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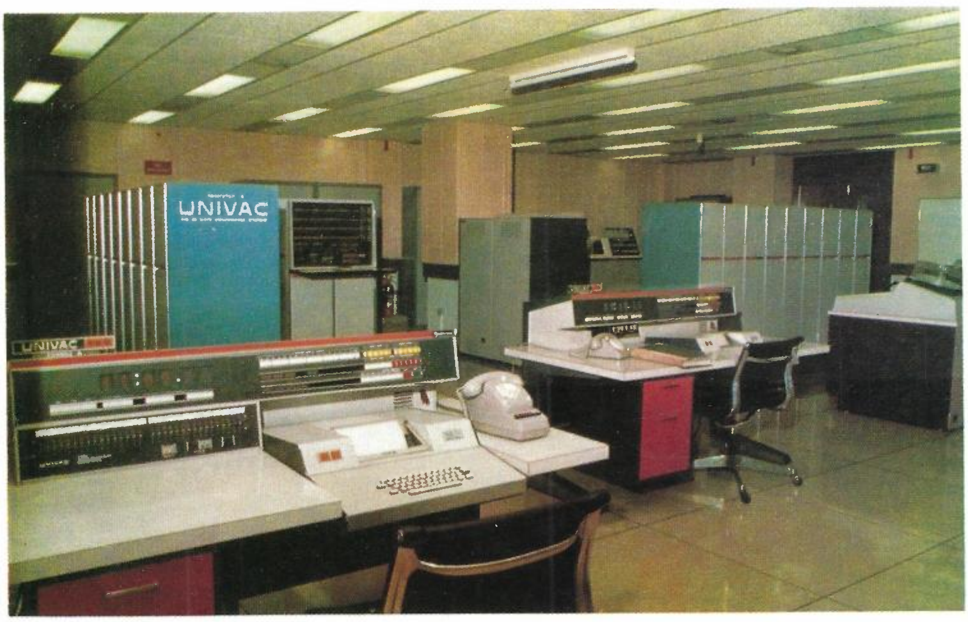

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THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

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COMPUTER ROOM
BRISBANE CUDN CENTRE

The Telecommunication Journal of Australia

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Common User Data Network - Part 1

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The Australian Common User Data Network (CUDN) is a store and forward message switching system designed to transfer data quickly and reliably from one location to one or more specified distant locations. Magnetic disc packs perform the storage function and computers perform the routing function. Several customers with independent sets of conventional and modern terminal devices can use the equipment concurrently and continuously without affecting one another in any way.

This is the first of three articles on CUDN and will describe the network facilities and the hardware used to implement them. The second article will describe the software programs necessary to control the hardware and switch the data from input to output. The third article will describe how the APO and the customers supervise the flow of traffic through the network.

INTRODUCTION

The schedule for the Common User Data Network (CUDN) was issued by the APO in 1969 and several tenders were received from suppliers of computer based communications systems. The Sperry Univac Division of Sperry Rand Australia (UNIVAC) was awarded a contract in 1970, and has complete design responsibility. The APO provides personnel who work full-time under UNIVAC direction in a joint development team. This will ensure that the APO has a sound knowledge of the system when it is fully commissioned.

CUDN is concerned only with switching messages and data. Customers who require data processing, e.g. preparation of accounts, must provide their own customer computing units (CCU) connected to CUDN by a CCU link. Both messages and data are information transmitted in digital form and the terms will be used synonomously in this article. CUDN input and output uses CCITT No. 2 alphabet (5 unit) or CCITT No. 5 alphabet (7 unit plus parity). All 5 unit code input is immediately converted to 7 unit code for storage and routing through CUDN and if necessary reconverted to 5 unit code for delivery.

Message switching is performed on a store and forward basis. Input is accepted continuously and stored immediately to prevent loss or mutilation. Preceding the text of each message is a heading which contains the required output addresses and this is analysed to determine the output routes. A message is delivered when it reaches the head of the output queue. There is never any physical connection between input and output terminals as there is in the telex and telephone networks. The terminals need therefore be compatible only with the switching equipment, not with one another. It is this feature which enables such a wide variety of terminals to be used. However communication is restricted to one direction only and if communication is required in the opposite direction another message must be sent.

The proposed initial network configuration is shown in Fig. 1. There is a CUDN centre in each mainland capital city and they are interconnected by CUDN links. There is provision for three initial customers each with a CCU for data processing. Two CCU's are connected to Melbourne and one to both Sydney and Melbourne. Each customer has many terminals connected to each centre. The Melbourne centre has interfaces with the telex network and TRESS. The types of terminals used depend on the traffic patterns involved and will be discussed later. The requirements of the initial customers are under constant review and are expected to change frequently. They may not always be provided as shown, or even by CUDN.

FACILITIES

The facilities provided by CUDN are largely determined by customer requirements and cost. All the usual facilities associated with conventional low speed message switching are provided in addition to new facilities associated with modern high speed data switching.

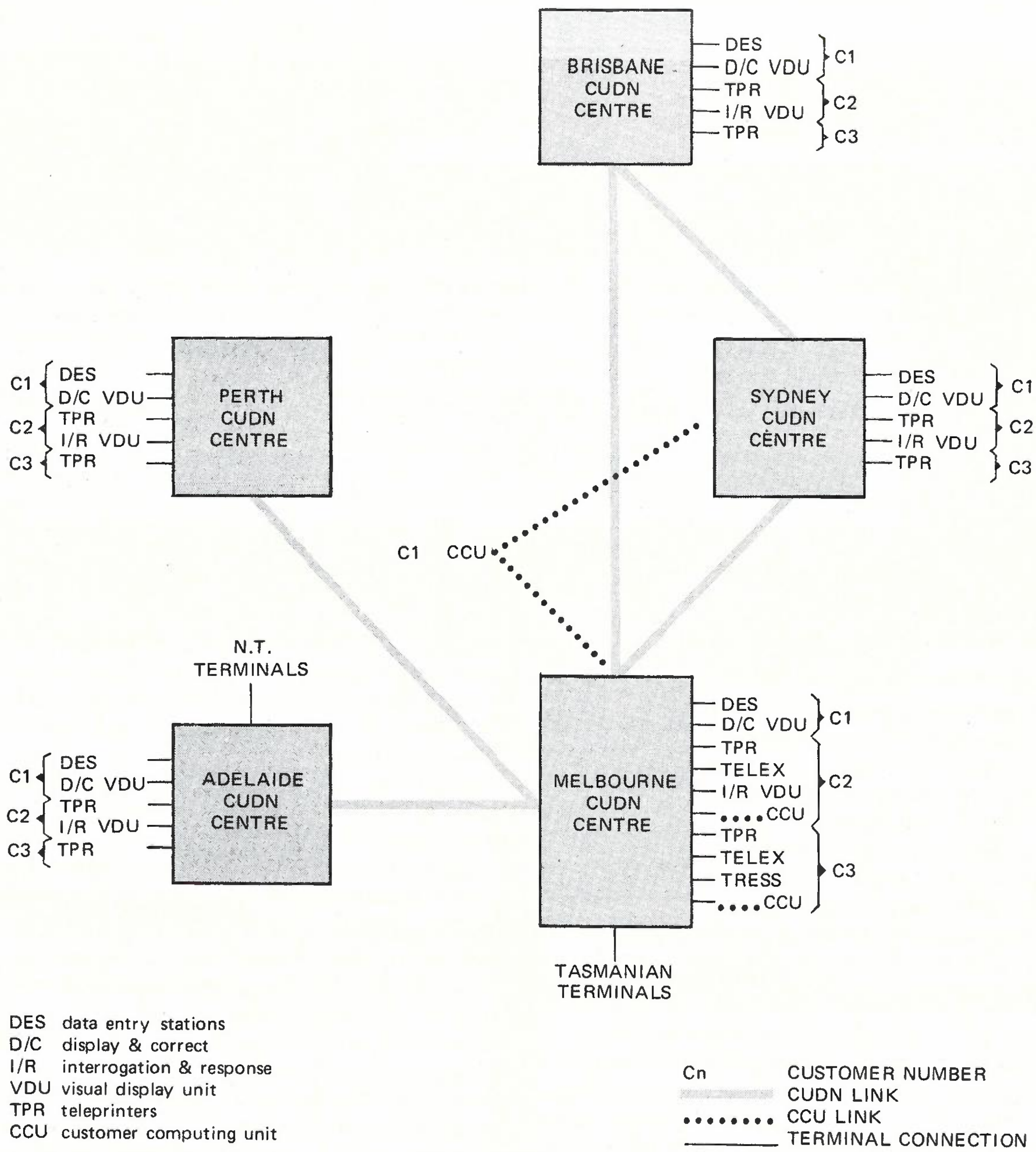


Fig. 1 — Proposed Initial CUDN Configuration.

Output Priorities

Customers may specify that some messages are delivered before other messages by allocating them one of four output priorities. The highest is Priority A and this is reserved for a special type of traffic called Interrogation and Response (I/R) which uses Visual Display Units (VDU) and will be described later. All other traffic is allocated Priority B, C or D. No priority C message will be delivered to a line until there are no priority B messages waiting for delivery to that line and so on. Thus each line requires a separate output queue for each priority that the customer decides to use on it.

Formats

The format is the specified sequence of characters which constitutes the message. Specification is necessary to enable the hardware and software to be designed to analyse each character in turn and know what it represents. Three standard formats are used namely the CUDN format for general use, the International Airline Transport Association (IATA) format for airlines and Priority A format. These will be described later.

Sequence Numbers

Input messages can be numbered sequentially either manually by the operator, automatically by the terminal equipment or automatically by CUDN and output messages are numbered sequentially by CUDN, This enables lost messages to be detected quickly and is convenient for statistical purposes.

Multi and Group Addresses

Each message can be delivered to several output terminals. If the required outputs are specified individually they are referred to as a multi address. If the same set of addresses is used regularly they are given a special single address code called a group address. When this single group address is used messages are automatically delivered to all the terminals it represents. This feature is particularly useful, for example, for the distribution of statistical reports.

Commands

Commands are short messages input from specially designated terminals which enable lines to be opened and closed to traffic, routes to be diverted to other routes and so on. They are the means of supervising traffic flow throughout the network and can be used by customers for their own routes and by the APO for common routes, and if necessary for customer routes.

Alarms

Alarms are short messages generated by the CUDN software and delivered to specially designated customer and APO terminals. They advise the operators of malfunctions which occur during operation such as incorrect formats, sequence number errors, and so on, so that appropriate corrective action can be taken.

Held Traffic

If a customer's computer is unable to receive data due to line or equipment failures, CUDN can store data temporarily on magnetic tapes to prevent disc storage being filled up too quickly and to enable the customer's terminal operators to continue to input data. Later the stored data can be delivered to the CCU at high speed and the backlog quickly overcome.

On-Line Retrievals

All messages can be retrieved, i.e. located and redelivered by the customer up to about three busy hours after they were input. This facility is necessary when messages are not delivered correctly due to mutilations, paper shortage, line faults, etc., and means that the disc packs used for storage must have capacity for three busy hours of traffic.

Off Line Retrievals

Priority B, C and D messages can be retrieved for the customer by the APO up to five days after they were input. About every three hours all the messages stored on disc are transferred to magnetic tapes. These are called history tapes. When a message is required the appropriate tape is selected from the tape storage area and mounted on the tape drive. The computer scans the tape for the required message and delivers it to the nominated retrieval terminal which may not necessarily be the terminal to which the message was originally addressed.

Recovery

All CUDN hardware which is used by more than one line is duplicated to improve reliability. One computer is switching (on line) and the other is spare (standby). The condition of the on line computer is continuously monitored by hardware and software. If a malfunction is detected the on line computer is stopped and the standby automatically assumes on line status without operator intervention and without any interruption to input. Messages which were being delivered are repeated in full.

Accounts

History tapes contain a record of all messages switched by CUDN and are therefore used to extract sufficient details for the preparation of customers accounts as well as for off line retrievals. Every day a special acounts tape is prepared in the Melbourne CUDN centre and delivered by hand to the ADP Branch. The accounts tapes are processed on ADP computers and monthly accounts are sent to each customer. CUDN charges are additional to the normal charges for teleprinters, private lines, telex sevices, etc., associated with CUDN, and are currently being reviewed.

TYPICAL TRAFFIC PATTERNS

The CUDN caters for conventional message switching using low speed teleprinters and modern data switching for collection, distribution, correc-

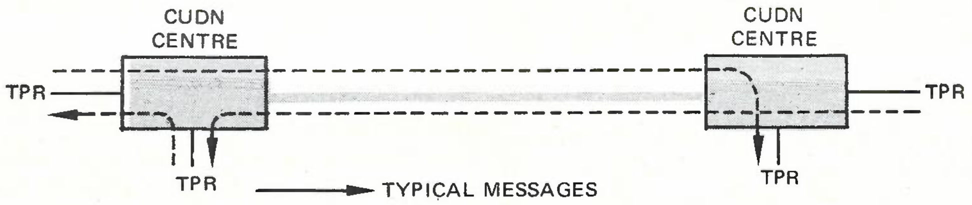


Fig. 2 — Conventional Message Switching.

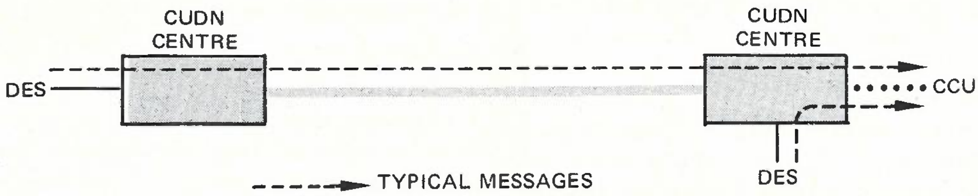


Fig. 3 — Data Collection.

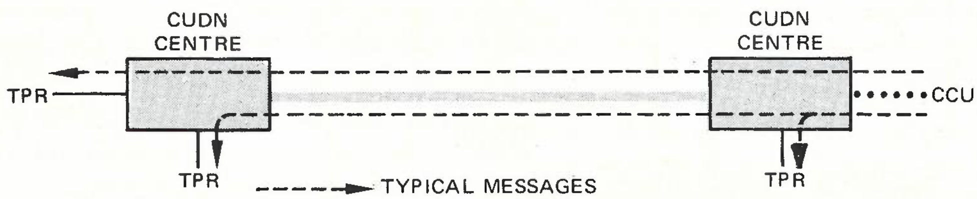


Fig. 4 — Data Distribution.

tion, and enquiry using higher speed terminals such as data-printers, data entry stations (DES) and visual display units (VDU). Each customer usually has more than one type of traffic.

Conventional Message Switching (Fig. 2)

This type of traffic is generated by teleprinters at widely dispersed locations. Each teleprinter has frequent direct communication with many other teleprinters in the customer subnetwork. A large national transport company could use this arrangement for operational control of its vehicles and for administrative purposes such as payroll. In the past this type of traffic has been handled by electromechanical equipment and paper tape telegraph machines, e.g. the TRESS network for public telegrams. Initial customers 2 and 3 can have this type of traffic.

Data Collection (Fig. 3)

This type of traffic is usually generated by data entry stations (DES) located in groups in Capital Cities. Information concerning accounts, spare parts or payroll, etc., is required at the customer computing unit (CCU) from the various locations. Large quantities of data are switched from the remote terminals to the CCU which processes it and subsequently produces account payment cheques, spare parts replenishment lists or salary cheques, etc. All initial customers can have this type of traffic.

Data Distribution (Fig. 4)

This type of traffic is the opposite to data collection. It is very useful for the distribution of statistical reports which the CCU has produced by processing the raw data collected. Usually data would be distributed to terminals other than the originating ones, e.g. stock market details collected from Stock Exchanges would be distributed to stock brokers. Initial customers 2 and 3 can have this type of traffic.

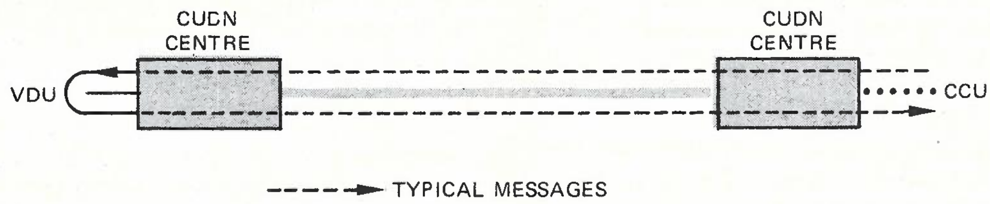


Fig. 5 — Display and Correct.

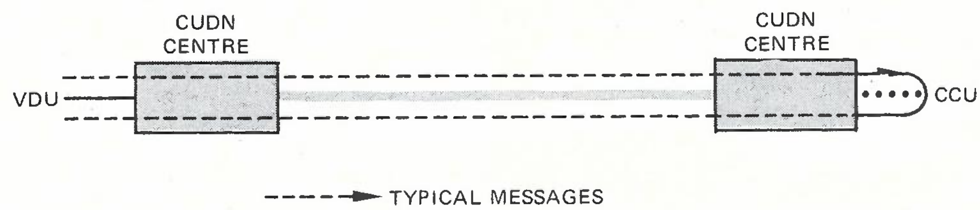


Fig .6 — Interrogation and Response.

Data Display and Correct (Fig. 5)

When large amounts of data are being collected for transmission to a computer it is inevitable that the source of data will contain mistakes which the operators will repeat and that the operators themselves will make mistakes. In the past some form of manual checking or duplication was used to detect these mistakes but CUDN allows the CCU to detect them. Incorrect messages are returned to the operating area and displayed on a VDU. The VDU operator can correct errors using the sophisticated editing featues of the VDU such as backspace and overwrite. The corrected message is then sent back to the CCU via CUDN. Initial customer 1 can have this type of traffic.

Data Interrogation and Response (Fig. 6)

The operations of large companies such as banks and airlines are too complex and variable to maintain in written form and be suitable for quick easy access and quick reliable updating. Customers with a large computer and widely dispersed VDU's can overcome these problems. The operator interrogates the computer for information or alteration and the computer responds with information or confirmation of the alteration. Since the operator may be handling enquiries from clients who are waiting on the telephone for an answer, the turnaround time must not exceed a few seconds. This means the messages must be kept short and switched via core memory rather than the slower mass storage disc. Switching via core memory however means that in the event of equipment failure the data is lost. These are the fastest switched messages and are the only ones allocated Priority A. Initial customer 2 can have this type of traffic.

LINE CONTROL PROCEDURES

Standard telegraph or datel circuits are used for all CUDN connections. Since several types of terminals are used, different line control procedures are necessary to enable them to communicate effectively with CUDN.

Free Wheeling Procedures

Free wheeling means that input can occur at any random time. CUDN must always be ready to accept input from these lines without loss or mutilation. Considerable design effort in both hardware and software has been necessary to achieve this requirement.

Low Speed Polling Procedures

Low speed polling procedures enable up to nine geographically distant low speed stations to use the same line with input from only one station at a time and output only to designated stations. Each station has a unique address code comprising several characters which can be recognised by its selective calling unit (SCU). When a station address is recognised at the head of a message from CUDN that station's teleprinter will be activated and the message delivered. If more than one station started input at the same time the messages would be unintelligible. To ensure that only one station inputs at a time CUDN has control over input as well as output. CUDN sends a special short message called a "poll" to each station in turn. The SCU recognises the unique poll address and interprets it as a "request to send". The input is in the form of paper tape inserted in the gate of a tape transmitter (T108). If there is no tape waiting a special short message called a "no traffic response" is sent. This APO designed T108/SCU equipment has many options and many applications outside CUDN. With polling, input is no longer random and can be stopped if necessary during faults or traffic peaks, simply by not sending the polls.

Telex Procedures

Telex is a circuit switching system using conventional teleprinters and LM Ericsson crossbar ARB and ARM exchanges. The Melbourne CUDN centre interfaces with the Melbourne ARM exchange using software equivalents of the ARM line relay sets. This enables customers to have automatic access to their CCU's from their telex terminals as well as from their CUDN terminals. Each telex terminal which requires access to CUDN has telex category K8. The APO service centre with category K1 also has access to CUDN. Each customer is allocated a telex calling number in the range 070 to 099 so that his particular format can be used on his telex terminal as well as on his CUDN terminals. Telex ensures that the caller has the correct category and CUDN ensures that the caller has used the correct customer access number.

VDU Procedures

VDU's are high speed terminals and because manual operations are relatively slow many VDU's can be connected to one line. VDU procedures allow for polling and selective calling as described for low speed polling. Since higher transmission speeds increase the probability of errors VDU procedures also allow for error detection and retransmission. This is done by a compelled sequence of acknowledgements. When a message sent in one direction is received correctly a special short group of characters called an "acknowledgement" is sent in the opposite direction and the sender then knows his message was not lost or mutilated. If either the original message or the acknowledgement is lost or mutilated the message is retransmitted.

Once a message is sent no other messages can be sent in either direction until it is acknowledged. After several unsuccessful attempts an alarm is generated.

Link Procedures

A link is the connection between a CUDN centre and another CUDN centre (CUDN link) or a CUDN centre and a customer computing unit (CCU link). Each link can have up to seven full duplex circuits operating at 4800 bit/s using APO modems. The link procedures are implemented in software and all computers in the network must use them. They arrange the orderly transmission of messages on a priority basis and provide for error detection and retransmission.

All messages are split up into information blocks of 240 characters of text plus 10 characters of identification. Priority A messages must not exceed one information block in length otherwise they are automatically changed to priority B. Priority B, C or D messages must not exceed 16 information blocks. Every information block must be received correctly and acknowledged. When all blocks of a message have been received correctly an acknowledgement is sent for the whole message. The blocks comprising a message may use different circuits on the link and may therefore arrive out of sequence but must be reassembled in correct sequence. Control blocks of 6 characters are used for acknowledgements and other functions. If data received is faulty a negative acknowledgement is sent and the block is retransmitted. If no acknowledgement is received in a specified time either the block or the acknowledgement was lost and the block is retransmitted.

FORMATS

CUDN has three standard formats — CUDN, IATA and Priority A.

CUDN Format (Fig. 7)

The CUDN format has been specially designed for general use in CUDN. It has five sections the main contents of which are given below.

Preamble

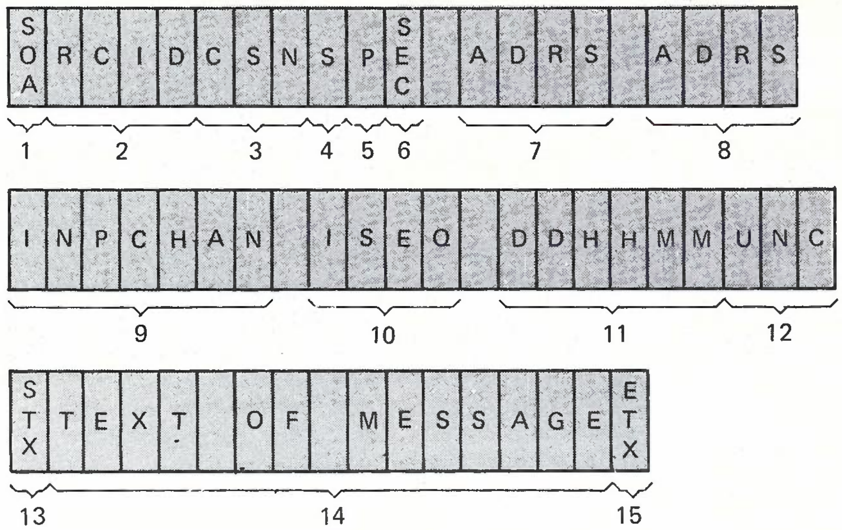
This section contains the input terminal identity and input sequence number. This information uniquely identifies the message and is used for reference and retrieval purposes.

Address

This section contains the addresses of the terminals to which delivery is required, the priority of the message, and the type of message (normal, command, diverted, etc.). This information enables all the routing requirements to be extracted and implemented.

Reference

This section contains the input details and the



PREAMBLE SECTION:
1. START OF ADDRESS CHARACTER
2. INPUT CHANNEL IDENTITY (4 CHARACTERS)
3. INPUT SEQUENCE NUMBER (3 CHARACTERS)

ADDRESS SECTION:
4. STATUS CHARACTER (N = NORMAL, ETC.)
5. PRIORITY CHARACTER (A,B,C OR D)
6. SECURITY CHARACTER (A,B OR C)
7. ADDRESS OF REQUIRED TERMINAL (4 CHARACTERS)
8. SECOND ADDRESS REQUIRED ETC.

REFERENCE SECTION:
9. INPUT CHANNEL IDENTITY.
10. INPUT CHANNEL SEQUENCE NUMBER.
11. INPUT TIME IN DAY, HOUR, MINUTE FORM
12. NATIONAL SECURITY (3 CHARACTERS).

TEXT SECTION:
13. START OF TEXT CHARACTER.
14. TEXT OF MESSAGE (MAX. 3840 CHARACTERS.)

ENDING SECTION:
15. END OF TEXT CHARACTER

Fig. 7 — CUDN Format.

time of entry. It enables customers to have input details delivered with the message so that the receiver knows where the message came from and when it was input.

Text

This section contains the text of the message.

Ending

This section contains the ETX (end of text) character.

IATA Format

The IATA format is an international standard airline format. It also has five sections with contents similar to the CUDN format, but there are different indications between sections, seven character addresses rather than four character addresses, and a different arrangement of spaces and line feeds.

Priority A Format

Priority A format is used by interrogation and response VDU's. There are three sections:

Heading

This section is made up by the CUDN and has five characters containing similar information to the preamble and address sections of the CUDN format.

Text

This section contains less than 240 characters or the CUDN will convert the message to Priority B.

Ending

This section contains the ETX character.

Format Options

It is usually desirable to reduce operator activity to a minimum by avoiding repetitive tasks. Some of the information in the format is the same for all messages from particular terminals and it is annoying if it must be typed in for every message. Parts of the format which can be fixed on a customer basis or calculated by CUDN are there-made optional and the customer may elect to enter them manually or have them automatically inserted by CUDN. For example all items in the preamble and address sections of CUDN format are optional including the actual addresses because some terminals may be allowed to send only to the CCU and this fixed address can be inserted by CUDN. IATA format also has optional elements but Priority A format is fixed.

TERMINALS

Teleprinters

Conventional teleprinters with keyboard and page copy and with or without paper tape attachments are used for message switching. They use CCITT alphabet No. 2 and operate at 50 or 75 bit/s.

Tape Transmitter (T108) and Selective Calling Unit (SCU)

When many teleprinters are connected to one line, input and output is controlled by CUDN using a T108 and an SCU at each station. Output can be directed to particular terminals and input is accepted from one station at a time by polling them in turn. Automatic numbering and header generation is provided by the T108.

Dataprinters

Dataprinters are modern types of teleprinters used in CUDN mainly for subnetwork supervision. They use CCITT alphabet No. 5 and operate at 110, 150, or 300 bit/s.

Data Entry Stations (DES)

Data entry stations are modern keyboards without page copy used for entering large volumes of data and requiring very competent operators. They were specially manufactured by a private contractor for an initial customer. They use CCITT alphabet No. 5 and operate at 150 bit/s.

Visual Display Units (VDU)

Visual display units comprise a cathode ray tube controlled as in a commercial black and white television receiver. They display alpha numeric and control characters by means of dots or strokes. A 7 x 5 dot matrix can be used to form all the characters either received from the line or typed on the associated keyboard for transmission to line. They use CCITT alphabet No. 5, operate at speeds up to 4800 bit/s, and require APO modern interfaces. They have sophisticated editing facilities which enable errors to be corrected quickly by backspacing and overwriting. The cursor shows the position on the screen where the next character received from line or keyboard will be displayed and this position can be set from the keyboard or by the distant computer.

Customer Computing Units (CCU)

Since CUDN only switches data from one location to another customers must provide their own computers to perform any data processing they require. These computers are not necessarily the same type as the CUDN computers. Provided they support CUDN link procedures there is no restriction on the type or size of customer computers.

Concentrators and Multiplexers

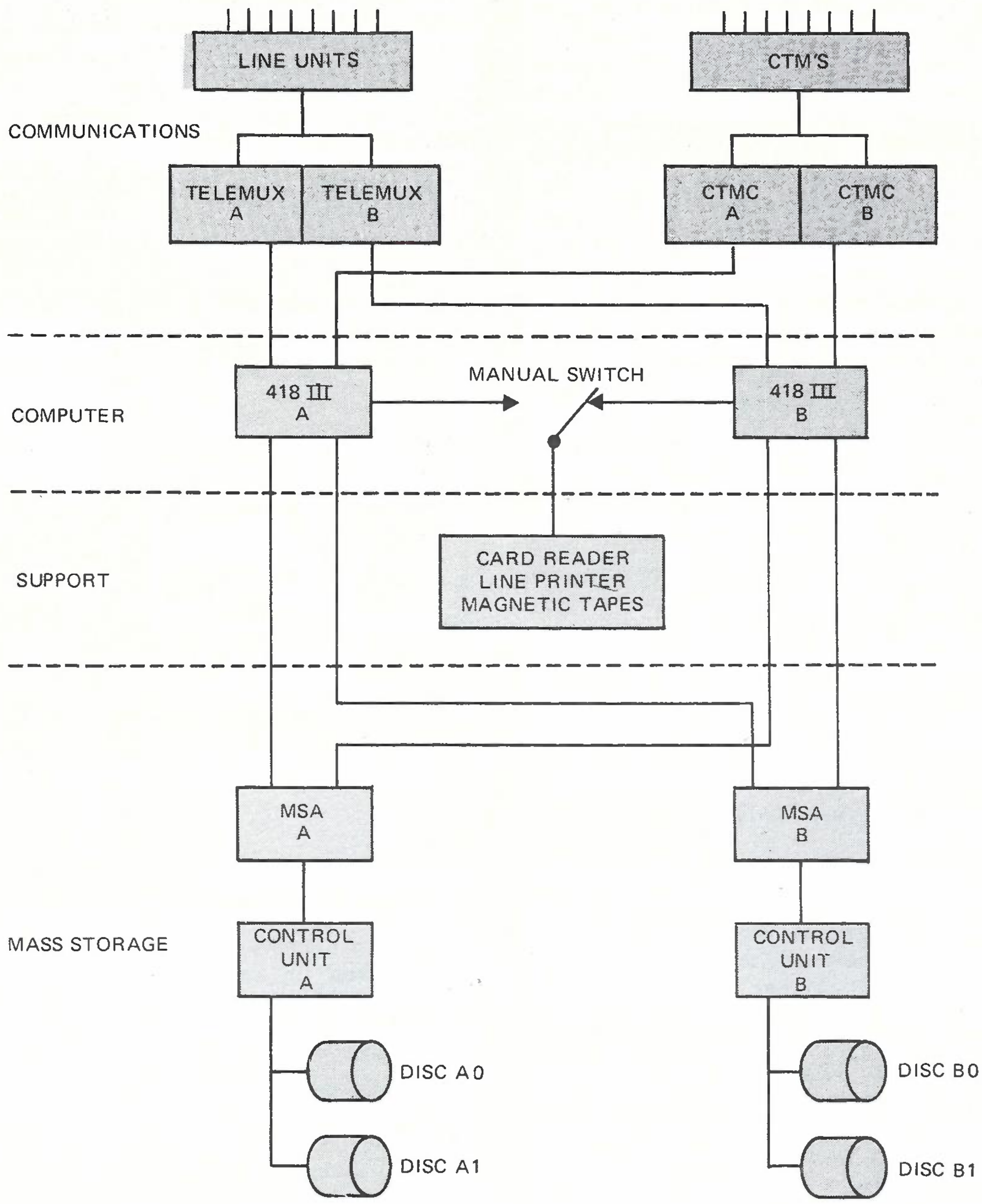
Maximum utilisation of a line usually cannot be achieved unless many terminals are connected to it. Several low speed terminals may be concentrated into one high speed line so that all can operate simultaneously. Parallel low speed inputs become a series high speed output. Mini computers are ideal for this purpose. Also several high speed terminals may be connected to one high speed line so that only one uses the line for transmission at any time. VDU multiplexers are ideal for this purpose because each operator spends most of the time typing or waiting and this time is available for transmission to and from other VDU's.

Telex Telemetry Stations (TTS)

These are ordinary telex services with a code recognition unit which activates a special attachment. After a telex call has been established receipt of the code SSSS will cause the attachment to transmit previously automatically recorded information to the caller. An approved attachment can be connected to an unattended telex terminal and interrogated when required by CUDN.

SWITCHING EQUIPMENT

Switching equipment is installed in Brisbane, Sydney, Melbourne, Adelaide and Perth, and a typical configuration is shown in Fig. 8. There are four types of equipment — communications, computer, mass storage and support.



CTMC — COMMUNICATIONS TERMINAL MODULE CONTROLLER

MSA — MULTI-SUBSYSTEMS ADAPTOR

Fig. 8 — Typical Hardware Configuration.

Communications Equipment

There are two types of communication equipment — telemux (telegraph multiplexer) and CTMC (communications terminal module controller). Both types send to both on line and standby computers but receive only from the on line computer.

Telemux

The telemux has been specially designed for CUDN to reduce hardware cost per line. It caters for inputs of 50, 75 and 150 bit/s in No. 2 and No. 5 alphabets and outputs of 50 or 75 bit/s in No. 2 alphabet. Bit serial information on the single input line is recognised as changes of state from mark to space or space to mark. The computer is notified every time any line changes state, and the software uses this information plus regular time pulses to reassemble characters for further processing. For output the lines are arranged in rows of 16 lines each and the computer sends line states row by row which the telemux gates to the appropriate lines. Telemuxes are equipped with 128 or 512 lines (8 or 32 rows) and the software must output the line states at the correct times. Since stop pulses in No. 2 alphabet can be one and a half elements (30 ms for 50 bit/s and 20 ms for 75 bit/s) the computer must specify the output state of every line once every half element i.e. 10 ms for 50 bit/s and 6.67 ms for 75 bit/s. All lines in the same row must have the same speed.

Communications Terminal Module Controller (CTMC)

CTMC is a multiplexer for up to 16 CTM's each of which has two input and two output channels. CTM is a serial/parallel convertor interfacing between the bit serial information on the communication line and the bit parallel information on the 18 wire connection to the computer. Two speed ranges are used — low speed up to 300 bit/s, and high speed up to 4800 bit/s. Low speed lines are connected to the telemux if possible but special lines such as 110 bit/s lines are connected to CTMC. High speed lines comprise VDU and link circuits. CTMC has been extensively modified for CUDN to check parity and substitute for illegal characters. Previously these functions were performed by the software so the modification has saved significant computer time.

Computer Equipment

UNIVAC type 418 III computers are used. They have ferrite core memories with a maximum capacity of 131,072 eighteen bit words. The cycle time is 0.75 microseconds and a typical command such as an addition requires two cycles. Parity is checked on every read operation and calculated on every write operation. The memory is expandable in modules of 16384 words to a maximum of 8 modules. The command/arithmetic (C/A) section which interprets instructions and performs computations and the input/output (I/O) section which interfaces with the communication, mass storage, and support equipment both have direct access to the memory. This minimises the involvement of the C/A section and enables computations to be performed during data transfers. Fig. 9 shows the major sections.

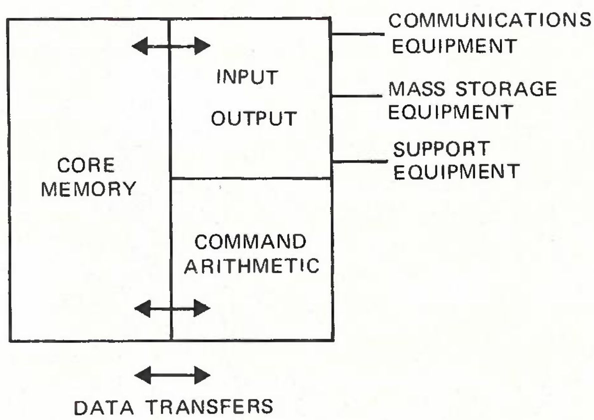


Fig. 9 — 418 III Computer; Major Sections.

Mass Storage Equipment

Mass storage equipment is necessary because ferrite core memory is expensive. Data which has to be stored for relatively long periods without alteration cannot be economically left in core. The mass storage equipment comprises a magnetic disc drive, disc control unit (CU) and multi subsystems adaptor (MSA). Each part is duplicated and both sets are available to each computer. Information is normally written on both discs but read from only one disc.

Magnetic Disc Drive

The magnetic disc, shown in Fig. 10 is a stack of eleven coaxial discs coated with a magnetic material similar to that used on magnetic tapes. For protection purposes the top surface of the top disc and the bottom surface of the bottom disc are not used leaving 20 surfaces for recording data. Each disc has 200 concentric circles or tracks on each of which magnetic heads can read or write 60,000 bits of information as the disc rotates at a constant speed of 2400 rpm. A hydraulic actuator positions the twenty heads fixed to ten arms between the discs over any track specified by the computer. The magnetic heads do not

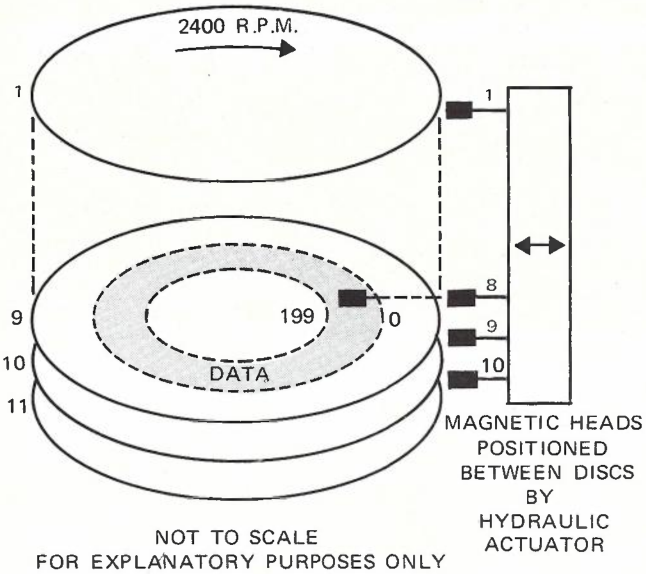


Fig. 10 — Magnetic Disc Pack.

actually touch the magnetic surface. The rotation creates a very thin film of air which keeps the heads separated from the disc or "floating" Precision mechanical construction is necessary to ensure reliable operation.

Control Unit

The control unit enables up to 8 disc drives to be connected to one computer connection.

Multi Subsystems Adaptor (MSA)

The disc is designed to use 8 bit "bytes" and the MSA is necessary to convert these to 18 bit computer "words", and vice versa.

Support Equipment

Support equipment is necessary to install, maintain and expand the software. Programs are initially assembled and entered into the system from a high speed card reader and copies are produced in the high speed line printer. These are controlled by a small UNIVAC type 9200 computer. Hardware and software diagnostic fault routines also require the line printer. Magnetic tape drives are provided for history and accounting purposes in the larger centres. Support equipment is not duplicated.

ACKNOWLEDGEMENTS

The author acknowledges the efforts of numerous past and present members of the UNIVAC, customer, and APO staffs who have contributed to the development of CUDN often under difficult working conditions and thanks his colleagues who suggested improvements to the original draft.

CONCLUSION

CUDN offers attractive message switching facilities for large geographically distributed organisations using very reliable electronic equipment. It is a very large complex system and has required many man years of effort. This article attempts to explain what CUDN does (facilities) and what equipment it uses to do it (hardware). The next article will explain in general terms the software programs necessary to control the hardware, accept input, analyse headings, store data on disc, and deliver output. At any time there may be hundreds of messages being switched at different stages and the software necessary to perform the various tasks in an orderly manner is complex but extremely interesting.

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An Historical Survey of Communications Satellite Systems (Part 2)

M. BALDERSTON, B.S.E.E., M.S.E.E., M.I.E.E.E., M.A.C.M.

Part 1 of this Survey discussed the early history of communications satellites and discussed the characteristics of the Intelsat, Western military, and Russian Orbit satellite systems. Part 2 reviews the different types of satellite systems and outlines experiments which have been undertaken on certain advanced technical and operational features. The Canadian domestic satellite system is discussed.

INTRODUCTION

Part 1 of this survey described the early history of communications satellites and discussed the characteristics of the Intelsat, Western military, and Russian Orbita satellite systems. Before continuing with the description of existing and planned systems, it will be useful to review and compare the different types of communications satellite systems. For example, each different satellite orbit—low random, geostationary, pseudosynchronous—has its own advantages and disadvantages, and imposes different requirements on the system and the spacecraft.

Although satellites are well into the operational deployment stage (it is nearly ten years since the first commercial communications satellite went into service), the need for experimentation with advanced technical and operational features continues. Some of the more significant completed and proposed experimental satellite programs are described.

The last section of Part 2 discusses the Canadian domestic satellite system. This is the Western World's first national system, and of particular interest for Australia because of the similarities between the two countries.

In the third and final part of the survey, descriptions of several other systems and discussions of operating frequencies and launch vehicles will be followed by a concluding section summarizing present trends in satellite communications and their significance for Australia.

COMPARISON OF DIFFERENT SYSTEM TYPES

Passive Reflectors

The simplest satellite is a passive reflector, and the superficial appeal of this simplest system led to the Echo and West Ford experiments, as well as a demonstration by AT & T which used the moon as a reflector. The orbit must be high enough to eliminate all atmospheric drag, but it must be as low as possible to limit the free-space transmission loss which increases as the square of the total length of the signal path, in both directions. The best compromise between these requirements still results in an unacceptably high transmitter power, too narrow a bandwidth, or both. In addition, most of the disadvantages of the medium-orbit system apply to these passive reflector systems as well.

Low-orbit Systems

The low- and medium-orbit active repeater systems such as Telstar and Relay have three advantages over the geostationary repeater. These are the lower launch vehicle capability required (or alternatively the greater payload capacity of a given launch vehicle), the much lower transmission loss because of the shorter path length, and the negligibly small signal delay. On the debit side, whereas a single geostationary satellite can provide continuous coverage for a whole country or region, many lower-orbit satellites would be required (between 8 and 20 depending on the particular orbit chosen). Since an earth station must track the satellite as it crosses the field of view, and switch to the next as the first passes outside that field, two antennas each providing a relatively high tracking rate are required. Two stations communicating with each other must switch from one satellite to the next simultaneously in spite of the fact that their fields of view in general are quite different. This synchronization problem becomes much worse as more stations are added, for example a TV transmission from one station to several others. Partly offsetting the lower path loss is the requirement for broader coverage and therefore lower gain from the spacecraft antenna, as compared with the geostationary case. And finally, the few hundred to few thousand kilometre altitude of these orbits puts them in the earth's radiation belts, which degrade the performance of the electronics unless special measures are taken. In the case of the solar cells which provide power to the spacecraft this is a particularly severe problem since the protective measures (shielding over the cells) themselves degrade the performance. On balance, then, lower-orbit systems are distinctly inferior to the geostationary one.

As the orbit altitude of a random-coverage system is raised, it approaches the characteristics of a geostationary system. The US military IDSCS was such a near-stationary system, the apparent drift of a typical satellite being about 20 degrees per day. This low drift rate greatly simplifies the tracking, switching, and synchronization problems and, of course, the satellite is no longer in the radiation belts. Compared with the geostationary case the chief advantage is that the spacecraft is much simpler. No provision for stationkeeping is required, which means typically a saving of perhaps 100 kg and the complexities of a control system. This control system and the possibilities it offers for hostile interference is of great concern to the military. By setting the orbits such that any earth station always sees at least two satellites spaced by at least 20 degrees, no provision of eclipse operation is necessary, saving about 25 kg for batteries and charge-discharge electronics. It is possible to provide high-gain satellite antennas and thus partially offset the greater path loss compared with a lower orbit system although this was not done in IDSCS. The chief disadvantage of the near-synchronous compared with the geostationary system is that many satellites (about 20) are required for continuous coverage. IDSCS used 26 for global coverage, but almost as many would still be necessary for a limited area such as Australia. Because of this the geostationary system turns out to be more desirable economically.

Geostationary Systems

The geostationary orbit proposed by Arthur Clarke has several advantages compared with the other systems. Earth station antenna tracking requirements are much reduced, in fact with present-day satellite stationkeeping most of the antennas in a national system do not need *any* tracking capability. Only one spacecraft is required for such a system although more might be provided, for example to increase system capacity by re-use of the frequency spectrum, or for redundancy to increase system reliability. In Australia's case, the satellite can be positioned so that it is at a high elevation angle at all earth stations, which reduces interference with the terrestrial network, and also avoids propagation problems associated with near-horizontal signal paths. There are many disadvantages but as far as Australia is concerned none is serious. The large transmission loss for the geostationary altitude may be overcome with high gain antennas and low-noise receivers. The signal delay of about a third of a second was of great concern initially, but this has not turned out to be serious. Double hops such as might be experienced by a caller reaching an international port via domestic satellite and then overseas via an Intelsat spacecraft *are* a problem. It is possible to incorporate protective routing to prevent this situation. However, in some circumstances even a double hop may be acceptable, as shown by the fact that in the Intelsat network there are a number of permanent double-hop circuits.

There are two control problems which must be taken care of. First there is the need for stationkeeping, that is, maintaining the position of the spacecraft at a particular longitude and at the equator. It would be possible to provide facilities in the satellite to do this automatically, but the more usual procedure is to provide tracking and command earth stations, which can be co-sited with communications terminals. Even with a self-contained stationkeeping system it would be desirable to monitor the satellite's position, and some command functions would still be necessary (for example, to turn transponders on and off as needed). Since the ground facilities would be provided in any case, it makes sense to keep the spacecraft simple and put the stationkeeping control on the ground.

While the ground facilities provide the "brains" for stationkeeping, the satellite must still supply the "muscle". This is in the form of several small jets which manoeuvre the spacecraft by reaction. A number of advanced reaction systems such as ion drives are under investigation. For the foreseeable future, however, the tried and proven hydrazine monopropellant system is likely to remain the standard stationkeeping mechanism. Hydrazine alone is very stable, but when passed over a catalyst it dissociates into hydrogen and ammonia with a great increase in pressure. The tanks, lines, valves, and jets of this system now have an indefinite life, and the spacecraft electronics expected life is over 20 years, so at present the limit to a satellite's lifetime is determined by the amount of hydrazine fuel it can carry. It would be possible to build a satellite with a very long lifetime by providing a large amount of hydrazine, but this would mean a very small communications capacity. Conversely, higher capacities than used at present could be provided at the expense of stationkeeping fuel and thus lifetime. The typical present-day satellite lifetimes of 7 to 10 years represent a compromise between capacity and stationkeeping fuel.

The second control problem is concerned with the provision of a high-gain, limited-coverage satellite antenna. As the antenna beamwidth is reduced, the accuracy with which it is aimed must be improved. An elliptical antenna pattern suitable for coverage of Australia, is about 4 degrees by 7 degrees, so the necessary pointing accuracy is better than half a degree. As with the stationkeeping, it would be possible to provide for a self-contained antenna pointing system using astronomical references (sun, moon, stars, earth horizon). A simpler system uses a beacon signal transmitted from one of the earth stations, which the satellite can lock on to. The details of the antenna pointing system will depend on the spacecraft stabilization method used, spinning or body-stabilized. For a spin-stabilized satellite the motor used to despin the antenna may be phased to provide pointing control in one direction, and the stationkeeping jets can be designed to give control in the other. For a body-stabilized satellite the antenna would normally be fixed to the body, so antenna pointing is accomplished by adjusting the spacecraft attitude, and this could also be done with the stationkeeping jets. For both types of stabilization the amount of fuel required for attitude/antenna control is a small fraction of that for stationkeeping.

Sun Transit and Eclipse

Two further problems are shared by all communications satellites. These are sun transit and eclipse. For the geostationary system both problems occur only for short periods twice a year. Sun transit occurs when the sun appears in the field of view of an earth station antenna which is directed at the satellite. Since the sun emits a great deal of radiation at all frequencies, the result is a large increase in noise at that earth station for two or three minutes on each of two or three successive days. The particular days and the time of day will vary for different earth stations. The simplest way of dealing with this problem is to ignore it and include these short outages in the system performance specification. It would be possible to maintain uninterrupted service by switching to another satellite but this would involve synchronization problems as well as a more complicated earth station antenna system.

Because the earth's equator is at an angle to the plane of the ecliptic (its orbit around the sun), a geostationary satellite is in sunlight for most of the year. For several days around the equinox it passes through the earth's shadow, remaining in darkness for a maximum of about 70 minutes. Since the satellite normally gets its power from solar cells, this means that batteries or some other energy storage device must be provided for any services which require continuous operation. There is no particular difficulty in providing batteries, but their weight subtracts from the part of the payload available for communications electronics. General-purpose satellites such as the Intelsats and the Canadian Aniks have enough batteries for full capacity during eclipse. The eclipse period is at midnight at the longitude of the satellite, so by suitable positioning it is easy to think of services which would not be needed during eclipse.

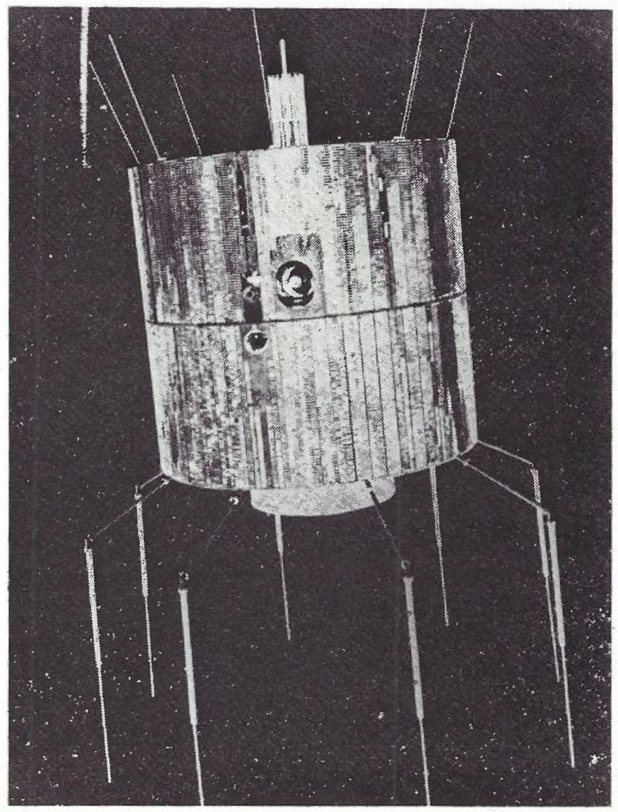

Fig. 1—The 350 kg ATS-1 Satellite was Launched in December 1966. Around the body of the spacecraft may be seen the solar cells which provide its primary source of power. The antennas projecting from the top and bottom of the satellite provide communications in several different frequency bands.

For example, by stationing an Australian satellite about 15 degrees west of Perth, the longest eclipse would be from 12.25 to 1.35 am there, and two hours later on the east coast. Very little television would be broadcast during these hours so any transponders reserved for television would not need eclipse power.

There is one disadvantage of the geostationary system which cannot be overcome. Fortunately it does not apply to national satellite systems such as for Australia. This is the lack of coverage in polar regions. The 12-hour pseudo-synchronous orbit used by the USSR and being investigated by the USAF retains some of the advantages of the geostationary system while providing polar coverage and so it is the only alternative to Arthur Clarke's 1945 proposal which is planned for any future communications satellite system.

Fig. 2—This Antenna is Typical of those which might be used for Providing Communications to Remote Areas via an Australian National Satellite. It is about 4 metres in diameter and uses a relatively simple mount which allows it to be manually aligned with the satellite. In 1969-1970, it was used in an APO demonstration experiment with the ATS-1.

EXPERIMENTAL PROGRAMS

During the time that the first operational communications satellite systems were being introduced, experimentation with new techniques and technologies by no means decreased. In fact, as more countries and organizations gain the necessary skills, and as the area of potential applications widens, the number of experimental programs actually seems to be increasing.

Before discussing the known programs, we can recognize that two groups in particular, the US military and the USSR, carry on a great deal of unpublicized investigation. The experimental satellites put into pseudo-synchronous orbit by the USAF, mentioned above, are typical. Only their existence and that they are communications satellites are acknowledged.

NASA's ATS Program

One of the most significant experimental communications programs is NASA's Applications Technology Satellite (ATS) series. The first, ATS-1, was launched in December 1966, and the last, ATS-6, in May 1974. Three further satellites, -G, -H, and -I* have been cancelled because of budget restrictions. Because so many other organizations are now capable and willing, NASA has decided to discontinue its communications experiments after ATS-6 and CTS (discussed below).

The area of investigation in the ATS program is very broad. It includes non-communications aspects such as earth imagery from synchronous altitude, ranging techniques for tracking satellites, and position location for terrestrial navigation. The communications experiments include propagation measurements at many frequencies, different modulation and multiple access methods, satellite antenna technology such as methods of despinning and the use of large deployable structures, high power transponders for TV "broadcast" (this will be discussed more fully below), communications with ships at sea and aircraft in flight, radio frequency interference (RFI) between satellite and terrestrial systems, and others. Most of the experiments having to do with spacecraft technology are applicable to communications satellites, for example attitude control and stabilization techniques, sensors to verify computer modelling of spacecraft mechanical and thermal characteristics, and measurements of the radiation environment at synchronous altitude and its effect on spacecraft electronics.

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* It has been NASA's custom to assign letter suffixes to spacecraft in their order of construction, and change to a number after successful launch. Thus ATS-A, the first to be built, became ATS-2, the second launched.

ATS-2 and ATS-4 were both the victims of upper stage failures in the launch vehicle, so neither was placed in the correct orbit. ATS-5 has not stabilized properly so that its success has been qualified. ATS-1 and ATS-3 however have exceeded all expectations, ATS-1 still being in use after over seven years in orbit. Besides the experiments mentioned, both satellites have provided many demonstrations, such as TV relays of Apollo 11 splashdown, Expo 67, the Japanese Prime Minister's visit to Australia, Pope Paul's visit to South America, and many others. Of particular interest were the series of experiments with ATS-1 between October 1969 and June 1970 performed by the Australian Post Office, which demonstrated the feasibility of a telephone service for remote subscribers (Ref. 1).

European Program

Japan and Europe both plan experimental spacecraft as pre-prototypes of their operational satellites. In Europe, there are three additional experimental programs: the Franco-German Symphonie, the Italian Sirio, and the British Geostationary Technology Satellite (GTS). Symphonie has been delayed several times because of troubles with the originally intended launch vehicle, the Europa, and then the change to a Delta rocket. It is true that because of the delays there is little in the program which has not been covered elsewhere, although one feature will be unique: a time-division multiple access (TDMA) telephony experiment in which all earth stations are permanently synchronized. Previous and present TDMA systems are asynchronous, requiring a time interval between accesses to allow for separate synchronization for each access. This reduces the system utilization efficiency.

Sirio is a more modest satellite whose function, aside from demonstrating the capabilities of Italian industry, is to provide propagation data at frequencies up to 18 GHz. The GTS will provide both 11/14 GHz and 1.5/1.6 GHz transponders, the former for future commercial communications such as those of Intelsat and the European system, the latter for maritime use. Another experiment is the use of polarization discrimination for frequency re-use.*

Symphonie and Sirio are presently scheduled for launch in 1975, while GTS is planned for late 1976 or early 1977.

* "Polarization" refers to the direction of oscillation of electromagnetic signals such as radio and light waves. It is possible to separate two similar signals if their directions of polarization are mutually perpendicular. This principle is also used in Polaroid sunglasses, where only light of one direction of polarization is passed.

The LCS Consortium

The Lockheed Communications Satellite (LCS) is a unique program. Except for Telstar, most previous satellites have been commissioned by government agencies or consortia. The LCS has been funded by an international consortium of private companies, led by Lockheed Missiles and Space Company*. Since a launch vehicle would cost $15-$20 million, there are no plans at present to launch the satellite. Rather it is intended as a test vehicle for a number of advanced spacecraft features such as electric propulsion for stationkeeping and attitude control, flexible substrate solar arrays, multiple spot beam antennas, and onboard transponder and antenna switching. A full-scale satellite has been undergoing ground tests using simulated space conditions for over a year. The eventual goal of the program is profit for the consortium members, which could come about by the selection of a version of LCS for the Intelsat V mentioned above or for the space component of a US domestic system, or both.

NASA's CTS

NASA's final experimental communications satellite is the Communications Technology Satellite (CTS). This program is a joint effort with the Canadian Department of Communications. The main experiment is a very high power transponder with an operating frequency of 12 GHz. The uses for this transponder which are to be investigated include TV distribution to small communities, TV transmission from remote mobile terminals, sound broadcast to simple receivers, two-way voice communications, and wideband digital data transmission and distribution. In addition to the experimental transponder, the CTS will test several advanced satellite features, such as extendable solar power arrays, liquid-metal slip rings for transmission of power from the solar arrays, new types of jet for stationkeeping, and the use of the small Delta launch vehicle for a body-stabilized synchronous orbit spacecraft. Launch is currently scheduled for October 1975.

OSCAR

One program which deserves mention even though it has little applicability to communications satellite systems in general is the series of OSCAR satellites. Project OSCAR (Orbital Satellite Carrying Amateur Radio) was founded in 1960 by a group of American amateur radio operators. It has since become the international Radio Amateur

* The members: Lockheed, AEC-Telefunken, Aeritalia S.p.A., Contraves A. G. (Switzerland), ETCA (Belgium), Compagnia Generale di Elletricita Fiar (Italy), GEC-Marconi, Mitsubishi, Selenia S/S.p.A., SAT (France), SAFT (France), SEP (France), Spar Aerospace Products Ltd. (Canada), Teldix GmbH (Germany), Thomson-CSF.

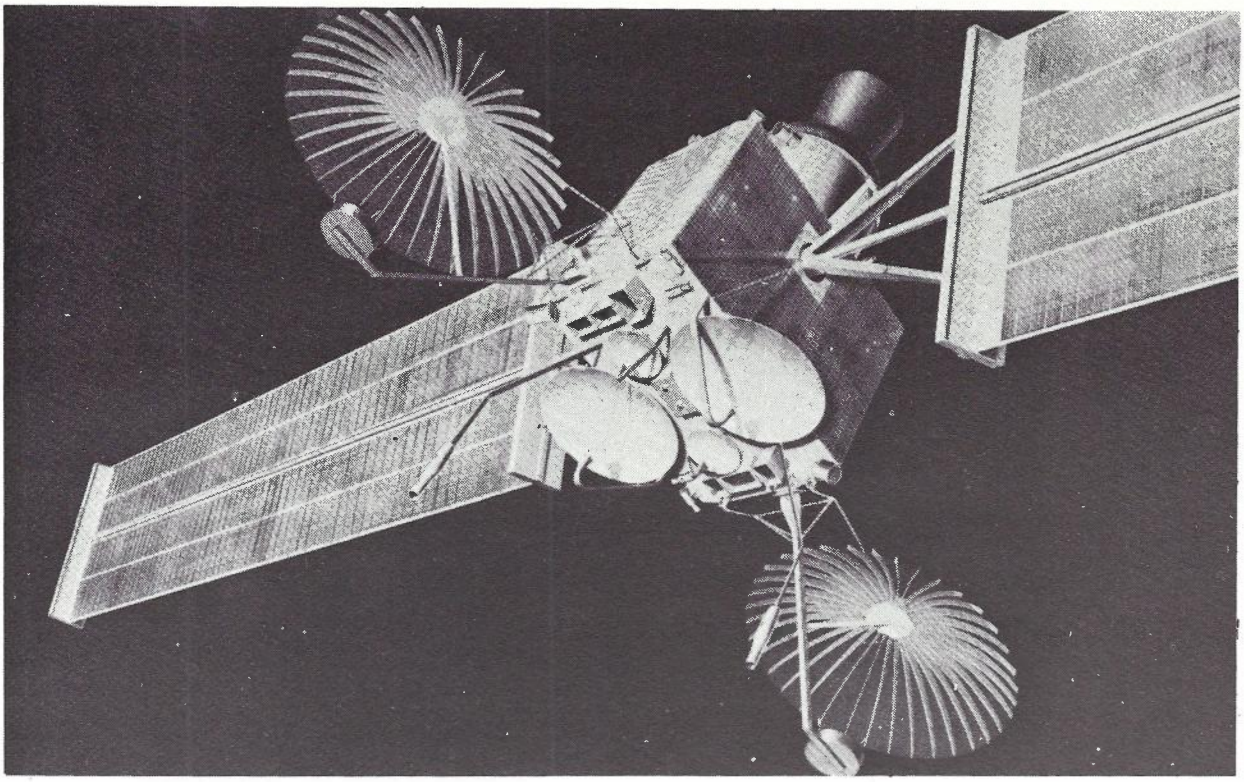

Fig 3—Lockheed Communications Satellite. It would be capable of providing 48 communications channels divided between the 6/4 and 14/11 GHz frequency bands. Horn Antennas would be used for earth coverage and unfurlable 7 ft. diameter antennas for spot beams in the lower band.

Satellite Corporation, or AMSAT. The purpose of the program has been to use any spare payload capacity of scheduled launch vehicles to orbit small experimental satellites. This procedure, called "piggybacking", in effect provides a free launch. The penalties, small satellite size and no control over launch time and orbit, are of little consequence for amateur radio experimentation. OSCAR-1 was launched in December 1961, and OSCAR-6, the most recent, in October 1972. The latter had some Australian content, but of more interest is OSCAR-5, launched in January 1970, which was entirely built by a group of students at the University of Melbourne.

Intelsat Programs

In addition to the satellite projects mentioned above, several other experimental programs relate to communications satellite systems. Intelsat sponsors a number of these dealing with spacecraft and earth station technology. Comsat performs some of the work for Intelsat, and also carries on its own investigations. Two programs of particular interest are the digital television system called DITEC-1 (*Di*gital *Te*levision *C*ommunications), and a new type of earth station antenna.

DITEC-1 combines use of digital techniques with video signal processing to reduce the bandwidth required for a TV signal by half or, alternatively, to reduce the satellite power required by as much as 90 per cent. Some beneficial side effects are the ability to carry up to 29 telephone channels along with the video and sound channel signals, with no increase in bandwidth or power, and a much higher tolerable level of interference. The technique could be of some use in terrestrial microwave systems since it would allow a doubling of capacity, but its importance to satellite systems is even greater. To show its possibilities, Comsat demonstrated TV transmission through an Intelsat IV satellite to an earth station in central Washington, DC, consisting of a 5 metre antenna and a small caravan containing all the station electronics.

The new antenna uses a fixed toroidal section as a main reflector rather than the usual steerable parabolic dish. Pointing capability is provided by steerable feeds located in a separate building. A demonstration unit measures about 10 by 18 m; three feeds are provided, each of which can be pointed anywhere along a 20 degree arc. This could replace three steerable 10 metre dishes, at much less than half the cost.

TV Broadcast

The television broadcast demonstrations using ATS-6 merit separate detailed discussion. Other programs, CTS for example, will also test the equipment necessary for "direct broadcast". Such equipment comprises both the satellite hardware and the earth station antenna, preamplifier, and signal converter. The ideal earth station would be an unaugmented television receiver, but this would require impractically high satellite transmitter power, as well as intolerable interference levels for terrestrial services. So the goal is a degree of augmentation which could be afforded by a small town, a mining community, or in Australia's case even an outback station: a small antenna and simple preamplifier which together might cost from a few hundred to two or three thousand dollars. The ATS-6 demonstrations include hardware tests, but their unique feature is the attention given to "software", the uses to which such a service might be put, the structure of the earth station network, and most importantly the programming and content of the transmissions. The importance of these features may be deduced from the estimates made for the cost of *one part* of the ATS-6 demonstration: $US 13 million *excluding* hardware (Ref. 2). Program production costs alone have ranged from $US2500 per hour for educational TV by NHK in Japan to $US48,000 per hour for "Sesame Street".

For the first year of its life, ATS-6 will be positioned at 94° West (over North America). During this time it will be used to provide educational TV broadcasts to three relatively remote areas and disadvantaged groups: the Indians, Chicanos and others in eight sparsely populated Rocky Mountain states; the coal miners and farmers in Appalachia; and Indians and Eskimos in Alaska. At the same time, demonstrations of the use of TV for medical purposes are planned. These will involve transmissions between hospitals and clinics in cities and those in country areas, giving the latter some of the benefits of the technology and expertise found in the former. The high power 2.5 GHz transponder can carry a video signal with four audio channels on subcarriers, and also telephone/data channels on separate RF carriers. Several applications of this capability are possible. For the Rocky Mountain educational demonstrations, for example, the four audio channels will be used for simultaneous sound in four languages (English, Spanish, and two Indian dialects), while the telephone/data channels will be used to test the most effective method of teaching for different student groups:

(i) One-way television, sound and digital data.
(ii) Two-way interactive sound and digital data.
(iii) One-way television with two-way sound and data.
or (iv) Two-way interactive video, audio, and data.

After about a year, the satellite will be moved to 35° East, where it will be visible from the control earth station in Europe and from India. Whereas the US educational experiments are to be at pre-school and primary school level, India is more interested in adult education, her primary objectives for the ATS-6 program being to contribute to family planning goals, to improve agricultural practices, and to aid national integration. The use of television in support of these objectives has been under study for some time. Conventional terrestrial broadcasting and the use of circling

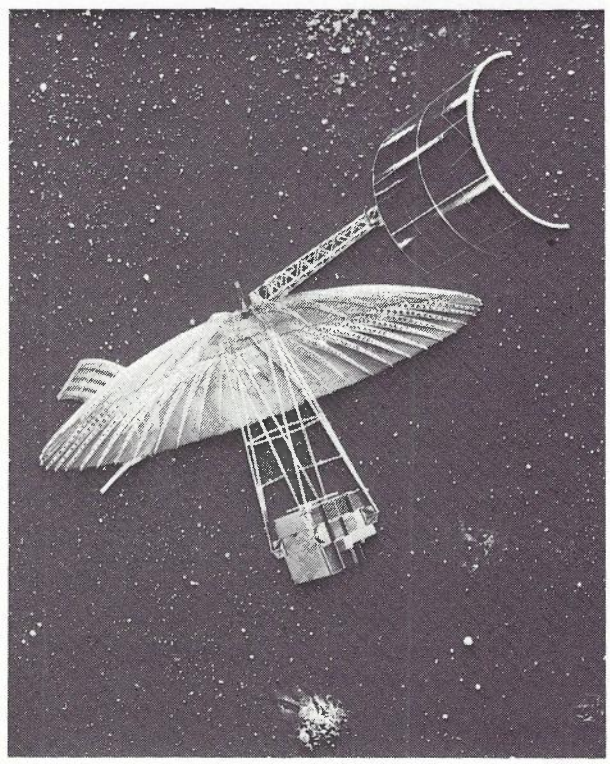

Fig. 4—The ATS-6, Launched in May 1974, is the Latest in the Series. The umbrella-like antenna is nearly 10 metres in diameter, and the spacecraft mass is 1375 kg. ATS-6 is being used to broadcast educational television to several areas. (Photo courtesy of Fairchild Industries).

aircraft have been considered and will probably be used, but a satellite service is seen as indispensable to complete TV coverage. ATS-6 will provide a means for investigating the formidable problems of the overall program. For a year, it will be used to broadcast instructional TV to as many as 5000 villages. About half will receive the transmission directly, through community receivers with the augmentation discussed above. For the rest, the satellite will serve to distribute the programs to regional transmitters, which will broadcast to conventional TV receivers. The emphasis on hardware (the TV sets themselves, the direct reception antenna and front end, the power supply, the maintenance problems) and unavailability of any description of the programming and operations for the Indian experiment are in marked contrast to the U.S. and other experiments, but after all the software represents the biggest unknown in educational TV and it may be hoped that India will find some solutions to these problems.

Following the Indian experiment, ATS-6 will be returned to 94° West where it will be available for further experiments. Before it was cancelled, ATS-G was to have been used by Brazil in another educational TV experiment, and it is possible that ATS-6 will be used for this purpose. In the meanwhile, Brazil has been engaged in a much more modest program with Stanford University using the ATS-3 to exchange data, voice, and slow-scan visual communications for seminars and lectures. Demonstrations such as this and a similar one in the Pacific by the University of Hawaii with ATS-1 indicate that the use of satellites as an educational aid is possible today.

THE CANADIAN DOMESTIC SYSTEM

In 1966 the Canadian government set up a project group to study and plan for a domestic communications satellite. With a large sparsely populated country, the government felt that a satellite could offer much improved communications, particularly in the north, and aid in implementing a two-way TV network. The geostationary orbit satellite had been proven, and Canada had some experience in satellites, having built the Alouette series of spacecraft and subcontracted on several other satellites. It is also likely that she wanted to "reserve" some orbit space ahead of the US, which had several domestic systems under consideration.

Telesat Canada was established in 1969 as the private corporation which would own and operate the system. Ultimately, Telesat shares would be divided equally between the government, the common carriers, and the public. Telesat began designing a satellite which would have six transponders and would have an in-orbit mass between 220 and 270 kg. This was a result of the earlier studies, which indicated that the most cost-effective satellite would be slightly larger than the Intelsat III then in use, but still within the Delta launch vehicle's capability. Two such satellites would be launched initially, fully using the available bandwidth and providing the desired capacity with a little to spare.

Before .nis effort had progressed very far, Hughes Aircraft Company, which had built the Syncoms and Intelsat IIs and was then building the Intelsat IVs, proposed to Telesat a design which would still fit the Delta but which would have a capacity nearly that of Intelsat IV (see Table 1 Part 1). The changes to the Intelsat IV design which allowed a size (and cost) reduction of 50 per cent were the elimination of redundant power amplifiers, a simplification of the transponder antenna configuration, and removal of the

Fig. 5—The Canadian ANIK Spacecraft. Two have been launched, in November, 1972 and April, 1973, and a third is scheduled for launch in 1975. The body, covered with solar cells, rotates to provide gyroscopic stabilization, while the antenna on top of the satellite stays pointed at earth. (Photo courtesy of Hughes Aircraft Company).

delay equalization filters at the transponder outputs. Only the last has had any impact on the Canadian system since it required the addition of special compensating equipment at many of the earth stations. Twelve transponders were provided but because of the reduced power available compared with Intelsat IV only ten could be used at a time during eclipse at the end of the seven year life (the worst-case situation; all twelve could be used under other conditions). Besides these advantages, the cost was lower than that projected for the original design. The proposal was accepted and a contract for three spacecraft was issued. The winner in a national contest to choose a name for the satellite was "Anik", which is Eskimo for "brother".

The system is intended both to supplement existing telecommunications services and to aid national development by providing services impractical by other means. In the first category are heavy route telephone traffic between east and west, connection of the Cantat-2 transatlantic cable to central Canada, and distribution of network television to major centres in the relatively populous southern part of the country. Examples of the second are distribution of TV to northern communities previously either served by video tape flown in once or twice a week, or without TV service; small group telephone service between a few northern centres and the southern network; and single channel telephony and radio to small arctic communities. The earth stations to provide these services include two heavy route stations, near Toronto and Vancouver; six network TV stations near other large cities in the south; two northern telecommunications stations (Frobisher Bay, on Baffin Island; and Resolute in the northern most part of the country); twenty-five remote television stations spread across the centre and north; and two thin-route stations, to be increased to nine in 1974 and to sixteen in 1975.

The heavy route stations are similar to the standard Intelsat earth stations, with 30 metre dish antennas. They are the only manned stations, all the others being designed for unattended operation with fixed mount, 10 to 12 metre diameter antennas. The network TV stations provide television reception and transmission, while the remote TV stations provide reception only. The design of the remote TV stations allows the addition of other capabilities (e.g. telephony) if necessary. The northern telecommunications stations can provide up to 60 telephone circuits as well as TV reception, and the thin route stations provide capacity for one telephone circuit with the capability of expanding to include one or two more plus TV reception.

Telesat is a "carrier's carrier", that is it only implements services actually provided by others. Thus its plans must be based on estimates not only of projected traffic but also of the sort of group which might want to lease capacity. Its earlier plans called for launching two satellites, with one used for backup, and keeping the third satellite as a ground spare for launch if one of the others failed. As it turned out, the capacity of Anik 1 was fully leased before its launch in November 1972, and between further growth in Canada and lease of capacity to several U.S. companies, Anik 2, launched in April 1973, will shortly be filled also. Telesat has already requested NASA for a 1975 launch of Anik 3. Similarly, the initial ground network was to include fewer remote TV stations and no thin route stations. Further expansion of the earth station network is a near-certainty.

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The Melbourne Semi-Automatic Wake-up Service

D. JOHNS

The existing wake up service in Melbourne has for some years been experiencing operational difficulties and financial loss. In order to overcome these problems a semi-automatic wake up service based on magnetic disc memories with hard wired logic controllers has been developed.

Manual booking and automatic sending are used, the maximum sending rate being about 750 calls in five minutes.

OPERATION OF EXISTING SYSTEM

The existing system was introduced in Melbourne in the early 1930's and is entirely manual. It basically requires the subscriber to dial a service level and provide details which an operator records on a docket. The operator calls back to the subscriber to verify that a genuine booking has been made and that the details are correct. The docket is sorted and stored until maturity, when it is handed to another operator who calls the subscriber at the requested time. After the call has been made, the docket is forwarded to Finance and Accounting Branch for charging to the subscriber's account.

Need for New System

With the growth in population and telephone density, demand for the service increased rapidly and additional staff were needed just to cope with the high peaks. Calling out presents the greatest problems because 4000 to 5000 calls have to be made in about two hours, and during the peak hour of 6 am to 7 am up to 40 operators are required.

Staffing costs resulted in the service running at a financial loss, and demand for the service, which has been increasing by about 15% annually, led to increasing financial loss and operational difficulties. Hence it was decided to overcome these problems by means of a partially automated service.

THE SEMI-AUTOMATIC SYSTEM

A simple block diagram of the system is shown in Fig 1. The main elements are a memory unit into which operators load details of calls, a real time clock and automatic senders. Each entry (word) in the memory includes details of the date and time the call is to be made. Every entry is checked every five minutes against the real time clock, and when a time and date match is achieved, the telephone number part of the word is fed to an automatic sender which calls the subscriber and transmits the number to accounting and service printers. On answer, the subscriber is connected to the speaking clock.

Choice of Memory

The most important part of the semi-automatic wake up service is the memory because it determines the facilities which can be provided, speed of operation and system reliability. Design of all other parts of the system is also greatly influenced by the type of memory. Disc memory is the best compromise between cost, speed and reliability. In order to provide high reliability, two discs are used, one is a standby; Fig. 2 shows the discs installed in the equipment cabinets.

Word Format

Fixed length words of 88 bits are used, made up as shown in Table 1.

TABLE 1.

Name	Function	No. of bits
Operator Code	Identifies Console from which call booked	4
Digit 1-9	Telephone Number to be called	36
E.O.N.	End of Number Code	2
Start Date	Date call to be made	11
Time	Time call to be made	10
Stop Date	Date regular booking stops	11
Public Holiday	Stops regular calls on those days	7
Day of Week (1-7)	Used for regular bookings	7
	Total	88

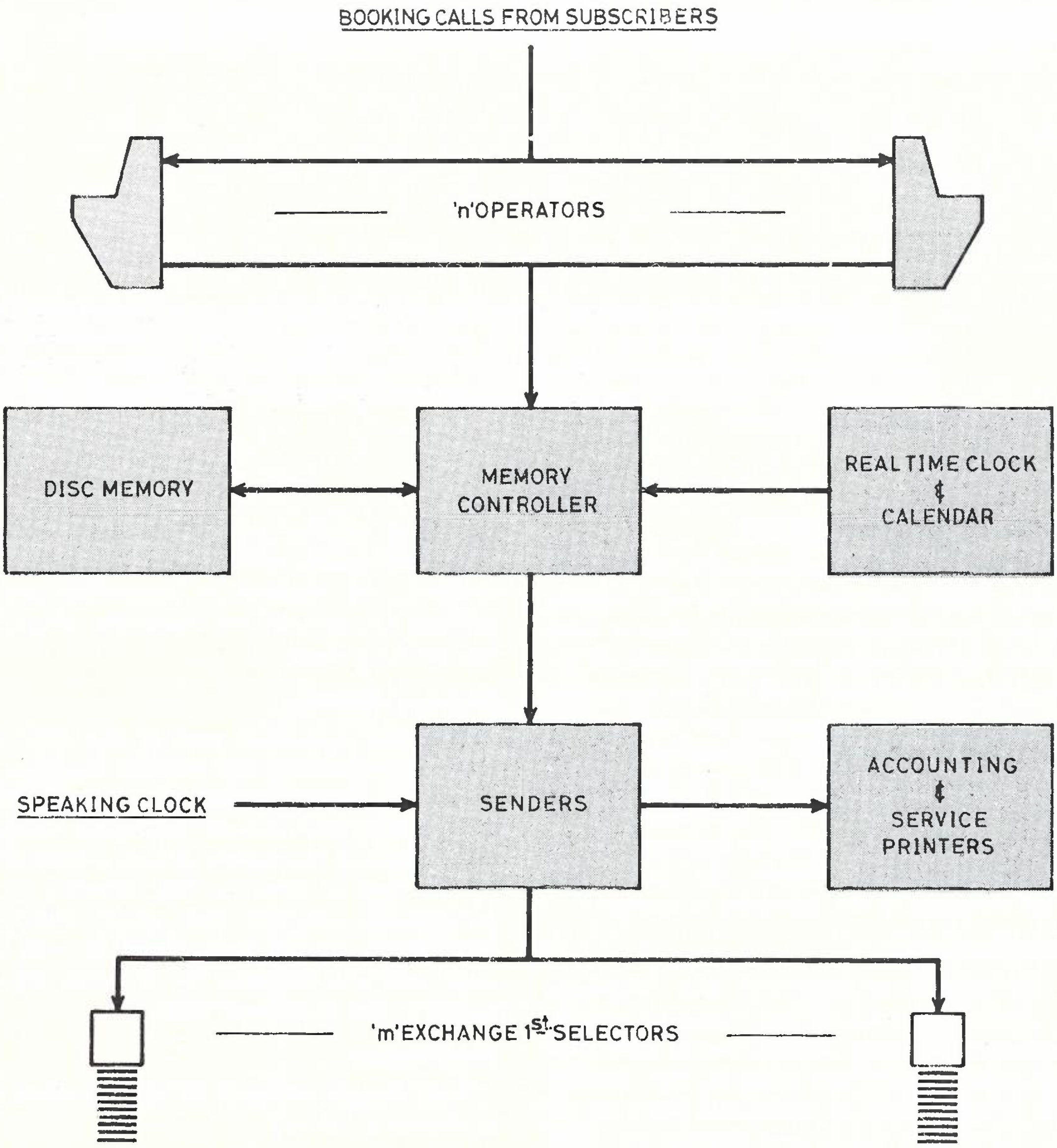

Fig. 1 — Simplified Block Diagram of Wake Up Service.

Data Packing

The actual word length received from the operators is 106 bits because full 4 bit BCD (Binary Coded Decimal) characters are used. Storage efficiency is improved because some characters have bits which are always zero and hence can be omitted. For example the days tens digit can be only 0, 1, 2 or 3 and so only two bits are required instead of the normal BCD character of 4 bits. By removing the constant zeros the 106 bit word is packed down to 88 bits. On readout the reverse process occurs so that the normal word format is available for operators and test panel displays.

Types of Call

By using different parts of the word, three types of call can be made; these are:

Casual Call

A single call is sent and then erased from the memory. About two thirds of the calls are of this type and are mostly booked on the preceding evening. The operator inserts only the start date and time parts of the word and this causes the disc control unit to recognise it as a casual call.

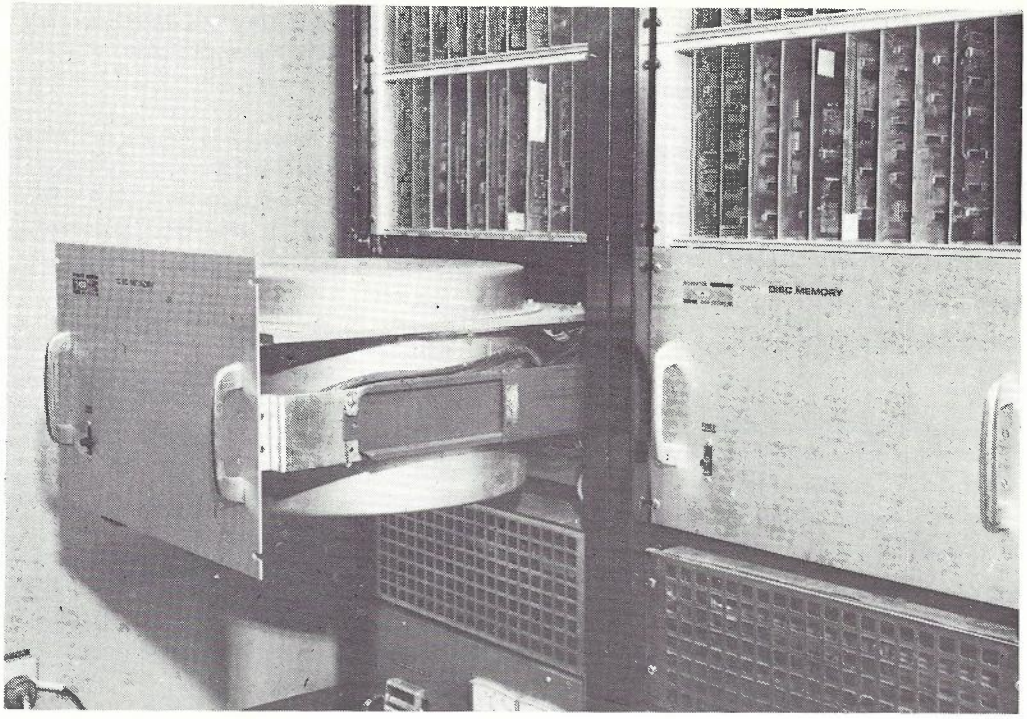

Fig. 2 — Disc Memories.

Fig. 3 — Operators' Consoles with Monitor's Post.

Permanent Call

If data is entered as for a casual call and one or more of the Day of Week keys is pressed then the call is recognised as permanent. If, for example the start date is a Monday and the Monday key is pressed the call will be made on the start date and on every Monday thereafter. If any of the other day keys are also operated then calls will be made on those days as well. Operation of any of the seven public holiday category keys will result in calls being inhibited on those days.

Regular Call

Similar to a permanent call but is for a fixed period of from 2 to 365 days. This is achieved by including a stop date in the entry. When this date is reached the call is made and the entry is then erased from the disc.

OPERATOR'S CONSOLE

The operator's console shown in Fig. 3 consists of an AFG type framework modified to house equipment necessary to input data to the discs, cancel data or interrogate as required. The equipment consists of a keyboard, storage registers with displays and an automatic dialler. The system has a maximum capacity of 30 consoles which are connected to the discs via a common data and control circuit bus.

Booking a Call

On receipt of a booking call the operator obtains the information from the subscriber and keys it into the console registers; it then appears immediately on the console display. On completion the details are read back to the subscriber to verify accuracy. The LOAD key is then pressed and the data is transferred to the disc memories.

The disc controller carries out a read-after-write check and sends the data read off the disc back to the operator. In the meantime the subscriber has hung up, so the operator presses the RECALL SUB key which causes the automatic dialler to call the number using the data returned from the disc. This call to the subscriber thus guarantees that the data has been correctly entered on the discs. The normal booking procedure outlined above does not entail the preparation of dockets or other paper work and so results in a reduction in booking time and an increase in accuracy.

Cancel

The same basic procedure described for booking a call is followed except that the CANCEL key is operated. This results in the entry being found and erased from the discs. As an indication that the correct entry has been erased, the data read off the discs is returned to the operator for calling and verification with the subscriber.

Check Data

This facility enables a check of the disc to see if a particular word exists. The operator keys up the complete word and operates the CHECK DATA key; if the word is on the disc it is returned to the operator, if not, the display shows all zeros.

Search

This facility is similar to CHECK DATA but is used in the case of multiple entries against one telephone number. The operator keys up only the telephone number and presses the SEARCH key. This causes a check of the disc for all entries associated with that number. If after the first entry is returned the search key light glows, then further entries remain and the SEARCH key is pressed again which results in the second entry being returned. The process is repeated until the search light extinguishes indicating that all entries have been returned.

Other Facilities

Two further facilities for operating staff have been provided. These are:

- 'Peak Time Slots Display' which shows the number of calls booked for busy time slots for the next mornings' calls. This allows operators to control bookings so that the sending capacity is not exceeded.
- 'Daily Dump' gives a print out of all calls due to be sent for the next 24 hours from 4 a.m. each day. This provides a valuable service aid for dealing with subscribers' complaints, and could also be used as a listing for a last resort manual back up in the event of total failure of the automatic system.

SENDING

Calls are made by 64 automatic senders. This enables about 500 calls to be sent in a 5 minute time slot. Calls can approach 1000 at the peak time which is usually 6 a.m. or 6.30 a.m. At these times traffic is spread over more than one time slot rather than increase the number of senders, although if necessary up to 96 senders can readily be provided. Data, clock and control signals from the discs are connected to all senders by a common bus. A multiplexer continuously scans, searching for a free sender which when found is enabled on to the bus. When a call is to be sent, one revolution of the disc (40mS) is allowed to elapse. This provides time for checks to ensure that data has been transferred correctly to the sender and for the multiplexer to find another free sender. If all senders are busy, a signal (No Free Senders) is returned to the disc which then goes into standby until a free sender is available.

Sending Reliability

Ineffective calls due to network switching loss and congestion average 1% to 2%. Assuming a loss of 1%, since congestion is unlikely in the early morning hours, then up to 50 calls a day could be lost. As this is not acceptable, something more than a single call is necessary. One solution would be to make two separate calls from different senders which would reduce the loss to an acceptable level of 0.01%. However, this has a serious disadvantage in that up to 100 subscribers a day still called in error would be subject to the annoyance of a full length wake up call which rings for 90 seconds.

Dual Call Sending

Two calls are sent to each subscriber, the second being delayed by a period of 0.8 seconds. Under normal circumstances the delayed call should receive busy tone, and unless a positive identification of busy tone is made, then both calls are cleared down and further attempts are made. After three failures the call is printed out for operator attention. For this method to fail, the second, delayed call must not only reach a wrong number, but one that is also busy and the probability of this occurring is low. Some minor annoyance is still possible because about 8 seconds must be allowed for post dialling delay and for busy tone identification.

Busy Tone Detection

Busy tone is detected by counting pulses. This has advantages over analogue methods in that cheap digital integrated circuits can be used, no critical adjustments are necssary and a very high degree of noise immunity is achieved. Many problems were encountered because the quality of busy tone in the network was found to be in general, very poor.

These problems have been solved by replacing capacitors, fitting new cams and replacing tungsten with precious metal contacts on all ring and tone machines in the Melbourne network. A regular programme of checking tone quality from all exchanges has been started.

SYSTEM RELIABILITY

One of the major considerations was to ensure a very high order of reliability. Electronic components taken individually are extremely reliable, particularly after an initial "burn in" period, however, they still have a finite probability of failure, and in a large system the sum of the individual probabilities can be quite high. Hence at some stage components will fail and if the system is to be kept operational, redundancy must be provided so that failure of a single component or unit does not result in total failure of the system.

Reliability of Discs

The disc memories are, because of the problems inherent in all mechanical devices, probably the least reliable part of the system. To improve reliability and to ensure that error-free data is always available for sending calls, the system has been designed as follows:

- Two discs are used, one of which normally drives the senders while the other is on standby. Both are loaded in real time by operators, so that the standby is always updated and can immediately take over the send cycle if the operating disc fails.
- Each disc is divided into two separate memories with separate read/write and control hardware. A common clock track is used for the two memories on each disc surface — hence the two outputs are synchronous and equivalent words can be compared as they are read off.
- Operators load new data into both halves of the disc so that there are normally four sets of updated information, any one of which can be used to drive the senders.

  Tests are carried out to establish that data read from the memories is error free, and in the event of errors, which memory is faulty.

Configuration of Supervisory Circuits

The basic configuration of the two dual memory discs, various supervisory units and senders is shown in Fig. 4. The senders are divided into two groups, one of which is fed from memories 1A or 2A and the other from 1B or 2B. Thus the senders are not dependent on a single highway or line driver and receiver. Under normal conditions with disc 1 operational and disc 2 on standby, memories 1A and 1B both send data to the senders. The status of all supervisory checks is continuously monitored by the Supervisory Test and Automatic Changeover (STAC) unit. In the event of a fault on disc 1, the STAC unit automatically transfers the senders to disc 2 which takes over the full load. If a fault arises on disc 2, the STAC identifies which memory, (2A or 2B) has failed and disables it. All functions are still available except that the number of senders is halved. During the peak call time this could result in some calls being up to 5 minutes late. However, this would require two simultaneous faults so its

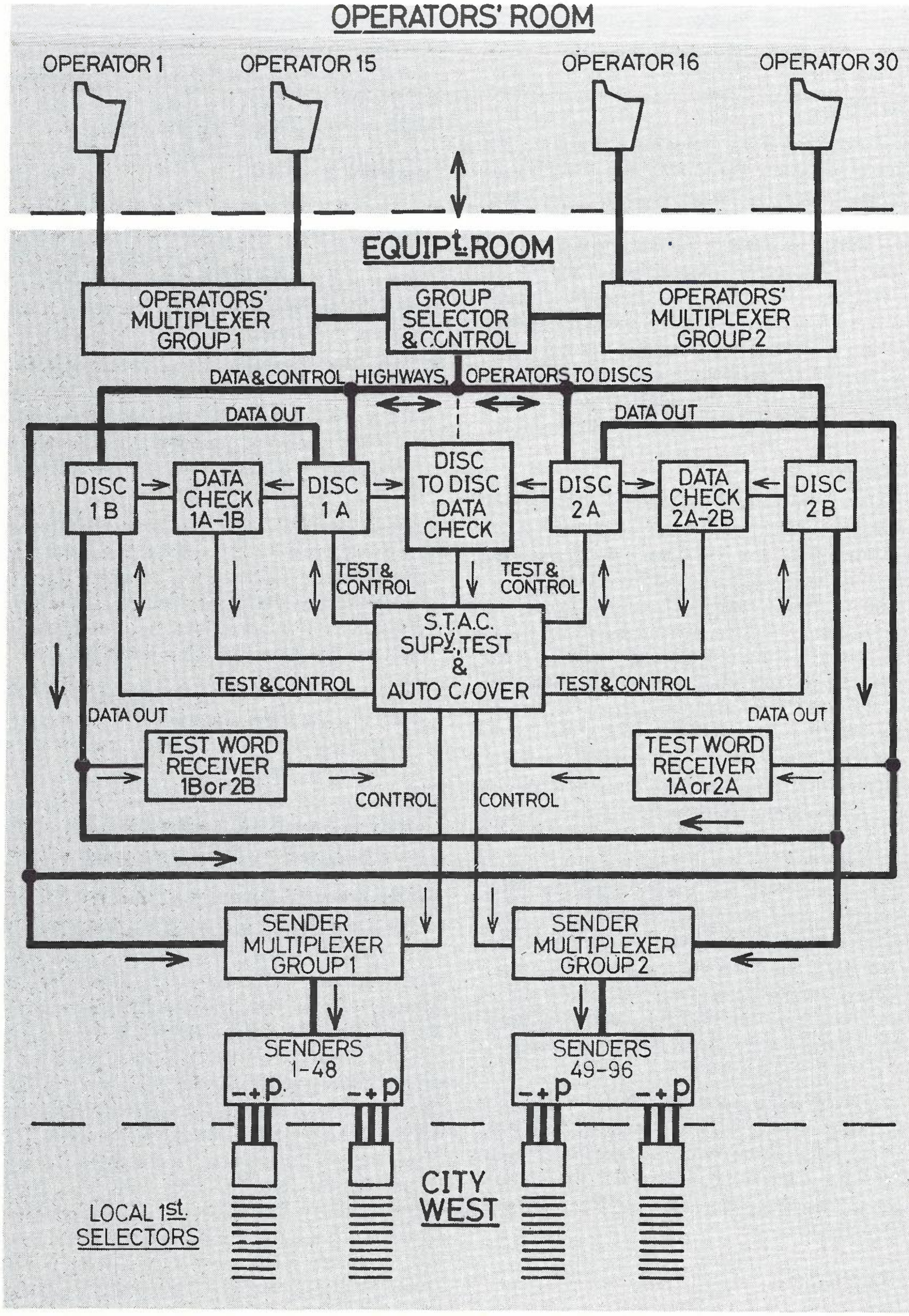

Fig. 4 — Configuration of the two Dual Memories and Supervisory Circuits.

occurrence is likely to be very infrequent. If both memories 2A and 2B should fail, that is, three simultaneous faults, then manual control can be used to switch back to the remaining good half of disc 1.

System Partitioning

As far as is possible, the system has been partitioned into two equal sections, both normally sharing the load, but either on its own able to maintain a reasonable grade of service. Each section consists mainly of half the operators' consoles and senders, a disc memory, real time clock and power supply. Two power feeds from a "No break" power supply are used, one for each section.

MAINTENANCE AIDS

Results of the automatic supervision exercised by the STAC unit are displayed on the test panel in the form of memory number and nature of the fault. The test panel also provides the following facilities:

Word Display

By means of thumbwheel switches any sector in any of the four memories may be addressed and its contents shown on the test panel display. This enables rapid identification of faulty memory following an A-B or disc-disc mismatch.

Write Sector or Track

Any sector or track may be written into with 'I's, 'O's or patterns. This is for busying sectors, clearing contaminated sectors or loading test words.

Update

Any memory may be completely updated from any other memory.

ACCOUNTING

Accounting is by means of a paper printout of chargeable calls. This is processed by Finance and Accounting Branch in much the same way as the paper dockets arising from the manual system.

POWER

Power for the wake up service is supplied from a "No Break" 50 Hz 3 phase system. The 3 phase power is transformed to 9 volts and full wave rectified to produce the raw dc for the system power bus. An integrated circuit voltage regulator is used on every printed circuit board to provide the regulated 5 volts needed by TTL integrated circuits.

REAL TIME CLOCK

To automatically send calls at the correct times a real time clock is needed, and this provides the disc controllers with the date, time and day of the week number (1-7). The basic time period is 5 minutes, and this is derived from the 50 Hz power mains. If the mains fails, an internal oscillator continues functioning, but is free running. The free running frequency is set as closely as possible to 50 Hz and this provides sufficient accuracy to keep the system operating until the mains is restored.

Reliability

Two separate clocks are used and their outputs are continuously compared. If a mismatch occurs, an alarm is given and the faulty clock is quickly identified by checking the clock panel displays. Normally one clock is used for each disc but under fault conditions either clock can drive both discs.

Public Holiday Categories

Regular bookings usually require the call to be inhibited on public holidays. Automatic generation of public holiday dates is not convenient because of variations from year to year and also the possibility of unexpected proclaimed holidays. Hence, public holiday dates are generated manually by the operation of keys on the operators supervisor's console.

HARDWARE

General

The equipment cabinets and rack are shown in Fig. 5. The discs, disc controllers and power supplies are in the two left side cabinets and the senders in the right side cabinet and rack. The centre cabinet houses the test panel and miscellaneous units. Printed circuit boards are mounted in standard 'ISEP' frames and most boards use plated through holes. The cabinets are enclosed by front and back doors and therefore subject to build up of heat. Fans are used to keep the temperature at about 28°C, the maximum allowable being 40°C, which is the upper limit of the discs. Contact thermometers are installed in the cabinets and if the temperature rises to 32°C an alarm is given.

Components

The main components used are 74N and 74L series TTL integrated circuits, also used are P MOS static shift registers and fusible link Proms, (programmable read-only memories). All data highways are balanced using tightly twisted conductors with differential line drivers and receivers. This technique, together with the use of a voltage regulator on each printed circuit board, has ensured that the system is free of noise problems.

FIELD TRIAL

In December 1973 field trials were commenced in which about 800 regular type calls were made each working day of the week. The intention was to hold the trials for a number of months and then to take over the whole load of 4000 to 5000 calls. Unfortunately problems arose with the printers which produce the paper tape for accounting such that consistent quality of print could not be guaranteed. Naturally, as subscribers accounts are involved, this was not acceptable, and following a total failure of the printer and long delays in obtaining service from the manufacturer, the decision was made to change to a different type of printer. This required further design and development to produce the necessary interface, resulting in delay in full implementation of the system. At the time of writing trials with the new printers are underway and it is expected that the system will be fully operational by mid 1975. Trials of booking calls live from the operator's consoles have also been conducted and no problems were encountered.

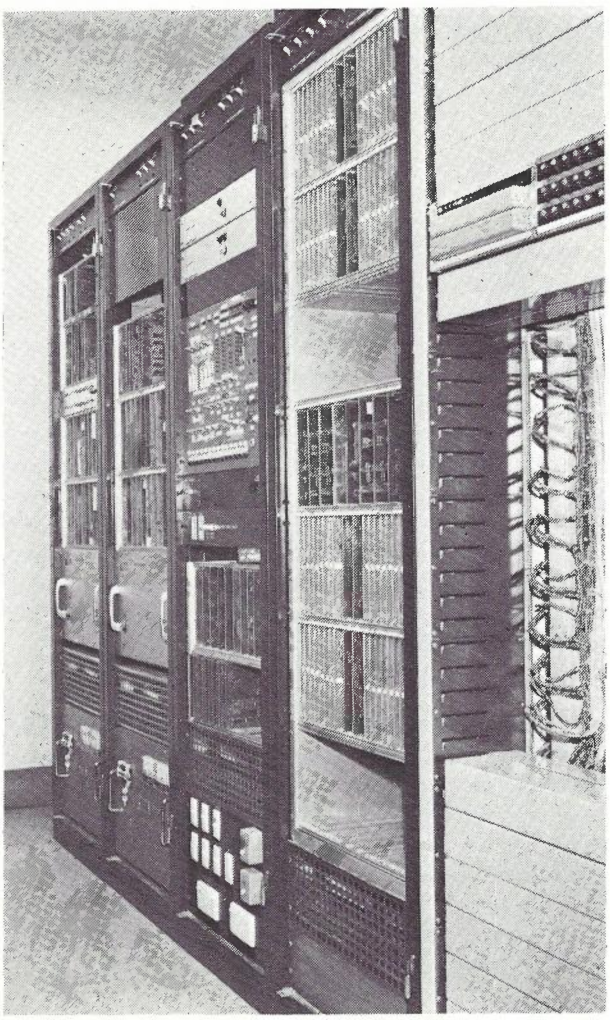

Fig. 5 — Equipment Cabinets and Rack.

Results of Trial

In a 15 month period, about 243,000 calls to subscribers have been made with the following results:

Automatic Call Successful	89.1%
Reverted to Operator — Sub not answering	6.8%
Reverted to Operator — Busy tone not detected	2.9%
Unsuccessful due to printer faults	0.6%
Unsuccessful due to No Break Power Supply problems	0.5%
Unsuccessful due to Wake up service equipment	0.1%

The majority of failures were in the early months of the trials and the causes have been isolated and remedial action taken. It is therefore confidently expected that future failure rates will be much lower. Improvement is also expected in the revert to operator figure due to busy tone failure as the busy tone upgrading programme removes the few remaining weaknesses.

CONCLUSION

Full implementation of the system has taken longer than originally foreseen largely due to the difficulty in producing printed paper output for accounting purposes. The equipment described will however continue to provide the service in Melbourne for a number of years during which time stored program controlled trunk exchange equipment will gradually take over first the growth component and later the facility totally. The locally developed equipment will at that stage be available for use in a large country or small capital city.

Experience gained in designing and developing the system has been invaluable and will be of great help in many other applications.

ACKNOWLEDGEMENTS

I would like to thank Mr. R. W. Cupit — Supervising Engineer Network Performance and NES — for his oversight of the design philosophy of the system, and Mr. Eacott and other members of the Network Performance Laboratory staff whose contribution to the development of the system was invaluable. I wish to also thank Mr. W. Hockley for his valuable contributions to the design of the Real Time Clock and the Peak Time Slots Display.

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Dynamic Programming — An Application To Telecommunications Planning

C. W. A. JESSOP, B.Sc., M.Eng. Sc.

The technique of "Dynamic Programming" is briefly described, and its use in telecommunications planning is illustrated. The technique is a powerful planning tool, which could be utilised more frequently than it is, in the planning of telecommunications projects.

INTRODUCTION

Decisions related to the economic development of telephone networks often require the undertaking of a cost/benefit study to determine the most economic method of providing service to subscribers. Such a study could well require analysis of the comparative cost of telephone plant to be provided according to two or more different tactical plans. Within the APO this provision would be planned on a yearly basis, and the typical period of the study would be 20 years.

An efficatious method of undertaking such a study is by the use of Dynamic Programming, and this article is written with the intention of describing this technique, and giving an example of its use. Dynamic Programming is basically a simple technique which optimises a multi-stage problem. Its application can involve complicated mathematical functions if required; the example in this article, however, involves only simple arithmetic. Use of the technique usually requires a computer, as even a small problem requires a large amount of storage memory, in fact the application of Dynamic Programming is mainly limited by the amount of computer memory required, as we shall see.

The example in this article involves the use of Dynamic Programming to find the optimal method of providing service for subscribers in a newly developing area, adjacent to an older established area, over a period of 20 years. This is by no means the only way in which this technique could be used in Telecommunications planning, for example the technique has been used successfully to determine the spacing of telegraph poles where time is not a factor in the problem, but the optimal provision of equipment over a 20 year period is a common planning problem, and will thus serve as a satisfactory vehicle for an explanation of Dynamic Programming.

"DYNAMIC PROGRAMMING" DESCRIPTION

Despite the esoteric sounding name, Dynamic Programming is a fairly simple technique. The mathematics can be as simple or as complex as desired, but in this case they are fortunately simple. With Dynamic Programming, instead of calculating the cost of every combination of events starting at the beginning, we work backwards from the end of the problem to the start, recording at each point the lowest achievable cost at each stage. Thus the technique optimises a multi-stage problem.

The concept is best explained by example, and we will consider the case of a car driver who wishes to get from a — b in the shortest possible time (see Fig. 1).

He can go via any of the routes shown and will take the times shown by each route. If he takes the quickest section from each point his route will be:—

a — c = 1 min.
c — f = 3 min.
f — b = 4 min.

Total 8 min.

However it is easy to see that by sacrificing a little time on the first section he can save time on a later section. In fact with a problem of this size we can quickly calculate the times for each route:—

a — c — d — b = 8 min.
a — c — f — b = 8 min.
a — e — d — b = 7 min.
a — e — f — b = 9 min.

and thus select route a — e — d — b as being the quickest.

Using dynamic programming we would start at b and work backwards, viz:—

d — b = 2 min.
f — b = 4 min.

From c we have two alternatives

c — d — b = 5 + 2 = 7 min.
c — f — b = 3 + 4 = 7 min.

hence from c whichever route is taken the time required will be 7 minutes.

From e we also have two alternatives

e — d — b = 2 + 2 = 4 min.
e — f — b = 2 + 4 = 6 min.

hence from e our best time is 4 minutes via d and we will use this time when we consider point a

From a we have two alternatives

a — c — b = 1 + (best time c — b) = 1 + 7 = 8 min.
a — e — b = 3 + (best time e — b) = 3 + 4 = 7 min.
hence the best possible time for the trip from a — b is 7 minutes, starting with a — e, and looking back to the next step e — d — b.

The explanation of dynamic programming may appear to have taken longer than simply calculating all the alternatives, but in fact only required 6 additions, whereas the full calculation required 4 x 3 = 12 additions. It can be appreciated that as the complexity of the problem increases, the number of calculations required for full enumeration increase alarmingly, while those for the dynamic programming method increase linearly.

Further reading for a more complete description of the theory of dynamic programming can be found in most text books dealing with Operations Research, and specific references are given later.

EXAMPLE OF APPLICATION OF DYNAMIC PROGRAMMING

The Problem

The problem to be considered is that of provision of telephone service to a newly developing area. Should the area continue to be served from the existing exchange, or should a new exchange, in a new building, be provided to serve the area?

Residential development around the city of Lismore, in the north east corner of NSW, is mainly concentrated along the Ballina Highway between Lismore and Ballina, and it is expected that this trend will continue. Close to Lismore the development is in the Lismore Heights – Goonellabah area (see Fig. 2). This newly developing area referred to simply as the Goonellabah area in this article is

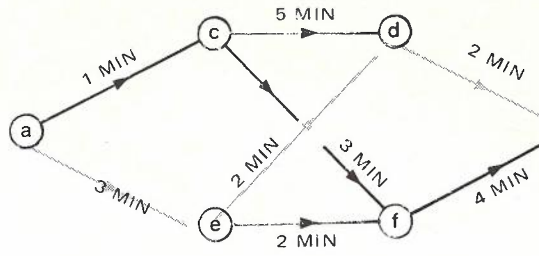

Fig. 1 — Car Driver Problem.

part of the present Lismore telephone exchange area and existing subscribers are connected to Lismore telephone exchange via a 1200 pair 0.64 mm cable which is nearly fully occupied.

If the Goonellabah area is retained as part of the Lismore area, a large 0.64 mm cable would need to be provided to serve the area, and some subscribers would still be beyond the transmission limits. These subscribers, approximately 130 by 1990, would require 0.90 mm cable to be within transmission limits. In addition to this expensive method of providing cable pairs for Goonellabah subscribers, an extension to the Lismore telephone exchange building would be soon required. This building extension, involving the re-location of a radio tower, would also be expensive, and its deferment is economically advantageous.

The First Approach

From the conditions described it can be appreciated that the provision of a telephone exchange at Goonellabah is an attractive proposition. It would:

- Avoid the need for major cable relief
- Defer the extension of Lismore telephone exchange building
- Simplify subscriber cable reticulation and transmission problems.

Despite these obvious advantages, economic studies perversely showed that provision of an ARF telephone exchange to serve the Goonellabah area was a less economic approach than retaining the area as part of Lismore, and undertaking the major relief projects for cable and building. Further analysis indicated that the reason the alternative scheme was uneconomic was due to the poor utilisation of existing equipment. Approximately 1000 lines of subscribers equipment at Lismore and a large part of the 1200 pair cable would become spare if an ARF exchange were provided at Goonellabah, and it would be some appreciable time before all this equipment would be re-utilised.

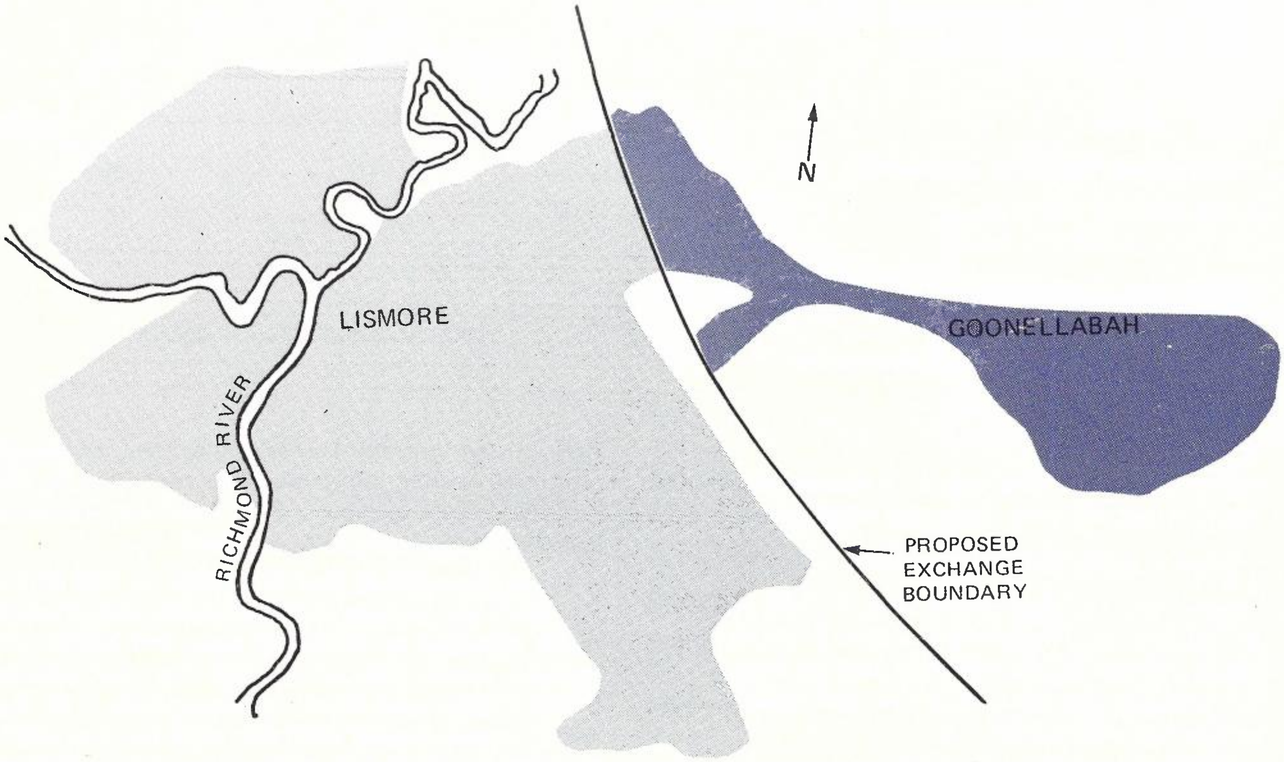

Fig. 2 — Lismore and Goonellabah Exchange Areas.

The Second Approach

From this analysis emerges the kernel of a third scheme. Could some of the Goonellabah subscribers be served by a portable exchange initially, thus avoiding the major relief projects, then, over a period of years, transfer Goonellabah subscribers from Lismore exchange to Goonellabah exchange to maximise utilisation of existing equipment. As part of this scheme a permanent building would be erected at Goonellabah at a later date. An attractive common sense approach, but considering a 20 year period and dividing Goonellabah area into 6 separate areas, there are aproximately 3 million possible combinations. Many of these could be eliminated by inspection but there would still remain a large number of feasible possibilities, far too many for each one to be studied individually.

For a compromise scheme, as suggested above, to be successful there must be more than one economic solution. Circumstances will change to a greater or lesser extent over a period of 20 years, and a plan to cover that period can only be regarded as a basis for further planning. Thus, of the feasible possibilities, we would expect several, not just one, to be economic. It was felt, however, that a lot of effort could be involved in discovering an economic solution by hand and that using a computer and by dynamic programming would be preferable.

Re-examination of the Problem

At the time of the study the following information was known:

- 5000 lines of subscribers equipment existing at Lismore.
- Lismore building capable of housing 7000 lines.
- 1200 pair / 0.64 mm cable existing to Goonellabah with capacity for 1000 subscribers.
- Survey of subscribers development for Goonellabah and Lismore for a period of 20 years.

To provide an economic solution, answers were required to the following future events:

- Year of the Lismore building extension.
- Year of the Goonellabah permanent building.
- Year of the cable provision.
- Equipment provision each year at Lismore.
- Equipment provision each year at Goonellabah.
- Pillar areas served by Goonellabah exchange.

For the sake of simplicity the following assumptions have been made:

- The Goonellabah exchange will be located at the ultimate copper centre for the area.
- Goonellabah can be partitioned into six separate areas by the locations of existing pillars.
- Subscribers reticulation cost is unaffected by the various schemes. (It is expected that reticulation will in fact, be most economic following the scheme proposed).
- The cost of the major projects (i.e. Lismore building extension, Goonellabah new building, and large 0.64 mm cable) will not vary, but will be the same in whichever year the work is undertaken.

Equivalent annual costs were used throughout the study, and a suitable loading applied to the first installation cost of ARF at Goonellabah to allow for the recovery costs of a 1000 line ARK portable.

Using the Computer

Having described the dynamic programming approach we will now apply it to the problem under discussion. If we use the classic approach and choose years as the variable, then each year we have the possibility of: 30 equipment configurations at Lismore; 20 different equipment configurations at Goonellabah; 6 different possibilities for the pillar areas, and 2 different configurations for each of the three major projects. This gives a total of 30 x 20 x 6 x 2 x 2 x 2 = 28,800 different possibilities each year — too large a problem for the available computers at that time to be able to store in main memory.

As the proposed site for Goonellabah exchange is at the end of the Goonellabah area distant from Lismore, another approach suggested itself — use the pillar areas as the multi-stage variable. A computer program was written which performed the calculations, and derived an optimum solution in the following manner.

Firstly the costs for 20 years were calculated with no pillar areas available to be served by Goonellabah exchange, i.e. all subscribers retained at Lismore exchange. The years in which the major events occurred were retained for future use. Next one pillar area was allowed to be connected to

TABLE 1—COMPUTER SOLUTION TO LISMORE/GOONELLABAH PROBLEM

Year	Lismore Equipment	Goonellabah Equipment	Remarks
1	5000	200	Establish Goonellabah ARK with area 1
2	5000	500	Add area 2
3	5200	500	
4	5400	600	
5	5600	600	
6	5800	700	
7	6000	700	
8	6400	800	
9	6600	800	
10	6800	900	Goonellabah permanent building
11	6800	1400	Establish Goonellabah ARF add area 3
12	6800	1600	Add area 4
13	6800	2000	Add area 5
14	6800	2400	Add area 6 to Goonellabah
15	7200	2400	Extend Lismore building
16	7600	2600	
17	7800	2600	
18	8200	2800	
19	8400	2800	
20	8800	3000	

Goonellabah, and starting at year 20 and working backwards to year 1, the costs of this scheme were compared with the first scheme and the second scheme adopted wherever it became more economic than the first. In fact the connection of one pillar area to Goonellabah exchange proved more economic for all 20 years.

The more economic scheme and associated major projects dates were retained in memory as the current basic scheme and the process repeated allowing the possibility of 2 pillar areas to be connected to Goonellabah. Again the more economic scheme was retained as a base (2 pillar areas at all but year 1) and the process repeated for 3, 4, 5, and 6 pillar areas in that sequence. The final computer result is shown in Table 1.

RESULTS AND CONCLUSIONS

Inspection of the computer results in Table 1 shows that some variation can be made to improve the scheme in practice. It is APO practice to install equipment capacity for a two year period, and in Fig. 3, the scheme finally proposed, equipment extension sizes are for a minimum period of two years. Also by allowing for equipment utilisation at Lismore to be above the normal 95% of the installed capacity in year 15, the Lismore building extension has been deferred by 2 years. Note that the Goonellabah and Lismore building projects should be completed a year before the equipment is required to allow time for installation of that equipment.

Another feature of the scheme is that the large

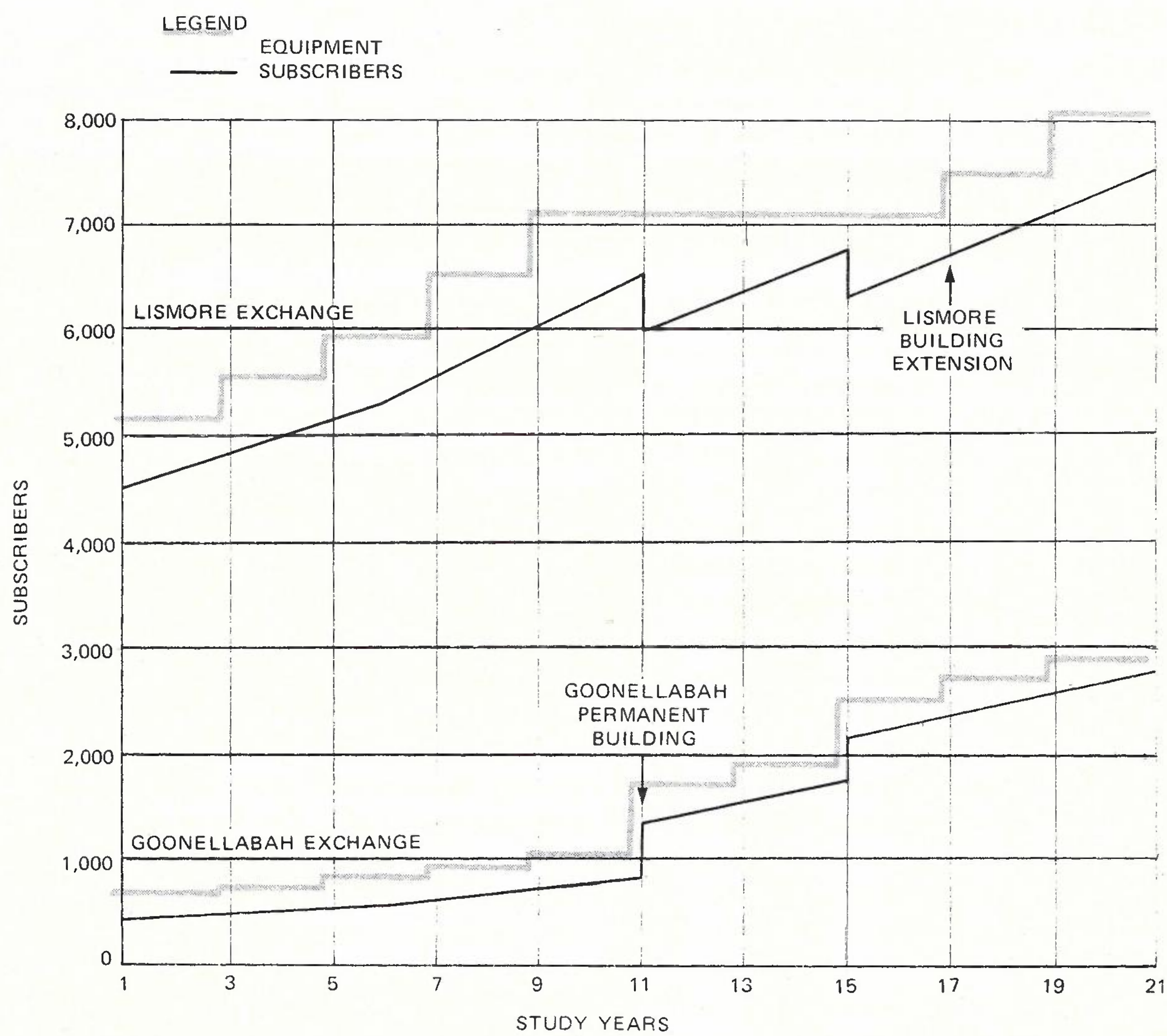

Fig. 3 — Scheme Finally Proposed.

cable relief project has been avoided entirely, and that the subscribers outside the transmission limits of 0.64 mm cable from Lismore are part of the initial areas connected to Goonellabah exchange.

The proposed scheme will serve as a basis for detailed planning of the Lismore and Goonellabah areas during the coming years but changes will probably be required as the actual subscriber demand varies from that originally forecast. However, as this scheme is considerably more economic than the two alternatives originally considered (i.e. all or nothing at Goonellabah) there can be considerable fluctuation in Subscriber demand before a revision of the fundamentals is required.

The computer program was written and results obtained during a period of two weeks, and most of this time being spent waiting for cards to be punched, or output to be returned from the computer. Although the proposed scheme appears straightforward, and, with hindsight the obvious solution, to explore the economics of all the more feasible schemes would have occupied a longer period than two weeks, and even then one would have been left with the suspicion that something had been overlooked.

Use of a computer and the dynamic programming technique, as described in this article, enabled an economic study, with an alarmingly large number of computational steps, to be solved with a minimum of manual effort. In this example the computer has clearly been used to perform the tedious and time consuming computational aspects, and to present information which can be utilised by the planner to derive a scheme which suits the requirements of the APO.

It is suggested that this technique could be applied to many telecommunications situations, both within and outside the planning area, as multi-stage projects are a common aspect of our industrialised society, and provision of telecommunication services is one of the more complex aspects of this society.

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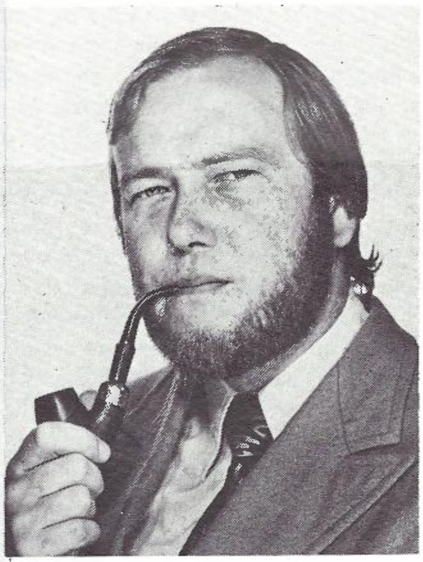
To further his knowledge of planning and administrative techniques, he undertook a part-time post-graduate course at the University of NSW, and graduated in 1973 with a Master of Engineering Science degree in Industrial Engineering (Operations Research). In the same year he was promoted to Senior Engineer, Telephone Switching and Facilities Planning, Headquarters, assuming responsibility for the forward planning of the interstate trunk network, and production of the National STD Newsletter.



A New Letter Sorting Machine for the Australian Post Office

D. Y. McFADDEN, AMTC, AFAIM, MIREE (Aust.), FIE (Aust.) and I. W. PAYNE, Dip. EE.

The Australian Post Office was one of the pioneers in the advancement of mail handling technology when it installed the Australian made letter coding equipment in the Sydney Mail Exchange in 1966. The new letter sorting machine described in this article has been developed in Australia as a joint venture between the APO and an Australian manufacturer as a result of experience gained from the operation of this plant. It employs a number of novel techniques in performing its sorting function, and is being considered for use in new letter handling installations, and for the eventual upgrading of the Sydney system, which has been in operation since 1966.

INTRODUCTION

It has been recorded that a State Postal Service existed in China under the Tchu dynasty in 1100 BC (Ref. 1) and there is evidence of the use of postal communications in biblical times (Ref. 2). However, it was only in relatively recent times that the concept of an international service was made a reality when the universal postal rate was established in 1840. Although evidence exists that attempts were made to mechanise some of the processes not long after that period, until fairly recently the majority of mail processing has been carried out by hand. For example, individual letters in a fully manual system have to be handled, in most cases, six times during the process of sorting them to ensure that they reach their correct destination. This process involves the facing up of the letter (orienting it to bring all the addresses into the reading position) cancelling the stamp, and then sorting the letters through a number of stages in a mail exchange until it is directed to the post office from which it is finally delivered to the addressee. Even at this post office the letter has to be sorted to the correct postman's round and by each postman within his own round. The final handling takes place when the letter is dropped into the addressee's letter box.

Advances in technology, and increases in labour costs in what is a highly labour intensive industry, have prompted many postal administrations to strive toward mechanising the handling of their mails. In this regard the category most suitable for mechanisation is the letter class, and schemes aimed at automating its handling from posting, to sorting down to individual postmen's rounds, have been developed by some administrations.

The process of the facing and cancelling of letters by machine is now well established throughout the developed countries, and 17 culler-facer-canceller units are in operation in Australian mainland capital city mail exchanges.

Most Australian mail exchanges now employ varying degrees of mechanisation of the sorting process, mainly concerned with the automatic or semi-automatic collection and distribution of letters sorted by manual means. One such type of machine is the horizontal or "flat top" letter sorting machine developed in the early 1950's, and still in use in most mail exchanges. (Ref. 3).

The one exception is in Sydney, where an advanced form of letter sorting called "letter coding" or "letter indexing" has been in use since early 1967 at the mail exchange at Redfern (Ref. 4). This is still the largest letter indexing system in the world.

As a matter of interest, Sydney also featured as a pioneer in the field of mail mechanisation in 1930, when a comprehensive mail handling installation was cut into service there at that time. On the letter handling side this system automatically collected mail from a number of posting boxes in the GPO colonnade on a sequential basis, and distributed it by a timed conveyor system to the various sorting points in the building (Ref. 5).

With the letter indexing system, the number of handlings a letter receives during its passage through the mail exchange is reduced to a minimum. To achieve this, the letter is "indexed" (a series of bars giving the routing information are printed on the envelope) and thereafter further sortation is carried out by machines which "read" the index. These are the later generation of the letter sorting machines, and the development of a new type is described in this article. The original index used in Sydney was printed on the rear of the envelope, and contained information to route the letters through a particular sorting machine. The Australian Post Office is now adopting an index printed on the lower front of the envelope which denotes the destination of the letter, rather than giving simple routing information.

A BRIEF HISTORY OF LETTER SORTING MACHINES

The Keyboard Operated Letter Sorting Machine

The earliest form of letter sorting machines evolved when thought was being given in a number of postal administrations to the possibility of presenting letters in front of an operator, allowing him (or her) to key in data from the address, so that the letters were then carried automatically to a destination bin. The first of these machines introduced into actual service was the Transorma which began operating in the Rotterdam Post Office in 1930. It was not until 1957 that this machine reached the USA, where it was hailed as the "first mechanical sorting machine in the US Post Office", although a locally designed machine had been demonstrated to the US Post Office some years previously.

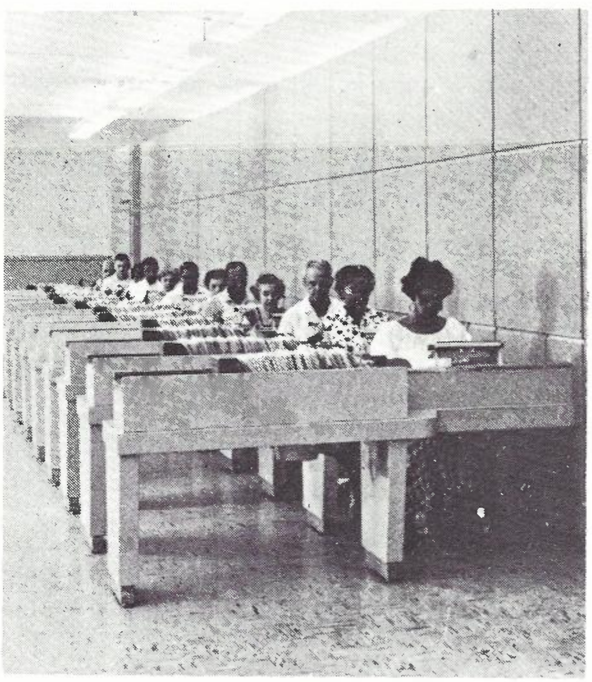


Fig. 1—Multiposition Letter Sorting Machine.

However the Transorma, and similar machines such as the Bell, manufactured in Belgium, were in use in Europe in the early 1950's. These machines, which were very large in size, comprised a number of keyboard positions (usually 4), which fed letters into a complex of carriers on a continuous chain system. These carriers passed over the destination bins (usually around 300), and deposited the letter in the appropriate bin when the letter in the carrier, and the bin it was to go to, coincided. The coincidence was registered by an electromechanical arrangement which caused the box to open and drop its contents into the bin. To cover the 300 boxes, the chain, and its carriers, followed a path so that it wound back and forth over 5 rows of 60 bins each stacked vertically. The size and complexity of the machine can be gauged from this concept. However this principle has been followed by other manufacturers with various refinements, and machines such as the Burroughs, which cater for up to 12 operators, are still in use in large numbers in the USA (Fig. 1).

The Concept of Letter Indexing

Late in 1959 and the early 1960's (Ref. 6), the technique of letter indexing offered the very distinct advantage of reducing the number of manual sorting processes by applying a machine readable index on each letter, when the address was first read by a manual operator. From then on the letter, when passing through subsequent sorting stages would have its index read by the sorting machine, and delivered to the appropriate sorting bin. This sorting machine could even be located in another State, thereby increasing the potential gains over a network of indexing installations. Work commenced on the design of the system for Redfern in 1961, and as mentioned above this was cut into service in early 1967. With this system mail transferred from the culler-facer-canceller machines is fed automatically to a number of indexing operators (up to 150 in Sydney), where individual letters appear in viewing windows in front of them. Without touching the letter the operator reads the address, and keys in the destination data (usually the POSTCODE and first character of the place name).

This data is fed to a central computer where it is checked for validity and translated into binary form to give the following:

- Information which denotes to which sorting machine the letters have to be directed; and
- information which denotes to which bin the letter has to be directed on that sorting machine.

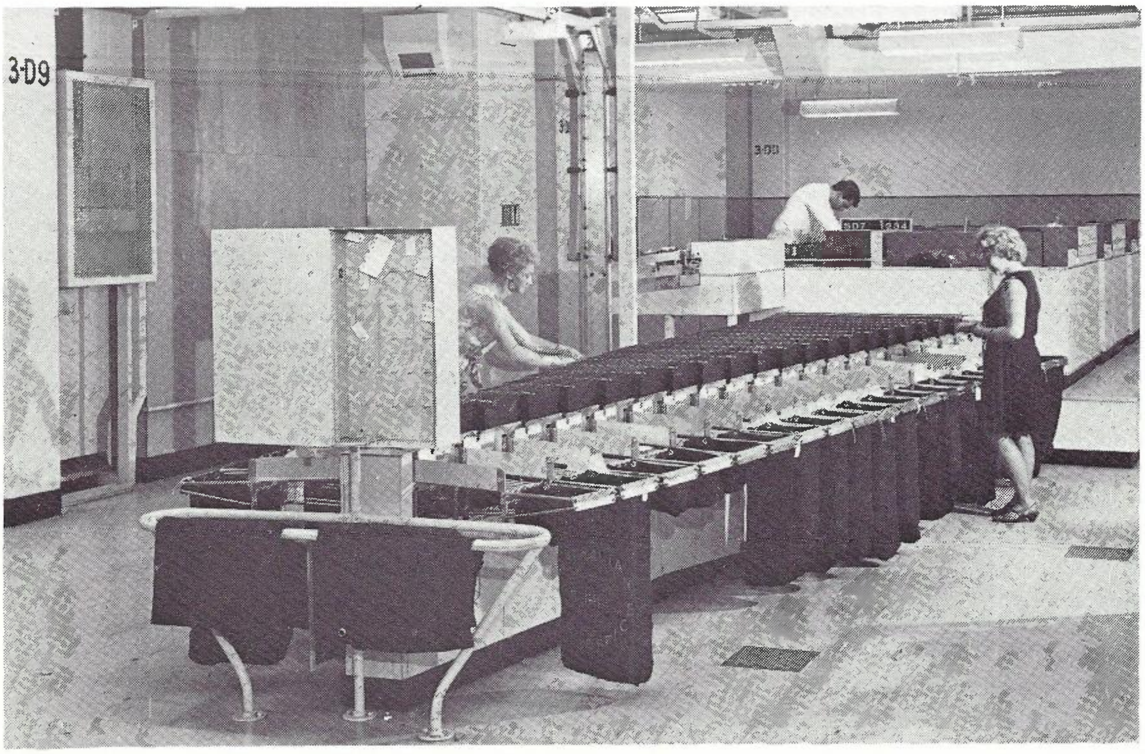


Fig. 2—View of Decoder, showing Stacker and Bag Racks to Receive the Sorted Mail.

The computer returns the information to the indexing desk where it is printed on the letter in the form of a bar/no-bar machine readable index. The letter is then automatically despatched to a conveyor leading to the appropriate sorting machine, where the index is read to select the required destination bin.

The 20 letter sorting machines used in the Sydney system were called "decoders" at that time, but as the use of letter indexing by other administrations grew, the terminology "letter sorting machine" has been almost universally applied to machines performing the function of reading the index and sorting the letters into bins or stackers.

In the case of the letter sorting machines used in the Rerfern installation, each machine is capable of sorting letters to 30 destinations. As there are 20 such machines, a "break" of 600 destinations is therefore immediately available from the initial primary sortation achieved by operators keying in the address information at the indexing desks.

The Australian concept for a mechanised letter system includes the automatic transfer of mail from primary (indexing desks) stages to all secondary stages, including the index reading LSM's. With this concept the time consuming and congestion producing tasks of transferring large quantities of letters by hand wheelers, baskets, etc., are eliminated, but the problems of equating the flow from the transfer system to the LSM's have to be overcome.

THE DECODER OR ORIGINAL LETTER SORTING MACHINE AT THE SYDNEY MAIL EXCHANGE

Fig. 2 shows one of the letter sorting machines at the Sydney Mail Exchange, viewed from the stacker end. Letters from the indexing desks located on the floor above are automatically delivered to the machine by means of the distribution channels of a letter transfer system. This channel can be seen entering the machine at the upper centre of the photograph. At this entry point the letters are passed through an input separation device to absorb large peaks in the flow and the output of this device is automatically switched to the reading heads in the machine, on a demand basis. In the case of the 8 letter sorting machines handling suburban mail in Sydney, the throughput of each is 20,000 letters per hour, made up of the totalled output of 3 individual reading heads rated at just under 7000 letters per hour.

The principle of operation of one of the reading heads is shown in Fig. 3. Letters from the input separator are stacked in a stacker/feeder, which as its name implies stacks the incoming stream, and then feeds them to the index reader. To achieve this each stacker receives about 300 letters, and moves these forward in a batch to the feeder, whereupon it is ready to receive another input.

The feeder contains a separator or singler which sends letters, one at a time, past the reading head where the index is read, and the letter proceeds to the diverter which directs it to the appropriate channel in which it is transported to its stacker. The three reading heads can be working simultaneously, each one diverting letters to channels common to all, with the decision as to which channel being based on the index read from the letter itself.

THE NEED FOR AN IMPROVED LETTER SORTING MACHINE

Early in 1969, after the Letter Indexing System at Redfern had been in use for about two years, it became obvious that one of the mechanical units in which improvement could be made, particularly in terms of maintenance cost, operational efficiency, and the need for attention by machine attendant staff, was the letter sorting machine.

As outlined above the design of this machine provided for incoming letters to be stacked, the sorting index to be read, and the diversion of the letters to appropriate stackers. It involved the stopping and starting of the incoming mail stream, and this practice made it necessary for a mail attendant to be available to monitor the stacking, de-stacking and machine operation. The machine was made up of a number of parallel units which ensured at least partial operation of the machine during the breakdown of one unit. This however increased the complexity, and maintenance requirements of the overall machine. In particular the mail attendant, who was not actually involved with the clearing of the sorted output of the machine was generally carrying out duties of a non-productive nature, and yet because of the vagaries of mail flow had to be available to keep it moving, especially during periods of heavy traffic.

One of the problems associated with the exist-

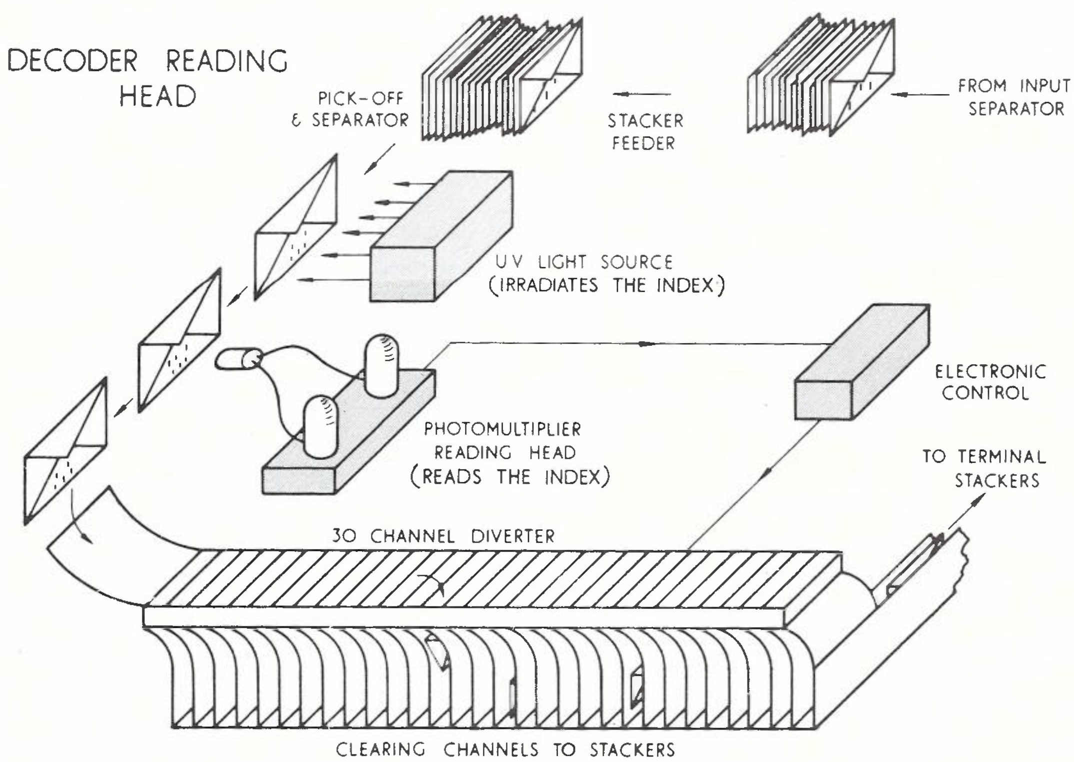


Fig. 3—Principle of Operation of Decoder Reading Head.

ing letter sorting machine concept, and in fact with many letter sorting machines of similar design from other manufacturers, is the absorbtion of the peaks in the incoming volume of letters whilst generating an outgoing stream of singled letters to the reading head.

This singling of the letters to allow each index to be read individually is one of the most important factors in the design of a letter sorting machine, as the error rate (number of letters missorted to incorrect bins) is almost in direct proportion to the efficiency of this device. Where the singling device allows more than one letter to pass the reading head, in the majority of cases the second letter is missorted with the one on which the index is read.

The singling function is particularly important whenever one sorting stage is directly connected to another by conveyors aggregating the sorted output, as is the case in Sydney, but it still poses a problem with a machine that is fed with letters by hand from a manual feeder unit.

In the existing letter sorting machines in Sydney, the device which buffers the incoming stream and generates a singled flow of letters which then pass the reading heads, is the stacker/feeder. Other types of machines currently available overseas often use an equivalent device called a "buffer stacker", but the aim is the same, to receive letters randomly from one source and present singled letters to the index reader.

The weak point in the use of such devices is the fact that letters in movement are required to be halted, and then moved off again, often at quite high speeds. This introduces the problems of letter bounce, flimsy letters crumpling, and the need for constant attention or supervision to ensure an uninterrupted mail flow, and freedom from blockages in the machine.

To overcome the recognised shortcomings of the existing machines in Sydney and current overseas designs, a new machine was envisaged which would accept incoming indexed mail, read the index and divert the letter in flow, all in the one operation. In other words the machine would sort letters as they arrived without the need to stack and destack, thereby eliminating one of the main difficulties encountered with the original letter sorter.

The four main objectives of this approach were:

- Elimination of the need for an attendant to be stationed on the machine.
- A reduction in machine complexity with a view to reduced maintenance requirements and greater reliability..
- A reduction in noise level.
- Lower missort and reject figures.

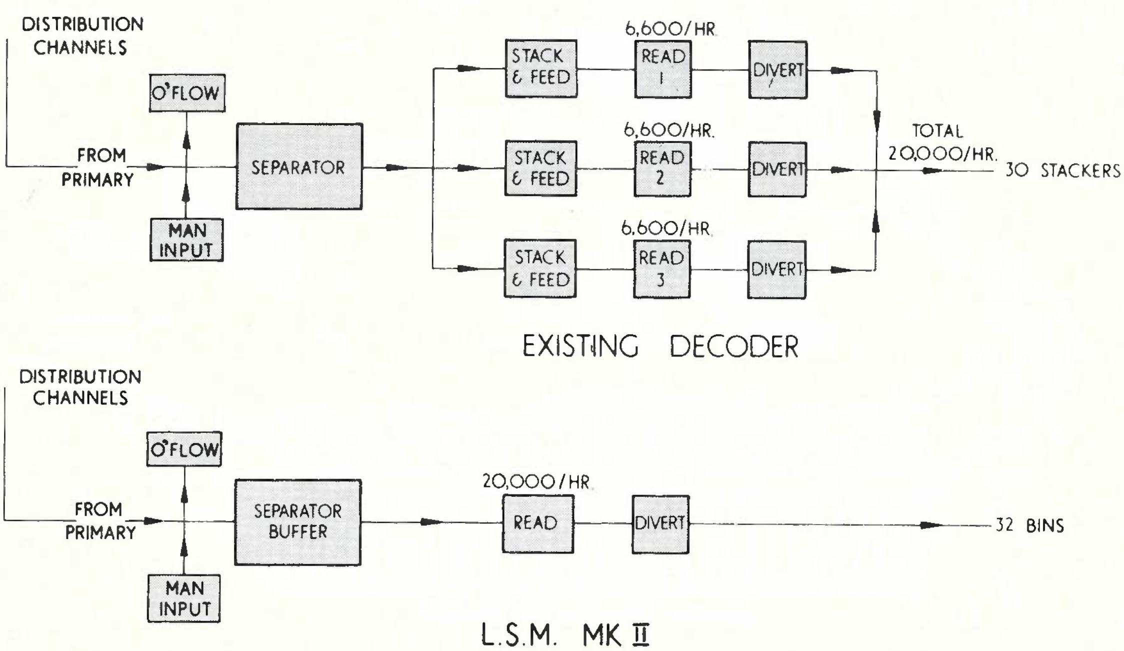


Fig. 4—Block Schematics Showing the Difference in Concept between the Existing Decoder and LSM MK II.

THE DEVELOPMENT OF THE NEW LETTER SORTING MACHINE

Fig. 4 shows the schematic diagram of the existing letter sorting machine, and the new machine which was given the title Letter Sorting Machine Mark II, or LSM MK II. The simplicity of the approach is obvious, but it is also obvious that much greater reliability is required, as only one read head operating at 20,000 letters per hour is provided, instead of 3 at a much lower rate.

In addition to the main objectives quoted earlier, a number of other specific features were required, many of these included as a result of experience gained from the operation of the original LSM's at the Sydney Mail Exchange.

These included:

- an improved work situation, whereby machine control and manual loading can be carried out from floor level. (The original LSM required the machine attendant to work on a platform).
- an improved design for the output bins, so that operators would not have to stoop to clear bins and load bags.
- modular construction to allow for ease of maintenance or machine relocation.
- the design to allow for increasing the bin capacity to provide a multi-bin machine if required.
- inclusion of checking devices to detect overlapped letters to reduce missorts.
- positive control of letters whilst in transit.
- provision for automatic monitoring and statistical recording.

A specification was produced by the Department incorporating these features, and covering the main objectives detailed earlier. The almost unique experience gained from operating a large letter coding system was also used in preparing the specification, and assisted greatly in determining performance objectives, maintenance requirements and the like.

A developmental contract was placed with Telephone and Electrical Industries (now Plessey Australia Pty. Ltd.) of Sydney, who had manufactured and installed the original Redfern equipment.

The Developmental Contract

Since it was a developmental contract, the work was programmed in four stages:

- concept development
- development and manufacture of feasibility model
- manufacture of prototype
- installation and testing of prototype.

The feasibility model was to test the soundness of the design concepts, and to determine the economic and technical practicability of proceeding with the project.

The prototype to be developed from the feasibility model to produce a machine meeting the requirements of the specification. It was to be suitable for commissioning as a working unit, and to represent the final production design as closely as possible.

A design review committee, comprising representatives from the Department and the contractor was formed to oversight the development, and review the progress. This group met at regular intervals throughout the term of the contract.

The prototype was installed in the Sydney Mail Exchange in May 1973, and placed in operation on a trial basis, handling live mail over the day shift only. The performance of the prototype under these trial conditions is discussed later in this article.

DESCRIPTION OF THE MACHINE

In common with almost all letter sorting machines available today, the LSM MK II is modular in construction, simplifying manufacture, installation and maintenance. The modular approach also facilitates planning, in that a number of different configurations can be arranged to suit particular applications, taking into account floor space and traffic considerations. Relocation of the machine because of changes in traffic patterns is also facilitated, giving a high degree of flexibility unattainable with earlier designs which were generally "built in" to the exchange.

The full machine as installed in the Sydney Mail Exchange, is made up from the following:

- feed control module
- buffer separator module
- elevator module
- index reader module
- tail unit, comprising a number of bin unit modules (32 bins in total).

Fig. 5 is a diagramatic sketch showing these modules assembled to form a complete machine, which can be operated as a self contained unit, ie without recourse to a central computer.

Fig. 6 is a view of the MK II machine installed in the Sydney Mail Exchange looking from the input module, showing the bin units at the far end. The input transfer can be seen entering the

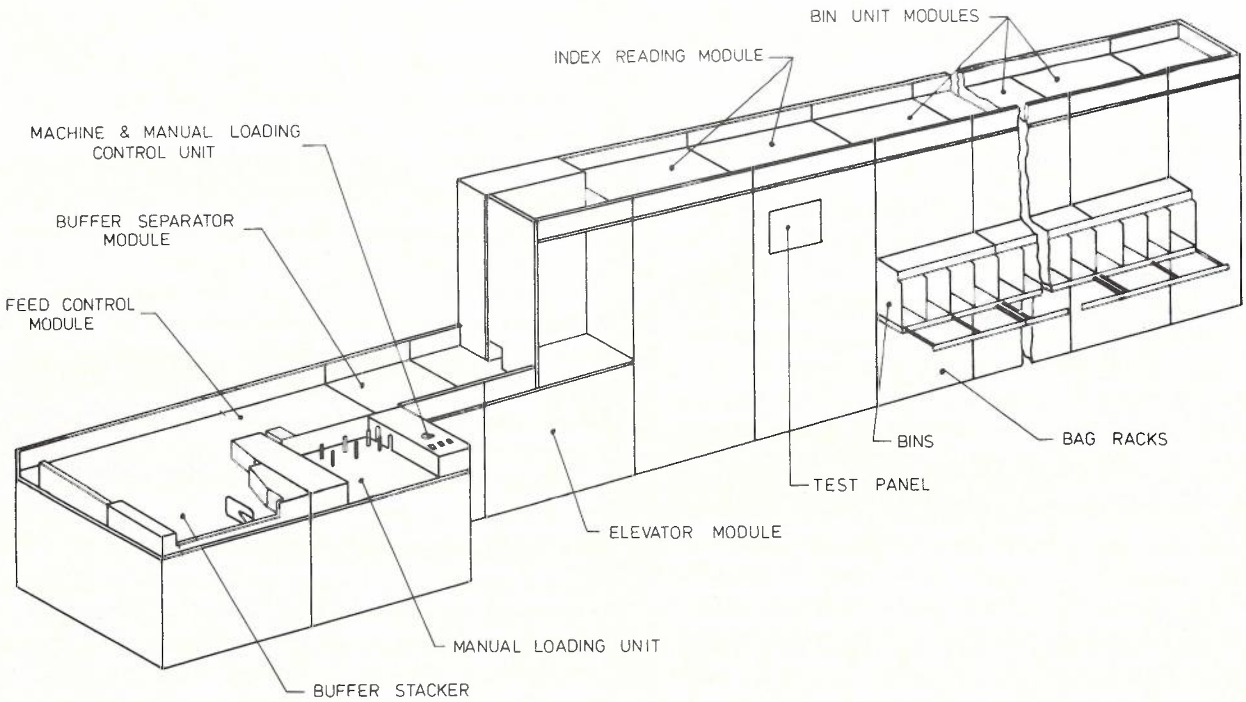


Fig. 5—The Assembly of the Various Modules to Form a Complete Machine.

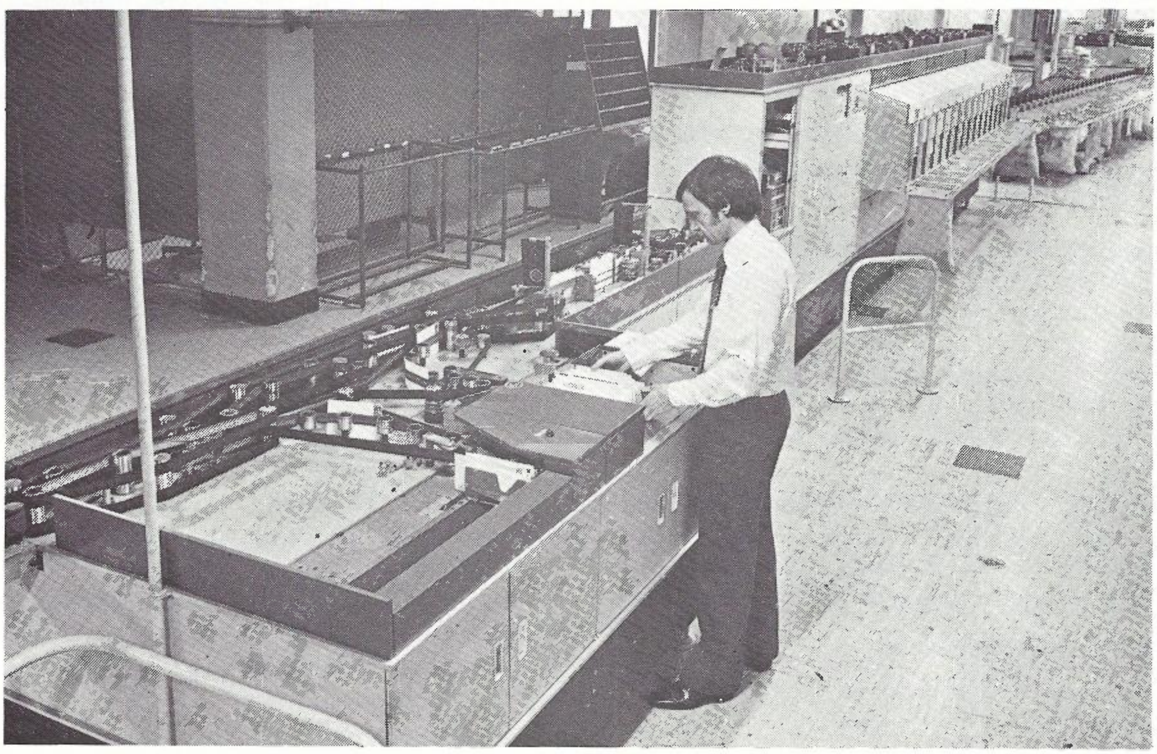


Fig. 6—The LSM MK II Installed in the Sydney Mail Exchange, Viewed from the Feed Control Module End.

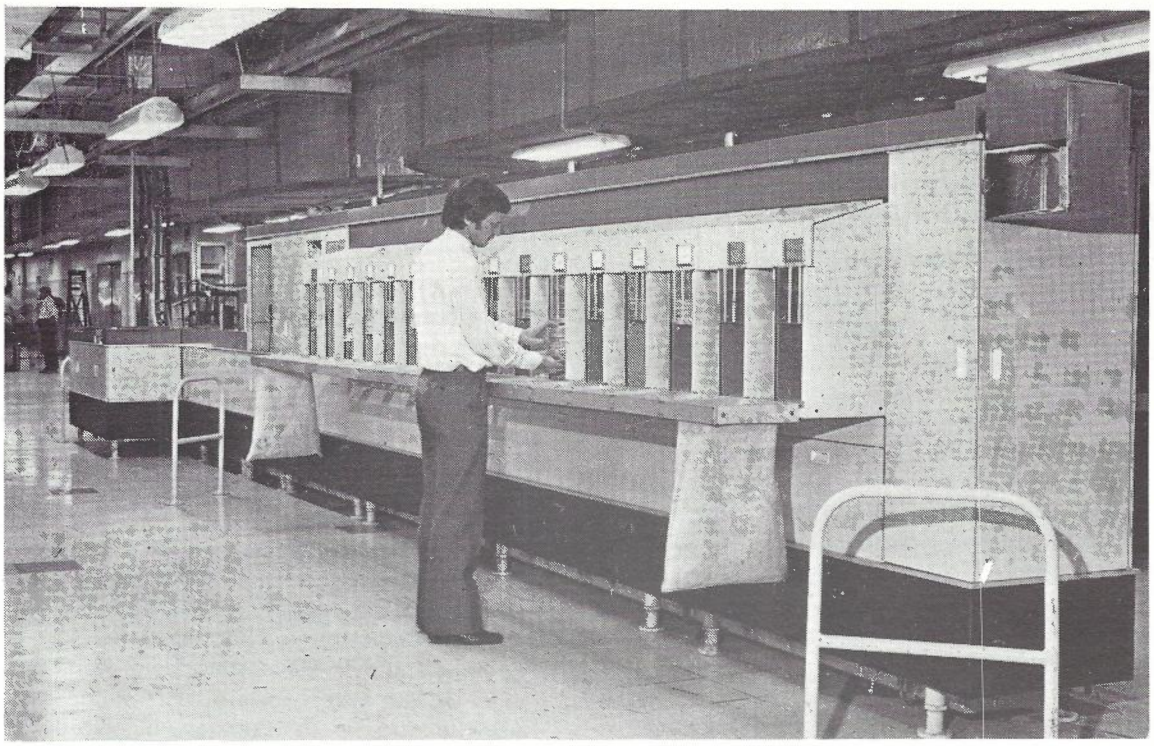


Fig. 7—The LSM MK II Viewed from the Tail Unit End, Showing the Bin Units and Bag Racks.

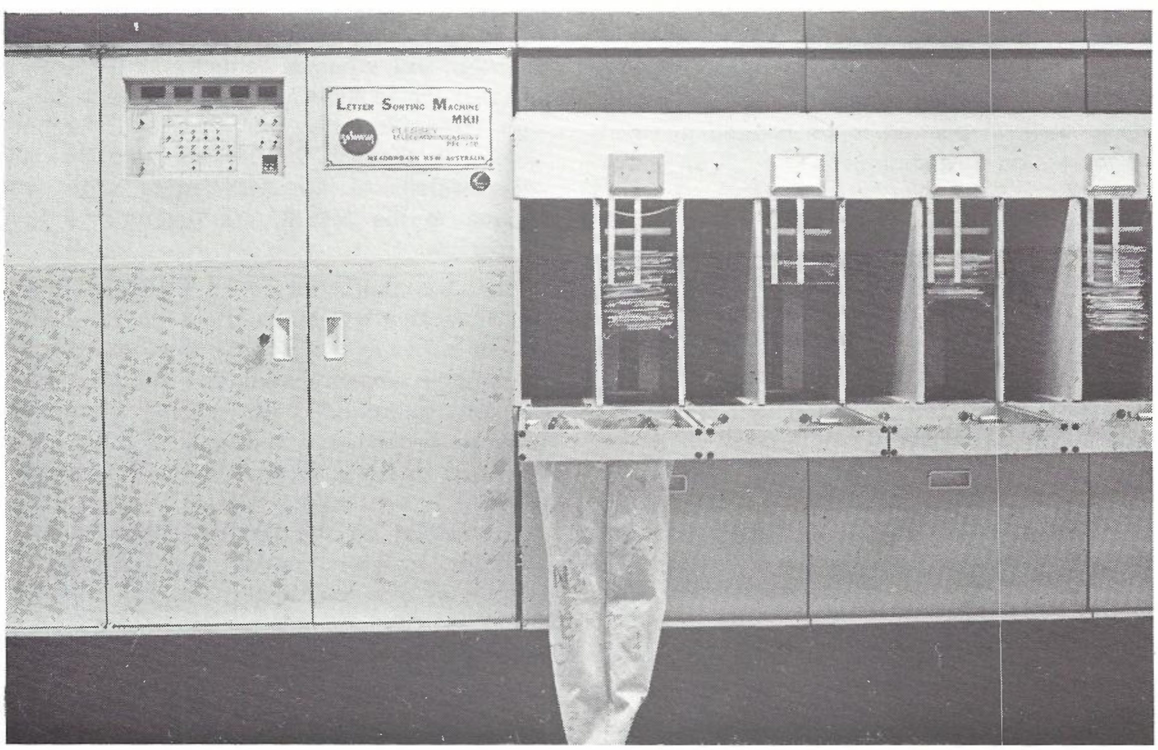


Fig. 8—A Close-up of the Bins and Bag Racks. The Test Panel can be seen in the top left of the feature; The electronic controls are housed behind the two doors.

machine at the left of the picture.

Fig. 7 depicts the machine from the bin unit end, showing the bin units, and bags hanging from the bag rack. Details of the bins are shown in Fig. 8. The labels which are attached to each bag when it is tied off are accommodated on hooks in the space adjacent to each bin.

General Principle of Operation

The general principle of operation of the machine is very much the same as currently available machines from manufacturers overseas, ie, the letters are singled, the index read, and the letters diverted into bins, at a throughput rate of between 20,000 and 26,000 per hour. However it is in the performing of these functions that the LSM MK II is unique. It should be pointed out at this stage that one big difference between various available LSM's is the total number of bins to which letters can be sorted. This of course depends on the application, but two main types are in existence:

- The multi-bin type, with a large number (from 100 to 600) of bins, each bin being of relatively low capacity.
- machines sorting to between 12 and 36 destinations, with the letters being deposited in relatively large capacity bins, containers or stackers.

The LSM MK II comes into the latter category, and in the Australian situation is ideally suited to the sorting of suburban mails, particularly where the sorted mail is required to be bagged in small letter bags for onward despatch.

Machine Operation

Letters from the transfer enter the feed control module in a random stream. They are fed into the buffer separator module where they are separated so that singled letters only are presented to the following index reading stage. The buffer separator has a temporary storage capacity of up to 20 letters, and if this amount is exceeded the overflow is diverted to the overflow stacker in the feed control module.

The overflow stacker also accepts mail from the transfer should the machine be temporarily out of service.

The manner in which the buffering and separation functions are carried out is a major departure from any known previous design and is one of the features which has made the MK II performance so notable.

The feed control module contains a manual loading unit, which allows the overflow mail to be re-introduced to the stream, in addition to providing a means of infeeding for indexed mail. Pre-indexed mail is mail indexed in another exchange (maybe in another State), which can be fed direct to the LSM, bypassing the primary sortation.

After leaving the buffer separator module, the singled letters (with a controlled gap between them), are raised by the elevator module for presentation to the index reader.

Since the letters in the feed control and buffer separator modules are processed at a low height suitable for general supervision by the operator, it is necessary to raise them in order to present the sorted mail in the bin units at a height convenient to the operator unloading it into bags. The relative heights of the bin units and bag racks in relation to an operator can be seen in Fig. 7.

The letters leaving the elevator module enter an edging unit which ensures that they are presented correctly to the reading head, and are then processed through the reading head itself. The reading head extracts the sorting data from the index marks on the letter, sorts it, and at the same time causes a diverter to operate which determines to which half of the tail unit the letter is to be finally sorted.

In the tail unit, the letter travels along held between two elasticised belts. The relevant sorting data is also shifted along an associated shift register, and when a comparison is made denoting that the letter is above the required bin, a turn unit takes the letter from between the belts and diverts it, through 90 degrees, into the bin unit. More details of this 90 degree turn, which is unique to the MK II, are given in a following paragraph.

The bin unit modules comprise vertical bins which receive the letters from their associated 90 degree turn units, and stack them for the operator to remove when convenient. The bin unit has a PE cell controlled base which is automatically lowered as the stack builds up. Visual alarms are provided to signal when a bin is $\frac{3}{4}$ full, and again when it is full. In the case of a full bin which is not attended by the operator, the machine automatically transfers further mail destined to that bin to an overflow bin in the tail unit, to allow sorting to continue without causing machine blockages.

As was stated at the beginning of this paragraph, the manner in which the performance of the various functions necessary to sort a letter by the LSM MK II are carried out makes it unique in comparison to other machines. The more important of these features are discussed below.

DESIGN FEATURES OF THE LSM MK II

Buffer Separator Area

Earlier in this article it was pointed out that one of the most critical areas in an LSM was the means of ensuring that singled letters are presented to the reading head. This is particularly so when the LSM is coupled direct to a letter transfer, as is the Australian philosophy with regard to a fully integrated sorting system. Almost all known designs require that a relatively large number of letters can be held in the buffer, with fairly complex vacuum and mechanical devices to control the operation of the unit, and single the letters. Often critical adjustments are involved to ensure satisfactory operation of these devices.

The MK II design performs the function with the minimum of mechanical components, requires no vacuum devices or critical adjustments, and yet is capable of giving a much better separation performance (and therefore missort figure) than is available on any other known machine.

This is achieved by the reduction of the temporary store to a maximum of 20 letters, and a new approach in separation achieved by the judicious use of belts of various frictional properties arranged in a particular way.

The main reason for the success of this method is that the letters are not stacked for buffering, but merely slowed down momentarily, without imposing excessive forces on them. The process is carried out in two stages to achieve firstly shingling (staggering the stream so that they are overlapped but not separated) and then singling in the second stage.

As well as providing an excellent separation performance, with very little noise, this method provides a much higher machine throughput than conventional singling devices which generally feed letters in a stream with a constant distance between the leading edges. This distance has to be around 300 mm to accommodate the largest standard letter plus a gap. The MK II unit produces a stream with a constant gap of around 60 mm between the tail of one letter and the leading edge of the next, irrespective of the letter length, giving optimum utilisation of the letter transport conveyors, and reducing the buffering requirement.

Letter Transport

One of the specified requirements for the development of the LSM MK II was that letters passing through the machine were under positive control, to minimise blockages and rejects due to letters turning over or being held on a chute or slide. This requirement has been fulfilled in the transportation of letters through the machine, and letters are held between belts or rollers in almost all situations. The use of elastic belting greatly assisted in reducing the mechanical complexity usually associated with this requirement.

90 Degree Turn Unit

This unit is the means of diverting the letters, after the index has been read and the appropriate side of the tail unit selected, to the correct sorting bin. Many forms of diversion are used in letter sorting machines of various types, from the chain and carrier, to the flap diverter which is the most common. A completely new approach has been adopted in the MK II whereby the letter is virtually plucked from between two belts, and directed, at high speed, into a chute feeding into the vertical stacker or bin.

The principle of operation is shown in Fig. 9. The sequenced pressure rollers which grip the letter against the loop of belt are of course precisely timed, as a second letter destined for a different bin may be following 60 mm behind the one being turned in the unit, and the rollers have to be free to let it pass. The turn unit developed for the machine utilises a rotating cam to achieve the turning sequence, but a new one being tested by the Post Office is electronically operated.

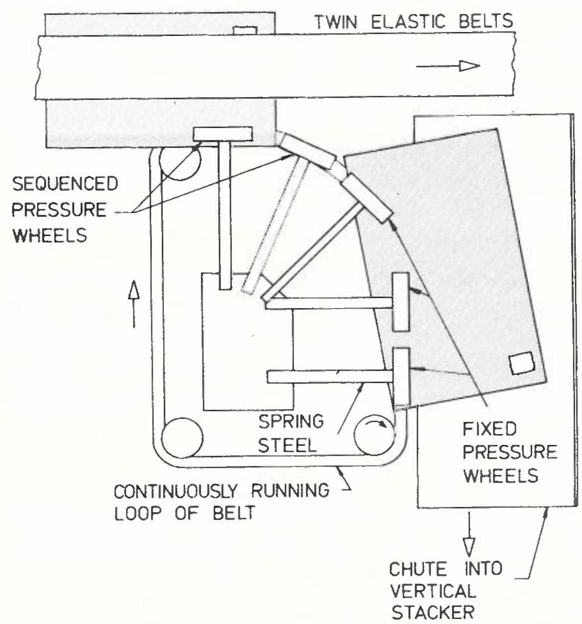


Fig. 9—The Principle of Operation of the 90 Degree Turn Unit.

In the MK II this turn unit is a jack-in/jack-out device, and this feature, coupled with the relative simplicity of the letter transport needed, make it a very useful and unique form of diversion. The principle also lends itself to multi-bin diversion, which was also one of the requirements of the development.

Elevator Unit

This unit utilises two 90 degree turn units operating in a fixed mode (without sequenced pressure wheels), and also in opposing directions. The letters are received into the lower turn travelling on their longer edge, are turned 90 degrees and fed vertically upward where they encounter the upper turn unit, and their direction is changed back again to cause them to continue their journey travelling on the longer edge. This form of elevator occupies less space than conventional elevators using twin belts or the elevating medium.

Electronic Control

Solid state circuits using TTL logic are featured in the control of the machine. The machine is fully alarmed against blockages, and also is fitted with statistical data gathering equipment, and a comprehensive test panel for routining purposes. This can be seen in the top left hand corner of Fig. 8.

Maintainability

Besides the modular construction adopted for the main units of the machine, individual sub-assemblies are designed on a plug-in/plug-out basis, to allow quick replacement during operation and servicing off the mail room floor. The need for critical mechanical adjustments, often a requirement with many LSM designs, has been reduced to an absolute minimum. In the event of a blockage in the feed control, buffer separator or elevator modules the appropriate sections automatically stop and display an alarm.

In the case of the bin units, a blockage causes the affected bin to be "inhibited", and the mail for that bin to be fed to an overflow, thereby not requiring the machine to close down. This feature is not possible with LSM's using the conventional forms of letter diversion.

Noise Levels

Particular attention has been paid to noise levels, and the adoption of the vacuum-free buffer separator contributes considerably to this, as no vacuum pumps are required. The use of elastic belting, and treatment of panelling with acoustic absorbing material are also important factors in the low noise level emanating from the machine of around 75 dbA.

Performance

Although the specification called for a throughput rate of 20,000 letters per hour, under average conditions this can be considerably exceeded, as the machine runs in an asynchronous mode, with a controlled gap between successive letters.

The machine has been designed to process letters within the standard (Universal Postal Union size) range.

Missort (error) and reject percentages vary according to a number of factors, including mail quality being processed, but under trial conditions with live mail, missort percentages of around 0.2% of throughput have been recorded, with rejects of 2% or less.

The ability of the machine to run without a machine attendant has been proven in the trials, and to date reliability has been of a very high order.

CONCLUSION

The LSM MK II is a unique letter sorting machine developed by Australian industry and the Australian Post Office. It encompasses a large amount of postal mechanisation experience gained by the Post Office and the manufacturer over a number of years, and appears suitable for inclusion in future letter indexing systems. It also offers a suitable replacement for the decoders in the Sydney Mail Exchange, with a potential for reduction in operating costs, and improved sorting efficiency.

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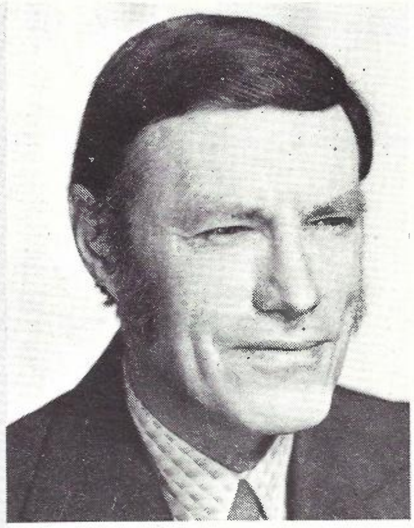

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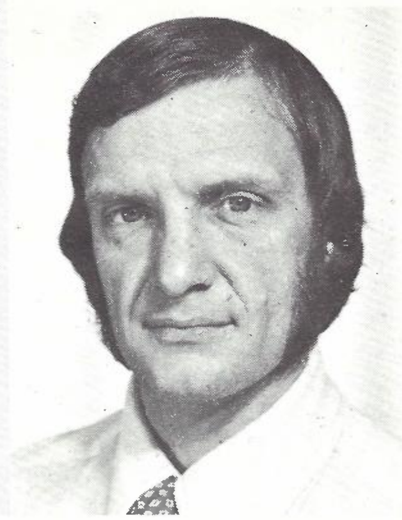

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Automatic Testing of Telephone Cable

A. H. HAMBLETON, B.E., M.I.E. (Aust.) and R. R. LLOYD, M.Sc.

With the increasing complexity of the Telecommunication Network, the performance requirements for component cables have increased. Cable testing to provide both Quality Assurance and design information, has assumed a significant role in cable manufacture, leading to the development of more and more sophisticated measuring systems.

This paper discusses the current generation of computer-controlled cable-testing equipment and explains its application to cable testing.

INTRODUCTION

In modern telecommunications cable manufacture the testing operation is assuming greater importance, due to the more stringent requirements of recent APO specifications.

Whilst in some aspects of cable testing, quality assurance has been increasingly provided by the performance of tests on a statistical sampling basis, other testing including requirements for network design has steadily increased and the level of final cable testing required has shown a corresponding growth.

Capacitance and resistance measurements have always represented the major part of the testing carried out on telecommunication cables and therefore the increase in testing levels has been most marked in these areas; as a result, a great deal of innovation of new testing methods has occurred, leading to the development of computer controlled automatic test sets for measuring capacitance and resistance parameters of telephone cables and providing statistics of these parameters. The test sets in particular allow the proper testing of unit twin cables at reasonable cost.

CABLE DESIGNS AND TESTING METHODS

Early designs of Australian paper insulated telephone cables were based on star quad elements, assembled in concentric layers. The evolution of the junction and subscribers' network produced a requirement for crosstalk which could not be achieved in quad cables and as a result unit twin construction cables replaced concentric quad types in paper and unit quad in plastic insulated constructions (Ref. 1).

The predominant source of voice frequency crosstalk in a quad cable is the side to side capacitance unbalance within the star quads. In capacitance unbalance testing, consideration of this parameter is all-important and less attention is paid to the unbalances between pairs in different star quads.

A further factor which reduced the need to comprehensively test unbalances between pairs in different quads was the use of concentric layers stranded in opposite directions. This construction produced stable configuration and virtually eliminated quad movement. In addition, parallel adjacency of pairs in adjacent layers did not occur as pair combinations between successive layers became adjacent only once in each interference lay length.*

The nett effect was thus to reduce the adjacent pairs to a limited set of known combinations.

With the introduction of unit twin cable a number of design changes were introduced:

- 10 to 12 twist lay scheme (to reduce high frequency magnetic couplings between non-adjacent layers in the unit).
- All layers in each unit stranded in the same direction (to simplify and cheapen manufacture).
- Tighter unbalance limits between pairs (to avoid the need for APO field staff to upgrade crosstalk performance while installing the cable).

* This is the reciprocal of the sum of the lay stranding reciprocals, i.e. $\frac{1}{T} = \frac{1}{T1} + \frac{1}{T2}$.

The combination of unit construction with the twin design introduces the possibility of adjacency between pairs on a much larger and less predictable scale than was the case for concentric quad. Coupled with this, the increase in the number of lay lengths has reduced the effective differences between lays which can become adjacent and the tighter unbalance limits for cables with heavier gauge conductors has reduced some of the conformance margin. This has become most noticeable in plastic cables, as demonstrated by the specification limit for 0.9mm cable pair to pair unbalances which is now 62 pF/500m compared with 315 pF/500m in the early concentric twin specification, and 135 pF/500m in the unit quad specification.

In early quad cables capacitance unbalance testing had been limited to side to side capacitance unbalance within each quad for up to 20% of the quads in the cable, and small samples of other unbalance combinations. The side to side unbalance tests were combined with measurements of mutual capacitance and side to earth unbalance.

This was traditionally accomplished using a manually-operated transformer ratio arm bridge connected to the cable using a lead with a cable clip on the remote end and an operator connecting pairs in sequence to the clip. Communication between the clipper and the tester used lights, buzzers, or other similar devices.

Resistance and resistance unbalance measurements were carried out on very small samples as a separate operation.

In order to make some savings in costs, a number of semi-automatic test sets were developed. These usually comprised some form of sequencer, together with a bridge which balanced automatically and printed the results on a teleprinter or similar machine. The sequence was traditionally controlled by hardware, although later designs use tape control with some form of tape output also available. Almost without exception these machines were designed for quad cable and their test modes were those required for quad.

With the introduction of unit twin cables, testing methods initially remained basically similar to methods used for concentric cables. The concept of sampling 20% of all pairs for capacitance tests was replaced by a sample comprising one or more complete units.

Measurements within units were limited to unbalances between combinations assumed to be adjacent and between a few combinations involving pairs in adjacent layers in the unit.

Resistance measurements were made using a small sample of conductors connected in series and did not indicate the variation which could be expected within the pairs in the cable. This was also of limited value for the requirements of network design.

Even this testing programme, assuming as it did a cable structure akin to a concentric cable, was expensive and time consuming and did not really provide the required assurance that cable passing the test programme really met the intentions of the specification.

COMPUTER-CONTROLLED AUTOMATIC TESTING

The description by Fulks & Lamont (Ref. 2) in 1968 of a computer-controlled automatic capacitance test system excited considerable interest in the cable industry. The test set described used an inbuilt mini-computer to control the testing through a scanning unit and to process test results and present them in a usable form.

The original test set was limited to capacitance measurements but versions with other parameter capabilities have since been developed and reported (Refs. 3 and 4).

The computer-controlled test set offers many advantages and enables the testing of unit twin cables in a proper manner without the prohibitive cost which would be associated with equivalent manual testing.

Advantages offered by the computer-controlled system include:

- Programme control of scanning, allowing variations to be built in at later dates, so as to maintain testing programmes in accordance with up-to-date requirements.
- Intelligent control of testing routines to provide inbuilt self-check and error routines.
- Electrical determination of pair adjacency rather than assumption of pair position.
- Direct output of results in converted meaningful form.
- Increased accuracy.
- Increased speed of testing.
- Reduced cost of testing.
- Provision of statistics and summaries for use by cable and system designers.

A number of different types of automatic test set are now available, but all have similar characteristics. European-manufactured instruments all tend to be made to test quad cable, as this type of construction predominates in Europe. On the other hand American test sets are made to test twin cable and have been found to be best suited to Australian requirements.

In Australia, Austral Standard Cables has installed three 'General Radio' Automatic Test Sets, specially adapted to Australian requirements, and these have been in operation for some two years. One other similar General Radio instrument is in service at another manufacturer's works and a third manufacturer has a semi-automatic cable test set.

AUTOMATIC TEST SET CAPABILITY

Testing

The capacitance and resistance parameters of interest in a twin cable are defined in Fig. 1 and are listed below:

- Mutual capacitance — this quantity is closely related to the insertion loss of the pair. Measured results are normalized to a standard length, ℓs, by multiplying by $\frac{\ell s}{\ell}$.
- Pair to earth capacitance unbalance — determines the susceptibility of the pair to noise pickup. Measured results normalized by multiplying by $\frac{\ell s}{\ell}$.
- Pair to shield capacitance unbalance — similar to pair to earth unbalance except that only the unbalance to the shield is measured, all other pairs are grounded.
- Pair to pair capacitance unbalance — index of audio frequency crosstalk between two pairs. This quantity varies as a random function with length, and hence the measured results are normalized by multiplying by $\sqrt{\frac{\ell s}{\ell}}$ or other more complex factors.
- Resistance — this is the second quantity determining the insertion loss of the pair. Measured results must be corrected for the following:
  (a) Length — normalized by multiplying by $\frac{\ell s}{\ell}$.
  (b) Temperature — normalized to 20°C, different temperature coefficients are required for copper and aluminium conductors.
  (c) Stranding — an allowance for the extra length of the conductor due to stranding is required. The allowance is a function of the cable core diameter. For a given conductor size and cable type, the core diameter can be determined by the computer from the total number of pairs in the cable.
- Resistance unbalance — this quantity gives rise to high frequency crosstalk. Measured results are expressed as a percentage of the deviation from the average pair resistance.

Except for one, all the above quantities involve a single pair, giving the same number of results as number of pairs tested. The exception, pair to pair capacitance unbalance, involves two pairs and for a 100 pair unit a total of 4950 possible combinations exists. Electrostatic screening by intervening pairs results in only the combinations where the two pairs are adjacent being meaningful and to reduce the total number of measurements an electrical determination of pair adjacency, referred to as the skip test, is included in the testing programme.

The skip test can also provide an insight into the sequential retention of pairs within a cable unit. If pairs move from their expected positions, then they form unintended adjacencies to other pairs within the unit for part of the cable length. Where manufacture results in the loss of designated position for pairs the number of combinations skipped will decrease and the total number of unbalance measurements will increase.

Table 1 gives the total possible number of combinations for different unit sizes and the typical number of unbalance measurements performed.

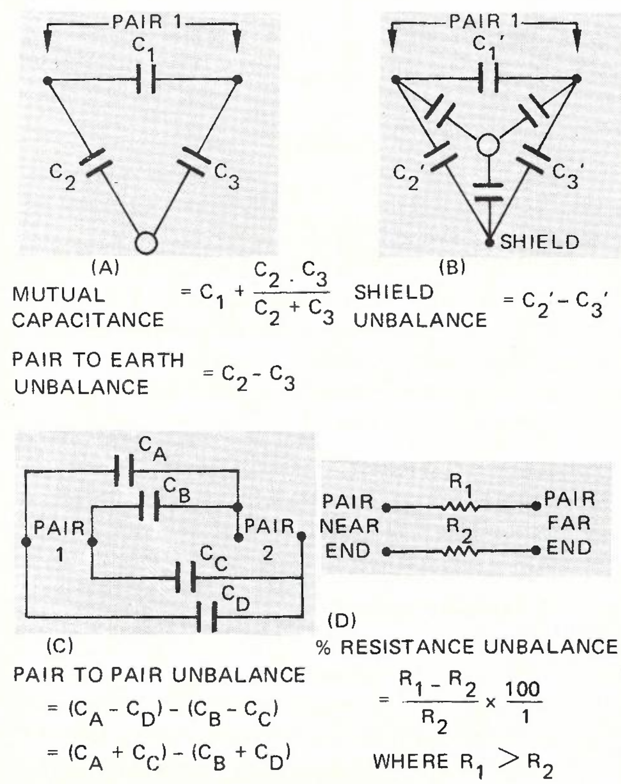

Fig. 1—Capacitance and Resistance Parameters of Twin Cable.

TABLE 1 — PAIR TO PAIR COMBINATIONS TESTED FOR UNBALANCE

Unit	Total Number of Combinations	Typical Number of Unbalance Measurements
100	4950	600
50	1225	250
25	300	130
10	45	45

Output and Statistics

Once the cable parameters have been measured and normalized for length and temperature, a printed summary must be produced. With computer-controlled testing equipment, it is not difficult to arrange for processing of the test results so that the information provided is in a directly usable form. In addition, several forms of output can be provided depending upon the requirements.

For routine acceptance testing, a simple summary giving the basic results related simply to specification requirements is adequate. Appendix A shows an example of a routine acceptance test print-out, giving mean, RMS and maximum statistics for each parameter, together with the number of pairs actually tested. Appendix A also shows statistics called MEAN MAX, STD DEV MAX, and MAX MAX for pair-to-pair unbalance. These results were specially provided for Australian requirements and represent statistics on the set of maximum unbalances associated with each pair tested. The maximum value is stored in the computer memory in a table form and each time a test is performed the value obtained is compared with the stored maximum for both pairs in the combination. If the measured value exceeds the previously stored maximum value, the maximum is reset to the measured result. Once the full test is completed the stored maximum values are converted into the three statistics above. In this case the standard deviation is given rather than the RMS, as the distribution of maximum values has a non-zero mean. There is, of course, a simple relation between the RMS value, the mean value, and the standard deviation about that mean.

Further information is also provided by determining the proportion of pairs with unbalances over 20% of the maximum limit.

A more complete statistical result is provided in the COMPREHENSIVE printout, where a histogram is given for each parameter in addition to the information included in the NORMAL printout. This more complete summary is particularly important for prototype cables. A typical COMPREHENSIVE printout is shown in Appendix B.

For a complete listing of the individual values the ALL MEASUREMENT output can be used. Here the individual elements of the cable capacitances are also provided. The use of this printout is of major importance for determining the cause of defects in cables.

Appendix C shows an ALL MEASUREMENT print-out. In Appendix C only two pairs have been included, as the ALL MEASUREMENT print-out would show a result for all combinations and therefore for a full 100-pair unit the testing and printing times are very extensive.

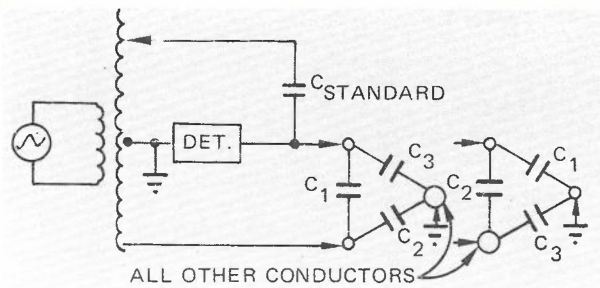

Fig. 2—Transformer Ratio Bridge for Direct Capacitance Measurement of C_1 and C_2.

EQUIPMENT

Measuring Technique

The major difficulties in automating cable resistance and capacitance measurements are from the stray capacitance and series resistance associated with the connecting leads and reed relays. The development of automatic digital three terminal capacitance bridges largely eliminated the effect of stray capacitance. In a three terminal bridge, such as a transformer ratio bridge shown in Fig. 2, only the capacitance placed directly between the oscillator and detector is measured. Capacitance between either terminal and ground is merely shunting the oscillator or detector, not affecting the accuracy of the measurement. With this arrangement the direct capacitance between any two remote points can be measured if all other points in the system are grounded. To measure the three individual elements associated with a single pair (see Fig. 1(A)), three separate measurements are therefore made.

The pair to earth capacitance unbalance for a pair (see Fig. 1(A)), could be obtained by the subtraction of the results for the individual elements but to achieve the required accuracy, extreme accuracy of the individual measurements would be necessary. This is avoided by using a differential technique. An additional connection is made to the bridge to provide a signal, shifted in phase by 180° from the main signal, as shown in Fig. 3, and the capacitance $C_2—C_3$ is measured differentially.

To measure the pair to pair unbalance (see Fig. 1(C)), two separate differential measurements are required, the first yielding $C_A—C_D$ and the second $C_B—C_C$. If the results are subtracted, i.e. $(C_A—C_D) — (C_B—C_C)$ then the desired result $(C_A+C_C) — (C_B+C_D)$ is obtained.

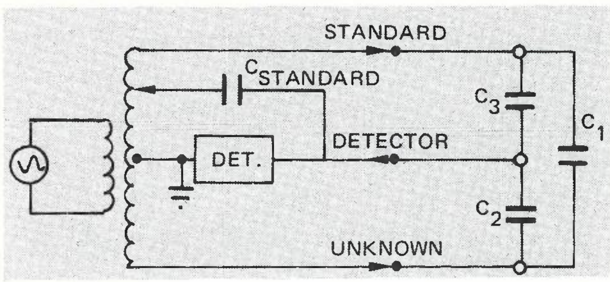

Fig. 3—Transformer Ratio Bridge for Differential Measurement of (C_2-C_3).

As mentioned previously a test for adjacency of pairs, the skip test, is required to reduce the total testing time for pair to pair unbalance measurements. An index of this adjacency is provided by the capacitance elements between the conductors of the pairs, designated C_A to C_D (Fig. 1). To measure one such element required one complete bridge measurement. A rapid indication of this element can be obtained by using a variable capacitor, C_V, formed by switching-in fixed capacitor elements, and measuring the sign of the difference $C_A—C_V$. The value of C_V controlled by the computer from the cable type and length. If $C_A—C_V$ is positive then $C_A>C_V$ then further measurement between these two pairs is skipped. The test for sign can be made about ten times as fast as a complete balance of the bridge.

The measurement of shield unbalance is similar to that for pair to earth unbalance except that the increased capacitance shunting the detector, i.e. the capacitance between the shield and all other pairs, may be sufficiently large to reduce the detector sensitivity and require the use of an additional amplifier (Ref. 3).

The advent of digital four terminal DC ohmmeters provided a solution to the problem of series resistance for resistance measurements. Although measurements are not feasible with four terminal connection to the conductor itself, four terminal connection can be extended to the test clip, onto which one end of the conductor is connected, and up to the actual clamp used as the common point for the whole cable at the far end. The accuracy available with this equipment is sufficient to enable the resistance unbalance to be computed directly from the values for the separate conductors and not require a differential measurement.

Measuring System

Fig. 4 shows the block diagram for a typical system using the above two instruments for the measurements. The major elements are:

- Computer — provides the control, storage and data processing functions.
- Control unit — decodes instructions from the processor for driving the scanners and allows the operator to select the measurements and printout desired.
- Scanning — reed relays to switch the cable pair under test to the measuring instrument.
- Capacitance bridge — automatic digital three terminal bridge.
- Ohmmeter — automatic digital ohmmeter with four terminal connection.
- Test Network — fixed components to enable the system operation to be verified.
- Teletype — printing of measured data.
- Tape reader — loading the test program into the computer.

A general front view of a General Radio unit is shown in Figure 5.

Cable Connection Fixtures

The design of the fixture to which the cable under test is connected affects both the accuracy of the measured results and time required to connect the cable. Important aspects are:

- Contact resistance of the conductor to the fixture must be low and uniform over the full range of conductor sizes used.
- Stray capacitance must be minimized.
- Suitable connection points for pairs not under test.
- Fixture size.
- Number of fixtures.
- Ease of loading — no special position on the clip for the pairs within the unit under test.
- Fixtures must be robust and manouverable.

Fig. 6 shows a 100 pair fixture, two of which are used for the testing of paper insulated cables. The 100 pair size is required because these cables use units with 100, 50 and 25 pairs and the use

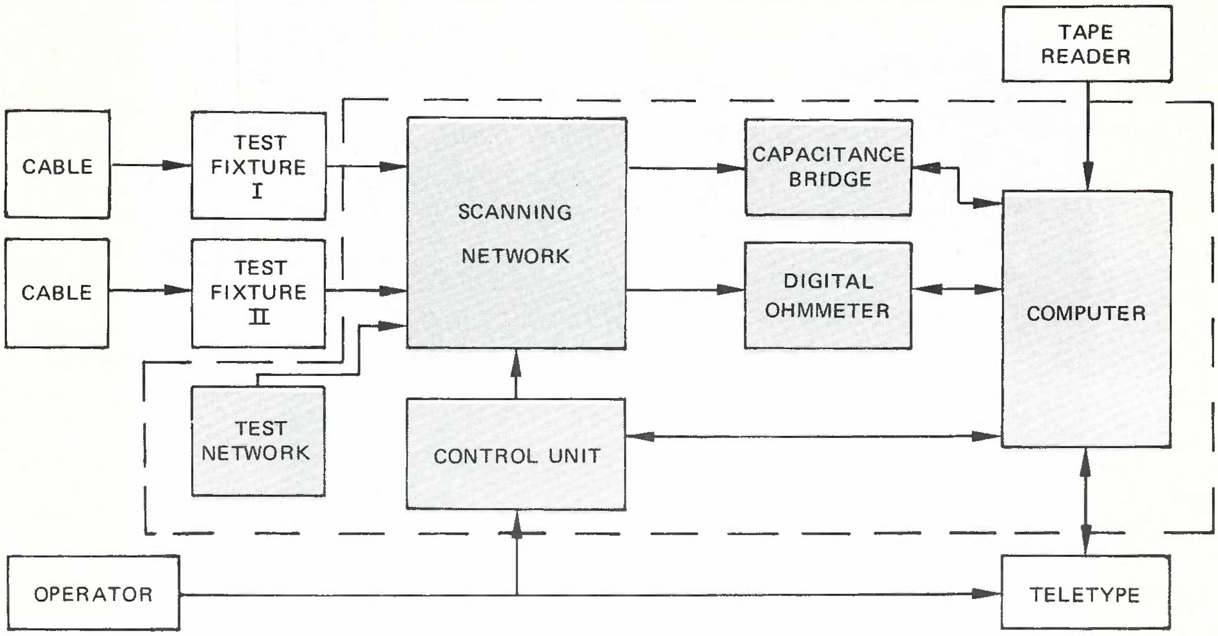

Fig. 4—Simplified Block Diagram.

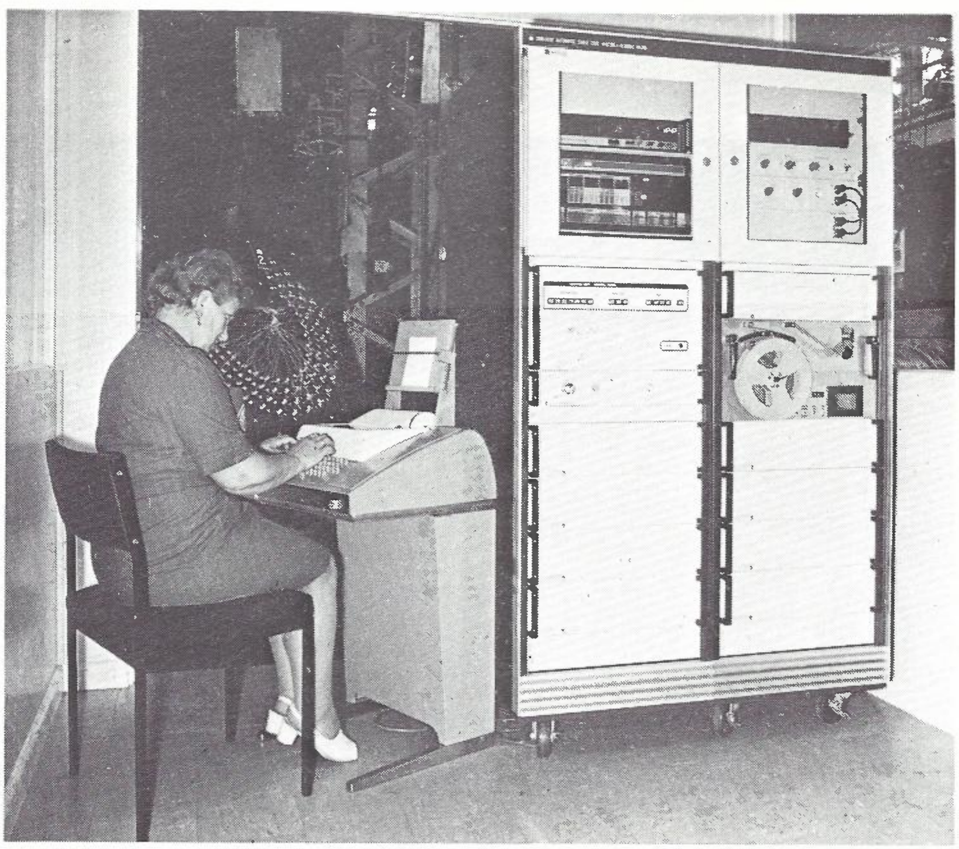

Fig. 5—'General Radio' Automatic Cable Resistance and Capacitance Test Set.

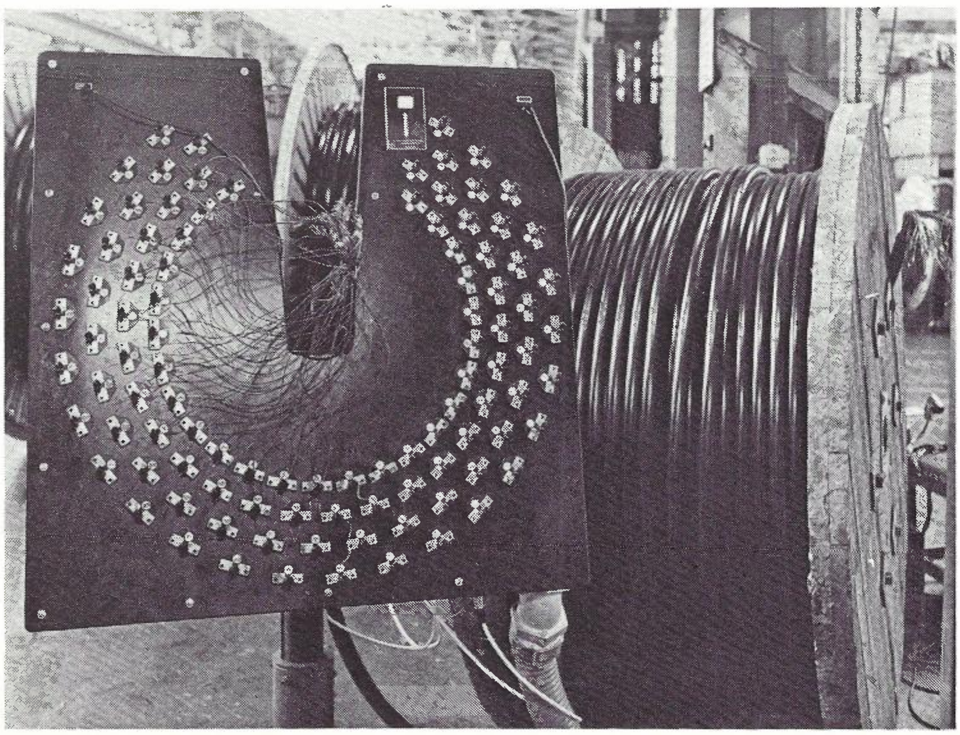

Fig. 6—100 Pair Test Fixture.

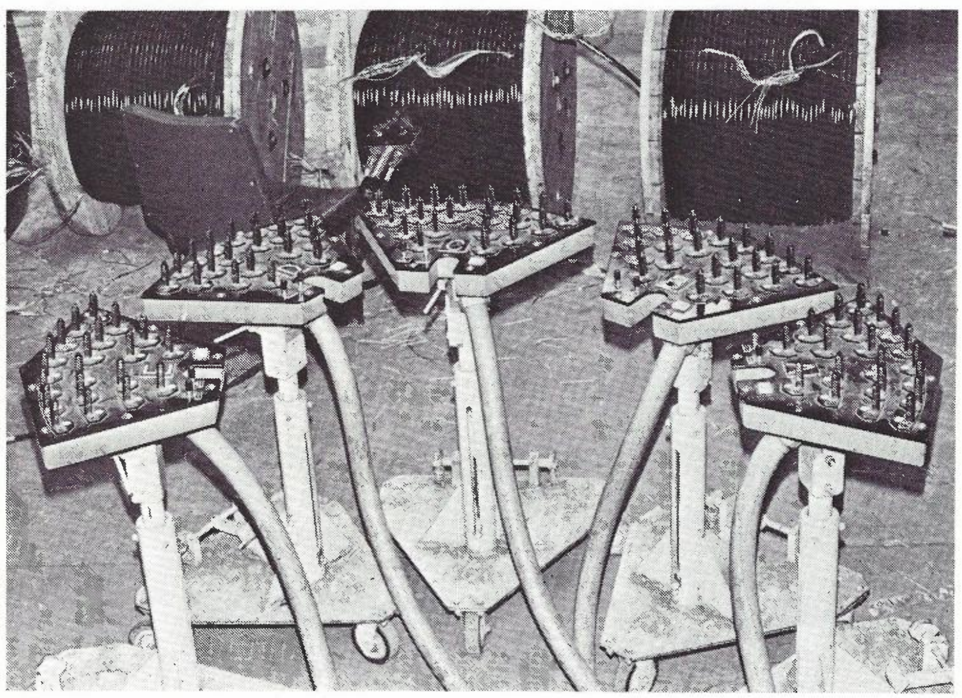

Fig. 7—Five 20 Pair Test Fixtures.

of two fixtures allows one operator to load a second clip while the first is being measured.

The majority of plastic cables are small and all use 10 pair units. Only two units are fully measured on cables of 20 pairs and more. However, there is also a significant amount of large sized plastic cable manufactured which requires a 100 pair test fixture. The most economical method of satisfying these requirements is to have five separate 20 pair fixtures which can be used either individually or combined both electrically and mechanically to provide a single 100-pair fixture. When the five test fixtures are used independently, the system can allow reloading of those fixtures not under test, and hence testing efficiency is improved. Fig. 7 shows the five 20 pair test fixtures.

CALIBRATION

Fast automated measuring systems are only useful if reliable data is obtained. To assist in this respect, the automation can be extended to the calibration. If Networks with fixed and stable components, chosen to suit the range and parameter required, are switched in and tested on the measuring instruments, the values obtained can be compared to constants held in the computer program. When errors are detected, an error message is generated on the teletype notifying the operator which parameter is incorrect and the value obtained; otherwise no print-out of the self-check measurement is given.

To guard against possible program malfunction, eliminating the correct self-check procedure, a separate test program may be provided, which when loaded into the computer allows direct measurement with full print-out of all the self-check network and variable capacitor elements.

In addition, if the cable test clips are first measured open circuit and then short circuit, a full test of the system can be performed. This test is easily carried out on a regular basis. The only remaining calibration procedure required is to use external standards for verifying the accuracy of the two measuring instruments, which is not necessry if the self-check network is calibrated using external equipment.

APPRAISAL

The introduction of automated cable measuring systems in Australia has been an effective solution to the increased quantity of cable manufactured and more stringent limits of current specifications. The more rapid measurement rate has permitted fewer assumptions regarding the cable construction, for example, pair adjacency where the actual pairs are tested for adjacency rather than assuming adjacency and only measuring certain combinations.

An important consequence has been with plastic insulated cables, which use 10 pair units. Previously only 25 supposedly adjacent combinations were measured from the total of 45. With automatic testing all 45 combinations are measured, and excessive pair to pair unbalances, caused by pairs out of sequence, has almost doubled the rejection rate of some cable types.

With paper insulated cables, which use units with 100, 50 and 25 pairs, the conformance was such that the increased testing caused little change in the rejection rate.

Another important aspect which has occurred, is the increased reliability of the measured data, which has occurred because of the increased accuracy and inbuilt self-check functions of these systems

FUTURE DEVELOPMENTS

Extensions of cable testing requirements in the past two years have been adequately handled by the present generation of Automatic Test Systems. Future requirements (quantity, quality and labour costs), will require faster systems, covering a wider range of measurements made necessary by higher operating frequencies of the developing telecommunications network. Important areas will be

- High speed print out of test results.
- High frequency measurements — crosstalk and insertion loss.
- High voltage testing of the integrity of conductor insulation.

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APPENDIX A

```
IDENTIFICATION       CABLE       DRUM      UNIT NO      DATE
? 10C800/74/                 NORMAL MODE

FIXTURE NO ? 2
TESTED PAIRS (IN GROUPS) ? 4
LENGTH (M) ? 245
TEMPERATURE (C) ? 24


***RESISTANCE
LIMITS (20C) MAX    58.37  OHMS/KM, UNBALANCE   3.00%
             CONNECTION   49.62  OHMS/KM,   58.37  OHMS/KM


MEAN (20C)     53.91   OHMS /KM
STD DEV (20C)     0.224  OHMS /KM
NUMBER OF TESTS    8

***RESISTANCE UNBALANCE

MEAN     0.34 %
RMS     0.37 %
MAX     0.56 %
NUMBER OF TESTS    4

PREPARE FOR CAPACITANCE MEASUREMENTS     C


CONNECTION ERROR THRESHOLD       490 PF

***MUTUAL
LIMITS     35.88 NF/KM,   55.88 NF/KM


MEAN     43.00 NF /KM       LIMIT    47.00 NF/KM
STD DEV        730 PF /KM
NUMBER OF TESTS    4


***EARTH UNBALANCE
MAX LIMIT    2.000 NF/ 500 M


MEAN        328 PF / 500 M
RMS        388 PF / 500 M
MAX        609 PF / 500 M
NUMBER OF TESTS    4


***PAIR TO PAIR UNBALANCE
MAX LIMIT      190 PF/ 500 M             SKIP LIMIT       28 PF


MEAN (EXCL SKIPPED)       11 PF / 500 M
RMS (EXCL SKIPPED)       19 PF / 500 M

MEAN MAX        26 PF / 500 M
STD DEV MAX        21 PF / 500 M
MAX MAX        46 PF / 500 M

NUMBER OF TESTS/1000 TESTED OVER 20% OF MAX LIMIT   167
NUMBER OF TESTS      6      COMBINATIONS SKIPPED      0
```

APPENDIX B

```
IDENTIFICATION      CABLE      DRUM      UNIT NO      DATE
? 10C800/74              COMPREHENSIVE MODE

FIXTURE NO ? 2
TESTED PAIRS (IN GROUPS) ? 4
LENGTH (M) ? 245
TEMPERATURE (C) ? 24


***RESISTANCE
LIMITS (20C) MAX     58.37  OHMS/KM, UNBALANCE   3.00%
              CONNECTION    49.62  OHMS/KM,    58.37  OHMS/KM


MEAN (20C)     54.00  OHMS /KM
STD DEV (20C)     0.242  OHMS /KM
NUMBER OF TESTS    8

***RESISTANCE UNBALANCE

MEAN     0.35 %
RMS     0.39 %
MAX     0.60 %
NUMBER OF TESTS    4

RESISTANCE UNBALANCE DISTRIBUTION: CELL NUMBERS ARE CELL MAX %

  0.15  0.30  0.45  0.60  0.75  0.90  1.05  1.20  1.35  1.50
     1     0     2     1     0     0     0     0     0     0

  1.65  1.80  1.95  2.10  2.25  2.40  2.55  2.70  2.85  3.00      H
     0     0     0     0     0     0     0     0     0     0      0


PREPARE FOR CAPACITANCE MEASUREMENTS     C


CONNECTION ERROR THRESHOLD      490 PF

***MUTUAL
LIMITS     35.88 NF/KM,    55.88 NF/KM


MEAN     43.00 NF /KM       LIMIT    47.00 NF/KM
STD DEV       725 PF /KM
NUMBER OF TESTS    4

C MUTUAL DISTRIBUTION: CELL NUMBERS ARE CELL CENTRE VALUE NF/KM

     L 36.38 37.38 38.38 39.38 40.38 41.38 42.38 43.38 44.38 45.38
     0     0     0     0     0     0     0     2     1     1     0

 46.38 47.38 48.38 49.38 50.38 51.38 52.38 53.38 54.38 55.38      H
     0     0     0     0     0     0     0     0     0     0      0


***EARTH UNBALANCE
MAX LIMIT    2.000 NF/ 500 M


MEAN       329 PF / 500 M
RMS       388 PF / 500 M
MAX       609 PF / 500 M
```

NUMBER OF TESTS 4

C.U. DISTRIBUTION: CELL NUMBERS ARE CELL MAX PF/ 500 M

100	200	300	400	500	600	700	800	900	1000	
1	Ø	Ø	2	Ø	Ø	1	Ø	Ø	Ø	
1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	H
Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø

***PAIR TO PAIR UNBALANCE
MAX LIMIT 190 PF/ 500 M SKIP LIMIT 28 PF

MEAN (EXCL SKIPPED) 11 PF / 500 M
RMS (EXCL SKIPPED) 19 PF / 500 M

MEAN MAX 25 PF / 500 M
STD DEV MAX 20 PF / 500 M
MAX MAX 45 PF / 500 M

NUMBER OF TESTS/1000 TESTED OVER 20% OF MAX LIMIT 167
NUMBER OF TESTS 6 COMBINATIONS SKIPPED Ø

C.U. DISTRIBUTION: CELL NUMBERS ARE CELL MAX PF/ 500 M

SKIP	9	19	28	38	47	57	66	76	85	95
Ø	5	Ø	Ø	Ø	1	Ø	Ø	Ø	Ø	Ø
104	114	123	133	142	152	161	171	180	190	H
Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø

APPENDIX C

IDENTIFICATION CABLE DRUM UNIT NO DATE
? 10C800/74 ALL MEASUREMENTS MODE

FIXTURE NO ? 2
TESTED PAIRS (IN GROUPS) ? 2
LENGTH (M) ? 245
TEMPERATURE (C) ? 24

***RESISTANCE
LIMITS (20C) MAX 58.37 OHMS/KM, UNBALANCE 3.00%
CONNECTION 49.62 OHMS/KM, 58.37 OHMS/KM

PAIR	R UNB	R LEFT	R RIGHT
1	Ø.30%	13.301 OHMS	13.222 OHMS
2	Ø.60%	13.291 OHMS	13.134 OHMS

MEAN (20C) 54.03 OHMS /KM
STD DEV (20C) Ø.269 OHMS /KM
NUMBER OF TESTS 4

***RESISTANCE UNBALANCE

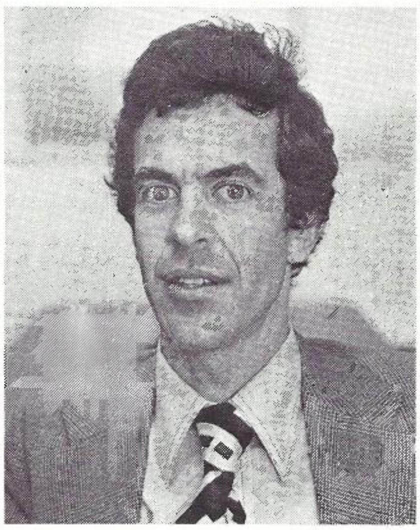
MEAN Ø.45 %
RMS Ø.47 %
MAX Ø.60 %
NUMBER OF TESTS 2

```
RESISTANCE UNBALANCE DISTRIBUTION: CELL NUMBERS ARE CELL MAX %

 0.15   0.30   0.45   0.60   0.75   0.90   1.05   1.20   1.35   1.50
    0      1      0      1      0      0      0      0      0      0

 1.65   1.80   1.95   2.10   2.25   2.40   2.55   2.70   2.85   3.00      H
    0      0      0      0      0      0      0      0      0      0      0


PREPARE FOR CAPACITANCE MEASUREMENTS     C


CONNECTION ERROR THRESHOLD       490 PF

***MUTUAL
LIMITS     35.88 NF/KM,    55.88 NF/KM

PAIR     C MUTUAL       C1          C2          C3
  1    10.640 NF    6.501 NF    8.203 NF    8.354 NF
  2    10.373 NF    5.534 NF    9.530 NF    9.832 NF


MEAN     42.88 NF /KM        LIMIT    47.00 NF/KM
STD DEV        544 PF /KM
NUMBER OF TESTS    2

C MUTUAL DISTRIBUTION: CELL NUMBERS ARE CELL CENTRE VALUE NF/KM

     L 36.38 37.38 38.38 39.38 40.38 41.38 42.38 43.38 44.38 45.38
     0     0     0     0     0     0     0     1     1     0     0

 46.38 47.38 48.38 49.38 50.38 51.38 52.38 53.38 54.38 55.38     H
     0     0     0     0     0     0     0     0     0     0     0


***EARTH UNBALANCE
MAX LIMIT    2.000 NF/ 500 M

PAIR    UNBALANCE       C2          C3
  1 -      149 PF    8.205 NF    8.353 NF
  2 -      298 PF    9.533 NF    9.832 NF


MEAN        457 PF / 500 M
RMS        482 PF / 500 M
MAX        609 PF / 500 M
NUMBER OF TESTS    2

C.U. DISTRIBUTION: CELL NUMBERS ARE CELL MAX PF/ 500 M

   100    200    300    400    500    600    700    800    900   1000
     0      0      0      1      0      0      1      0      0      0

  1100   1200   1300   1400   1500   1600   1700   1800   1900   2000      H
     0      0      0      0      0      0      0      0      0      0      0


***PAIR TO PAIR UNBALANCE
MAX LIMIT      190 PF/ 500 M            SKIP LIMIT       28 PF

PAIR PAIR    UNBALANCE       C1          C2          C3          C4
  1    2          0 PF    1.989 NF    2.037 NF    2.089 NF    2.036 NF
```

```
MEAN (EXCL SKIPPED)         1 PF / 500 M
RMS (EXCL SKIPPED)         1 PF / 500 M

MEAN MAX          1 PF / 500 M
STD DEV MAX           0 PF / 500 M
MAX MAX  .       1 PF / 500 M

NUMBER OF TESTS/1000 TESTED OVER 20% OF MAX LIMIT        0
NUMBER OF TESTS        1      COMBINATIONS SKIPPED      0

C.U. DISTRIBUTION: CELL NUMBERS ARE CELL MAX PF/ 500 M

  SKIP     9     19     28     38     47     57     66     76     85     95
     0     1      0      0      0      0      0      0      0      0      0

   104   114    123    133    142    152    161    171    180    190      H
     0     0      0      0      0      0      0      0      0      0      0
```

A. H. HAMBLETON is a graduate in Engineering from the University of Western Australia. After graduation in 1961, Mr. Hambleton joined the Australian Post Office in Western Australia working in various areas of outside plant operations before transferring to APO Headquarters Lines Branch.

In 1966 Mr. Hambleton joined Austral Standard Cables as Cable Engineer Plastic Group. He has subsequently held the posts of Development Engineer and Quality Engineering Manager before being appointed as Technical Manager in April 1973. As Technical Manager Mr. Hambleton is responsible for all Technical operations of the Company.



R. R. LLOYD graduated from the University of Auckland, New Zealand with a degree in Radiophysics. Upon completion of his University studies Mr. Lloyd worked for three years as an Electronic Engineer on Instrumentation and Control.

Mr. Lloyd joined the Planning and Research Division of Austral Standard Cables as Communications Engineer in 1971. Before being appointed Planning and Research Manager he also held the post of Senior Engineer—Product Development.

Retirement of Mr. Evan Sawkins, Deputy Director-General.

Mr. Evan Sawkins, OBE, Deputy Director-General of the Australian Post Office has retired because of ill-health.

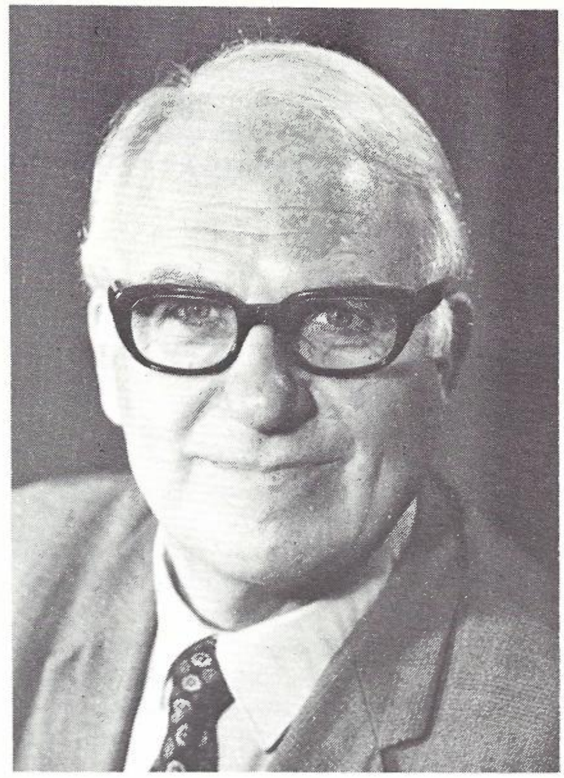
A native of Bowral, (N.S.W.), he joined the Department in Sydney as a cadet engineer in March, 1928.

Twenty-six years later he held the top engineering post in the N.S.W. Administration. In 1956 he was promoted to Deputy Engineer-in-Chief in Central Office. He went on to become Engineer-in-Chief, and in June, 1964 was appointed Deputy Director-General.

For his great contribution to the development of telecommunications engineering in Australia, he was awarded the OBE in 1966. A Bachelor of Science, Member of Institution of Engineers (Australia) and a Fellow of the Royal Institute of Public Administration, he was known throughout the APO for his intense interest in the problems at the work face.

He travelled extensively to gain a first hand appreciation of the engineering work in the field. In recent years Evan Sawkins earned and enjoyed a great deal of respect in international circles. In his twelve visits to International Telecommunication Union and other top-level important overseas meetings, he was the Australian representative on six occasions and led the Australian delegation on three occasions.

The Secretary-General of the ITU in a greeting to Mr. Sawkins said "Your services over many years on the ITU Administrative Council, your important contributions to the future of the Union and your very useful work as Chairman of Committee Seven of the Plenipotentiary Conference will be remembered with gratitude."



Private Telephone Meter, Type 2

W. J. TREBILCO, ARMIT

This article describes a new subscribers private telephone meter which will be introduced by the APO in 1975. The meter can be installed at a subscribers premises to record the charge unit registrations for local and STD calls from his telephone. In addition the meter can be equipped to enable the subscriber to control the use of his telephone by the public.

INTRODUCTION

The private telephone meter Type 2, shown in Fig. 1, will shortly supersede the meter No. 19 shown in Fig. 2. The meter is connected to the subscribers telephone to indicate the charge units incurred during local, STD or ISD calls. Fig. 3 shows a typical application in an office situation where the executive is using a meter to keep a tally on his calls.

In addition to its use as a charge unit recording device, the type 2 meter can also be installed to control the use of the associated telephone, in a similar manner to a remote control lock on the telephone. In this latter application it could be installed in shops, hotels, clubs and service stations to allow use of the telephone service by the general public, with the subscriber being able to calculate the call fee at the end of the conversation. Fig. 4 shows a typical application in a golf club.

Like the No. 19 meter, the type 2 meter responds to 50 Hz longitudinal pulses of 180-400 milliseconds in length. These signals are generated at the telephone exchange in synchronism with the pulses which cause the exchange meter to operate. Fig. 5 shows a schematic of the circuit.

The meter is manufactured by SODECO, Switzerland, a member company of the Landis and Gyr group and is being supplied to the APO through Landis and Gyr, Clayton, Victoria. The manufacturer is well known in the field of telecommunication and electrical switching and measuring equipment.

FACILITIES

Private Mode

The meter has two registers which both record the cumulative total charge units, however, the lower register can be reset by depressing the white reset button on the right hand side of the meter after each call. This feature allows the charge units for each call to be recorded on the meter, noted by the subscriber, and then cleared back to zero in readiness for the next call. Although the private mode facility is identical with the No. 19 meter, the charge units on the type 2 meter

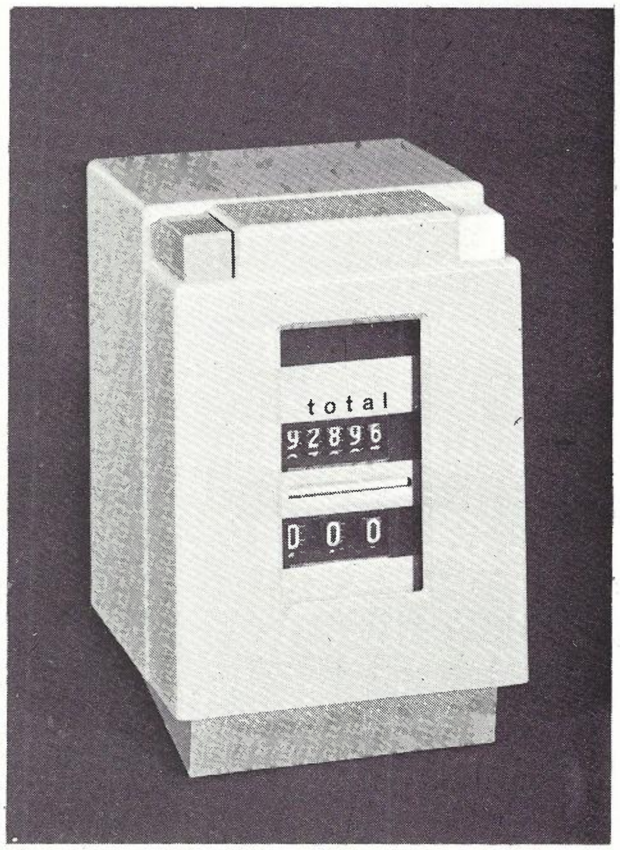


Fig. 1—Private Telephone Meter Type 2.

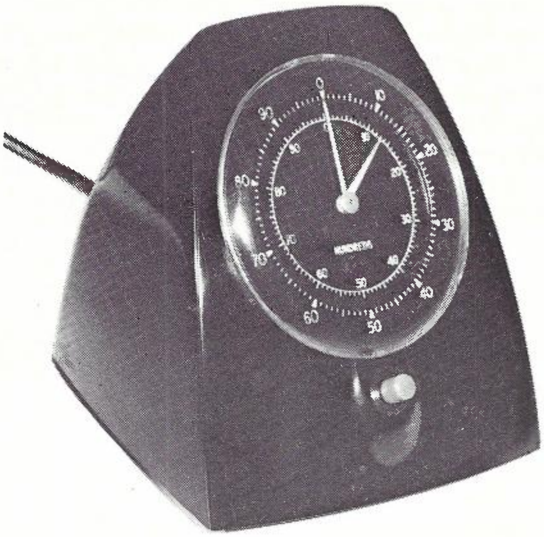


Fig. 2—Private Telephone Meter No. 19.

are shown on cyclometer registers, which are much easier to read than the clock face of the No. 19. In the private mode the meter is fitted with one button only, the white button. The other button position (see the top left hand position in Fig. 1) is fitted with a fixed grey insert which is inoperable.

Control Mode

In the control mode the meter would be installed remote from the telephone instrument, at some point convenient for the subscriber to use. In the control mode the fixed grey insert at the top left hand side is replaced by a red control pushbutton and some wiring alterations are made in the telephone. This allows automatic and manual barring of the associated telephone dial contacts. To allow calling from the telephone the subsrciber presses the white button which resets the trip register and releases the dial blocking contacts. When the telephone user establishes his call, the first 50 Hz metering signal received from the exchange causes the meter to step one charge unit. With the first meter step, control contacts

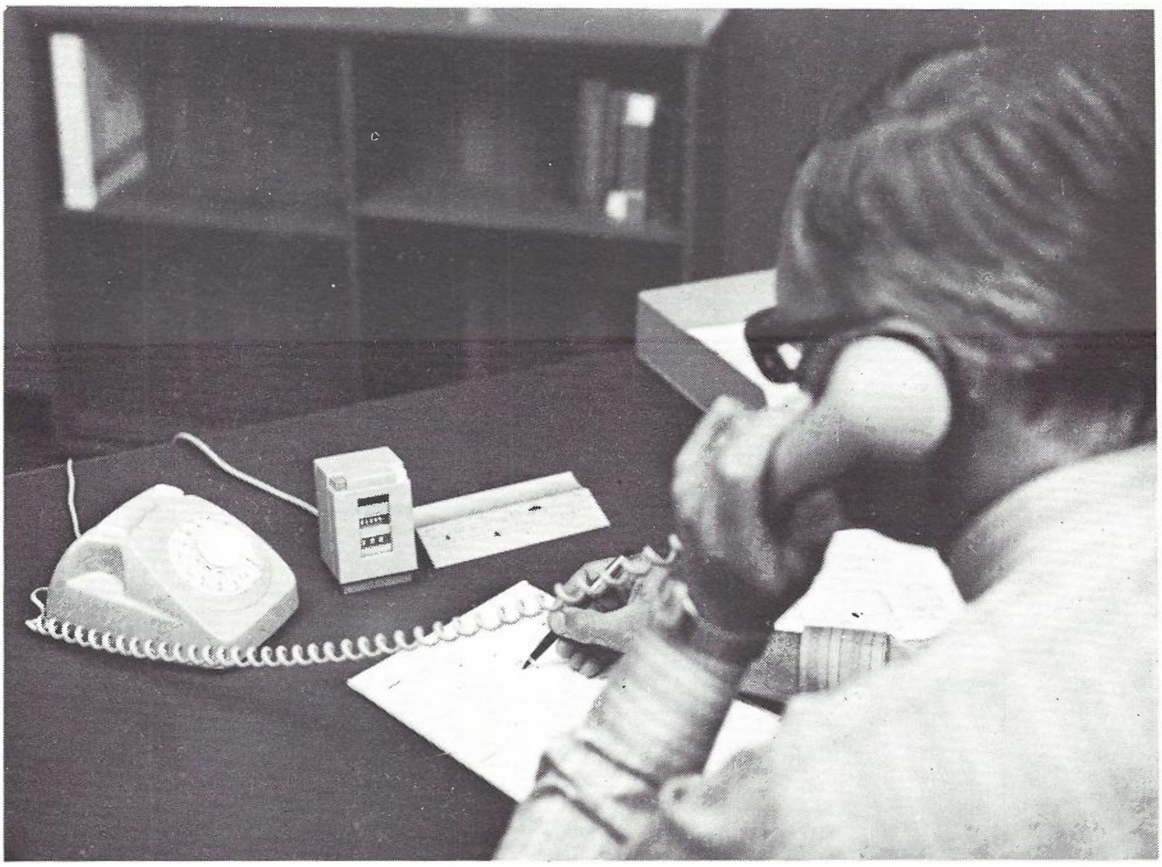


Fig. 3—Meter used to record calls.

are operated which short circuit the dial, preventing a second call without the subscribers knowledge. The red button is used to re-operate the control contacts if an unanswered or non-metered call has been made.

DESIGN FEATURES

Physical

The meter is quite robust in its design, relying on semiconductors for detection of the metering signal and control of an electromagnetic cyclometer register, compared with the delicate clockwork type movement of the No. 19, which is easily damaged by rough handling.

Installation

The type 2 meter is designed for both table and wall mounting without the need for a special wall mounting bracket. The APO 800 series telephone line cord can be used for interconnection when desk mounted.

Electrical Operation

Metering signals of less than 1 milliamp are detected by a photo coupled transistor circuit to electrically isolate the metering circuit from the telephone line. The output of the detector is applied to a digital filter and delay circuit. The filter rejects signal frequencies above 60 Hz and below 40 Hz and the delay circuit rejects any signal of less than 50 milliseconds. Thus only true metering signals are passed to turn-on a switching transistor which operates the cyclometer electromagnet. Fig. 5 shows a block schematic of the meter circuit.

Battery

As the 50 milliamp operate current needed for the electromagnet is too great to be drawn from the exchange line, a rechargeable nickel cadmium battery is included in the meter to supply this heavy intermittent current (See Fig. 6). The battery is continuously trickle charged from the exchange line battery feed while the telephone is

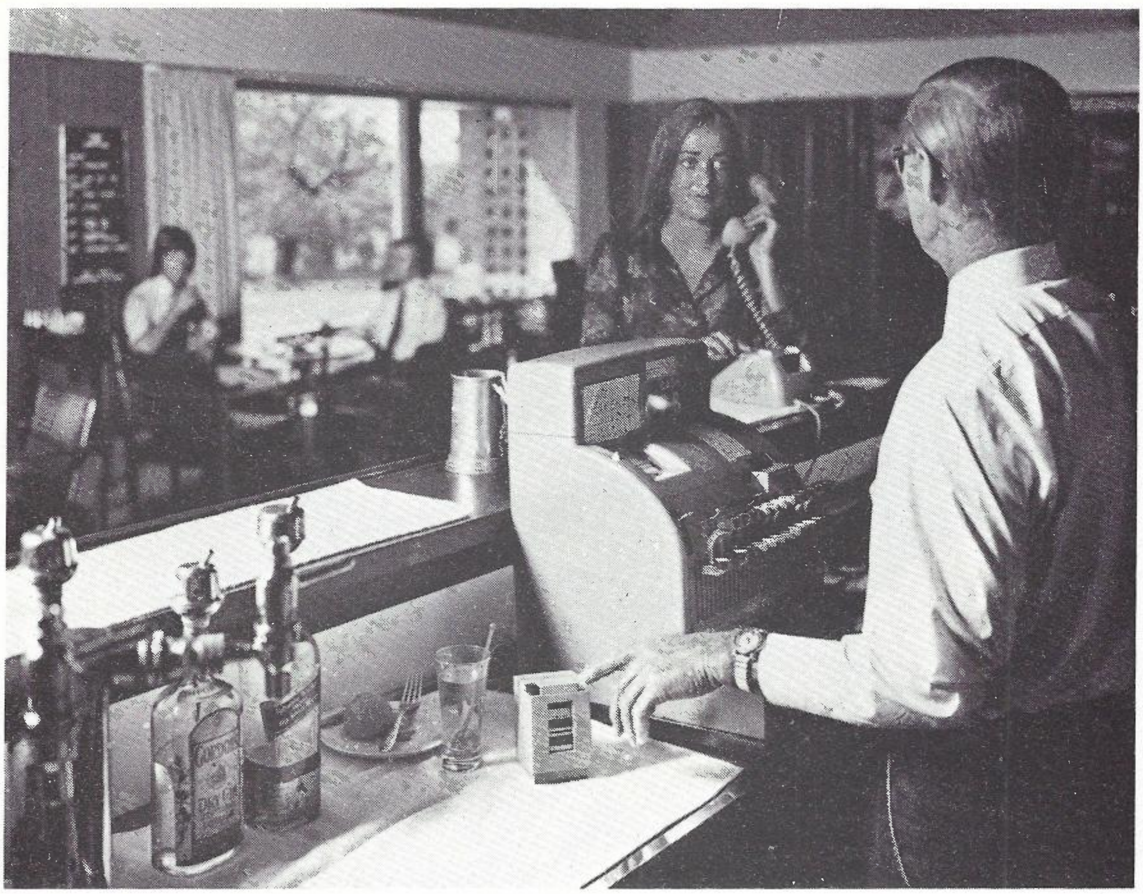


Fig. 4—Meter used to control a telephone.

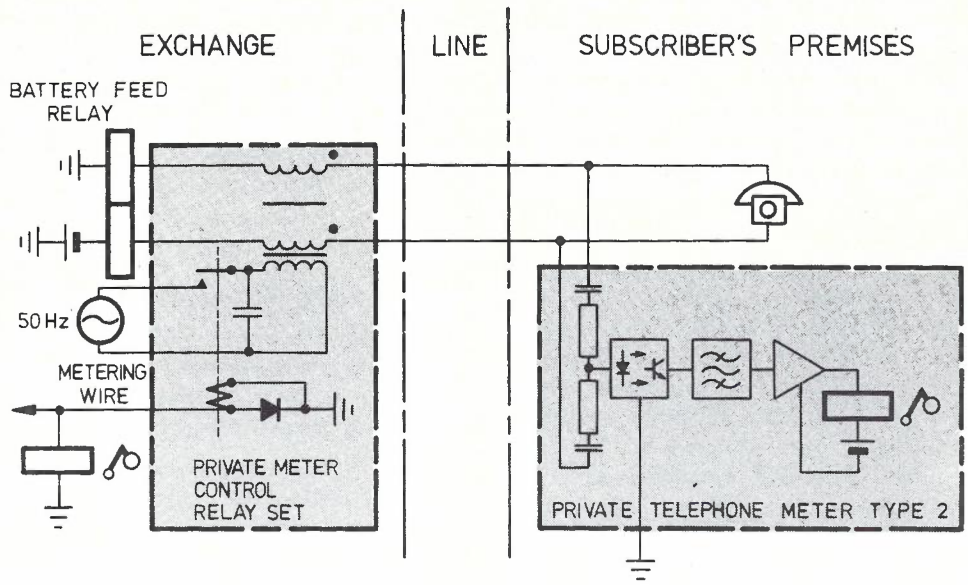


Fig. 5—Schematic of 50 Hz Signalling and Meter circuit.

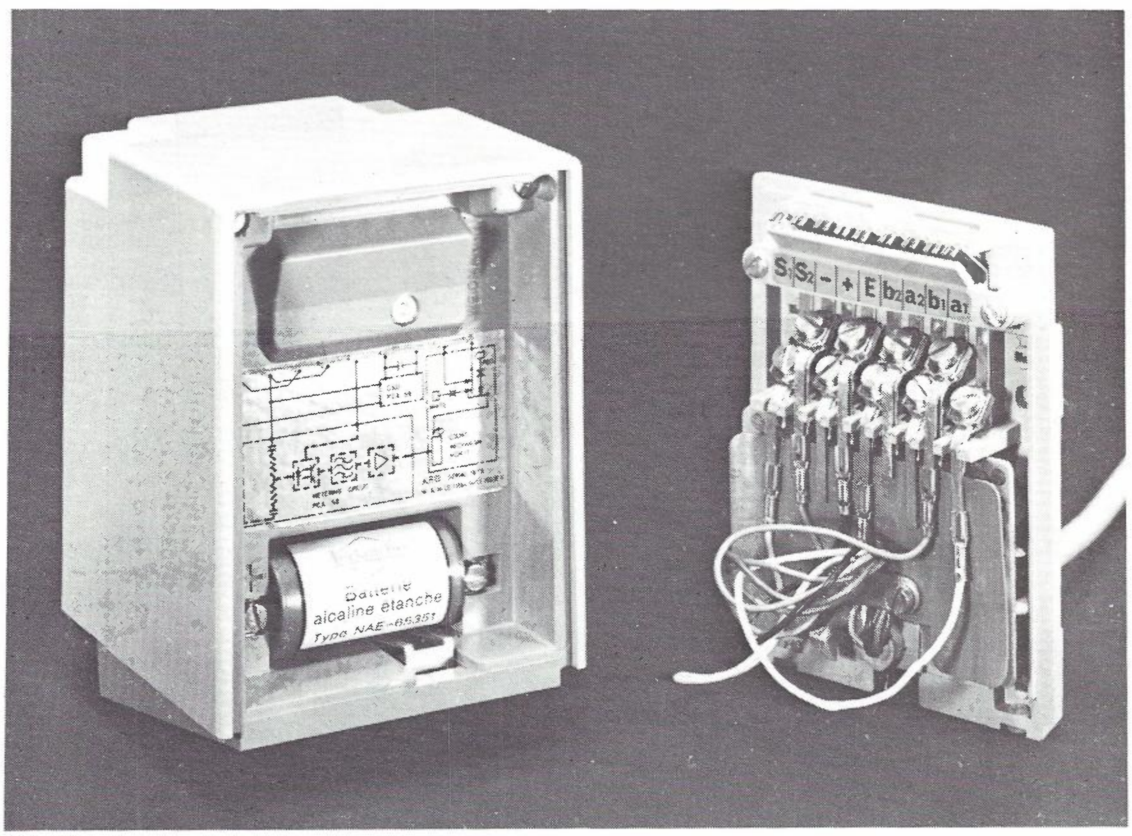


Fig. 6—Meter with Rear Section Removed.

not in use. When fully charged, the battery is capable of supplying power for 14,000 continuous registrations. This represents an STD call of 933 minutes duration between, say, Melbourne and Perth. The battery could recover from such a call after 5 minutes trickle charge to give a further 200 operations, and is fully recovered after 30 hours.

Charge Switching Unit

The battery charging circuit presents an impedence of 15,000 ohms to the exchange when the telephone is not in use. Although acceptable in European countries this circuit would have tested as low insulation resistance on APO exchange test desk or automatic test equipment. To overcome this problem the APO arranged with the manufacturer to include a switching unit in the meter to automatically disconnect the battery charging circuit during exchange testing. The APO was aware that the BPO and GEC, England, had been involved in the design of such a unit, called a charge switching unit, for use in a battery operated push button telephone and subscribers carrier equipment. Landis & Gyr were advised of this development and they were able to arrange for the charge switching unit to be adapted to fit into the meter. The right hand side of Fig. 7 shows the charge switching unit printed circuit located on the rear of the meter back plate.

METER PULSE SIGNALLING SYSTEM

The 50 Hz longitudinal earth return signalling system used by the APO for transmission of metering signals to the subscribers equipment has the following inherent problems:

- Only a small amount of line unbalance need be present to cause the metering signals to be audible.
- A large line unbalance, such as a recall earth, will prevent the meter from functioning.

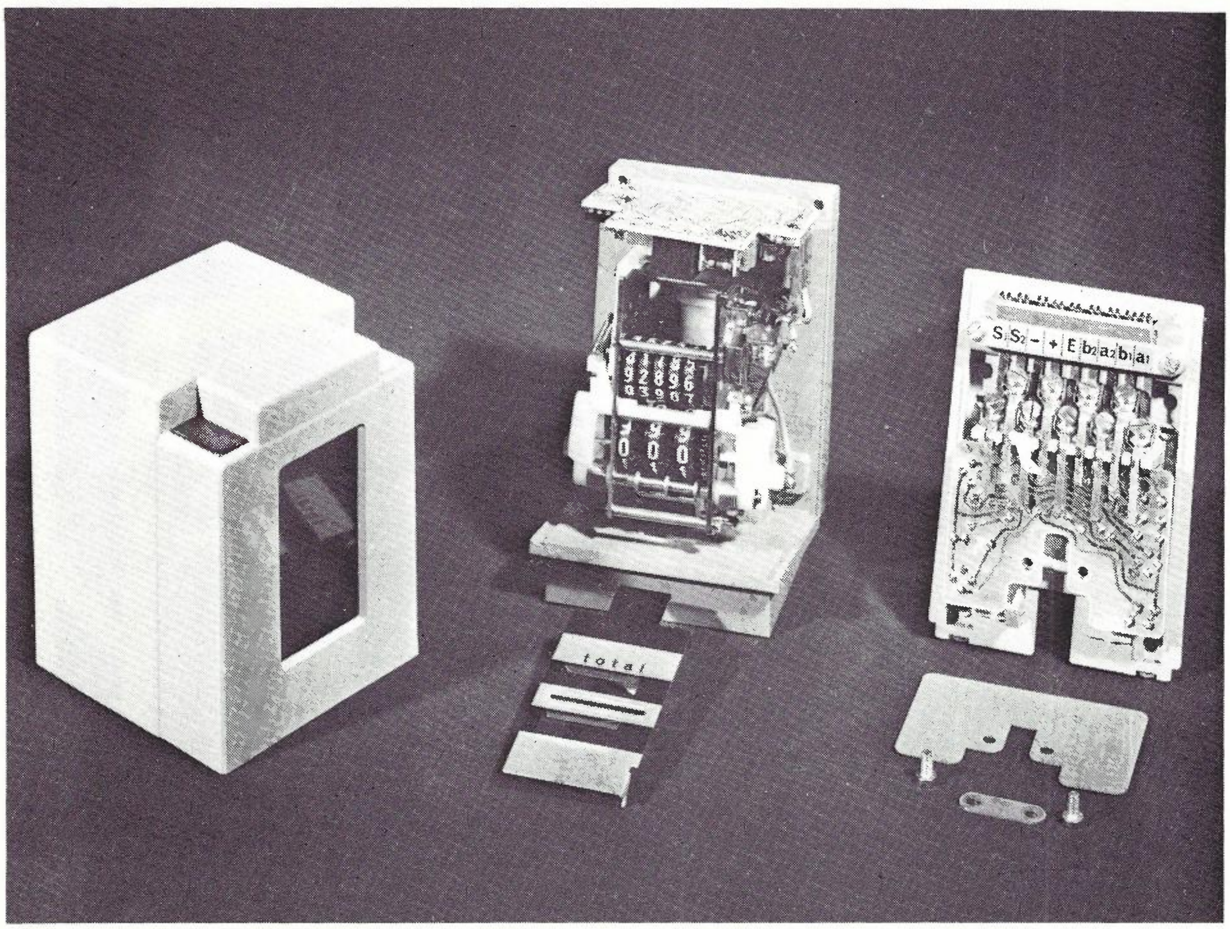


Fig. 7—Mechanism, Circuit, and Charge Switching Unit.

Therefore, the meter is not suitable for use on equipment such as the 1/3 intercom with 2 wire extensions and the cord type lamp signalling switchboard (CE 250).

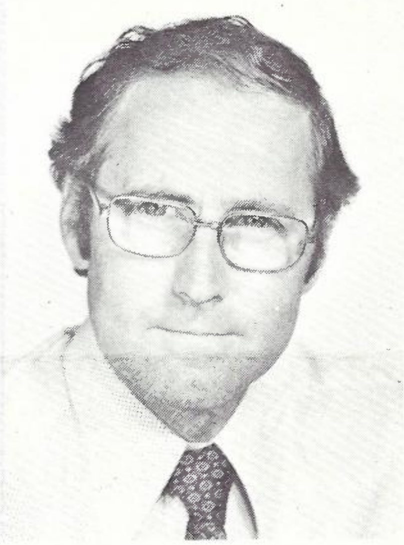
- The 50 Hz signal can be blocked or shunted by transmission bridges which prevent use of this equipment on extensions off certain PABX's and PMBX's.
- The installation of an earth stake and wiring is required at the subscribers premises, which may be both difficult and costly to provide.
- If the ac power to the exchange fails no 50 Hz metering signals will be sent to line until emergency power plant at the exchange is started.

With the introduction of more subscribers equipment requiring the receipt of metering signals, the above weaknesses in the current APO 50 Hz system calls for serious consideration to be given to an alternative system such as the 12 or 16 kHz transverse signalling systems used by many European administrations. These systems transmit the 12 or 16 kHz signals to line in a similar manner and level as the voice signals.

CONCLUSION

The type 2 meter is expected to be robust and reliable, and in addition to providing a basic subscriber private meter facility, it can be used to control the use of a telephone, thus offering a simple but effective STD "public telephone" facility. However, the meter has the disadvantage of needing a rechargeable battery, with the consequent problems associated with charging before installation, line testing and battery replacement. Ideally we require a meter with the same facilities and robustness as the type 2 meter but one which is designed to be powered directly from the exchange battery feed, thus eliminating the need for a local power source.

W. J. TREBILCO joined the APO as a Technician-in-Training in 1955 and was attached to the Research Laboratories until he commenced as a Trainee Engineer in 1961. After completion of his Diploma, he spent 4 years in Metro Exchange Installation, Melbourne, before going to Subscribers Equipment, Headquarters, as Engineer, Class 2, where he is currently Engineer, Class 3.



Retirement of Mr. O. G. Bartlett

Mr. Oliver Bartlett retired from the position of Superintending Engineer Metropolitan Operations Branch, Adelaide, on 20.12.74, after nearly 49 years' service with the Australian Post Office.

Mr. Bartlett's career was closely identified with the key mechanisation phases for local and trunk services in South Australia. He participated in the introduction of pre-2000 type exchange equipment in Adelaide in 1927 and spent most of 1939 with a team which assisted with the introduction of the first 2000 type switching plant in the Sydney network.

During the post-war years of rapid network expansion he made a significant contribution towards the development of trunk transmission and switching equipment associated with the establishment of the single operator dialled trunk system. A major responsibility was the installation and commissioning of Siemens Semi-automatic trunk exchanges throughout South Australia.

Oliver Bartlett was a member of the original South Australian Division committee of the Telecommunication Society when reconstituted in 1960 and he was its Chairman during 1966/67.

Traffic Fail Alarm and Display Map at the Melbourne Trunk Terminal

B. W. MILLER

To minimise duration of outages on a broadband bearer network, it is necessary to obtain prompt indication of bearer failure, and to locate the failed section of the broadband bearer geographically. This article describes the facilities for broadband bearer supervision which have been in use for several years at the Melbourne trunk terminal.

INTRODUCTION

With the introduction of broadband systems into Victoria during the early 1960's it was realised that a new approach to maintenance facilities would be needed. In particular the immediate indication of a Traffic Fail condition, and later, the Route Alarm Display Map were considered necessary. The first coaxial system in Victoria was located between Melbourne and Morwell with drop-out stations at Dandenong and Warragul. This was a Siemens type system fitted with line pilots and remote supervision equipment designed to indicate the location and nature of any system faults which occurred. Although these system devices operated effectively, the vital question as to whether the traffic lines had actually failed remained unanswered. This took quite some time to establish, if indeed it could be established at all with certainty.

The first method was to send tone on spare speech channels to each of the drop-out stations and the far terminal. These were looped back to Melbourne where each channel could be individually switched to a level meter. Although this did not provide an alarm indication when the system failed, it did provide a means of indicating the drop-out section at which the failure had occurred. With the commissioning of the first of the Melbourne to Sydney coaxial systems and with spare speech channels becoming more difficult to obtain, thoughts turned to a method of using spare inbuilt signalling channels for our purpose. Even with future loading of systems, signalling channels associated with VF Telegraph systems, 2VF lines, etc., did assure that a reasonable number of spare signalling channels would be available for the foreseeable future.

THE TRAFFIC FAIL ALARM

A relay and control panel named 'Traffic Fail Alarms' was then set up in the Trunk Test/Line Control area whereby an earth via a test key was extended over inbuilt signalling channels to the various stations. These signalling channels were looped back to Melbourne so that upon failure of the system in either or both directions, the loss of this earth provided the necessary alarm. Figs. 1 and 2 show the schematic circuit and control layout of the Traffic Fail Alarm panel. The red alarm lamps are displayed for circuits which have failed together with an audible alarm. Operation of the 'defer' key silences the alarm. When the fault is cleared the alarm again operates until the 'defer' key is restored. A test key is provided which breaks the originating earth and an alarm condition should be received.

Over the years this supervision has been maintained where possible on all the broadband systems which have channels entering Melbourne and now consists of sixty alarms. Although remote from Melbourne and in many cases in other States a large number of these systems are being continuously supervised to indicate sectional failures and the areas affected by such failures. Extended supervision has been provided to other stations such as the Surrey Hills broadband radio terminal, to indicate immediate traffic fail conditions occurring on circuits via radio bearers.

THE SHORT BREAK DETECTOR

A high speed device has additionally been connected to the alarm relays associated with certain circuits to enable detection of extremely short duration breaks. No matter how short the break on the system relay, this device enables the Traffic Fail Alarm to remain operated for approx. 0.5

second which allows sufficient time for observation of the fault condition.

Circuit operation is briefly as follows: (Refer Fig. 3). Under normal conditions with an earth on the receive signal wire, TR1 is unbiased and non-conducting whilst TR2 is conducting. During the period of a short break, loss of earth on the signal wire provides bias to TR1 which conducts and TR2 becomes non-conducting. TR2 collector voltage then charges capacitor C1 via 56K ohms and the base circuitry of TR1. During this charging period of approx. $\frac{1}{2}$ second, conducting bias is maintained on TR1 although at the conclusion of the short break, an earth had been replaced on the receive signal wire. Alarm relay "AL" operates to TR1 collector current during its $\frac{1}{2}$ second conducting period. The purpose of the OA91 diode is to rapidly discharge C1 at the completion of an alarm in readiness for further $\frac{1}{2}$ second alarms, should successive short breaks occur.

ROUTE ALARM DISPLAY MAP

Although the circuits are grouped to best advantage into various routes on the Traffic Fail Alarm panel, it was realised that a far better concept of a fault condition could be achieved more readily by placing the alarm lamps geographically. Accordingly, a large wall map of Victoria was drawn up showing all broadband bearers including drop-out stations and terminals. Where appropriate these were extended out of Victoria to show stations and terminals in other States.

Miniature 6 volt lamps representing drop-out stations and terminals, are connected in parallel with the respective lamps on the Traffic Fail panel — see Fig. 1. System bearers and lamps are coloured red for broadband radio and green for coaxial cable.

Further appearances of the map can be provided by extension of the alarm lamp connections via multiple cable to other locations as required.

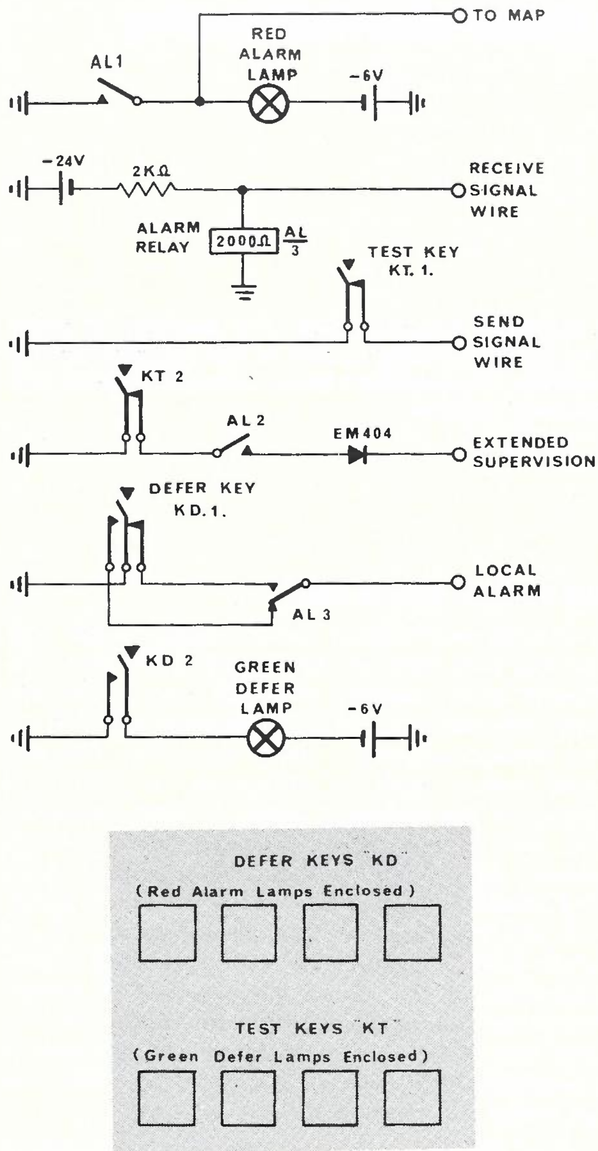


Fig. 1—Traffic Fail Alarm, Schematic Circuit and Control Panel.

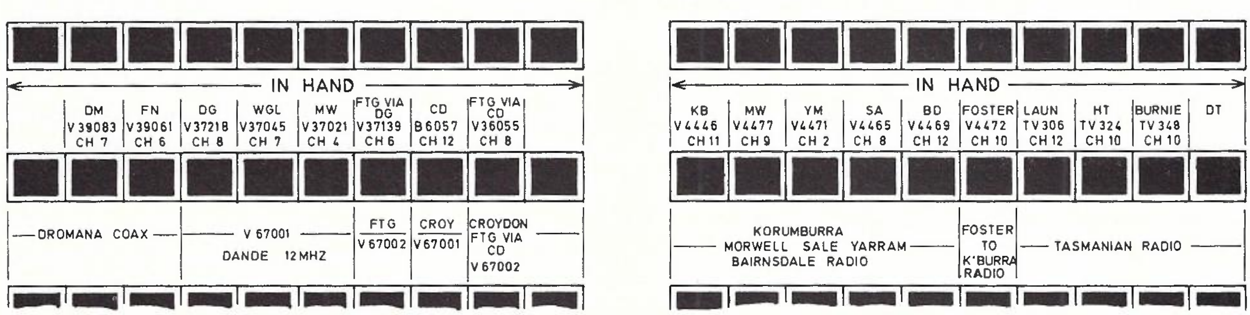


Fig. 2—Traffic Fail Alarm, Control Panel Layout.

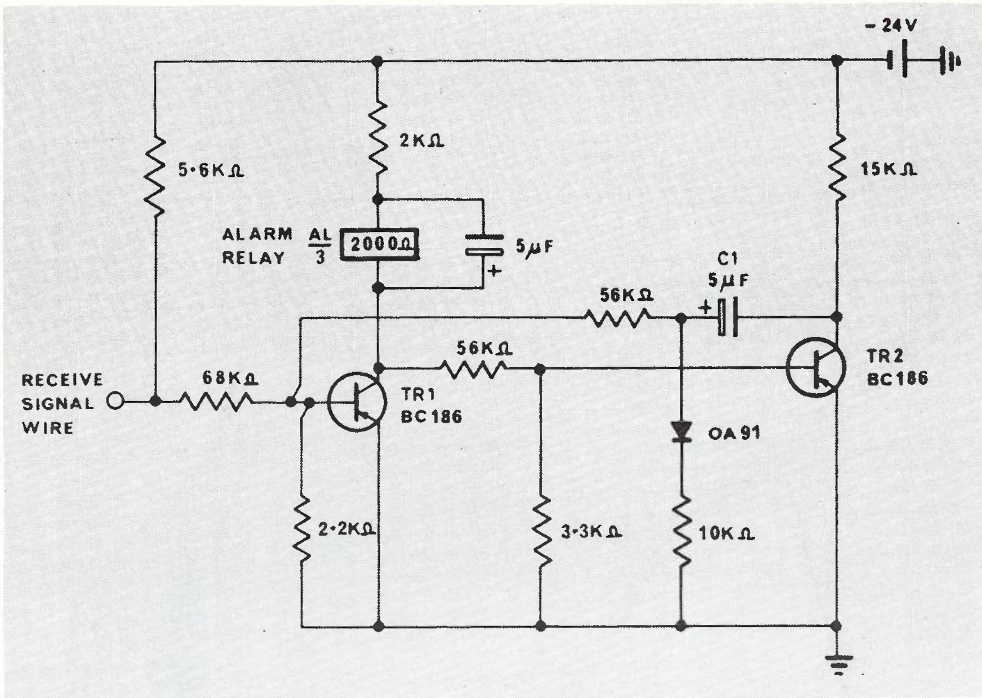


Fig. 3—High Speed Drive for Detection of Short Breaks.

Such an extension is at present being prepared for a display map to be located in the Long Line Equipment room at the new Lonsdale Exchange.

CONCLUSION

The Traffic Fail Alarm and Route Alarm Display Map have proved most useful for the overall observation of the trunk network. These are the first indication of a system failure to be received by the Trunk Terminal, enabling preliminary action to be taken prior to reports being received from Telecommunications Division or other stations affected by the fault. The ability to observe and sectionalise short breaks provides useful information about remote faults which affect the performance of telegraph and data circuits in particular. Major faults involving a large number of systems or a large number of repeater stations, can be assessed at a glance using the map, so too can the changing pattern of a progressive fault be observed.

An example of this type of fault occurred some months ago when a major coaxial trunk cable was destroyed by fire on a bridge located some eight kilometres from Melbourne. This 'Radio Tail' cable carried a number of intrastate and interstate systems between the Trunk Terminal and Surrey Hills radio terminal. As the cause of the fault was not known at the time, it was with some surprise that we saw the map display indicating one route failure after another due to the successive failure of the coaxial tubes as the fire progressed.

In conclusion, I would like to point out that we have accepted this means of overall supervision as a necessity at the Trunk Terminal. Additionally it has been provided at low cost and it operates over signalling channels which are not required for any other purpose.

EDITORIAL NOTE

The supervision of breakdowns of the broadband bearer trunk network is now one of the key functions of the newly created Service Restoration and Traffic Control Centre established in each capital city. These centres will ultimately be equipped with the type of facilities outlined in this article. A subsequent issue of this Journal will contain an article describing the Service Restoration and Traffic Control Centres.

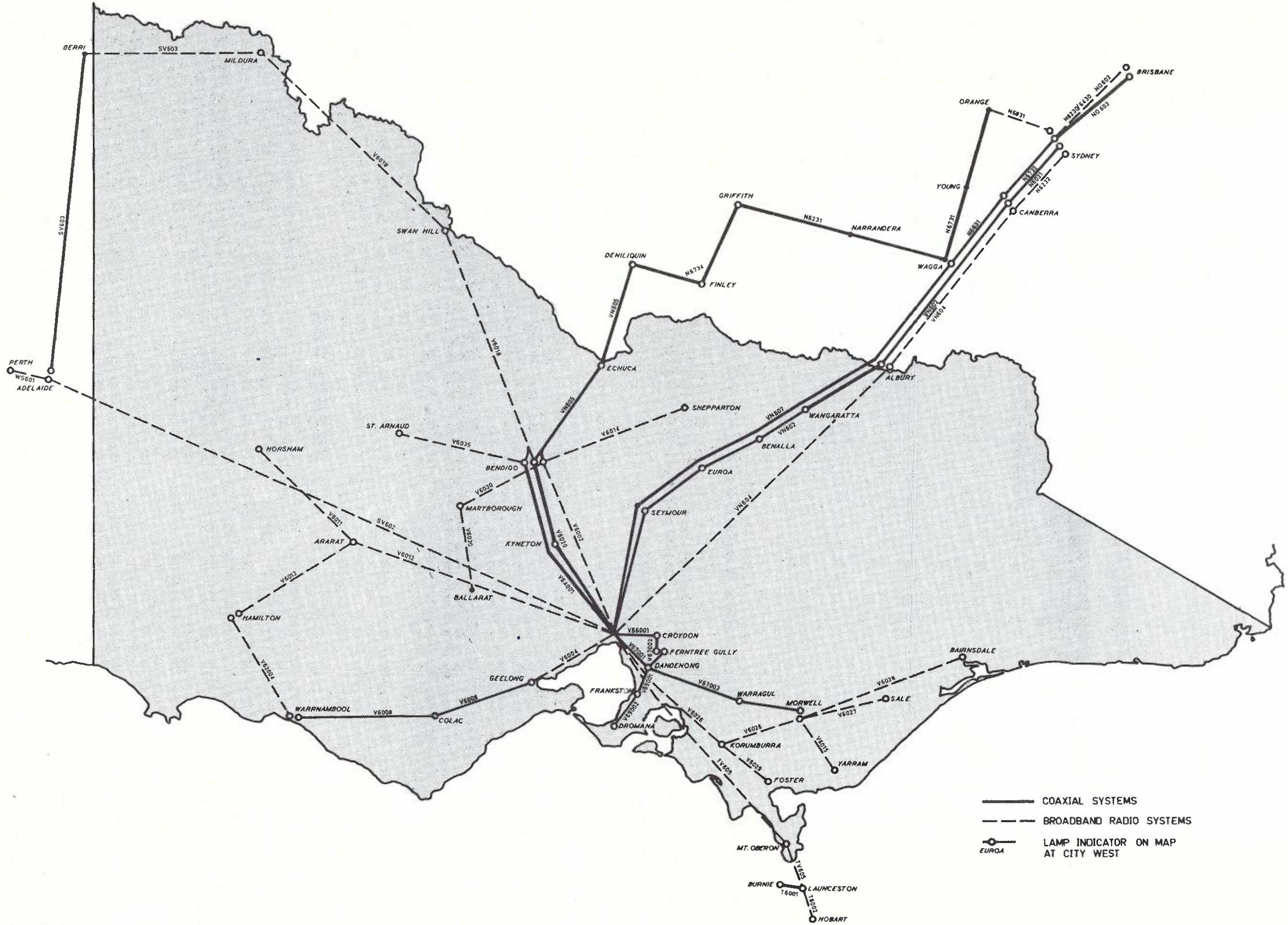
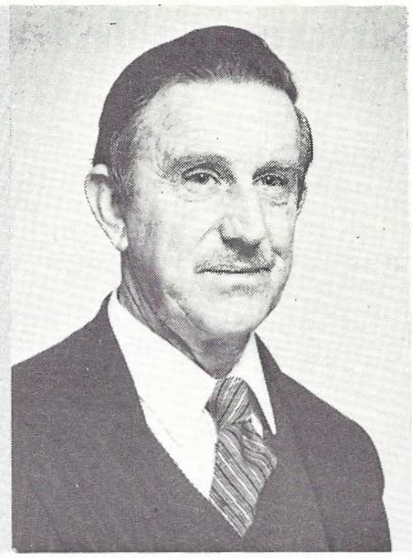


Fig. 4—Route Alarm Display Map.

B. W. MILLER joined the APO as a temporary Technician in 1939. He was appointed as a permanent Technician in 1949 and Senior Technician in 1950. He has been closely associated with the Melbourne Trunk Terminal since 1941, being appointed to that location as Shift Supervising Technician in 1958. He is still occupying this position in his present capacity as Shift STTO 2.



Underwater Cable Locator

G. JACKSON, B.E.

Much time and money can be spent in tracing underwater cables. The increasing costs of hiring divers warrant the development of quick and accurate methods of underwater cable location.

INTRODUCTION

There is no suitable cable tracer commercially available for underwater uses, although the APO has equipment for use above the surface which is capable of tracing the path of submerged cables. Because of the increasing number of cables in the rivers and estuaries around Sydney, attention has been focussed on the development of a unit capable of locating submerged cables.

Earlier attempts produced an 800 Watt audio amplifier which was used to energise a cable with a 400 Hz tone. A diver reached the bottom with a coil connected by cable to a boat. When the diver was in the vicinity of the energised cable he was notified by way of underwater headphones. Although this method was used with some degree of success it had its problems. The alignment of the search coil was critical to the output signal observed in the boat and there was a time lag between the signal being detected in the boat and the diver's knowledge of that signal. With these inherent problems underwater cable detection was time consuming and expensive.

A new underwater cable locating system which is the product of more recent developments has the detector unit operating without any cables connecting it to the surface and with an output readily interpreted by a diver.

OPERATING PRINCIPLES

The value of the locator is dependent upon high sensitivity in the detector stage but to permit telephone cables in the vicinity of power cables to be located total rejection of 50 Hz and its harmonics is essential. For this reason 25 Hz was chosen as the operating frequency. This frequency has the further advantage of being almost non-audible and thus there is very little risk of introducing noise into any unbalanced circuits in the cable being located.

The Sender Unit

To energise the cable with a 25 Hz signal a small motor generator unit is used, run at half speed. As a large current is necessary this method is the most convenient and does away with large and bulky amplifiers which in most locations need a motor generator to operate. The 25 Hz current flows down the cable sheath, the return path being by earth. To control the current, a 25A variable transformer is used to vary the output voltage between 0 and 32V. Precautions must be taken by the diver and other personnel to avoid contact with the cable as a relatively low voltage can be hazardous in a wet environment. This is found quite sufficient, a low earth resistance being always obtainable in the vicinity of a river crossing.

Due to the sharp cut-off of the filters in the detection unit the sender unit's output must be controlled at 25 Hz; to ensure this a frequency

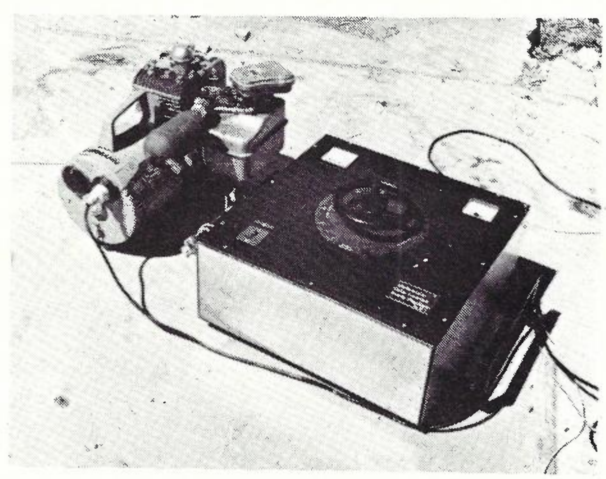


Fig. 1 — Sender Unit.

meter was developed reading 25± 5 Hz. The frequency meter consists of a wheatstone bridge which is at balance only when the frequency is 25 Hz.

The generator used was a Honda 1.5 kVA, however most other 240V 50 Hz generators could be used successfully.

The Detector Unit

Types of Output:

As this detection unit is designed primarily for use in water, a visual type of output is necessary. To achieve this a bank of light emitting diodes (LED's) is used. These diodes are easily seen in dark or murky water, however, in bright sunlight difficulty has been experienced in determining the state of an LED and so a small meter has also been fitted. The detection unit is made to operate directionally with a null reading being given when the search coil is aimed directly at the cable. The maximum number of LED's are on when the detector is aimed slightly off the cable. The response of th unit is best explained by Fig. 2.

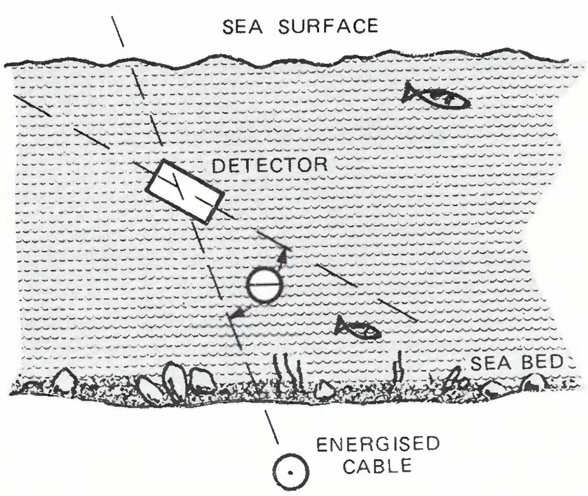
This null method provides a very accurate means of tra ng a cable's path. When the coil is oriented vertically over the cable the precise alignment is indicated by obtaining a null; the depth of the cable, with reference to the detector coil, is found by inclining the coil axis at 45° to the horizontal and moving away from, and perpendicular to, the cable run until a null occurs whereupon the depth of the cable will be equal to the horizontal displacement of the coil from the cable run.

Circuit of the Detection Unit: (See Fig. 3.)

The detection unit makes use of a high 'Q' resonant L.C. circuit tuned to 25 Hz. The coil is wound on a long transformer lamination (see photographs) to give this unit its directional properties. Various filters are incorporated to ensure that 50 Hz and its harmonics are totally rejected and a high pass filter is included to ensure that movements of the search coil through the earth's magnetic field will not produce a response. External control of the overall gain of amplification is provided to prevent overload of the amplifiers in the close vicinity of a cable.

The Underwater Housing (Figs. 4 (a) and (b))

The underwater housing for the unit is manufactured in GRP (glass reinforced plastic). This has many advantages over the more conventional perspex and dicast aluminium housings, being light, extremely strong, and easy to work. It also allows the moulding of reasonably complicated shapes, such as the cylindrical section holding the search coil; see Fig. 4. The face plate of this unit is made of $\frac{1}{8}$ in. thick perspex; the bulk of the unit being attached to this plate for easy removal. The face plate is sealed by a $\frac{1}{4}$ in. by $10\frac{1}{2}$ in. inside diameter 'O' ring. The gain control on/off shaft passes through this plate and is double sealed by a pair of $\frac{1}{16}$ in. by $\frac{1}{4}$ in. 'O' rings. This unit is designed to resist water pressure of at least 70 ft. The density of this unit is designed to ensure easy handling in the water and the colour, orange, is chosen in case the unit is dropped overboard by the diver, and must be recovered.



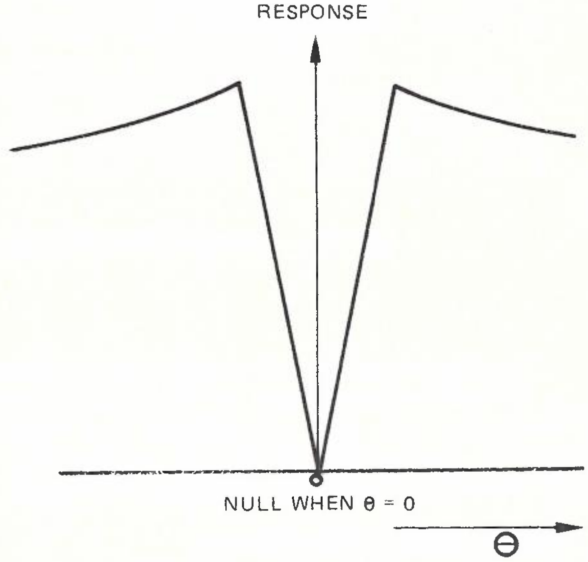


Fig. 2 — Response of Detector Unit.

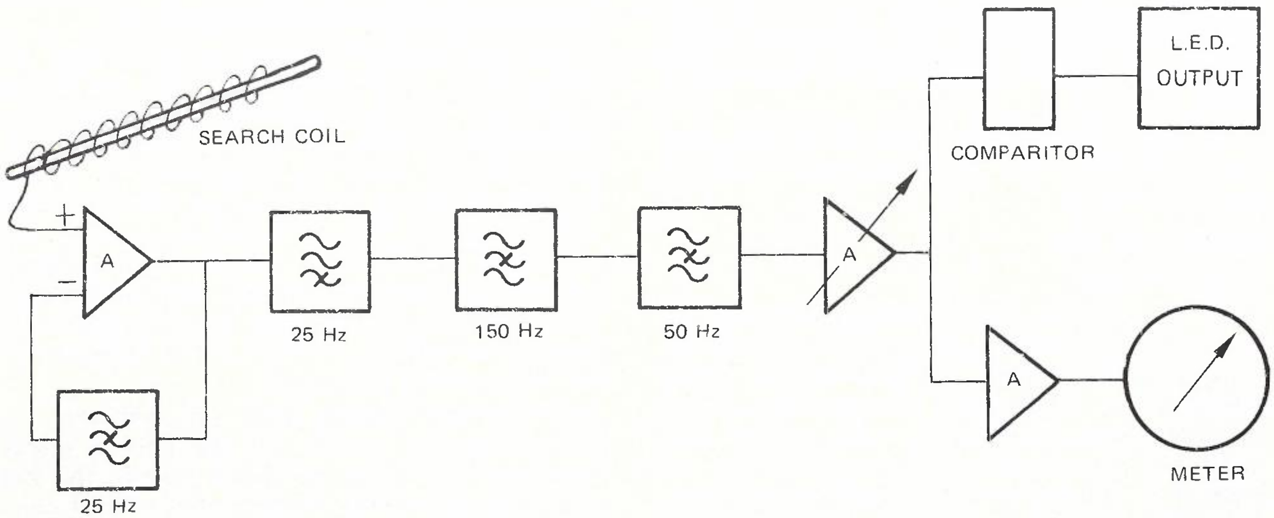


Fig. 3 — Block Schematic of Detector Circuit.

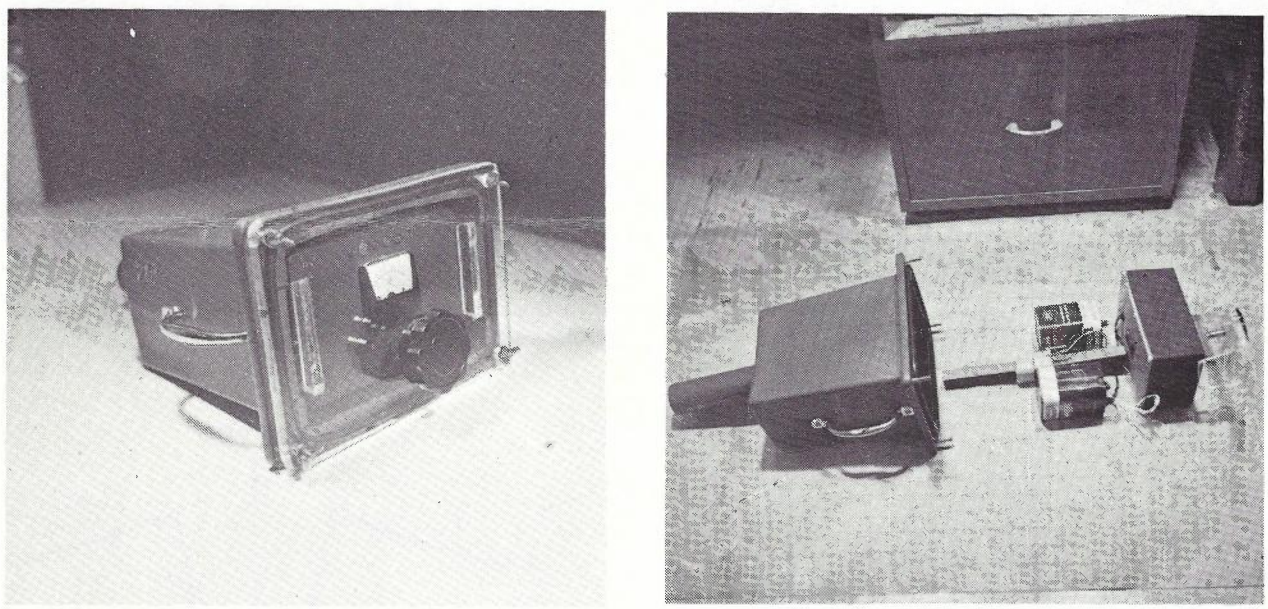


Fig. 4 — Detector Unit: (a) Complete unit; (b) Case and Electronics Module.

Housings of this type have been used consistently for underwater cameras for some years without developing any leaks or suffering any apparent loss in mechanical strength. No maintenance of any kind is necessary for this type of housing.

ABOVE WATER PERFORMANCE

The above water test chosen was to trace an armoured cable under the rubbish tip near Como exchange. The cable had been laid prior to the area becoming a rubbish tip and approximately 8 metres of rubbish now covered the cable. A manhole 200 metres from the tip was opened and the motor generator used to inject 3 amps through the cable. No attempt was made to isolate the cable from earth along its length and it was found unnecessary to ensure that all the current flowed in the required direction by removing the sheathing from a joint.

It was possible to determine the route of the

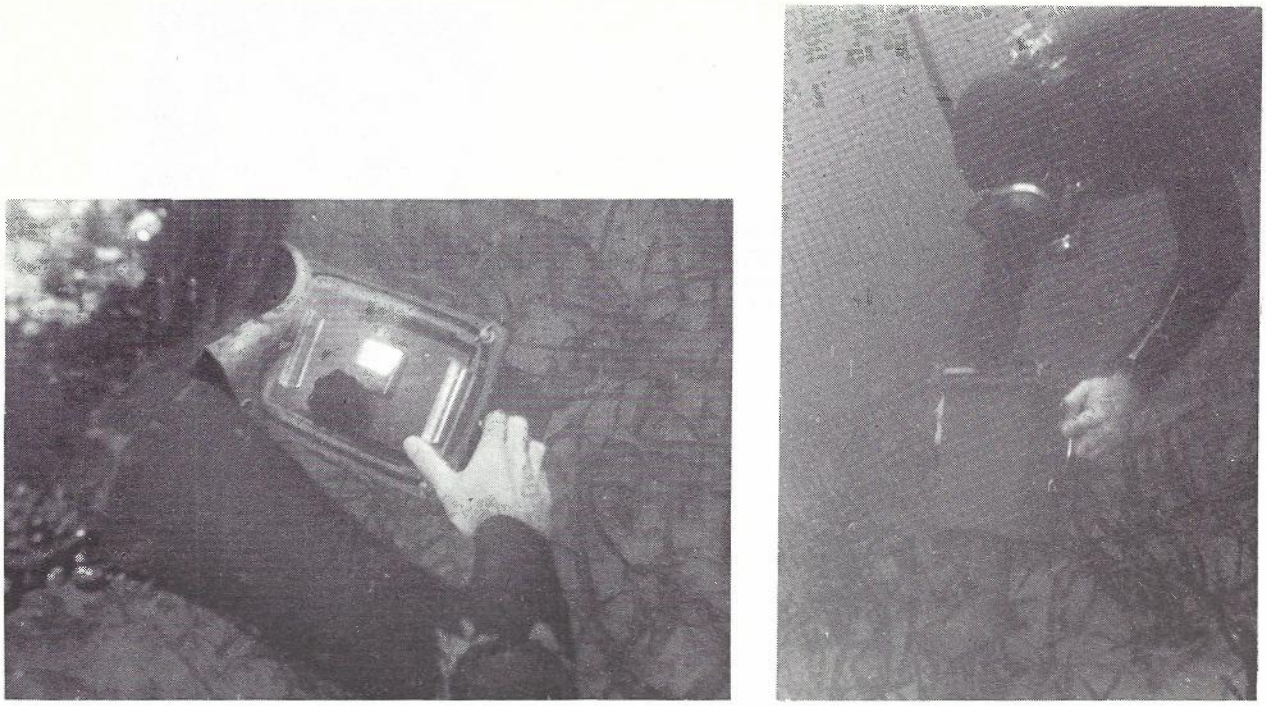


Fig. 5 — The Locator in Use.

armoured cable under the tip with a great deal of accuracy and by inclining the detector until it was at 45° to the vertical and moving away from the cable until a null was found, the depth of the cable could also be determined. By accurate measurement of this 45° angle the precise depth of the cable could be obtained.

The cable could be traced under the rubbish tip and through several manholes and up to the exchange, a distance of about 600 metres from the generator. The cable could also be traced at least 1,000 metres away from the generator in the other direction with no apparent drop in signal strength.

BELOW WATER PERFORMANCE

The underwater test chosen was to trace an armoured cable from Lilli-Pilli Point to Costens Point, a distance of about 400 metres across the Port Hacking river estuary. The generator was connected to the Costen's Point end of the cable, a length of GI pipe was placed in the water to be used as an earth connection.

In this test a variable transformer ("VARIAC") was used to adjust the voltage between the cable sheath and earth until 10 to 15 amps flowed; this is easier to control than adjusting the earth resistance. This high value of current was necessary because of the many leakage paths between the armoured cable and earth due to the low saltwater resistance.

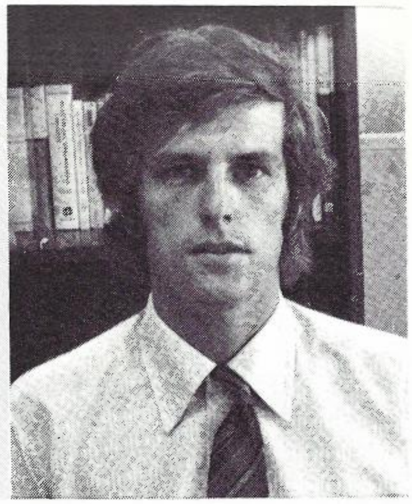
The cable was traced by a diver from water-edge to water-edge and the signal showed only a small and gradual decrease in strength over its entire length. No difficulty was experienced in tracing the cable and the high angular resolution obtainable on land was also obtained under the water. The time taken to trace this cable was no longer than the time required to swim along the cable length.

CONCLUSION

This detector has been developed over a number of years by Messrs. Fred Goddard, Testing Officer, and Greg Jackson, Engineer Class 1 from Sutherland Operations, in conjunction with Graham Johns, STTO 1 from Transmission Measurements Studies and Design Section, Sydney.

In its present state this detector would appear to provide a means of locating cables, above or below water.

G. JACKSON joined the A.P.O. in 1968 as a Technician's Assistant and in 1970 was awarded a Commonwealth Public Service Cadetship. By 1972 he graduated in Electrical Engineering at the University of N.S.W. and is currently an Engineer Class 1 in Sutherland Operations Section. Since 1973 he has been studying for his Bachelor of Science degree majoring in Applied Mathematics.



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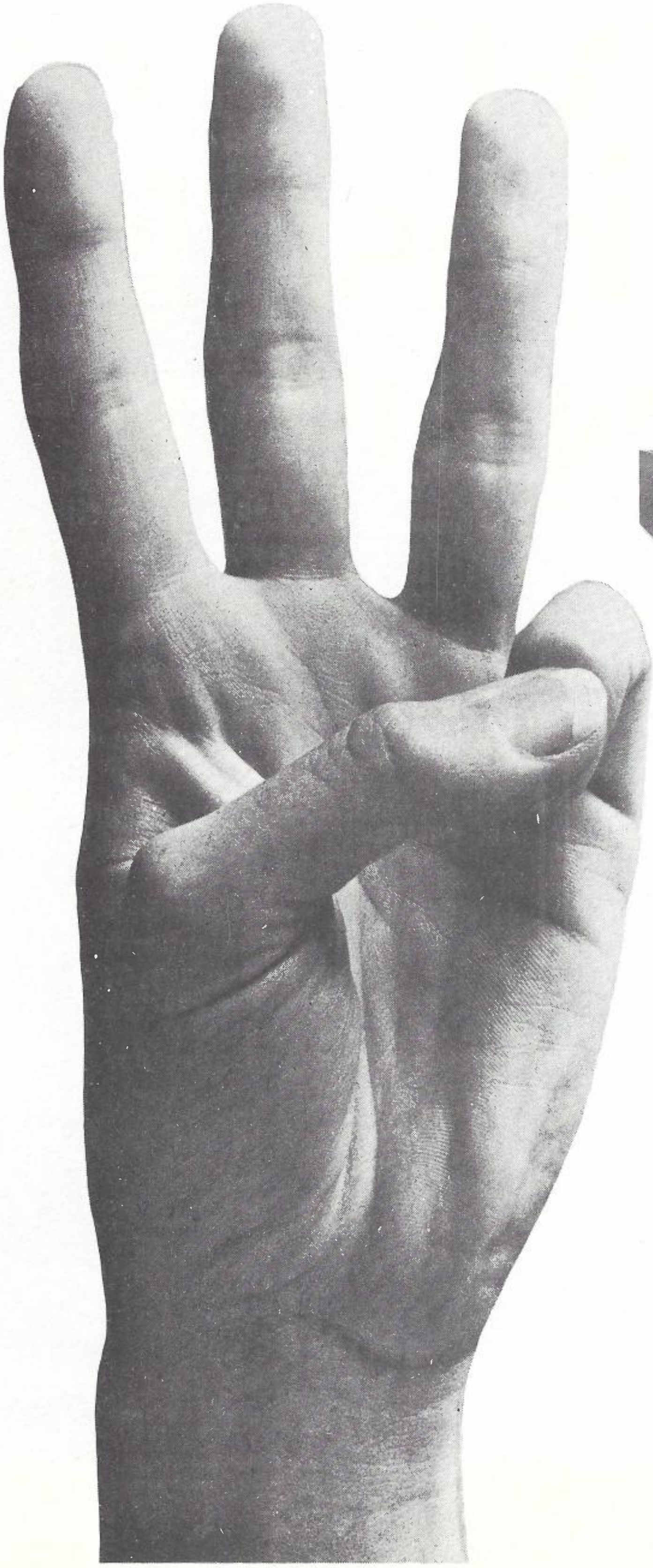

The GEC 746 table telephone
–an instrument making full use of printed circuit techniques and tropicalised components.
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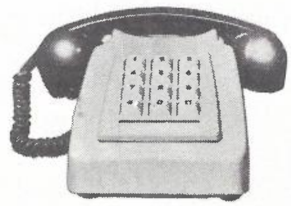

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–hand-free operation with full automatic voice switching so that loud-speaker and microphone cannot be 'alive' at the same time.

The GEC 740 1/2 and 1/3 switching telephone
–independent access to one exchange line from two or three telephones. Also provides an efficient intercom system.

Dial or pushbutton versions available for all telephones.

GEC manufacture telephones for world markets: table and wall-mounting models in a number of attractive colours, loudspeaking telephones, pushbutton telephones and switching telephone systems.....

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The GEC 746 table telephone – You can depend on it. That's the most important thing you can say about a telephone, a very essential tool of modern society. Important as it is, it is often taken for granted.

When you buy a telephone you obviously want good styling at a low price. In the 746 we provide both but more importantly we offer an instrument of high performance and unique flexibility with the widest available choice of options. These options include:

* 1 or 2 switching buttons for recall, shared service, conference, priority access, bell on/off.
* Seven colour options.
* Handset: Lamp calling; deaf aid; press-to-talk.
* Table or wall mounting.
* Dials: 10 or 20 i.p.s; dial lock; C.B. working.
  Number rings – to suit any requirement.
  Pushbutton signalling – three versions available:
  Self-contained MOS loop dis-connect for all types of exchange.
  Multifrequency for large exchanges.
  D.C. leg for PAX/PABX exchanges.
* Ringer: High or low impedance. Extension Bell.
* Automatic volume regulator optional.
* Line cord 1.5 m, 2 m, 3 m Plug or Jack.

Someone, somewhere may think they have a requirement that cannot be met by the GEC 746 range. We'd welcome the chance to prove them wrong.

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Dial or pushbutton versions available for all telephones.

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GF2

Presenting: a perfect level measuring set for in-service traffic.

New and already perfect? Don't wonder! It's true. Measuring Set PS-60/SPM-60 is an advanced version of the well known already proven Level Measuring Set PS-6/SPM-6. New features: Continuous frequency tuning over the complete range without switching, 10 Hz resolution and 6 digit flicker-free read-out of frequency. The SPM-60 has our patented automatic level control; manual calibration is superfluous, but high accuracy is assured over the whole frequency range.
A fast signal detector indicator simplifies finding unknown frequencies while fast-tuning through the range. Thereby, it simplifies the finding of interference voltages and the analysis of frequency spectrums.

* Level ranges: –130 dB/–120 dBm to +21 dB/+27 dBm
* Level range scales: 20 dB, 2 dB, ±0.5 dB
* Level magnifier for ±0.5 dB aids in reading level differences as small as 0.01 dB
* Sure, narrow-band measurements on CF systems during in-service operation; by means of exact frequency setting. Highest accuracy for frequency.
* Over-driven-signal check to prevent errors
* Noise bands: 1.74 kHz, 400 Hz (24 Hz in preparation)
* Test Probe: at high Z and low C

The PS-60 Generator in combination with Sweep Frequency Unit WZ-6 can be used for swept frequency measurements.

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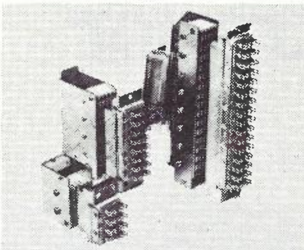
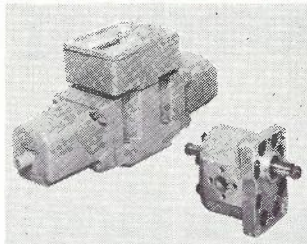
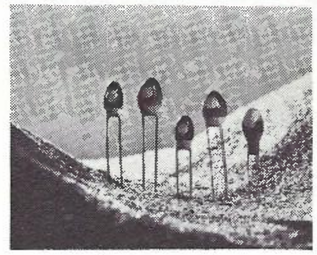
Australia



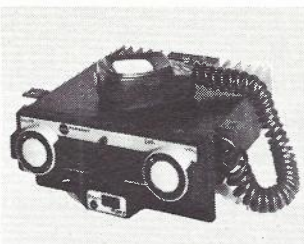
Plessey knife and fork connectors are part of the wide range of multi-circuit connectors marketed by Plessey Australia, Components Division. They are available in standard 20, 40 and 80 way sizes.



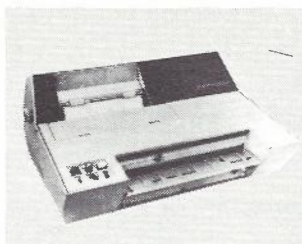
Internationally recognised "RACINE" hydraulic pumps and valves are sold and serviced throughout Australia by Plessey Australia, Telecommunications Division, Meadowbank, NSW.



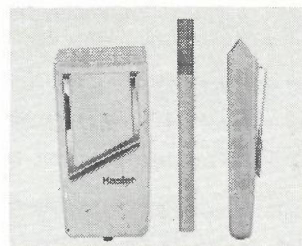
These NEC solid tantalum capacitors are designed for decoupling, by-pass, blocking and filtering applications in both professional and domestic electronic equipment. They are but one of the extensive range of professional components available from Plessey Australia, Components Division.



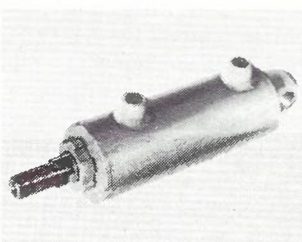
Illustrated is the MRT 40 mobile 2-way radio system with an SC 201 Decoder fitted. Developed by Plessey Australia Electronics System, Richmond, Victoria, the system employs a method of selective calling whereby each operator receives only those messages specifically directed to him.



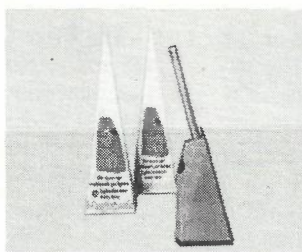
Marketed by Plessey Communication Systems, the Facsimile Remote Copier is a desk-top copier capable of transmitting and receiving over public or private telephone lines, printed, written or graphic material within minutes.



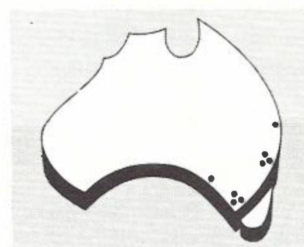
This radio paging miniature receiver uses the most advanced electronic circuitry to maximise efficiency in the location of staff. This inductive loop system is available from Plessey Communication Systems.



Designed and manufactured locally, Plessey hydraulic cylinders and presses are available for a variety of industrial and mobile applications. The cylinder illustrated is just one of the wide range available from Plessey Australia, Telecommunications Division, Meadowbank, NSW.



Marketed by Plessey Australia, Components Division the 'Magispark' is a compact electronic gas lighter providing a continuous spark suitable for use in kitchens, on boats, caravans and for outdoor stoves and gas barbecues.



Number of plants: 8
Factory capacity: 1 million sq. ft.
Employees: 4,000

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APP70/R1

No.1 EAX
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Flexible and ready for growth.

That's No. 1 EAX, a central office system that can be expanded up to 45,000 lines.

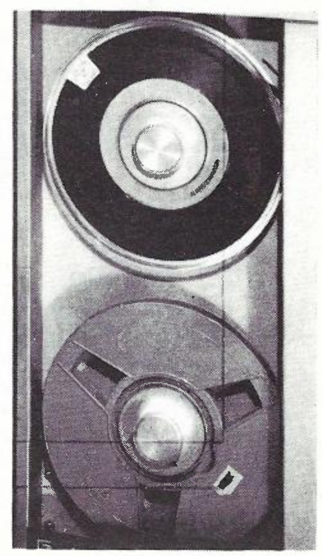
We've taken advantage of the latest developments in integrated circuits and computer logic to design a system that sets a completely new standard for local and local tandem exchanges.

For example, our stored program technique lets you keep up with changing customer requirements by inserting new instructions through a teletypewriter that can be built-in or located remotely.

No hardware or wiring changes are needed.

This lets you do things like changing dial to touch calling simply by typing a class-of-service marker into the computer memory. (The No. 1 EAX can handle both types of subscriber calls simultaneously.)

The No. 1 EAX also lets you offer your customers direct-distance dialing. The automatic message accounting system can be located right at the exchange or the information can be routed to a centralized toll ticketing or TSPS facility.



Both LAMA and CAMA toll ticketing systems can be installed as part of a No. 1 EAX system. The LAMA unit will handle up to 45,000 lines and store up to 1,000 completed calls on just nine feet of tape.

From GTE.

-the-art exchange.

And, LAMA records trunk number, called number, calling number, start and completion time, date, rate, and class of call for automatic billing systems.

In the No. 1 EAX, dual computer and data processing systems are on line simultaneously to give maximum security against malfunction.

In addition, a computerized diagnostic program constantly monitors the operation of these systems and all subsystems.

The No. 1 EAX can handle subscriber loops with total external resistance of up to 2250 ohms at 50 Volts. That means that fewer long line adapters are needed.

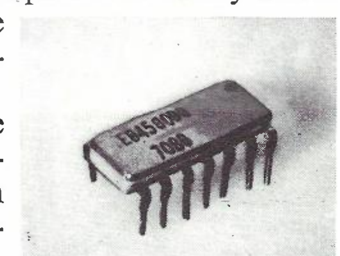
Expansion is also a simple matter.

You can add lines just by adding modules to the existing system.

If it's a bigger expansion, you can grow in 200 line increments just by adding factory-wired line frames and switching matrixes.

A lot of people realize the advantage of No. 1 EAX. Right now, there are 19 installations in full operation. And that number will grow to 26 by the end of 1974.

No. 1 EAX is only part of GTE's family of electronic telephone equipment. A family that is designed to meet the needs of every size exchange.



And they all have the same basic design concept that assures high reliability and wide flexibility.

After all, what else would you expect from the people who invented automatic telephony? We established the state-of-the-art in 1891, and we're still leading it today.

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In-service noise measurements with Siemens 18·6 MHz Set-up

The main application of Siemens 18.6 MHz Set-up is to make selective level measurements on carrier frequency broadband transmission systems, either in-station or along the route. Application of the level meter to in-service intermodulation noise measurements is extended with these features:

☐ Accuracy in frequency plus stability ensures perfect tuning to the channel under test

☐ High sensitivity allows measurement of low noise levels considerably below signal levels

☐ High dynamic range with low residual distortion so that low levels can be measured during traffic

☐ Suitable selectivity is obtained by a mechanical filter with an attenuation of 80 dB ± 2kHz off-centre frequency. Effective band width of this filter is equal to the C.C.I.T.T psophometer curve

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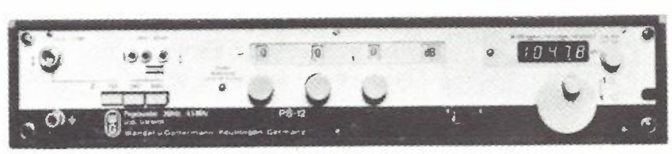
Selective and Wideband Level Meter with positive assurance for future system expansion to 960 channels

This small, portable and handy equipment will become your universal level meter whether you work in development, test department or in system operations. Due to its wide range of frequencies, the Level Meter SPM-12 is suitable equally for measurements on lower frequency channels as for CF-systems up to V 960. It has many new technical features and provides you with an easy means for measuring:

✳ Input sensitivity, selective −120 dB/dBm
  wideband −60 dB/dBm (at full scale deflection)
✳ High resolution of level readings;
  expanded scale for 2 dB
✳ Switchable measuring ranges; steps of 10 dB
✳ Five decades, flicker-free, digital display switchable to 10 Hz resolution
✳ Universal Versacon® 9 connectors for simple changeover to all usually available connectors
✳ Balanced input
✳ High impedance test probe
✳ Effective noise bandwidths of 1.74 kHz or 500 Hz; optional, 25 Hz

The Level Generator PS-12 and the SPM-12 combine into a complete level measuring set-up. Sweep Unit WZ-6 can be added for swept measurements.



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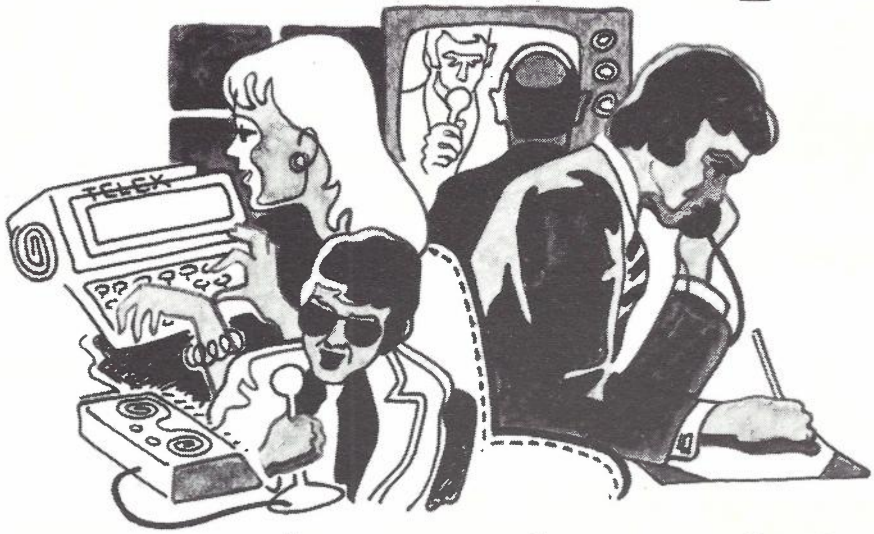
People have a lot to say



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is the most vital element in communications.
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Olex is a fully Australian owned and controlled
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The Telecommunications Journal of Australia

ABSTRACTS: Vol. 25, No. 2

BALDERSTON, M.: 'An Historical Survey of Communications Satellites (Part 2)'; Telecomm. Journal of Aust., Vol. 25, No. 2, 1975, page 98.

Part 1 of this Survey discussed the early history of communications satellites and discussed the characteristics of the Intelsat, Western military, and Russian Orbita satellite systems. Part 2 reviews the different types of satellite systems and outlines experiments which have been undertaken on certain advanced technical and operational features. The Canadian domestic satellite system is discussed.

HAMBLETON, A. H. and LLOYD, R. R.: 'Automatic Testing of Telephone Cable'; Telecomm. Journal of Aust., Vol. 25, No. 2, 1975, page 134.

With the increasing complexity of the Telecommunication Network, the performance requirements for component cables have increased. Cable testing to provide both Quality Assurance and design information, has assumed a significant role in cable manufacture, leading to the development of more and more sophisticated measuring systems.

This paper discusses the current generation of computer-controlled cable-testing equipment and explains its application to cable testing.

JACKSON, G.: 'Underwater Cable Locator'; Telecomm. Journal of Aust., Vol. 25, No. 2, 1975, page 160.

Much time and money can be spent in tracing underwater cables. The increasing costs of hiring divers warrant the development of quick and accurate methods of underwater cable location.

JESSOP, C. W. A.: 'Dynamic Programming — An Application to Telecommunications Planning'; Telecomm. Journal of Aust., Vol. 25, No. 2, 1975, page 116.

The technique of "Dynamic Programming" is briefly described, and its use in telecommunications planning is illustrated. The technique is a powerful planning tool, which could be utilised more frequently than it is, in the planning of telecommunications projects.

JOHNS, D.: 'The Melbourne Semi-Automatic Wake-Up Service'; Telecomm. Journal of Aust., Vol. 25, No. 2, page 107.

The existing wake up service in Melbourne has for some years been experiencing operational difficulties and financial loss. In order to overcome these problems a semi-automatic wake up service based on magnetic disc memories with hard wired logic controllers has been developed.

Manual booking and automatic sending are used, the maximum sending rate being about 750 calls in five minutes.

McFADDEN, D. Y. and PAYNE, I. W.: 'A New Letter Sorting Machine for the Australian Post Office'; Telecomm. Journal of Aust., Vol. 25, No. 2, page 122.

The Australian Post Office was one of the pioneers in the advancement of mail handling technology when it installed the Australian made letter coding equipment in the Sydney Mail Exchange in 1966. The new letter sorting machine described in this article has been developed in Australia as a joint venture between the APO and an Australian manufacturer as a result of experience gained from the operation of this plant. It employs a number of novel techniques in performing its sorting function, and is being considered for use in new letter handling installations, and for the eventual upgrading of the Sydney system, which has been in operation since 1966.

MILLER, B. W.: 'Traffic Fail Alarm and Display Map at the Melbourne Trunk Terminal'; Telecomm. Journal of Aust., Vol. 25, No. 2, 1975, page 155.

To minimise duration of outages on a broadband bearer network, it is necessary to obtain prompt indication of bearer failure, and to locate the failed section of the broadband bearer geographically. This article describes the facilities for broadband bearer supervision which have been in use for several years at the Melbourne trunk terminal.

TAYLOR, G. F.: 'Common User Data Network (Part 1)'; Telecomm. Journal of Aust., Vol. 25, No. 2, 1975, page 87.

The Australian Common User Data Network (CUDN) is a store and forward message switching system designed to transfer data quickly and reliably from one location to one or more specified distant locations. Magnetic disc packs perform the storage function and computers perform the routing function. Several customers with independent sets of conventional and modern terminal devices can use the equipment concurrently and continuously without affecting one another in any way.

This is the first of three articles on CUDN and will describe the network facilities and the hardware used to implement them. The second article will describe the software programs necessary to control the hardware and switch the data from input to output. The third article will describe how the APO and the customers supervise the flow of traffic through the network.

TREBILCO, W. J.: 'Private Telephone Meter, Type 2'; Telecomm. Journal of Aust., Vol. 25, No. 2, 1975, page 148.

This article describes a new subscribers private telephone meter which will be introduced by the APO in 1975. The meter can be installed at a subscribers premises to record the charge unit registrations for local and STD calls from his telephone. In addition the meter can be equipped to enable the subscriber to control the use of his telephone by the public.

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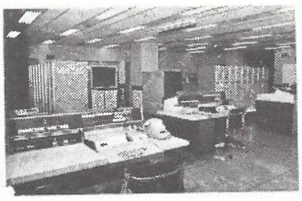

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