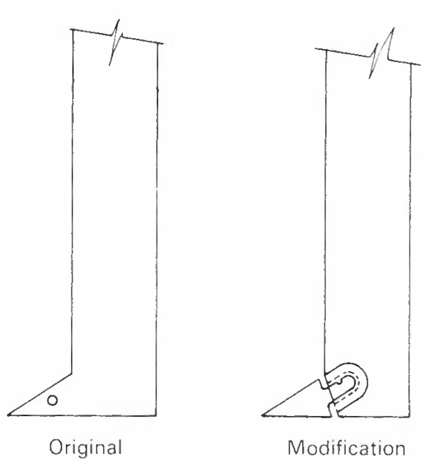


Fig. 5 — Mild Steel Ploughing Tyne Modification

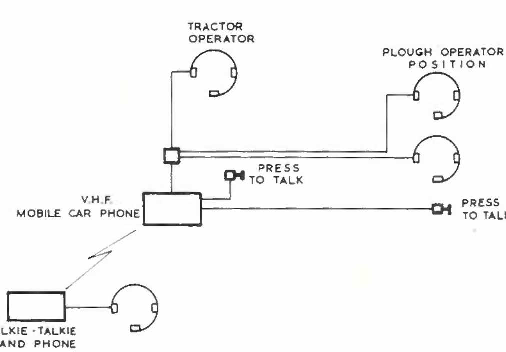


Fig. 6 — Ploughing Tractor Communications Circuit

The communication system on the tractor has been almost faultfree apart from an odd broken wire on the headsets. Due to the harsh dust environment, the carbon transmitters have a life of approximately three months. Their ambient noise rejection characteristic is quite satisfactory but it reduces as the transmitters age.

CONCLUSION

Prior to the start of the Ceduna to Cobar coaxial cable project, many hundreds of kilometres of cable had been ploughed without the use of a cable drum drive and using mild steel sliding surfaces in the plough box.

It can be asked, why should the tension in the cable be reduced during ploughing when coaxial cables during hauling into ducts can be subject to tension up to 9 KN? The answer lies in a heightened awareness of the need for productivity improvement. In the first 800 km of cable ploughing, only eight ploughing faults have occurred in the cable. Only one was attributed to the plough box. This is considered a substantial improvement on past projects.

In excavating for two other faults, the cable was predictably found to be under no tension, thus enabling jointers to effect immediate repairs.

The low fault incidence justifies the expense involved in the development of the drum drive and low friction plough box. In addition a ploughing tractor can now be operated by two men instead of four.

During the early stages of the project, all coaxial tubes of each drum of cable ploughed were routinely checked by high voltage ionisation. As a result of the low incidence of faults, the testing of cables in normal ploughing is now usually restricted to one 'sample' length a day. An illustration of the value of the overall system was the ploughing of 40 lengths of cable over some of the roughest country experienced in the first 400 km of the project without one ploughing fault occurring.

ACKNOWLEDGEMENT

The original design work of the drum drive and low coefficient of friction plough boxes was undertaken by Mr Alwyn H. Cheney M.I.E. (Aust), a Commission engineer now retired. It is on the basis of his original work that such a successful coaxial cable ploughing system is now in operation.

In Brief

RADIOCOMMUNICATION LINKS VITAL IN VAST NEW RAILWAY LINE

The Australian National Railways are currently building a 831 Km standard gauge railway line from Tarcoola in South Australia to Alice Springs in the Northern Territory. It is the largest rail project in Australia since the inauguration of the East-West Trans-continental Railway in 1912. The project estimated to cost $100M began 3 years ago and is expected to open in 2 years time. It will supersede the existing Port Pirie-Alice Springs narrow gauge line which is often closed because of flooding from the Lake Eyre basin. The new line will follow a much more elevated route to the west out of the way of floods but crossing trackless wastes of uninhabited deserts.

Communication along the route will be provided by a 1.8 GHz 300 channel line of sight radio relay system for the fixed communication and a VHF system between trains, railway service vehicles and the control centre in Tarcoola. All the 28 radio relay stations will be unattended and most will employ a solar power system.

NEC are supplying the radio relay equipment, AWA the VHF system and Andrew Antennas the guyed masts and the all metal naturally cooled shelters.

The radio relay system will provide railway circuits between Tarcoola and Alice Springs in addition to wayside circuits for railway stations and the VHF train system. The VHF system will provide constant communication between the trains (drivers and guards), railway service vehicles and the control station in Tarcoola. It will control the train movements, traffic arrangements, (passengers and goods) and maintenance goods. The VHF equipment will comprise 3 duplicated systems to ensure a high availability.

SWEDISH TELECOMMUNICATIONS ADMINISTRATION ORDERS AUSTRALIAN BOOKING SYSTEM

The Swedish telecommunications administration has placed an order with L M Ericsson for the delivery and installation of a number of fully electronic booking and information systems. The order value exceeds $6 million.

The system can be used for booking of tickets, advertisments and similar services and has been developed by L M Ericsson Pty. Ltd. in Australia. It has previously been installed in Australia and will shortly be introduced in Hong Kong and Saudi Arabia. Most of the equipment covered by the Swedish order will be manufactured in Australia.

There exists a considerable interest in many parts of the world for this new system to be used at betting offices, travel agencies, air line reservation offices, insurance companies and for alarm and maintenance centres of various kinds.

The equipment now ordered by the Swedish administration will be installed in Stockholm, Gothenburg and Malmoe within the administration's own service organization for sales, operation and maintenance. Deliveries will start in the Spring of 1979.

The "Touchfone 10" Push Button Telephone

G. J. ALDERSON B.Sc. (Eng.)

A locally manufactured pushbutton telephone, Touchfone 10, has now been released by Telecom Australia. Sophisticated semiconductor technology has been employed to realise the user-advantages of pushbutton dialling and to comply with the exacting requirements of the Australian telephone network.

This paper gives the background of the Touchfone 10 development, and describes the operation of the pushbutton dial. A summary of the product proving and testing programmes of both the development and volume production phases is also presented.

INTRODUCTION

Australia's first pushbutton telephone, a batteryless, decadic outpulsing instrument called Touchfone 10, has now been released by Telecom Australia. This telephone, developed specifically for the Australian network by Standard Telephones and Cables Pty. Limited (STC), represents a significant achievement in applying sophisticated semiconductor technology to the more traditional requirements of the telephone unit.

Touchfone 10 incorporates a special, low power, Metal Oxide Semiconductor integrated circuit (PMOS) which together with the interface and drive circuitry provides short term close access storage for the telephone number keyed in by the user. The integrated circuit then processes this information and automatically dials the number of the called party.

In summary, Touchfone 10 performs all the functions of a standard rotary dial 802 telephone whilst offering to the user the advantages of pushbutton dialling.

The most important of these advantages is that Touchfone 10 allows the user to perform the dialling operation at his own tempo. The user is then free to perform other duties, for example preparing for the call, whilst the telephone outpulses the number of the called party to the network.

A general view of the telephone is shown in **Fig. 1**.

This article describes the key requirements of the Australian network that were taken into account in the design of the dial circuit and how these requirements were fulfilled. The Keyblock selected for Touchfone 10 is described together with the physical construction and arrangement of the complete telephone. The article then briefly covers the qualification testing performed on the final design and the methods used for volume production at STC's factory in Sydney.

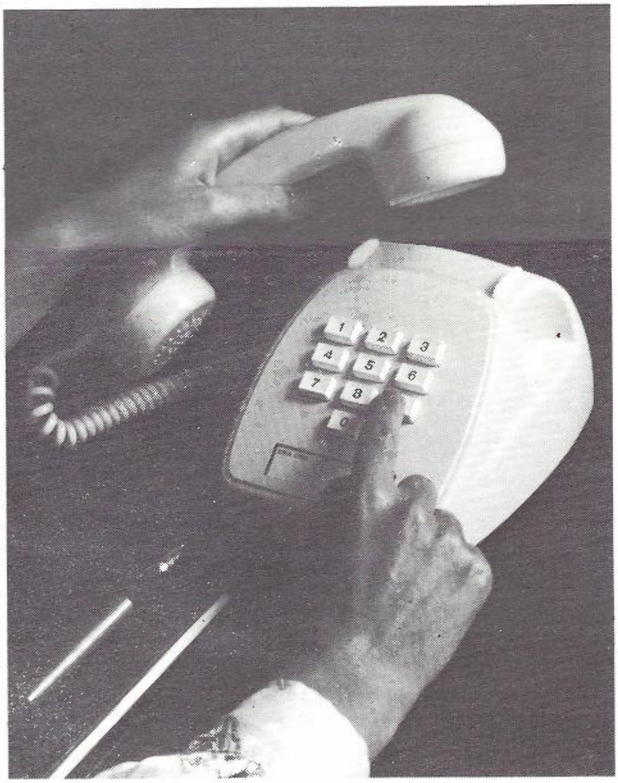


Fig. 1 — Touchfone 10

KEY REQUIREMENTS OF THE AUSTRALIAN NETWORK

At the outset of the development of Touchfone 10 Telecom Australia stipulated that the pushbutton dial for the telephone should perform all the functions of a standard rotary dial in every service application.

This meant, firstly, that the timing accuracy of the loop disconnect outpulsing (decadic outpulsing) was required to be equal to or better than the standard rotary dial.

Secondly, the dial had to be completely compatible electrically with all existing 800 series telephones. This meant in effect that the dial had to be a direct 5 wire replacement for the normal DMS-3 rotary dial incorporating both the normal loop disconnect outpulsing and also the off-normal switching functions of the rotary dial; the latter being used during dialling to short circuit the receiver transducer and transmission network.

There are situations in the Australian network where two telephones connected to a subscribers line must function in parallel (for example, operators telephone and extension telephone on a Type 2 PMBX). In these situations, to ensure transmission between the two instruments, an extra dc potential drop in series with the transmission circuit of only one of the two instruments is unacceptable. In practice this means that, if Touchfone 10 is to be freely mixed with other telephones in the network, the off-normal switching functions must be performed by low resistance metallic contacts. Because of the batteryless (line powered) nature of the pushbutton dial this meant that sensitive electro-mechanical relays had to be designed to perform this function in conjunction with the auxiliary springset of the Keyblock.

The third, major requirement for the Australian pushbutton dial, already noted above, was that it should contain no battery, i.e. it should operate from normal exchange battery supplies on lines up to 1500 ohms resistance where a supply of either polarity could appear at the subscriber's line terminals.

This is a particularly demanding design requirement which is made even more difficult by the existence in the Australian network of a Category-Test Signal (Fleeting Test Reversal) originating from local exchanges. This signal, used to control the access of the service to such facilities as Subscriber Trunk Dialling, is transmitted during the interdigital pause period and can represent an interruption in the power supply to the dial of 150 ms duration. The dial must remain fully operational and continue to store all digits entered prior to or during this period.

To achieve a design meeting all of these requirements it was necessary to evolve a minimum power consumption circuit. For space and other electrical considerations components of low thermal capacity were required, and consequently adequate electrical protection was of vital importance. In a telephone network, voltage surges can appear at the subscriber's line terminals due to a number of causes, including:

- lightning strikes
- power system induction
- ring trip failure of exchange equipment

PRINCIPAL CIRCUIT ELEMENTS

The central component of the pushbutton dial is the low power PMOS integrated circuit (IC) which performs the essential functions of the dial under the control of its

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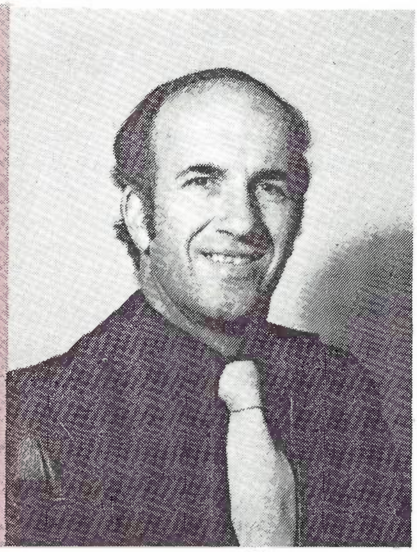

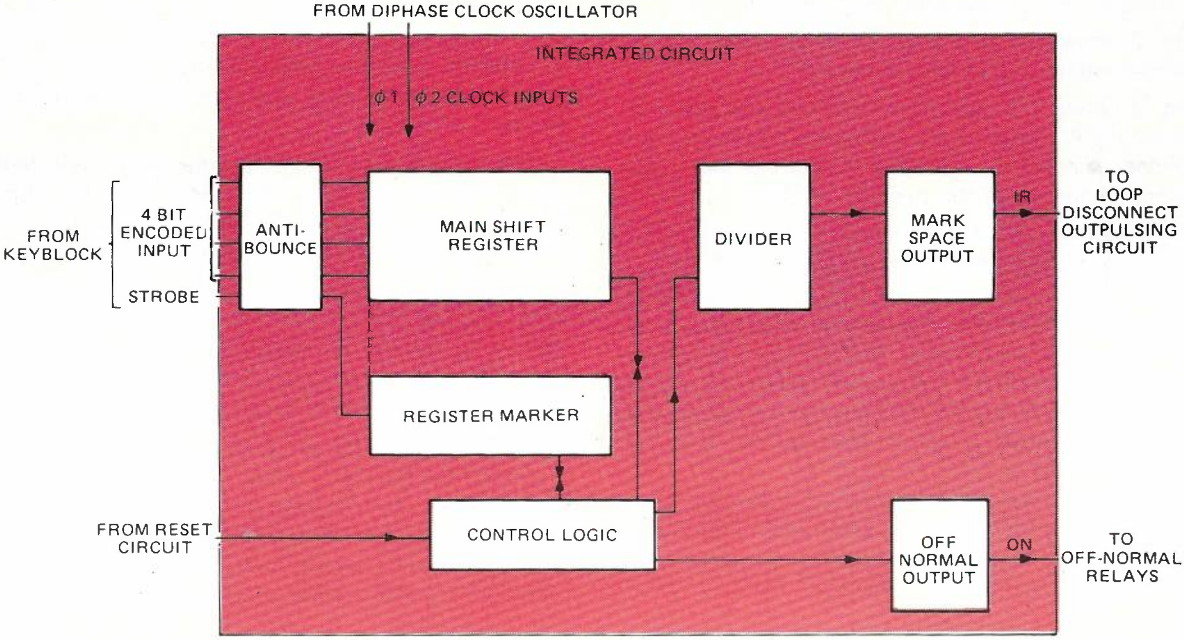

Fig. 2 — Block Diagram of Integrated Circuit

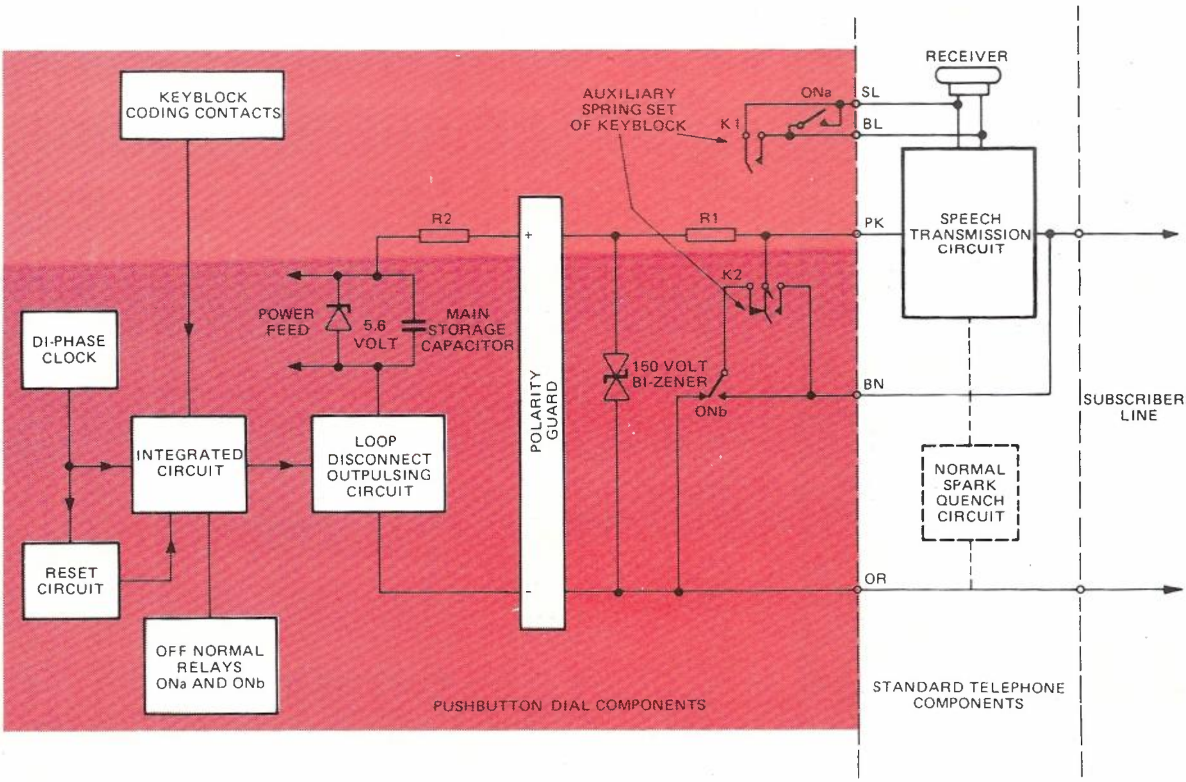

Fig. 3 — Block Diagram of Complete Telephone

own internal, pre-programmed logic circuits.

Fig. 2 shows a block diagram of the major circuits contained within the integrated circuit.

Fig. 3 shows the associated interface and drive circuitry for the IC including the interface with the standard telephone components, and **Fig. 4** sets out the typical operating sequence of the pushbutton dial.

The operation of the dial circuit is as follows:

Referring to Figs. 2, 3 and 4, as a button on the Keyblock is depressed the K1 contacts of the auxiliary springset on the Keyblock place a short circuit across the telephone receiver terminals and the K2 contacts operate to short circuit the path through the telephone speech transmission circuit thereby feeding current to the dial. The 18KHz Diphase Clock is then started and this provides power to the IC.

As the voltage of the Diphase Clock increases, the Reset Circuit changes state and clears information from the IC memory. The dial circuit is then ready to accept information for processing.

The four bit encoded input data is applied to the IC by the Keyblock coding contacts. The strobe is a fifth bit of information from the Keyblock that instructs the IC to process the input data and to operate the off-normal relays.

The input data is written into the Main Shift Register with address locations determined by the Register Marker. Up to 20 digits can be keyed into the dial and stored in the Main Shift Register.

Immediately the first digit has been stored in the Main Shift Register the control logic of the IC instructs the Divider to perform the requisite division of the 18KHz clock frequency to generate the Pre-digital Pause, Inter-digital Pause and Make/Break timings.

The Pre-digital Pause is of 800 ms duration commencing from the time the first digit is stored in the Main Shift Register. At the end of this Pre-digital Pause period the IC instructs the Loop Disconnect Outpulsing Circuit to commence line current interruption. Each digit is outpulsed with a Make timing of 33msecs. and a Break tim-

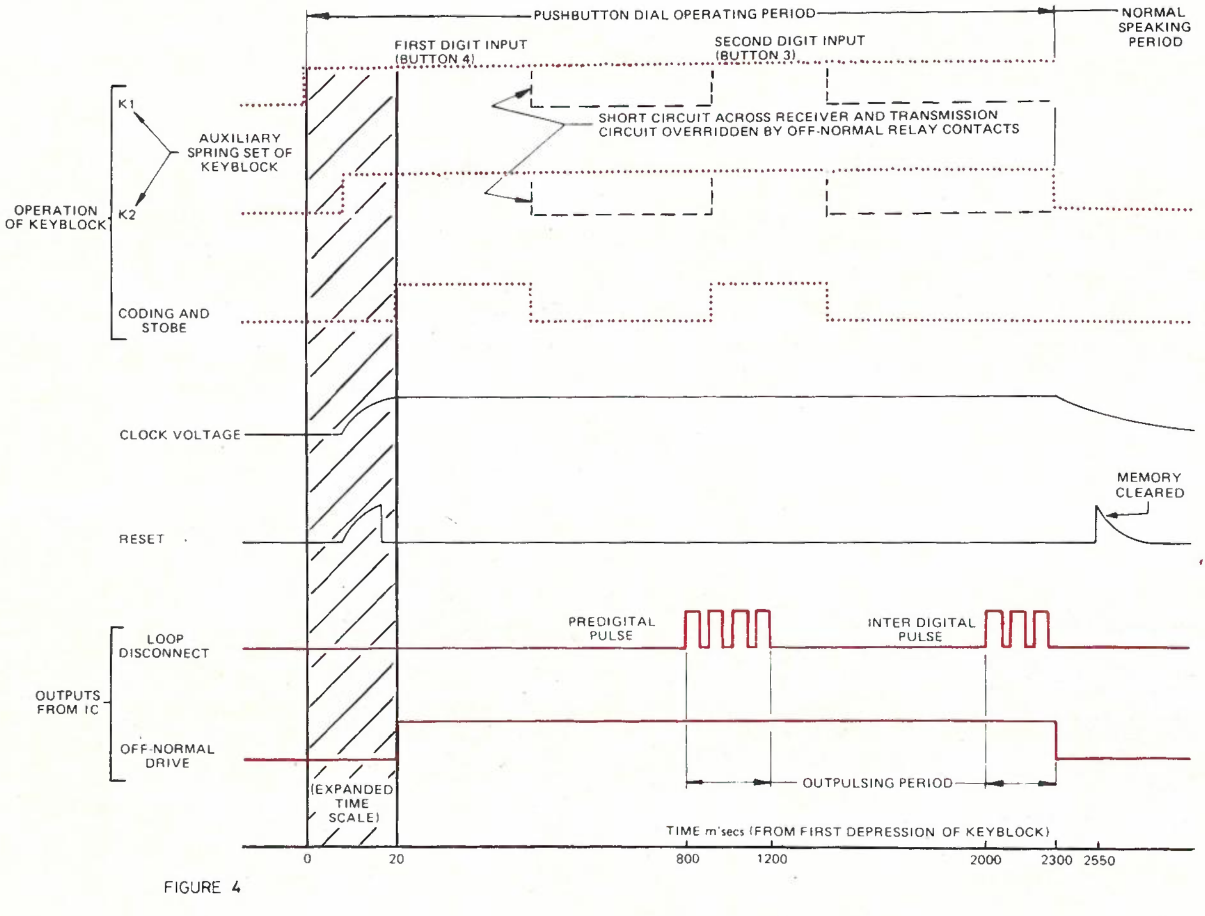

Fig. 4 — Typical Time Sequence Diagram

ing of 67msecs. and is separated from other digits by the Inter-digital Pause period of 800msecs.

After the last digit is outpulsed an off-normal instruction is given to return the off-normal relays to the non-operated state. The dial assembly is then disconnected from the line and the speech transmission circuit is restored. The Reset Circuit then automatically changes state which resets the IC memory in readiness for the next dialling operation. The user can, if he wishes, close down the dialling process at any time the dial is operating by merely operating the telephone gravity switch. This removes power from the dial and as before the Reset Circuit automatically resets the dial.

NETWORK AND OPERATIONAL REQUIREMENTS

Timing Accuracy.

As mentioned previously, the timing reference for all dial functions is the Diphase Clock. This consists of a temperature stabilised LC oscillator in which the positive temperature coefficient of the ferrite inductor and the negative temperature coefficient of the polystyrene capacitor are accurately matched.

5-Wire Direct Replacement for Rotary Dial.

Two off-normal relays were incorporated to simulate the standard rotary dial off-normal functions.

Batteryless Operation.

To obtain batteryless operation the Main Storage Capacitor in the dial circuit is charged from the exchange battery via the line resistance and exchange feed resistance. This capacitor maintains power supply to the pushbutton dial circuit during the line break periods that occur during outpulsing and during the fleeting test reversal.

Electrical Protection.

Referring to Fig. 3, the surge protection circuit consists of two stages. The first stage is formed by the current limiting resistance R1 and the 150V bi-zener diode and the second by R2 and the Power Feed zener diode.

KEYBLOCK

The Keyblock selected for Touchfone 10 consists of a moulded plastic frame supporting the electrical contacts required for digit encoding and auxiliary switching and equipped with ten button stems with detachable caps. The button layout is in accordance with the CCITT recommendation. Gold plated leaf-spring contacts are used throughout the Keyblock.

An exploded view of the Keyblock is shown in **Fig. 5.**

The Keyblock reflects the results of ergonomic studies to establish the optimum tactile reaction, shape, pitch and travel of the buttons. The operating force-displacement characteristic of an individual button is shown in **Fig. 6.** It is of course vital that the Keyblock buttons be operated correctly and to ensure this the Keyblock presents to the user an initial reaction force. This force reduces upon further button depression thus inducing the user to complete button depression. The contact operations of the Keyblock are completed shortly after the collapse of the reaction force ensuring, at all times, proper encoding of information into the IC.

A judicious choice of materials for the Keyblock resulted in a product with good dimensional stability, even under extreme environmental conditions. To establish the endurance limits of the Keyblock, a large number of Keyblocks were required to satisfy a comprehensive testing programme.

This programme included:

- storage tests − 40°C and + 70°C
- vibration (10-55 Hz at ± 0.75 mm amplitude for 30 minutes) followed by shock tests including drop testing onto a wooden surface (ten drops from 1 metre)
- operating temperature tests in which all parameters of the Keyblock must remain within specification over the range of −10° to +55°C
- life tests involving repeated operation in excess of 1 million operations per Keyblock
- contact resistance tests (resistance not to exceed 150 milliohms under all test conditions)

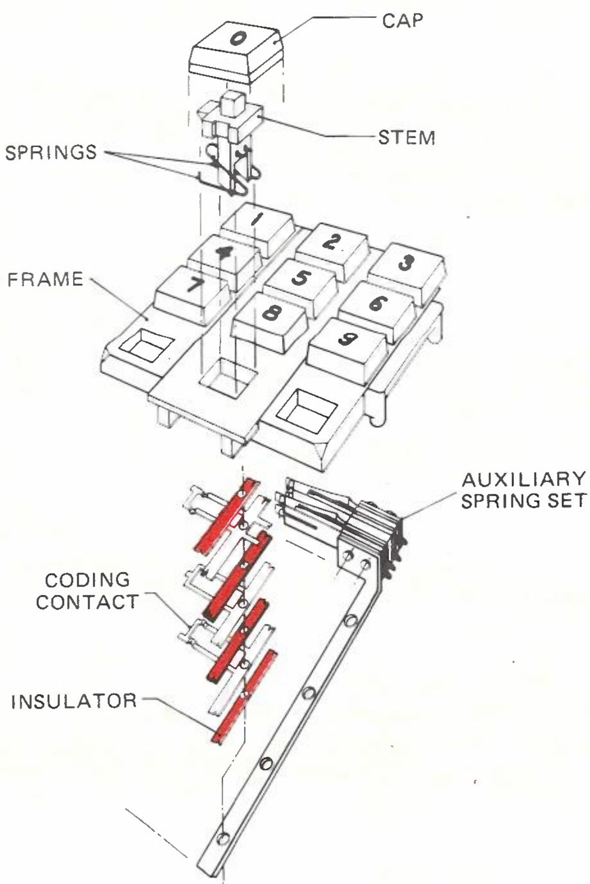

Fig. 5 — Keyblock — Exploded View

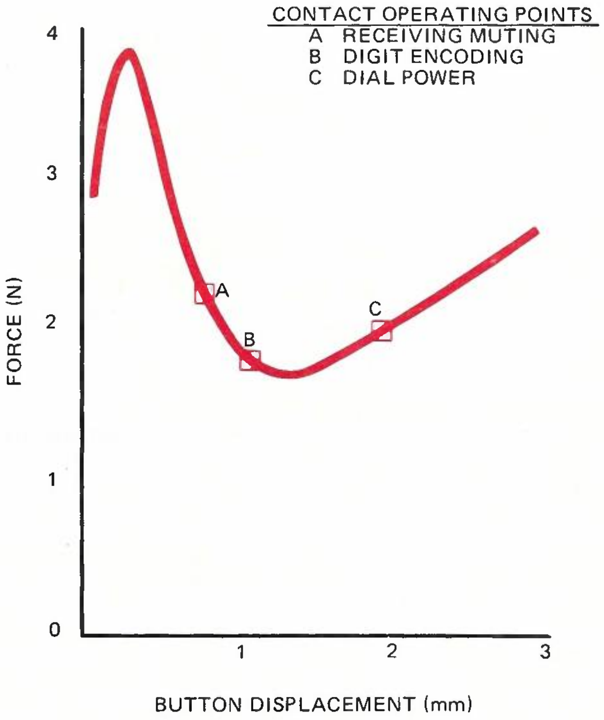

Fig. 6 — Typical Force/Displacement Characteristics of a Button

In addition, a number of Keyblocks selected at random were required to pass an Industrial Atmosphere test (IEC 68 Test Kc for 20 days), after which the following performance parameters were tested:

- contact resistance (150 milliohms maximum)
- insulation resistance (5 Megohms minimum)
- life tests (200 thousand operations per button)

PHYSICAL CONSTRUCTION AND ARRANGEMENT

With the introduction of the 10 button Keyblock into the 800 series telephone, a great deal of attention was given to retaining the telephone's original shape and appearance.

The initial approach was to have a dial fascia assembly that would fit directly into the round cavity of the standard dial. Although this did show merit, the fascia imparted an "added-on" appearance that was considered to detract from the total finished appearance of the 800 series telephone.

Subsequently, a complete one piece case was developed whereby the dial aperture was filled in and replaced by individual openings for the 10 buttons of the Keyblock.

A subscriber's number label was also provided in the telephone case below the individual button openings.

All other features of the telephone remained unchanged, except that internally the plastic dial mounting blocks on the pushbutton dial were reduced in height to allow for the increased dial volume when compared with a rotary dial.

The pushbutton dial assembly is shown in **Fig. 7** and consists of three main component assemblies, namely the Keyblock with attached cableform, a protective insulating tray, and a printed circuit board assembly.

During factory assembly, retention of the Keyblock to the protective tray is achieved by means of two interference fit spigots which protrude from the tray and locate into recesses within the Keyblock.

Four spigots located on the underside of the tray then locate into respective holes in the Printed Circuit Board, two of the spigots having a snap-in retaining feature for ease of assembly and removal.

The mounting of the Dial Assembly within the telephone is achieved via suitable plastic mounting blocks located on two sides of the Printed Circuit Board. These blocks fit onto the existing dial mounting posts to position the dial assembly in a suitable attitude for assembly with the telephone case.

Two locating spigots are situated on the underside of the telephone case and on assembly these spigots engage with the holes located on the top face of the Keyblock frame. These features ensure accurate registration of the numbered buttons to the respective button openings within the telephone case thereby preventing binding of the buttons with the case during dialling operation.

The dial connections are the same as for the standard rotary dial.

TESTING AND PROVING OF THE COMPLETE PUSHBUTTON TELEPHONE

A very important phase of the development programme was Qualification Testing during which a significant number of telephones were fitted with pushbutton dials and then required to meet a series of performance tests designed to reflect the extremes of the Australian environment.

The dialling performance of the telephone was measured with environmental extremes of temperature from -10°C to +55°C, humidity up to 95% RH, line resistance from 0 to 1500 ohms, and minimum button-depression times of 15 ms for short lines.

The telephones were then subjected to a range of adverse electrical conditions likely to be encountered in the network. A high-energy pulse of 1 joule at 1 Kv was applied repeatedly to each telephone during outpulsing to check the electrical protection circuits and to verify that the dialling performance was unaffected under these conditions. Further adverse line conditions applied to the telephones whilst outpulsing, were ring trip failure and fleeting test reversal. The dialling performance was not impaired.

Complete telephones were required to meet a drop

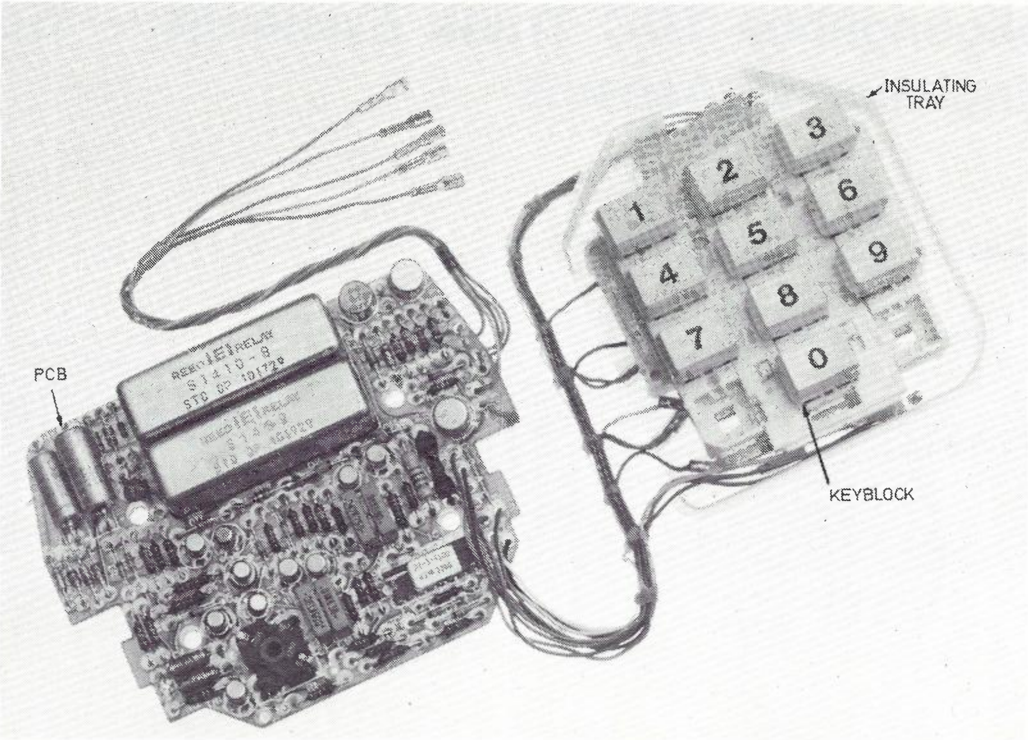

Fig. 7 — Push Button Dial Unit

test where each telephone was dropped 10 times from a height of 1 metre onto a wooden floor. The dialling performance was unchanged.

A number of telephones were subjected to 250V ac applied at the telephone terminals during dialling. Although this test was destructive to the dial assembly, the components of the dial did not support combustion.

VOLUME PRODUCTION AND QUALITY ASSURANCE

The Touchfone 10 units are produced at STC's Sydney factory using modern assembly methods and automated testing to ensure uniformity of performance and quality. All components are inspected for compliance with individual component specifications before being accepted for assembly. The Keyblock undergoes comprehensive electrical testing and other electronic components are pre-processed as appropriate before assembly onto the double-sided printed circuit board; for example, the axial leads of components are pre-formed to ensure retention in the printed circuit board during the wave-soldering process.

The fully assembled flow soldered printed circuit board is subjected to thorough electrical testing using automated test equipment which simulates the switching action of the Keyblock. The dialling performance of the printed circuit board assembly itself is verified at this point. The automated test equipment used has the ability to diagnose faults and to indicate the faulty component.

Once tested, the Keyblock and printed circuit board assembly are interconnected to form the complete pushbutton dial assembly which is then assembled into the telephone. The complete Touchfone undergoes final testing for acoustic and repetitive dialling performance under the direct supervision of STC's Quality Assurance Department. Audit checks, in which a thoroughly tested telephone is repetitively tested for correct outpulsing of up to 20,000 digits, are also carried out by the Quality Assurance Department.

Final acceptance of the telephones is the responsibility of Telecom Australia's Material Inspection and Quality Assurance Staff.

ACKNOWLEDGEMENTS

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Woolloongabba 10C Trunk Exchange — Some Engineering Aspects

J. R. EDMONDSON, BE (Hons)

The Woolloongabba Exchange is typical of the series of 10C Stored Program Controlled (SPC) Main Trunk Switching Centres being established in the mainland State capitals. The initial three installations at Pitt (Sydney), Lonsdale (Melbourne) and Waymouth (Adelaide) were engineered and installed under contract by Standard Telephones and Cables (STC) Pty. Ltd. of Sydney. Woolloongabba is the first large capacity 10C trunk exchange for which Telecom Australia has undertaken the engineering design and equipment installation.

This article describes significant design aspects of the project with particular reference to the installation engineering component.

INTRODUCTION

Installation of the Woolloongabba 10C trunk exchange as a new Main Trunk Switching Centre for Queensland commenced in May 1977. The decision to use 10C equipment for this stage of expansion of trunk switching capacity in Brisbane followed similar decisions relating to Sydney, Melbourne and Adelaide.

Pitt, Lonsdale and Waymoutn 10C exchanges were engineered and installed under contract by Standard Telephones and Cables (STC) Pty. Ltd. in conjunction with Bell Telephone Manufacturing Company (BTM) of Antwerp, designers of the 10C system. Previous articles in this journal have covered a number of facets of these projects, including installation, testing, commissioning and operation.

For subsequent installations, Telecom Australia has undertaken the majority of the engineering design and all installation and testing activities. The first of these was the Bendigo provincial 10C exchange which was commissioned in October 1977. This article describes significant aspects of the engineering design phase of the Woolloongabba 10C project which involved the establishment of a new telecommunications complex. Reference is made to a series of engineering documents prepared as a guide for staff involved in 10C installation engineering activities.

TRUNK NETWORK DEVELOPMENT

The Edison ARM exchange, commissioned in 1968 as the Main Trunk Switching Centre for Queensland, was expected to provide for trunk network growth up to 1974. Although action was inhand to establish a major trunk switching exchange on a new site at Woolloongabba, the lead time associated with such a project precluded network relief from this source before 1977. By this date it was estimated that a further 3200 trunk terminations would be required to supplement the ARM, which was installed to its maximum capacity of 7600 terminations (4000 inlets, 3600 outlets) by 1973.

To overcome the shortage of terminations in the intervening period, initial consideration was given to the establishment of a second ARM exchange in a vacant floor of the Central Exchange Building. The solution finally adopted as a temporary expedient embraced the establishment of Originating and Terminating Trunk tandems (OTT and TTT) (Ref.1). As a two wire switching machine with a terminating secondary status the TTT violates both switching and transmission plans.

Due to slippage in the commencement date of the Woolloongabba installation, further interim network relief was necessary and this was obtained by expansion of the OTT and TTT to their current capacities of 1600 inlets and 900 inlets respectively. Commissioning of the Woolloongabba 10C Trunk Exchange is now scheduled for March 1979.

NETWORK SIGNIFICANCE OF THE 10C

Switching and Charging Functions

Initial plans for the integration of the 10C into the network provided for the 10C to assume the State Main Switching Centre role, with the ARM restricted to a Secondary function for the Brisbane 07 Closed Number Area (CNA) and the Brisbane Country 075 CNA, including the terminating function of the TTT which would be withdrawn. Part of the OTT would be retained as a first choice outlet for STD traffic.

For better network security, it is now proposed that the 10C and ARM function as co-main exchanges, each with direct and final routes to all interstate, intrastate and local destinations. Incoming STD routes will be split over the 10C and ARM Exchanges. There will be no traffic between the 10C and ARM except for operator and testing codes. The ability of the ARM to function as an effective co-main will decrease as network growth requires the extension of the 10C from its initial size of 8192 terminations (8K, where 1K = 1024) to a predicted 24K in the mid 1980s. By this time development of a second SPC trunk switching exchange is considered necessary to provide network security. In the meantime, an increase in the effective switching capacity of the ARM could be obtained in the early 1980s by the recovery of the Edison AFG Manual Assistance Positions which currently occupy some 1600 terminations.

Retention of the OTT and TTT at their current capacities as first choice switchblocks for Brisbane trunk traffic has been justified on economic grounds. The charging function for originating STD traffic from the Brisbane Inner Telephone Zone will be shared by the 10C and OTT. Terminating access to the Brisbane 07 and 075 CNAs will be available via both the 10C and ARM. The TTT will be restricted to first choice terminating traffic to selected Brisbane terminal exchanges from intrastate origins. By reducing the TTT to true tandem status, current switching and transmission plan violations will be eliminated. The originating and terminating functions of the 10C for Brisbane area traffic are represented in **Fig 1**.

Spare capacity in the 10C will be used to provide temporary relief for local tandem exchanges where convenient, thus postponing further growth pending the availability of SPC tandem equipment. Initially, the 10C will perform the Woolloongabba local X tandem function and operate as a Y tandem for certain Brisbane Outer Telephone Zone terminals.

The 10C will be the sole charging point for International Subscriber Dialled (ISD) traffic originated within the State, which is currently charged by Haymarket ARM (Sydney) on a multimetering basis. The Automatic Message Accounting (AMA) facility for ISD calls will become operative in all major 10C exchanges during late 1979, although its availability to individual subscribers will be dependent on provision of the Calling Line Identification (CLI) facility at originating exchanges.

Manual Assistance Functions

Manual Assistance Positions (MAPs) associated with the 10C exchange will replace obsolete switchboards in the Central Exchange Building which currently handle all operator-assisted international traffic originating in the State.

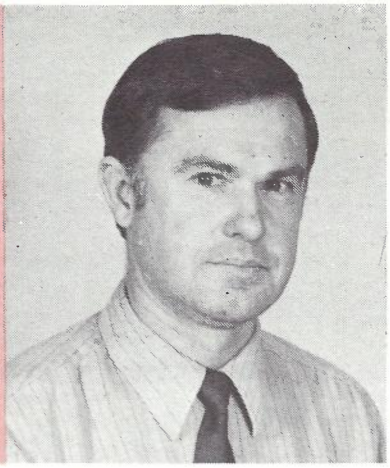
The 10C will be capable of providing manual assistance for national traffic originated within an area of south-east Queensland containing 68 per cent of the State's population (**Fig. 2**). Initially manual assistance for the Brisbane Secondary Switching Area will be shared with the Edison AFG Manual Assistance Centre (MAC) and local two wire MACs at Southport (Gold Coast) and Ipswich. In addition, the 10C MAPs will serve the Nambour Secondary Switching Area and portion of the Toowoomba 076 CNA, enabling the closure of existing two wire MACs.

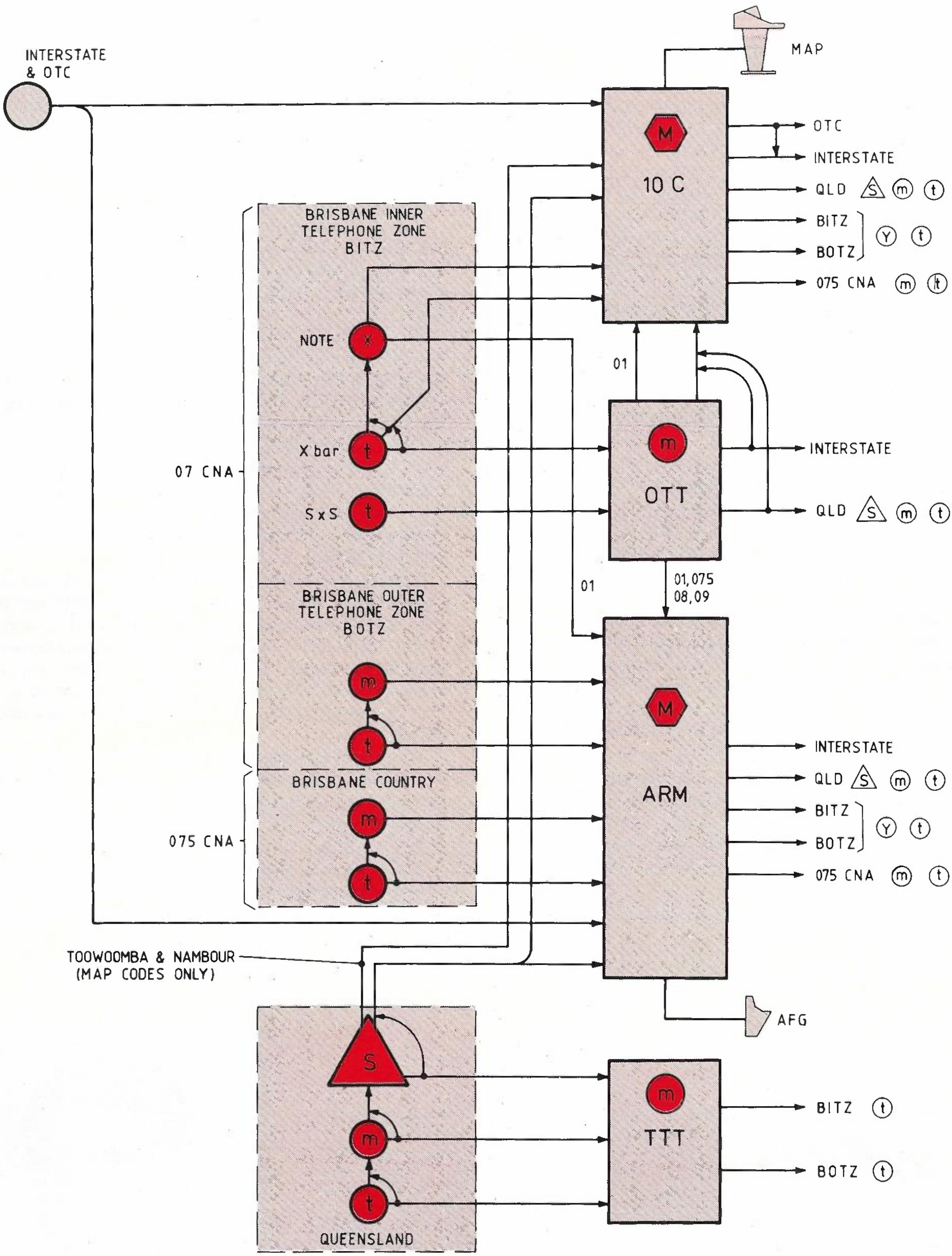
Provision within the 10C system for the remote operation of MAPs will permit the retention of MACs at Nambour and Toowoomba, which are situated 113 and 135 route kilometres respectively from Woolloongabba. Groups of sixteen MAPs at each location will communicate with the central processor unit via data links. The operation of the 10C MAP system is described in Ref. 2.

All national traffic will be handled on a "pooled" basis, with machine insertion of originating area code provided for operating convenience. Ultimately the A subscriber's national number will be displayed automatically when CLI is available.

The automatic charging of manually assisted calls demands the storage of information relating to charging zones and districts. While STD charging will be per-

JOHN EDMONDSON joined the PMG's Department in 1959 as a cadet engineer and graduated with Honours in Electrical Engineering from the University of Queensland in 1963. Except for four years spent in Trunk Service Section on power and network performance activities, he has worked mainly in the telephone exchange installation field. During this period he has been involved with a wide variety of switching equipment throughout Queensland. Since 1973 he has occupied the position of Senior Engineer, SPC Trunk Exchange Installation in Construction Branch with responsibility for the Woolloongabba 10C project. He holds a Diploma in Business Administration from the Queensland Institute of Technology.





NOTE: 10C PERFORMS X TANDEM FUNCTION FOR CERTAIN EXCHANGES

Fig. 1 Block Diagram Brisbane Trunk Network.

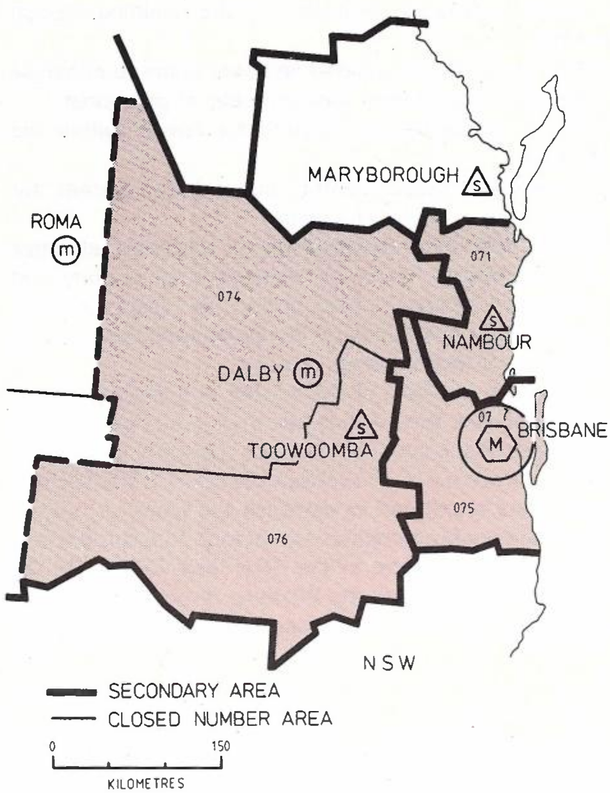


Fig. 2 Originating Area for 10C National Manual Assistance.

formed for seven zones (system capacity 32), 172 zones of origin exist in the area designated for national manual assistance (system capacity 512). In producing the zone-to-zone charging table, 213 zones in adjacent districts must be included as zones of destination, resulting in a 172 x 385 matrix. The storage of information for call charging represents a significant use of memory space.

The 10C will provide an automatic appointment and reminder (ANR) service and is planned to become the Interception Service Centre for Queensland when this facility is required. Service assistance facilities are proposed to supplement the existing centre in Edison, but as the design of this equipment is incomplete, the facility will not be available at cutover.

EXCHANGE DIMENSIONS

Provision has been made in the exchange design for expansion of the initial 4K/4K (inlets/outlets) installation to the maximum system capacity of 32K/32K. Initial switching network capacities are shown in **Fig. 3.** A general description of the 10C hardware system is presented in Ref. 3. To meet 1979 traffic requirements, the allocation of inlets and outlets is as follows:

	Inlets	Outlets
Brisbane local network	1135	1119
Trunk circuits — Qld	434	666
Trunk circuits — Interstate	324	446
International circuits	15	42
Manual assistance	624	373
Maintenance and test equipment	90	113
Echo suppressors	190	190

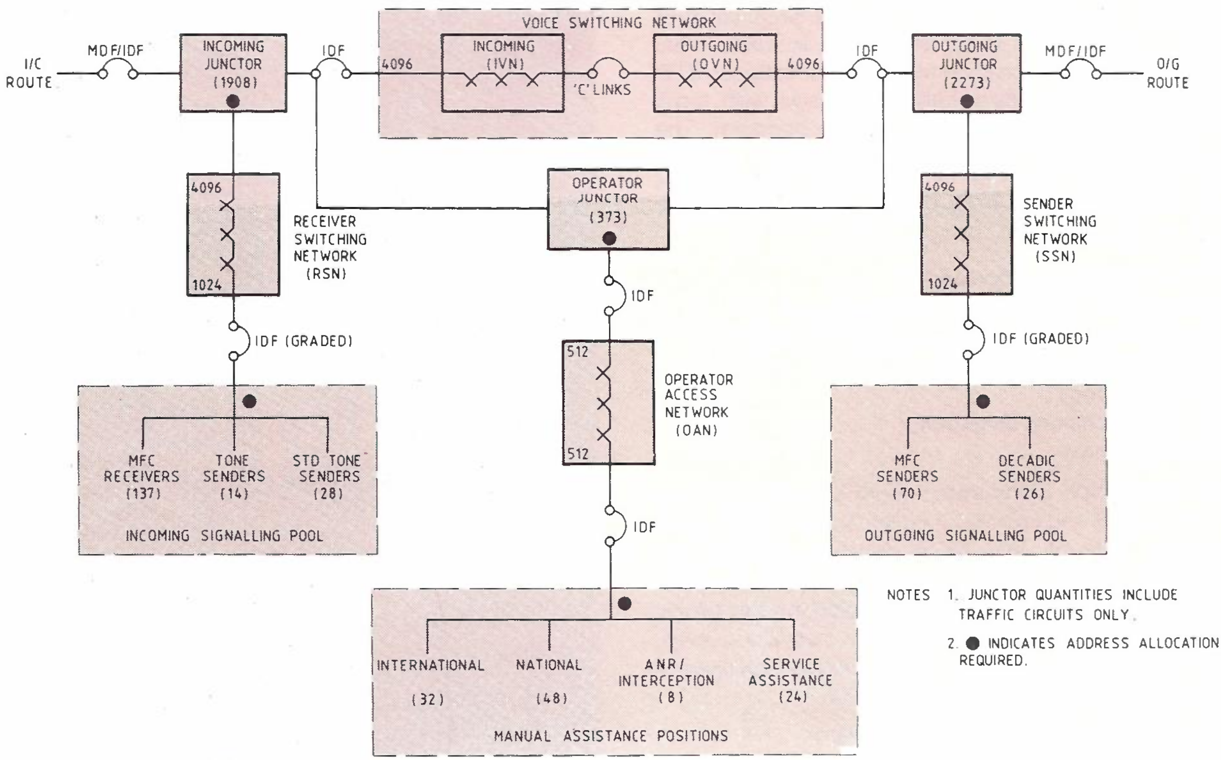


Fig. 3 Woolloongabba 10C Network Equipment.

The initial MAP requirements are:

International Manual Assistance Centre	32
National Manual Assistance Centres	
—Woolloongabba	16
—Nambour	16
—Toowoomba	16
Appointment and Reminder (ANR) and Interception Service Centre	8
Service Assistance Centre	24

A monitor's position is required for each group of eight positions, and each operating centre will be provided with a supervisor's position. Associated miscellaneous positions are:

Operator training	4
Operator training control	1
Service assessment (STD)	1
Operator information	2

SITE AND BUILDING CONSIDERATIONS

When the decision was taken in the mid 1960s to establish a new trunk switching centre in Brisbane, the lack of suitable equipment space in the central city trunk exchange buildings, congested line plant in their vicinity and network security dictated the establishment of a new telecommunications complex. The Woolloongabba site, located south of the Brisbane River 2.8 km from the Edison Building was proposed as it provided an opportunity to diversify the vital trunk switching and carrier terminal functions. As a site for a major carrier terminal, it had the advantage of being on the route of the Edison-Mt Gravatt and Edison-Sydney co-axial cables. Future relief could also be provided for the adjoining local telephone exchange building at Woolloongabba which was expected to reach full occupancy by 1975.

Approval in principle for the original proposal was granted in 1967. As a result of the rise in trunk traffic which followed the establishment of the national STD grid, the need for a larger building to cope with trunk development to the year 2000 became apparent. The proposal relating to a revised submission received Federal Cabinet approval in December 1972. This provided for a building of basement, ground and fifteen stories to house:

- 10C Trunk Switching Equipment
- The International Manual Assistance Centre
- A Manual Assistance Centre for National Traffic
- Major Broadband Equipment
- A Telex Exchange
- A Tandem Switching Exchange
- A Local Exchange

Site excavation commenced early in 1973 and the contract for building erection was let in July 1973 with a completion date of July 1975. Various problems including the placing of the contracting company into receivership have prolonged the completion date of the building from 1975 to 1978. However, installation work commenced progressively on a permissive occupancy arrangement as areas became available:

- December 1975 — MDF (Ground Floor)
- April 1977 — Long Line Equipment (Floor 7)
- May 1977 — 10C Trunk Exchange (Floor 10).

Some innovative features of the building design include:

- MAC and cafeteria located on lower floors to minimise vertical transportation requirements of personnel.
- An 11 kV distribution system for power within the building.
- A computer-based central supervisory system for monitoring of building services.
- Waffle slab floor construction to maximise effective floor to ceiling height by elimination of primary and secondary beams in floor slabs. This design permits greater heat absorption by the building structure in the event of air-conditioning failure.

Rising to a height of 90 metres in a predominantly residential area, the building dominates the skyline to the south-east of the city. **Fig. 4** shows a general view of the building. Because of its exposed position RF interference levels were monitored to establish the need for protective measures for computer equipment. Measured levels of 2.3 volts per metre in the 10th floor CPU room for signals emanating from the Brisbane Airport radar installations exceeded the recommended tolerable maximum

Fig. 4 Woolloongabba Building.

of 1 volt per metre and prompted the decision to incorporate screening in the walls of the CPU room. (Field strengths of 46 volts per metre were recorded at the building exterior.) A further site related problem is the high earth resistivity in the immediate vicinity which prevents the establishment of a satisfactory conventional exchange earth. As the building footings represent the lowest attainable earth resistance (approximately 0.3 ohms) in the area, these have been used as the exchange earth electrode. Because of the danger of corrosion of the building footings by electrolysis due to earth return currents, this will be supplemented by a cathodic protection system. The sacrificial anode is a large mass of steel rails buried in a park about 800 metres north of the exchange.To minimise earth return current, the use of earth return signalling (e.g. as used in telex systems and T-pattern signalling over physical circuits) has been discouraged.

INSTALLATION ENGINEERING OVERVIEW

The installation engineering component of a 10C trunk exchange project requires the co-ordination of inter-related activities which are performed over an extended period of time by a number of groups within the State and Headquarters organisations. The efficient flow of information among these groups demands uniformity of procedures and presentation. The stored program control concept of the 10C system introduces software and hardware constraints which reinforce this requirement. Layouts, configurations and environments have to be described precisely for later representation in hardware and software.

The need for a uniform approach was recognised by Telecom Australia, and resulted in the publication by the Headquarters Telephone Switching Construction Branch of a series of 'C' documents collectively referred to as "10C Trunk Exchanges — Installation Engineering Guide". The guide covers engineering tasks from initial planning through to the extension of 10C trunk exchanges. It sets out Telecom Australia policy and is the basic reference for staff involved in installation engineering activities associated with 10C trunk exchanges.

Engineering aspects covered by the series of sixteen documents include:

- Building Requirements
- Power and Earthing Requirements
- Layouts
- Material Estimating
- Tools and Test Equipment
- Circuit and Device Distribution Lists
- Cabling and Terminating
- Software
- Testing
- Extensions

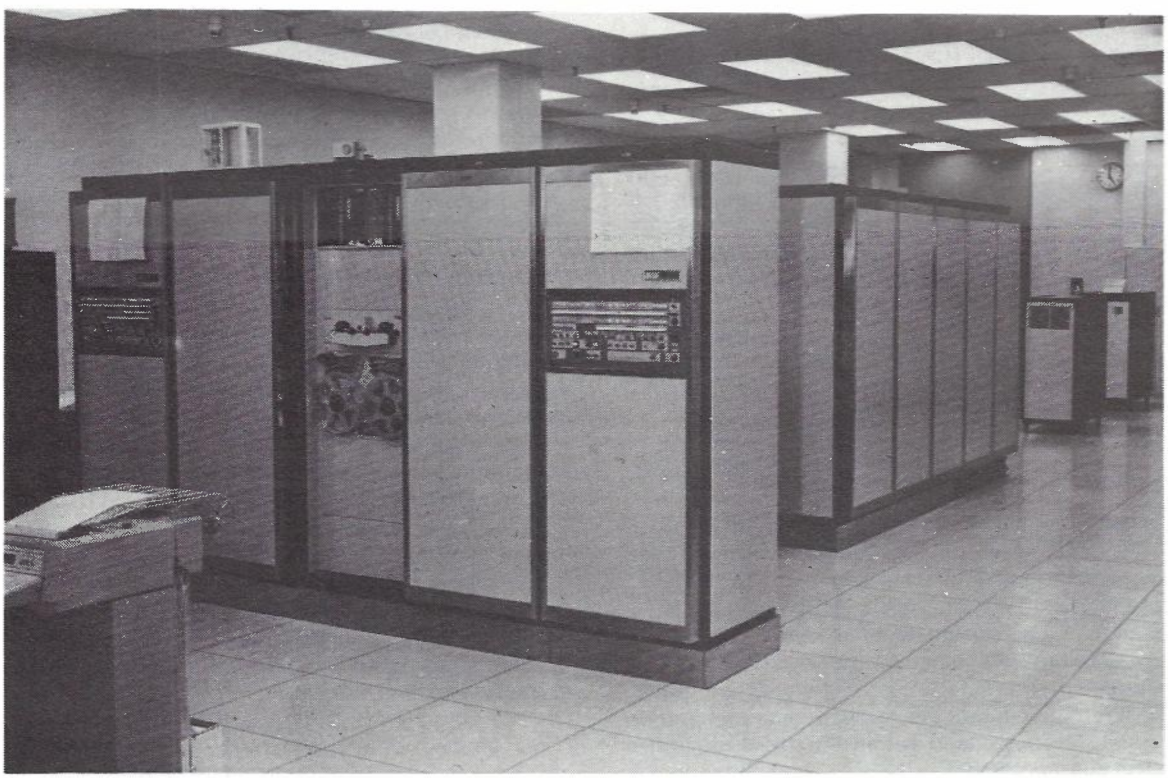


Fig. 5 Central Processor Room.

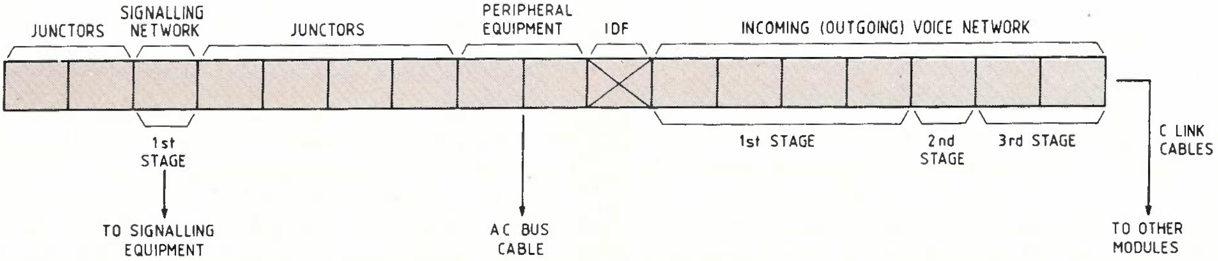


Fig. 6 Layout of Typical Voice Network Module.

The guides reflect the experience gained by staff involved in a number of facets of design, installation and testing of 10C exchanges.These include system design by BTM in Antwerp, acceptance testing of contractor installed exchanges, and design of the Bendigo 10C exchange which was the first involvement by Telecom Australia in the 10C installation engineering process.

A number of the guides were prepared in conjunction with the engineering design effort for Woolloongabba. Reference is made in the following sections to significant installation engineering aspects of the Woolloongabba 10C project.

EQUIPMENT LAYOUTS

Layouts for all equipment areas are a prerequisite to material ordering. Space is allocated on the initial 10C floor in Woolloongabba for:

- Central Processor Unit (CPU) Room — containing two processors and peripheral equipment, with space for an ultimate of six processors **(Fig. 5)**.
- Maintenance Control Room.
- Switchroom — accommodates one Exchange Unit (EU) of switchblock (4K inlets and 4K outlets). The nominal area of 350 square metres normally specified for one EU is exceeded on this floor due to the requirement for MAP equipment, echo suppressors and miscellaneous maintenance equipment.
- Inverter Room — contains 50 volt DC to 240 volt AC converters for AC powered common control equipment.
- Power and Battery Room — houses a conventional 50 volt installation to supply all of the above areas.

Subsequent floors will accommodate two EU of switchblock and the associated 50 volt power equipment.

The junction (trunking) diagram showing initial and ultimate exchange size for both common control and switching equipment is the starting point for detailed layout preparation. Fundamental to switchroom design is the allocation of junctors to inlets in such a way as to ensure even distribution of junctor types and maximisation of inlet/outlet usage. Final route and circuit quantities, although not required until the software data preparation phase, must be constrained within the initial quantities included in the equipment order. Major changes in the role of the Woolloongabba 10C and in the design of the metropolitan junction network since the initial order was placed in 1974 had to be accommodated within the original junctor quantities.

A departure from previous equipment room layout practice is the location of all equipment associated with each 512 termination module of the voice switching network within one suite **(Fig. 6)**. Previously the second and third stages of all modules in an exchange unit were grouped together separate from the first stage resulting in heavy transverse cabling between the first and second switching stages. Although longer 'C' link cables are required between modules, the advantages which result are:

- Elimination of transverse cabling apart from AC Bus cabling, junctor to MDF/IDF cabling, and certain signalling and peripheral equipment cabling. The resulting overhead cabling arrangement is illustrated in **Fig. 7**.
- Reduction in cabling time.
- Improved testing efficiency as related equipment is grouped together and testing of complete modules can proceed as the installation progresses.
- The exchange can be conveniently commissioned in stages. At Woolloongabba, the initial 2K/2K will be commissioned while testing proceeds on the remaining 2K/2K.

POWER AND EARTHING

A no-break power supply for the switchroom and common control equipment is provided by a conventional Integrated Power Suite using 800 ampere thyristor-controlled rectifiers and 2000 AH batteries. The design load is as follows:

- Switchroom (4K/4K) 1000 A.
- Common control (initial) 1100 A.
- Common control (ultimate) 1800 A.

Three sets of batteries will initially provide approximately one hour's reserve.

The star earthing principle of the 10C system aims to eliminate earth loops by providing only one point of connection to the earth electrode for equipment earths. Special measures to achieve this include the separation of equipment and AC mains earth in power equipment and the mounting of CPU and MAP equipment on false floors supported by earthed conductive grid systems which are insulated from the building structure. Although connection between the equipment and power earths is not required in a star system, the mesh earth practices of other equipment in the building force the existence of this connection.

An emergency 240 volt AC supply for the common control equipment is provided via an isolating transformer to avoid an earth loop condition which would otherwise be introduced by electrical safety earthing requirements.

INSTALLATION DOCUMENTATION

A prerequisite to the preparation of documentation required for the physical installation to proceed is the specification of relationships between hardware devices and software. The concept of addressing and data transfer is a fundamental feature of SPC systems.

In the 10C system, the CPU executes an operation on a particular device by transmitting the unique address of that device over the common address-bus and following this with data indicating the operation to be performed. The peripheral equipment associated with the device recognizes the address, then decodes and performs the order. An example of an operation is the transmission of a line signal by a particular junctor.

Circuit Distribution Lists (CDLs) are prepared to distribute circuits and devices over the available addresses in an exchange. This information is required for preparation of the data base for the exchange operational program and is also used in preparing cabling and terminating documents.

The addresses of switching network terminations are fixed by their physical rack location. Referring to Fig. 3, addresses are allocated to:

- Junctors
- MAPs
- Signalling pool devices.

Where a variable relationship exists between two hardware devices via an interconnecting frame, the relationship must be specified in terms of addresses. Examples are:

- Signalling devices to RSN/SSN
- Junctors to IVN/OVN
- C links
- Operator connect circuits to OAN
- Operator junctors to OAN

The allocation of junctors to routes is a CDL which becomes an input during the preparation of the exchange data tables. Performae were designed for the generation of CDLs and also for the preparation of installation documents which provide the information required for:

- Cable running and terminating
- Strapping (including address information)
- Jumpering

The basic set of standard documents developed for Woolloongabba will have general application for future installations.

Fig. 7 Overhead View of Switchroom Installation.

SOFTWARE PREPARATION

10C Software System

The memory contents of a 10C trunk exchange may be divided into three parts:

Operational Program — This contains the exchange logic which controls the operation of the exchange.

Buffers and Hoppers (temporary data) — These are the worksheets of the operational program in which details relating to the handling of a call are kept for the duration of the connection.

Translation Tables and Parameters — Tables and parameters contain the permanent and semi-permanent data necessary to describe an individual exchange to the general operational program.

The memory is initially loaded from a "system tape" which is suppled in the form of a magnetic tape by the Switching Design Branch, Telecom Headquarters. Preparation of the system tape is initiated on receipt of the following information from the State Construction Branch:

- Junction Diagram
- Circuit Distribution Lists
- Completed network and exchange based data proformae.

In the preparation of the system tape, standard program packages are selected according to the switching functions to be performed as specified in the junction diagram. These packages are identical for all Australian 10C exchanges. During the assembly of the system tape, the operational program is combined with the data base pertaining to the particular exchange.

System Tape Data Collection

Permanent and semi-permanent data may be classified as site dependent or system based, the latter being identical for all Australian 10C trunk exchanges. System based data, together with certain site dependent data which is extracted from files maintained on a national basis, is generated during the assembly process. The majority of site dependent data is entered by State Planning and Construction groups into series of proformae which have been designed to present the information in a format suitable for direct input to system tape assembly procedures.

Site dependent data may be considered under two headings:

Network data refers to the routing and charging information pertaining to the exchange. The starting point for this data is the junction diagram which yields the incoming and outgoing route information and the prefix translation (dialled code analysis) data. Charging information is obtained from the State Charging Plan.

Examples of network-based tables and parameters are:

- Tables
  - — Prefix translation (code analysis)
  - — Outgoing route
- Parameters
  - — Total number of routes
  - — Total number of zones of origin.

Exchange-based data refers to the tables and parameters which describe the exchange in terms of its internal hardware and software configurations. The switching network and common control junction diagrams are the source of this data.

Examples of exchange-based tables and parameters are —

- Tables
  - — Sender-receiver class
  - — Junction equipped
- Parameters
  - — Number of processors
  - — Switchblock configurations.

Test Software

Hardware testing in a 10C exchange is largely performed by test software running in the processing units of the operational system. Standard test software for common control and switchroom testing is available. Test programs for switchroom equipment require a special data base which describes the particular exchange under test. Data is collected on a set of proformae and forwarded to Switching Design Branch for program assembly.

Two separate assembly procedures are required according to the testing environment; one for the off-line situation (new installation) and one for the on-line situation (extension of an existing exchange). The initial stage of testing at Woolloongabba provides for off-line testing of the first 2K/2K. To permit the earliest possible commissioning date for the exchange the operational program will be loaded and the remainder of the hardware testing performed on-line during the operational testing phase.

CONCLUSION

The introduction of a major facility to the trunk network such as the Woolloongabba 10C exchange, which has involved the establishment of a new telecommunications complex, is the result of many years' planning and engineering activity. The installation engineering approach described here aims to make the best use of documented procedures to minimise the period from the preparation of the basic trunking diagram to commissioning.

With the Woolloongabba 10C exchange at the operational testing phase, installation and testing progress to date has vindicated this approach. The detailed specification of activities and interrelationships is of particular importance in the 10C trunk field where it is inevitable that the retention of expertise will become a problem due to the relative infrequency of ongoing projects.

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Improved Analysis and Presentation of Sydney Network Performance Statistics

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Classical statistics, network quality control needs and the power of the computer are expanded and blended to produce an improved statistical report presentation primarily for engineering use but also for general appreciation by non-engineering personnel. Emphasis is placed upon the study of variance of network performance data. A formula is derived relating customer technical assistance complaints to call failure indicators.

INTRODUCTION

Read the preface of any text book (Ref. 1) on statistics and you will be impressed by the intensity of debate about the ethics of its application. Statistics callously disregards the individual on the one hand whilst promoting democracy (greatest good for greatest number) on the other. Whenever there is something to be gained or lost one finds at least two equally forceful statistical arguments presented in the hope of winning the day. How then can such a dilemma be resolved? The answer may be in the way we present our statistical reports.

The statistical parameters of a telecommunications network are more dynamic than those usually studied by statistical processes. In addition management demands finer resolution of the parameters so that significant trends can be detected and corrective action taken. This paper approaches the problem with these issues in mind and develops a method of presentation which carefully defines the events that are being studied and acknowledges the error in the statistical analysis by performing a significance test on all data and presenting the conclusion by short hand symbols in network performance statistical reports. A list of the symbols used in the text is given as Appendix 1.

This article, examines the statistical properties of the switching loss (call failures due to plant defects) derived from service assessment sampling results, and establishes a relationship between switching loss and subscriber complaints concerning call failures.

The following brief outline will help those not familiar with detailed statistical theory to follow the main thrust of the article:

- The statistical nature of the switching loss of a large telephone network is reviewed. The concept of "population" is established in terms of call attempt events in defined periods of time and/or defined areas of network space.
- The importance of statistical data as indicators of trends over carefully defined sub-populations rather than absolute measures of the state of a network is discussed. By design of sampling schemes results can show predominantly time trends or comparisons of plant (network space).
- The variance of switching loss sample results is established (Binomial Distribution is assumed — see equations (1) and (2)).
- Equations (11) and (12) are derived to express the Standard Deviation of the Technical Assistance rate (subscriber complaints of call failures) in terms of:
  - (i) Sampled switching loss augmented by a loss to allow for call failures which would cause complaints but which would not be reflected in the nominal switching loss sampling results.
  - (ii) The volume of calls generated in a network.
  - (iii) The degree of customer irritation with call failures.

  Equation (11) and (12) are partly empirical, based on actual measurements made in the Sydney telephone network.
- Equations are then derived to determine the statistical significance of individual sample results of switching loss and complaint rate in relation to targets and to the statistical mean of many samples of these two parameters.
- A method of presentation of network statistics in terms of their statistical significance is presented.

CLASSICAL STATISTICS

What is a Population?

Statistics promotes the concept of individuals in a population and then studies the variations in the attributes of these individuals throughout the population which, as we shall see, has the dimensions of space x time. Combinations of individuals can be considered to form a system which exhibits measurable parameters. For example the switching loss in the Sydney telephone network is a parameter of a system composed of individual electromechanical devices whose reliability varies from one to the other, (i.e. population space) and also through the passage of time. For the statistical study of variations in parameters space and time may be considered equivalent and are therefore subjected to similar mathematical analysis.

In practical terms an example of variation in space would be the switching loss of step plant compared with crossbar, or all plant in Sydney compared with Melbourne. Such variance studies are usually referred to as plant, network, route etc., comparisons in existing reports. An example of variations in time would be the trend analysis of say, switching loss over 10 defined periods of observation.

Having made the distinction between space and time variations we must now realise that we can never ideally study either in isolation. Because time does not stand still every statistical measurement in a system must be a reflection of both types of variations. It is therefore important that engineering reports include information defining the space and time boundaries of the population. This is particularly important for such a dynamic population as a telephone network.

The concepts so far developed are illustrated by **Fig. 1.** The Sydney population is shown as a block inside the larger national population. Both move from time 0 to time (t) whilst the events under study are occurring inside the blocks. Especially observe that a particular population (say Sydney x t) forms part of the larger populations (National x t) and (Sydney x t') where t' is a time greater than (t). Also (Sydney x t) and (Sydney x (t' — t)) are **different** populations. The terms "batch" or "sample" to describe part or sub-populations must likewise have "space x time" boundaries defined in any engineering report. It follows that our network populations must always be regarded as infinite and all observations are in fact samples.

MEASUREMENT

If it were possible to know all events within a population up to time (t) then what real practical use would this be? Since in the next instant, $(t + \Delta t)$, a new population has commenced the value is purely historical. The real point of interest is to determine if the new generation is changing its character. As we shall see, no measuring technique of man, including statistics, will ever allow us to measure anything with absolute certainty even though we may think it does for populations with slow dynamics or with measurement techniques of low resolution. Our knowledge can only be of a relative nature. We can only measure differences from one defined population to another, and then only with a level of confidence limited

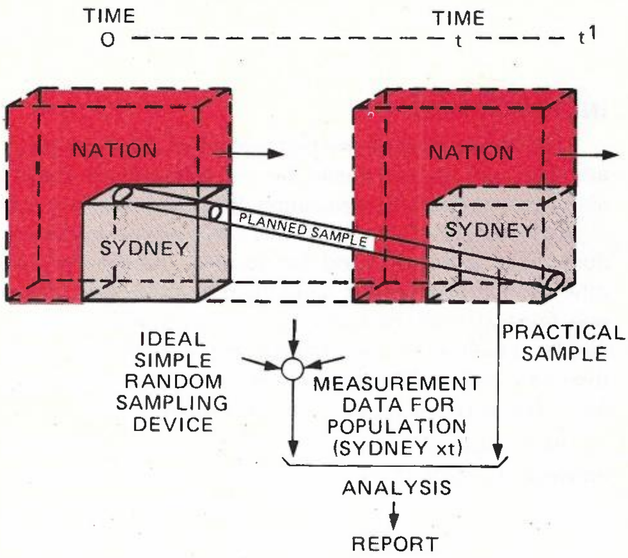

Fig. 1 — Network Population and Sampling System

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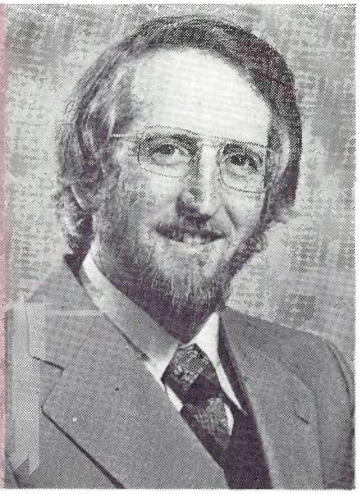
After some 16 years' experience in Country Installation and Metropolitan Operations engineering work, Mr Leverett took up his present position of Senior Engineer, Network Performance, in the Metropolitan Branch in Sydney in 1970.

Here he has developed computer processing of Service Assessment and Technical Assistance Reports and the format for presentation of the results in the Sydney Telephone Network Performance Reports.



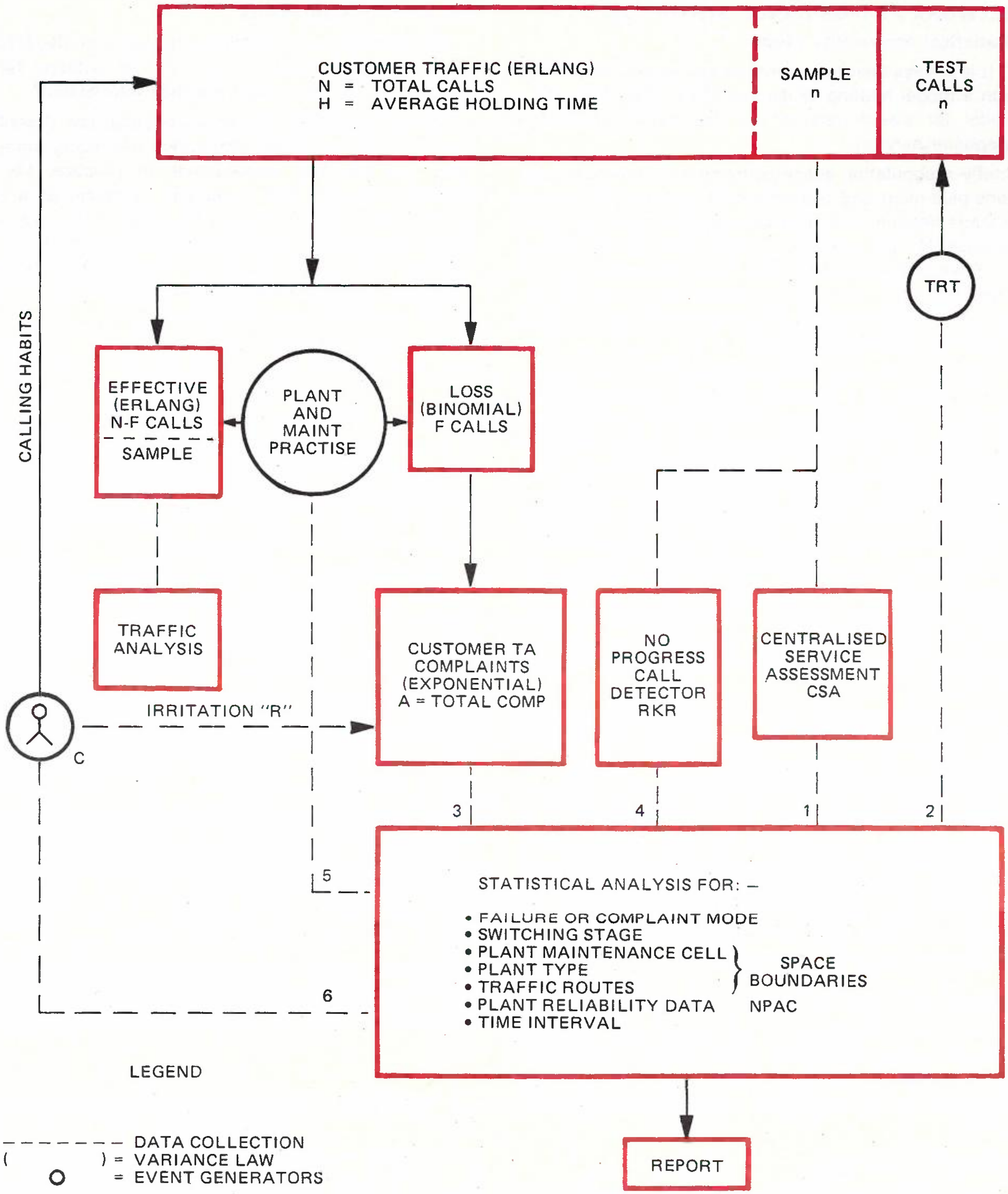


Fig. 2 — Probability Model for Network Traffic

by the integrity of our sampling techniques. Many reports fail to acknowledge these limitations but cheerfully present data in such picturesque forms as graphs and pilgrams which lead the user into errors of judgement of past trends and also future trends extrapolated from unreliable graphs.

NETWORK PERFORMANCE STATISTICS

Statistical Probability Model

It is always best to commence any statistical exercise with a model relating cause and effect. **Fig. 2** is such a model for events relevant to the maintenance of a telephone network.

Briefly a population space containing (C) customer stations plus plant and technical staff generate (N) calls of average holding time (H) over population time (t). Most of these (N) calls are effective but a quantity (F) are lost in various ways. These (F) calls irritate the customer and, depending upon the mode of failure and customer disposition, result in (A) complaints. These are known as TA (Technical Assistance) reports.

We are now particularly concerned with the analysis of (F) and (A) for significant statistical variations as the population boundaries are varied. We are also interested in subdividing (F) and (A) into specific modes of failure and attempting to relate significant variations to plant characteristics and/or maintenance practices. A knowledge of the variance associated with each event generator is therefore essential to the probability model.

Whilst all of (A) may be monitored at the Service Assistance Centre it is not possible to monitor all traffic to find (F). A "random" sample of size (n) is therefore used to measure (F) for a defined population and this immediately creates the numerous sources of error already mentioned.

The random sample (n) is usually taken manually in the box marked CSA (Centralised Service Assessment) but considerable machine sampling for the "no progress" mode of failure is also available in the Sydney Network.

The dotted lines in **Fig. 2** show how the flow of statistical data is directed to the box marked NPAC (Network Performance Analysis Centre) (Ref 3) where attempts are made to produce reliable reports on particular network trends, some of which are indicated in the diagram. For this purpose it is essential to study the variances of the event generators.

Variance of Traffic

The erlang distribution is well known as describing customer calling habits. For large groups of customers under smooth conditions the Poisson approximation can be used for the variance of (N). Hence the standard error is $\sqrt{N}$.

Variance of Call Loss

Since call loss is plant dependent the binomial distribution can be used for the standard error of sample means. (This is not strictly true for the congestion component but in a large network errors become very small). Hence the standard error in expected failures for a sample size (n) calls from a population of (N) calls with (F) failures is,

$\sqrt{[n \times F/N \times (1-F/N)]} = \sqrt{[n \times f(1-f)]}$ calls ......(1)

where f = probability of call loss

or $\sqrt{[f \times (1-f)/n]}$ as a proportion of (n) ....(2)

Variance for Complaints

The incidence of complaints depends upon (N), (F) and a psychological factor I shall call the irritation factor denoted by (R). How then are they interrelated?

Erlang postulated that an exponential law described the customer controlled distribution of holding times of calls and this has worked well in practice. Let us therefore assume that customers complain at a rate obeying an exponential law, the value of the exponent being determined by the failure rate (f) and the degree of irritation (R) from the customer. The probability (P) of a customer making a complaint given that failures (F) have already occurred could be given by,

$P = 1 - \exp(-RF/N) = 1 - \exp - Rf$ ....(3)

also $A = F \times P = F(1 - \exp - Rf)$

$= fN(1 - \exp - Rf)$ ....(4)

and $R = (-1/f) \operatorname{logn}(1 - A/fN)$ ....(5)

To test the formulae relevant data of sufficient accuracy for each of the last 6 years are listed in **Table 1** and plotted in **Fig. 3.** Attempts to fit the data to equation (4) by varying (R) fail for curves passing through the origin A = f = 0. Why is this so?

It has been suspected for a long time that a significant portion of complaints are generated by customer dissatisfaction of a general nature rather than with specific network plant failures. Also some complaints are confused by service assistance operators with subscriber's plant troubles which are not accounted for in limited samples taken for the measurement of (f). Network plant failures which give rise to complaints tend to be of the catastrophic nature which again are not reflected very well in measurements of (f).

It is therefore obvious that (f) must be increased to allow for these intangible factors. Let this increase be an **equivalent loss** (e) shown in the negative region of **Fig. 3.** Equation (4) now becomes,

$A = N(f+e)\,[1 - \exp - R\,(f+e)]$................(6)

and $R = [-1/(f+e)] \operatorname{logn}[1 - A/N(f+e)]$........(7)

The next task is to find values for (R) and (e). This has been done using extrapolation of **Fig. 3** for guidance and conducting a "trial and error" process from the data of

TABLE 1 — CORRELATION OF YEARLY STATISTICS

Year	Calls (N)	Observed Call Loss (f)	Total TA	
			Observed (A)	Calculated Equation (6)
	x10[6]			
76/77	3446	0·020 32	299 861	299 375
75/76	3330	0·0235	284 914	304 740
74/75	3195	0·029	303 423	318 998
73/74	3108	0·034	318 978	334 822
72/73	2892	0·034	313 813	311 529
71/72	2704	0·039	321 789	313 498

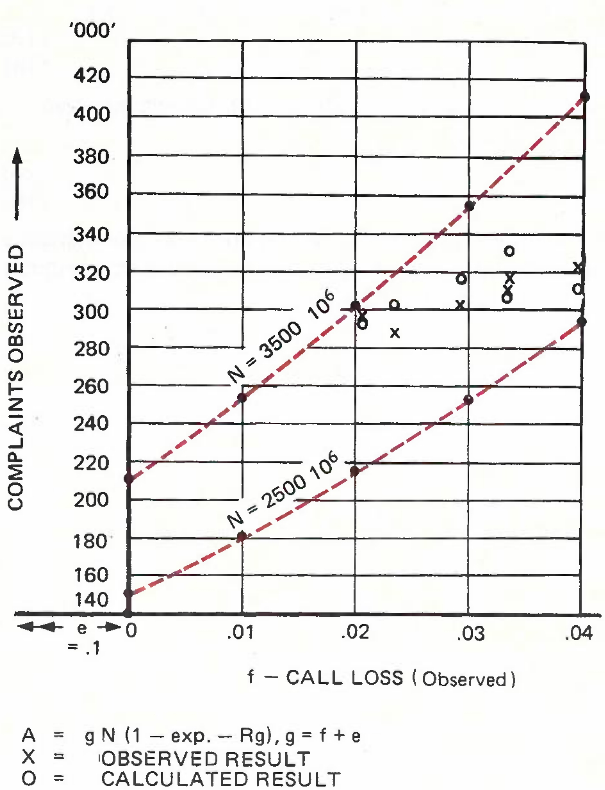


Fig. 3 — Relationship Complaints to Call Loss

Table 1 for total complaints. A similar process was conducted for all the modes of failure and results are listed in Table 2. A comparison of calculated and observed results for total TA is provided in **Table 1**. These results are also plotted in **Fig. 3** together with theoretical expectations for two values of (N).

Bearing in mind that (N) is varying coincident with (f) the values for (A) are seen to correlate well enough to accept the formulae for calculations of expected variance for all cases of customer complaints.

Application of the formulae to very old data for the Sydney network does not correlate as well as that presented for recent years. This is because the e loss of **Table 2** is not really a constant when longer periods are considered. Analysis of the limited data available suggests that,

$e \approx 0{\cdot}6 \sqrt{f}$ . . . . (7a)

Care should also be exercised in deriving the e loss for total complaints should the proportion of any failure mode vary. The values derived are for proportions implied by the target rates of **Table 3**.

The next question therefore is what variance in A can be expected? The standard errors for (N) and (F) have already been stated. Variances in (R) must occur but are unknown. However, we can measure by observation the actual variance in A for a particular failure mode in a large population with hypothetically constant (F) and (e).

This will allow us to deduce the standard error in (R) by using equation (6) in the following form.

let $g = f + e$ . . . . (8)

For maximum TA

$A + \Delta A = g(N + \sqrt{N})\,[1 - \exp - (R + \Delta Rg)]$ (9)

For minimum TA

$A - \Delta A = g(N - \sqrt{N})\,[1 - \exp - (R - \Delta R')g]$ . . . (10)

Typical data from a population (Sydney x 4 weeks) where total TA was observed for variance over the 76/77 year was,

$R = 0{\cdot}006,\ f = 0{\cdot}02,\ e = 0{\cdot}1$

$N = 265{\cdot}44 \times 10^6$ calls per 28 days

$\therefore \sqrt{N} = 16{\cdot}3 \times 10^3$

$A = 22\,846$ complaints per 28 days

$\Delta A = 2454$ complaints per 28 days (observed)

From equation (9)

$R + \Delta R = (-1/g)\ \log n\ [1 - (A + \Delta A)/N + \sqrt{N})g]$

$= 0{\cdot}006\ 58$

Similarly from equation (10)

$R - \Delta R' = 0.005\ 31$

$\Delta R\ (\text{average}) = 0{\cdot}000\ 635$

$100\ \Delta R/R \approx 11\%$

Standard errors in the (R) factor for all modes of failure are listed in **Table 2.** Note that reasonable consistency is displayed with the exception of busy during dialling (BD-D) where catastrophic plant failures and customer confusion with wanted party busy (WBY) apparently disturbs the results. Special account must therefore be taken of this effect when analysing the significance of BDD complaints.

As the expected errors in (R) were calculated over all seasons of the year it is reasonable to accept this as a constant for general use in equation (4). This equation may now be expanded to derive the expected standard error (ΔA) in (A) taking from **Table 2** an average value of 11.% for the standard error in (R).

$\Delta A = [g(N + \sqrt{N})\ (1 - \exp - 1{\cdot}11\ Rg)$

$-g(N - \sqrt{N})(1 - \exp - 0{\cdot}89Rg)]\ /2$ . . . . (11)

(ΔA) can now be used to significance test variances in (A) which will lead us to our acceptance or rejection of the previously assumed null hypothesis that there is no change in the failure rate (g) from one population to

TABLE 2 — SUMMARY OF CONSTANTS FOR TA EQUATION

Mode	e loss	R Factor	
		Value	Standard Error %
Total Complaints	0·1	0·006	10·6
No Progress	0·04	0·013	12·4
Wrong Numbers	0·041	0·018	10·2
Triple Connection	0·001	0·47	15·4
Cut off	0·012	0·065	15·2
Busy During Dialling (BDD)	0·007	0·06	71·0
Total TA less BDD	0·09	0·007	11·2

another. A more useful version of equation (11) is that expressing the standard error of A as a rate (Δa) per 100 customer stations per 28 days as follows,

$$\Delta a = 8400g[(1+1/\sqrt{N})(1-\exp - Rg(1+0.11B)) - (1-1/\sqrt{N})(1-\exp - Rg(1-0.11B))] \quad ......(12)$$

Where B = 1 for all modes of failure except busy during dialling when B $\approx$ 6 as suggested by **Table 2.**

SIGNIFICANCE TEST

On many occasions statistics are presented as the rate or proportion of the result to the sample size. Sometimes only the result data and sample size are presented. Both methods leave the user wondering if variations in results reflect a significant change in the character of the population from which the samples were taken. From the analysis so far developed significance tests can now be conducted and the result presented in reports in such a form that will solve this dilemma.

There are two comparisons that are generally of interest to users.

i) Is the deviation of the result (f) or (a) from a target (b) significant? Let this deviation be (SB) sigmas.
ii) Is the deviation of the result (f) or (a) of one sample significantly different from the mean (p) of many samples? Let this deviation be (S) sigmas.

Case (i) and (ii) for (f)

Now (f) is a binomial event measured by a simple random sample whose deviations may be described by **Fig. 4.** The rates (b), (f) and (p) are known and the problem is to find (SB), (S) and (h). The latter is a hypothetical population mean from which both (f) and (p) could belong with a confidence of (S) sigmas. Many texts, at this point, make h = p as a best estimate and proceed to calculate the deviation (S) similar to the method for (SB). However this can only be justified where the sample size used for (p) is very much larger than that for (f) or (a). In practice this is rarely the case.

The following analysis is therefore regarded as the fairest treatment.

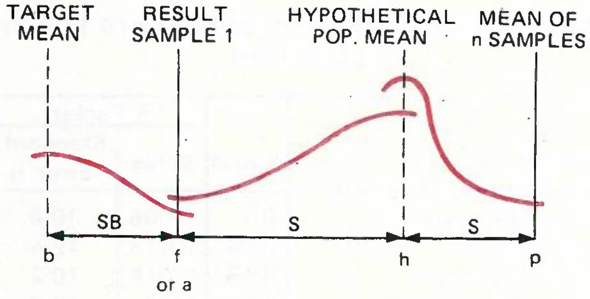


Fig. 4 — Typical Deviations for Reports

The equations that describe **Fig. 4** for (f) are,

$$SB = (b - f)/\Delta b \quad ......(13)$$

$$\Delta b = \sqrt{(b(1-b)/n)} \text{ see eq. (2)} \quad ......(14)$$

From (13) and (14) (SB) can be calculated. Also

$$f = h - S\Delta h$$

$$\therefore f = h - S\sqrt{[h(1-h)/n_f]} \quad ......(15)$$

$$p = h + S\sqrt{[h(1-h)/n_p]} \quad ......(16)$$

Equations (15) and (16) expand into simultaneous quadratic equations which can be solved by a computer search programme to obtain the two unknowns (S) and (h).

Case (i) and (ii) for (a)

Fig. 4 may also be used to describe the deviations for the customer complaint rate (a). However, the mathematics are far more complicated. They are,

$$SB = (b - a)/\Delta b \quad ......* (17)$$

$$b = 16\,800g\,(1 - \exp - Rg) \quad ...... (18)$$

$$a = h - S\Delta h \quad ......* (19)$$

$$p = h + S\Delta h \quad ...... (20)$$

$$h = 16\,800\,g\,(1 - \exp - Rg) \quad ...... (21)$$

* Δb, Δh derived as for Δa in equation 12.

Eq. (18) and (21) are eq. (6) expressed as the rate per 100 customer stations per 28 days.

Equations (17) and (18) are simultaneous with (SB) and (g) as the unknowns. A computer search program will readily provide us with the (SB) deviation.

Equations (19), (20) and (21) are simultaneous with (S), (g) and (h) as the unknowns. A rather more complex computer search programme will obtain the deviation (S).

THE NULL HYPOTHESIS TEST

Throughout this analysis the null hypothesis has established that differences between the compared means were due to normal statistical variance and therefore all measured means came from populations with the same performance for (f) or (e) or both parameters. Armed with sigma values for (SB) and (S) we are now in a position to reject the null hypothesis at a level of confidence defined by the sigma value. A clear rejection at high confidence levels is significant news worth reporting, especially to parties charged with responsibilities for maintaining the network at prescribed levels of performance.

STATISTICAL PRESENTATION

Computer output for Sydney network performance reports has been designed to summarise the information that this paper has tried to show is essential for engineering acceptance and valid interpretation of data collected. **Table 3** is a typical such print out from the programme "NETREP" which is available on the computer network of Telecom Australia. This programme accumulates the data of Table 3 and performs, on command, the desired trend analysis. Table 3 is a comparison of TA complaints of 3 STD routes outgoing from Sydney Network.

To facilitate explanation the first 17 rows of the printout have been numbered. The rows convey information as follows.

TABLE 3 — TYPICAL COMPUTER OUTPUT

```
1     Indicator:CUSTOMER COMPLAINTS (TECHNICAL ASSISTANCE)
2        Traffic:I(LN)--Z(ARM+10C)--J(NATIONAL)
3       Analysis:PERIOD ROUTE COMPARSION

4        Year(s):    77/78    77/78    77/78
5      Period(s):       11       11       11
6    Orig. Code:  Syd  02  Syd  02  Syd  02
7         Plant:      All      All      All     Mean
8    Term. Code:  Mel  03  How 044  Alb 060     Of  3
9         Plant:      All      All      All  Samples
        Sample
10     Stations: 1649171  1649171  1649171
11         Days:       28       28       28
12 Dispersion %:    0.028    0.076    0.065
13Seasonal Fact:    1.000    1.000    1.000
14        Calls: 1739941   210566   180089  2130597
      TARGET /            RATE / INPUT DATA / SIGNIFICANCE SYMBOL
    PARAMETER

15         4.24     4.13    10.21     1.03     4.47
16     Total TA      428      128       11      567
17___________      ..   ..   W4   W4   B4   B4

           1.74     1.26     4.23     0.56     1.50
    No Progress      131       53        6      190
 ____________      B3   ..   W4   W4   B4   B4

           1.74     1.14     3.11     0.09     1.25
   Wrong Number      118       39        1      158
 ____________      B4   ..   W4   W4   B4   B4

           0.04     0.04     0.08     0.00     0.04
    Triple Con.        4        1        0        5
 ____________      ..   ..   W4   W4   SS   B4

           0.48     0.80     2.15     0.28     0.89
        Cut Off       83       27        3      113
 ____________      W4   ..   W4   W4   B4   B4

           0.24     0.89     0.64     0.09     0.80
            BDD       92        8        1      101
 ____________      W4   ..   W4   ..   SS   B2

           4.00     3.24     9.57     0.93     3.67
    TA Less BDD      336      120       10      466
 ____________      B2   ..   W4   W4   B4   B4
```

	Row
• Type of indicator (data type)	1
• Type of comparison for significance	3
• Population space boundary	2, 6, 7, 8, 9
• Population time boundary (t)	4, 5
• Event generation details	10, 11, 12, 13

(Row 12 is measured traffic dispersion from the stations of row 10 to the defined population space. Row 13 is measured seasonal traffic variations for the defined population time).

• Total observed events (N)	14
• Failure events "TA" rate (a)	15
• Failure events "TA" data (A)	16
• Significance of failure event	17

(Left hand symbol is (SB) of Fig. 4)
(Right hand symbol is (S) of Fig. 4)

For row 17 a series of short hand symbols have been developed for stating the significance of the two deviations (SB) and (S). In each case two characters are used under the following convention.

W2 — the result is worse, confidence 2 to 3 sigma
B3 — the result is better, confidence 3 to 4 sigma
.. — the result is not significantly different
W4 — the result is worse, confidence over 4 sigma

This method allows managment to quickly recognise where or when action limits are exceeded or weaknesses exist. As action limits are usually specified as 2 sigma (97.5% confidence) there seems little point at first in resolving sigma into the intervals of 2-3, 3-4 and 4-. This is done to provide some flexibility to management for the allocation of scarce resources in the maintenance work force such as skilled manpower. All trends to poor performance are underscored by the computer for quick recognition by users. The monotony of large reports is also relieved by this practice.

Some of the structural advantages to a statistical report that the format offers are:

i) All parameters of the sample can be shown in less space than graphs, pillargrams, etc.
ii) Following from (i) the report is auditable.
iii) Typing effort greatly reduced.
iv) No drafting effort required.
v) NPAC staff may progressively store data on computer file direct from the field returns.
vi) Faster production of reports as the need arises.

CONCLUSION

Much of the content of this paper could come under the general heading "ethics of statistical reporting." As such the author feels obliged to point out an important omission in the output of **Table 3.** I refer to the lack of a statement or quantity which would indicate the bias contained in the sampling process.

Bias could be defined as that portion of the population space and time that had nil or relatively small chance of being available to the sampling method. Some work has already been done in this direction but much more is needed to close the ethical gap in presentation. Meanwhile a subjective assessment would accompany each statistical table somewhere in the report. No refinement in mathematical analysis will compensate for hopelessly biassed sampling procedures.

Another important conclusion from this paper is that TA complaints could now be used as the sole network indicator. This is because a correlation has been established between TA and the centralised service assessment sample for (f). Elimination of a costly and low accuracy measurement technique could therefore be contemplated.

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4. Telecom Australia, "A course in Telephone Traffic Engineering," 1967.

APPENDIX 1 List of Mathematical Symbols

A	Customer technical assistance complaints
a	Customer technical assistance complaints rate
b	Target rate
B	Failure mode scaling factor
e	Customer dissatisfaction equivalent call failure rate
F	Call failures due to network faults
f	Call failures rate due to network faults
g	$= f + e$
H	Average holding time of calls
h	Hypothetical population mean
N	Total customer calls
n	Sample size for (f) measurement
p	Mean (f) from many samples
R	Customer irritation factor
S	Sigma's of significance between two samples
SB	Sigma's of significance between sample and target (b)
t	Time
Δ	Standard error in following parameter

The Remote Monitoring of Building Fire Alarms

A. J. LEVERENZ B. Tech. B.Ec. MIE Aust.

Many of Telecom Australia's buildings are in remote localities and the fire detection system in those buildings is connected to the local fire service siren; it is essential to monitor the fire detection system to ensure that it is not faulty. Access to a building is given to the local fire service volunteers and this access is a security risk.

The remote fire/fire-fault monitoring system was developed to overcome the above problems. The system handles a multiplicity of alarm extension methods; it incorporates a means of obtaining greater light output from LED'S, is able to work where there is a high level of lightning activity and is fail-safe. This article outlines the implementation of this system in South Australia.

INTRODUCTION

In the days before subscriber trunk dialling, many country towns were served by either a manual telephone exchange or a small automatic local exchange together with an associated manual trunk exchange. A key for access to an unattended automatic exchange, or for any other Commission building, was usually held in the operator staff area and alarms from fire alarm panels serving buildings in the area were extended and monitored by the manual exchange staff. With the progressive introduction of STD into the network, the number of manual assistance centres has decreased markedly and this has posed several building surveillance problems.

Firstly, where can a key be left to provide authorised and responsible access to a building? Country areas are usually served by voluntary fire services, and a system where access to a key is such that only volunteers who attend the fire call can obtain the key is a complicated security problem. Secondly, the fire alarm board in a remote building extends an alarm if a fault on the building detection system develops and this fault condition needs to be monitored to avoid a false sense of security. The main faults that occur are an open circuit wire to a fire detector or an inverter failure.

The solution adopted in South Australia is to centralise the surveillance of buildings in an area with a 'watching station' calling out Telecom Australia staff

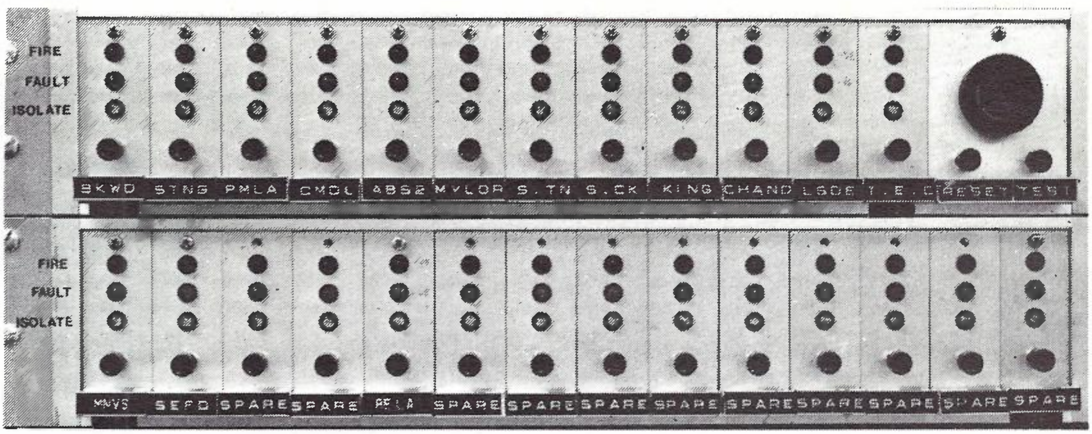


FIG. 1 — Rack Mounted Panel in a Suburban Exchange

Table 1 — Alarm Extension Methods

Extension Method	Received Signal	Typical Resistance Range (Ohms)
Cable	Resistive Battery	0 - 3000
Cable	Resistive Earth	0 - 3000
Open Wire	Resistive Battery	0 - 800
Open Wire	Resistive Earth	0 - 800
E&M leads	Earth	0
FIR-FUR-LT	Earth	0
FIR-FUR-LT	*Resistive Battery	300 ≠

* After modifications are completed. ≠ Current limiting resistor.

where possible, who would attend the station, open the building for the fire service, assist with the investigation and lend support where required. The fire alarm is usually connected directly to the town's fire siren as well. The watching station also receives an alarm if there is a fault on a fire alarm panel and notifies designated technical staff. Appropriate arrangements are made for the location of keys when Telecom staff are not locally available.

METHODS OF ALARM EXTENSION

Alarm extensions from fire alarm panels to the watching station make use of available network plant and mainly comprise cable, open wire, signalling circuits for carrier derived channels (E and M leads) and the exchange alarm transfer signalling system (FIR/FUR/LT). In the past, a specifically designed alarm box using relays and lamps was installed in the manual assistance area and relay coils were 'tailored' to the resistive value of either battery or earth, whichever was extended to the watching station. If an alteration was required for the method of extending the alarm, a change in the design of the receiver equipment was also entailed. Consequently, considerable time and effort were expended for each new installation or alteration to the alarm box.

DESIGN

With the above limitation in mind, the design was rearranged to handle a multiplicity of transmission methods, both reliably and with flexibility. The redesigned remote fire/fire-fault unit consists of a panel with plug-in printed wiring boards **(Fig. 1)** with each printed wiring board serving one station and incorporating one fire alarm and one fire-fault alarm **(Fig. 2)**. Links are included on the board to handle battery or earth, whichever is extended **(Fig. 3)**. The transistor voltage DC quiescent values are set so that a variety of resistive paths can be handled and General Electric metal oxide varistors are used for lightning protection.

An audible alarm is provided by a 'Sonalert', while flashing light emitting diodes (LED) are used for the visual alarm; the flashing is used to emphasise the urgent nature of the alarm. This flashing also serves another function which will be explained shortly. LED's were chosen for their reliability of operation, but until recently were limited by rather low light output. As the remote fire/fire-fault panel could be mounted in unfavourable lighting areas, it is essential to provide sufficient light output so that there is no doubt as to which building

A.J. LEVERENZ joined the PMG's Department in 1964 in South Australia as a Technician-in-Training. After working in subscriber and PABX installation areas, he commenced as a Trainee Engineer in 1969. On graduating in 1971 with the Degree of Bachelor of Technology in Electronic Engineering, he worked as a Class 1 Engineer in Transmission and Line Planning. Following a period in Training and Industrial Engineering, he took up a position of acting Engineer Class 2, Engineering, Services & Telepower Section, Buildings Branch. In this position, he specialised in computerised maintenance and fire alarm system design. He is currently acting Class 2 Engineer in the Trunk Service Section.
Mr Leverenz has completed a Bachelor of Economics at the University of Adelaide and is a Member of the Institution of Engineers, Australia.

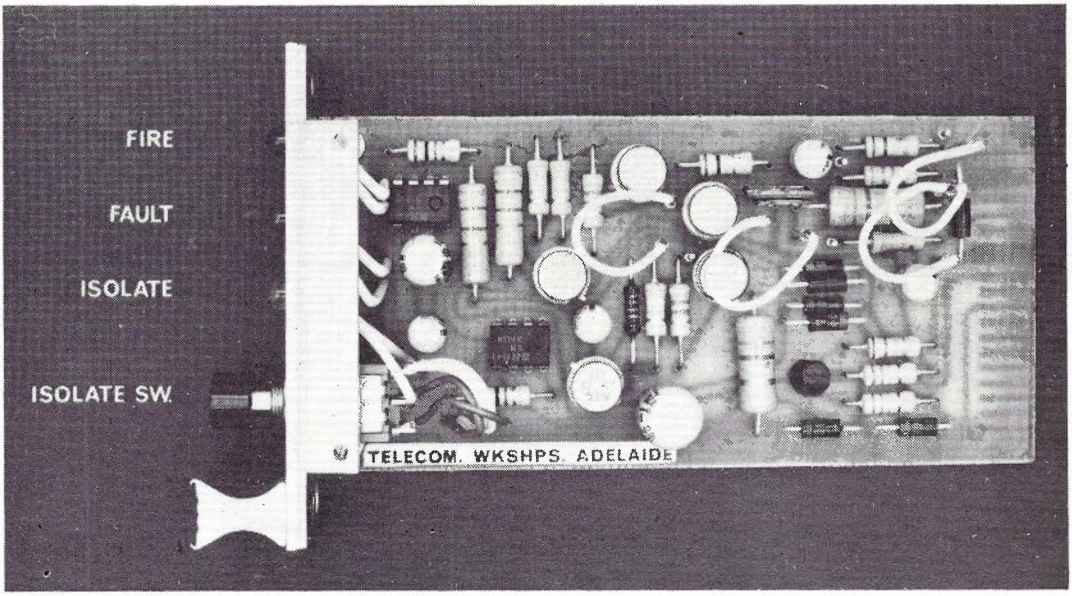
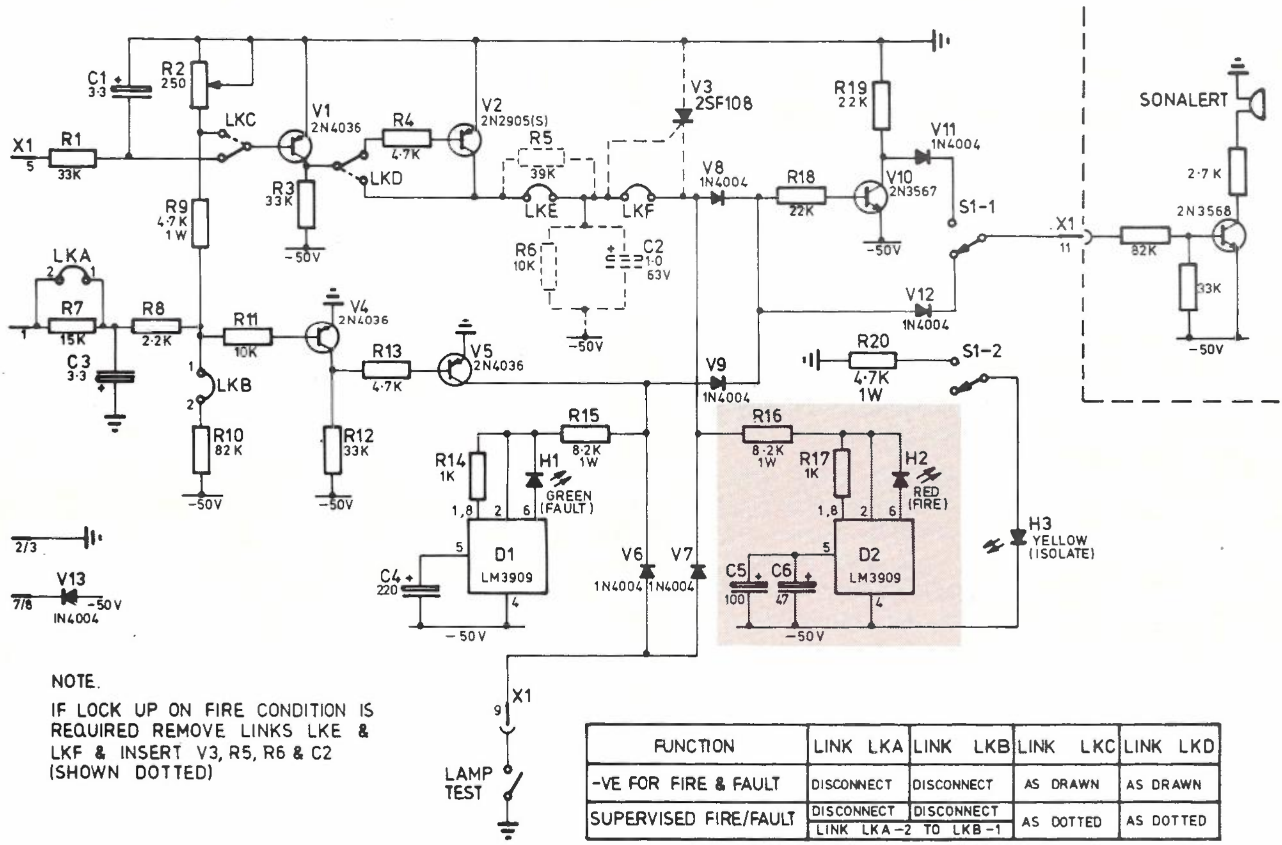


FIG. 2 — Plug-in Printed Wiring Board; Serving One Building



NOTE.

IF LOCK UP ON FIRE CONDITION IS REQUIRED REMOVE LINKS LKE & LKF & INSERT V3, R5, R6 & C2 (SHOWN DOTTED)

FUNCTION	LINK LKA	LINK LKB	LINK LKC	LINK LKD
-VE FOR FIRE & FAULT	DISCONNECT	DISCONNECT	AS DRAWN	AS DRAWN
SUPERVISED FIRE/FAULT	DISCONNECT LINK LKA-2 TO LKB-1	DISCONNECT	AS DOTTED	AS DOTTED

FIG. 3 — Circuit Diagram of Fire/Fire-Fault Board

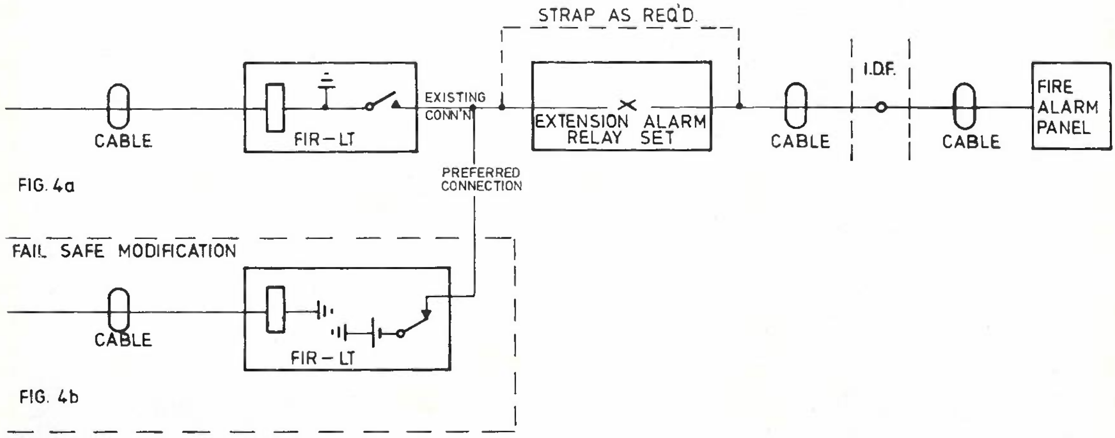


FIG. 4 — Exchange Alarm Transfer Signalling System
(a) Existing Connection
(b) Proposed Modification

alarm is operating. High intensity LED's are now available and cognisance has been taken of the characteristic of the eye whereby a flashing light appears brighter than a constant light source. There is an "effective perceived gain" as far as the eye is concerned. (Ref. 3).

Two properties of the LED are exploited. The life of a LED is proportional to its 'on' time, and if the LED is flashing its life is increased, not decreased, as is the case with other types of lamps. Secondly, if the quiescent current value of the LED is typically 10mA, the LED is able to handle (say) 40mA if it is switched on for one quarter of the nominal duration pulse. The light output is a function of the current, and thus greater light output can be achieved. This property of the LED is combined with the above characteristic of the eye to produce a flashing light signal of suitable intensity. (Ref. 5)

If one of the boards becomes faulty, the local watching station can arrange for the insertion of a spare board and return the faulty board to the Engineering Service Depot. If an alteration is made to the method of extending the alarm by, for example, an open wire route being replaced by cable carrier, the alterations to the remote panel can be made routinely by local technical staff. A saving is thereby made by obviating fire alarm maintenance staff visiting that area. The panel thus provides a gathering point for many remote buildings and indicates the status of those buildings. Controlled action can then be initiated following the receipt of an alarm.

FAIL SAFE EXTENSION

The fail-safe method of extending an alarm is to have battery present during normal conditions and battery off for the alarm. Where open wire or cable is used for extending the alarm, extension of battery is used in preference to an extended earth and any terminating points are protectively sleeved in the usual way as for fire alarm identification. Where a carrier derived channel is used, then earth is extended, and although this is not fail-safe, false operation is prevented by sleeving the terminating tags on distribution frames.

The exchange alarm signalling transfer relay set requires modifications to allow it to be used in the fail-safe mode. As initially designed, the output of the relay set is earth which is applied to the transmission circuit when an alarm condition is present **(Fig. 4a)**. With this arrangement, if the relay set is jacked out, there would be no indication that an alarm condition exists. Modifications are currently being undertaken incorporating a 'battery-off' system which is fail-safe. **(Fig. 4b)**.

INSTALLATIONS

A panel has been installed in the manual assistance centre at Darwin to serve Telecom Australia buildings in the Darwin urban area. The fire brigade alarm system in Darwin has proved unreliable during lightning activity and therefore this system maintains a reliable watch on Commission buildings and assets.

A large wall mounted installation has been made in the manual assistance centre at Mount Gambier. This serves exchanges, broadband radio buildings, and broadcast buildings in the south east of South Australia.

A rack mounted panel **(Fig. 1)** has been installed in an Adelaide metropolitan exchange (Edwardstown) and serves the outer metropolitan area buildings. The metropolitan buildings are covered by the fulltime fire brigade with a fail-safe alarm system. Further panels will be installed in other regional centres in South Australia in the future.

CONCLUSION

The remote fire/fire-fault system has been designed for flexibility and reliability. The flexibility is achieved by each printed wiring board being inter-changeable with variations in transmission methods being handled by straightforward link changes. Reliability is achieved by the use of solid state circuitry and exploiting the unique properties of LED's. Replacement value of building and equipment protected is some $9 million for the Darwin urban region, $17 million for the South east of South Australia and $14 million for the Adelaide outer metropolitan area.

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(I.B. refers to the "In Brief" items included in the Journal)

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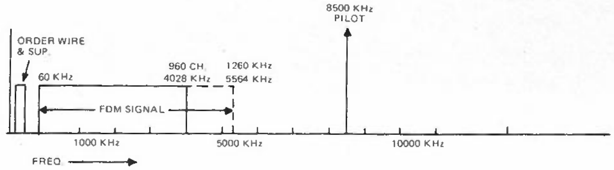
ERRATUM — Vol. 28, No. 2.

DIGITAL TRANSMISSION IN NATIONAL TELECOMMUNICATIONS NETWORKS by W. H. THURMAN.

An incorrect figure has been reproduced for Fig. 19.b in this article. The correct figure provided in this erratum should be pasted over that shown for Fig. 19.b on page 151 of Vol. 28, No. 2.



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The Telecommunication Journal of Australia

ABSTRACTS: Vol. 28, No. 3

ALDERSON, G.J.: "The Touchfone 10 Push Button Telephone"; Telecom Journal of Aust., Vol. 28, No. 3, 1978, page 259.

A locally manufactured pushbutton telephone, Touchfone 10, has now been released by Telecom Australia. Sophisticated semiconductor technology has been employed to realise the user-advantages of pushbutton dialling and to comply with the exacting requirements of the Australian telephone network. This paper gives the background of the Touchfone 10 development, and describes the operation of the pushbutton dial. A summary of the product proving and testing programmes of both the development and volume production phases is also presented.

BATE, W.K.: "Operation and Maintenance of AXE in the Australian Telephone Network"; Telecom Journal of Aust., Vol. 28, No. 3, 1978, page 236.

This paper, one of a series on the AXE System, provides a general description of the operations and maintenance facilities of the AXE system and outlines an organisation for control of the maintenance of the AXE exchanges.

BRANDON, J.S. and McMAHON, B.J.: "Manufacturing Aspects of AXE"; Telecom. Journal of Aust., Vol. 28, No. 3, 1978, page 242.

The characteristics of AXE related to its manufacture are reviewed, the manufacturing processes and test methods described and objectives for integrating AXE manufacture with the existing electronic equipment production at L.M. Ericsson's Australian plant are summarised.

CODY, T.S.: "Recent Developments in Cable Ploughing Techniques"; Telecom. Journal of Aust., Vol. 28, No. 3, 1978, page 252.

In the planning stages and during the first twelve months of the coaxial cable project linking Cobar in New South Wales to Ceduna in South Australia, considerable design and practical effort was directed towards developing a reliable ploughing tractor capable of laying hundreds of kilometres of coaxial cable virtually fault free and at minimal cost. Some of the factors investigated included a reliable cable drum drive, a low coefficient of friction plough box, a reliable ploughing tyne and a communications system on and to the ploughing tractor.

EDMONDSON, J.R.: "Woolloongabba 10C Trunk Exchange — Some Engineering Aspects"; Telecom. Journal of Aust., Vol. 28, No. 3, 1978, page 266.

The Woolloongabba Exchange is typical of the series of 10C Stored Program Controlled Main Trunk Switching Centres being established in the mainland State capitals. The initial three installations were engineered and installed under contract by Standard Telephones and Cables, Pty. Ltd. of Sydney. Woolloongabba is the first large capacity 10C trunk exchange for which Telecom Australia has undertaken the engineering design and equipment installation. This article describes significant design aspects of the project with particular reference to the installation engineering component.

LEVERENZ, A.J.: "The Remote Monitoring of Building Fire Alarms"; Telecom. Journal of Aust., Vol. 28, No. 3, 1978, page 283.

Many of Telecom Australia's buildings are in remote localities and the fire detection system in those buildings is connected to the local fire service siren; it is essential to monitor the fire detection system to ensure that it is not faulty. Access to a building is given to the local fire service volunteers and this access is a security risk. The remote fire/fire-fault monitoring system was developed to overcome the above problems. The system handles a multiplicity of alarm extension methods; it incorporates a means of obtaining greater light output from LED'S, is able to work where there is a high level of lightning activity and is fail-safe. This article outlines the implementation of this system in South Australia.

LEVERETT, R.A.: "Improved Analysis and Presentation of Sydney Network Performance Statistics"; Telecom. Journal of Aust., Vol. 28, No. 3, 1978, page 275.

Classical statistics, network quality control needs and the power of the computer are expanded and blended to produce an improved statistical report presentation primarily for engineering use but also for general appreciation by non-engineering personnel. Emphasis is placed upon the study of variance of network performance data. A formula is derived relating customer technical assistance complaints to call failure indicators.

MARSHALL, R.: "Construction Aspects of the AXE System"; Telecom. Journal of Aust., Vol. 28, No 3, 1978, page 230.

The adoption by Telecom Australia of the L.M. Ericsson AXE and AOM systems will involve the introduction of new switching equipment construction practices. This paper provides an overview of the techniques used in the construction of these systems.

POWER, K.W.: "History of Local Telephone Switching in Australia and Background to the AXE Decision"; Telecom. Journal of Aust., Vol. 28, No. 3, page 207.

Telecom Australia's decision to adopt L.M. Ericsson's AXE system as a new local switching standard for the 1980's and beyond is an important step in the development of the Australian telephone network. The availability of this new stored program controlled (SPC) electronic switching system for urban application will offer great economic advantages in future network expansion and operation. This article gives an outline of the history of local telephone switching in Australia and the background to the decision to buy AXE. The major impacts of this decision are also discussed.

WARD, M.K. and CRAIG, W.R.: "AXE/AOM — Some Design Aspects"; Telecom. Journal of Aust., Vol. 28, No. 3, 1978, page 217.

The relatively unique development history of AXE is discussed; followed by an outline of the basic design principles underlying both the AXE and AOM systems. The functional structure of both systems is described and the sub system functions are presented. Finally, software support for both systems is discussed together with an outline of the facilities available for the management of software.

THE TELECOMMUNICATION JOURNAL
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Volume 28, No. 3, 1978

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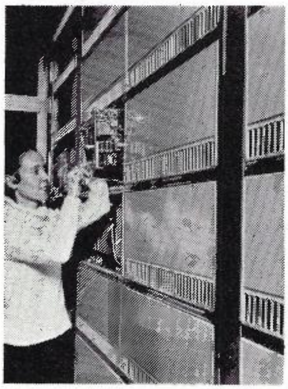

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AXE LOCAL — SWITCHING EQUIPMENT

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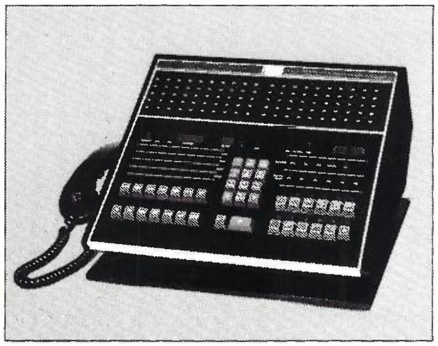

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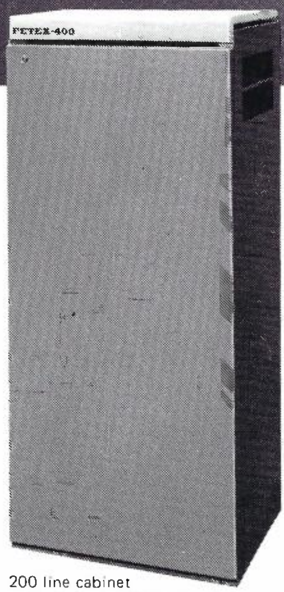

200 line cabinet
1,280(H) x 510(W) x 710(D)mm

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