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COVER
IMPROVED COIN TELEPHONE

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OVERSEAS APPLICATIONS

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The Improved Multi Purpose Coin Telephone: CT3(I)

W. J. TREBILCO, A.R.M.I.T.

Multipurpose Coin Telephone No. 3 (CT3) was introduced in 1971 to provide the public with STD calling from coin telephones and to reduce operator assistance traffic. However, CT3 was developed prior to the high inflationary upturn in our economy and it became apparent that its limited tariff facilities would restrict future policies. Therefore, it was decided to redesign the CT3 to provide it with an expanded and more flexible tariff ability and, in addition, incorporate a number of other electrical and mechanical improvements.

This article describes the design changes which have led to the development of the improved multi-purpose coin telephone CT3(1).

The green multipurpose coin telephone CT3 (**Fig. 1**) would now be familiar to most people in Australia, having been introduced in 1971. The public has willingly adopted the STD facility offered by CT3. One significant benefit of this has been that Telecom has not needed to expand a number of manual assistance centres, especially in holiday areas.

Following the successful public acceptance of the CT3, particularly of the STD facility, and perceiving the need to upgrade the coin telephone system, Telecom decided to replace all coin telephones, other than Red Phones, with CT3s.

This coin telephone replacement programme (COTERP) was commenced in 1976 and will be completed by mid-1983. By June 1979, 13,000 of the older coin telephones had been replaced by CT3s and another 24,000 will need to be replaced to complete COTERP. The programme also includes the replacement of all wooden public telephone cabinets with the new aluminium/glass cabinet. **Figs 1 & 2** show examples of typical new and old installations.

Whilst CT3 has proved an excellent facility for the public, particularly for people travelling, it became apparent that a number of features and facilities should be improved if the instrument was to replace all other coin telephones.

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This article describes the developments which have led to the improved CT3, known as CT3(I).

COIN TELEPHONE — CT3

The CT3 provides facilities for STD, local, operator assisted and non-chargeable calls.

The instrument operates on the pre-pay system, the user inserting coins before dialling. On STD calls a warning lamp indicates to the user when to insert more coins if he wishes to extend the call beyond the time paid for. Operator-assisted calls are controlled by tones sent from the CT3 when the user inserts coins or presses the collect button. No coins are required for emergency or enquiry calls, which are also available under power-fail conditions.

A detailed description of CT3 is given in Telecom Journal of Australia Vol. 22, No. 2, June 1972.

The CT3 has been a vast improvement over the older coin telephone types in providing STD facilities, greater resistance to vandalism and significantly reduced maintenance.

When it was decided to proceed with the COTERP programme it became necessary to seriously review the long-term tariff flexibility of CT3; also, experience with CT3 showed that certain facilities should be refined and improved if the telephone was to be installed as a replacement for all existing instruments. In addition, Telecom has learned that public confidence in coin telephones can be assured only if vandalism and fraudulent-use activities are largely overcome; Telecom decided that the replacement coin telephone should incorporate all possible reasonable safeguards against vandalism and fraud. However, it should be noted that most fraudulent-use techniques had been overcome by modification of CT3s in service.

CT3 IMPROVED — CT3(I)

Telecom decided to re-specify the multipurpose coin telephone incorporating the abovementioned improvements and others. A world-wide invitation for tenders was issued in May 1975.

The instrument chosen was that tendered by STC Pty Ltd the previous supplier of CT3; in both cases the coin telephone was manufactured in Japan by Anritsu Electric Company. The new offer was for an instrument which used the same basic CT3 case design but incorporated changes to the coin mechanisms and circuitry to meet the new specification.

Because of its almost identical appearance to CT3 this new instrument became known as the CT3 Improved or CT3(I), **(Fig. 3)**. Further, because the case structure and fittings are the same in CT3 and CT3(I), the main assemblies such as circuit board and coin mechanisms can be used to upgrade CT3s to CT3(I)s.

As outlined above, the main improvements in CT3(I) are to do with:

- Tariff Flexibility
- New and Improved Facilities
- Vandalism and Fraudulent-use,

and these three areas are now discussed.

TARIFF FLEXIBILITY

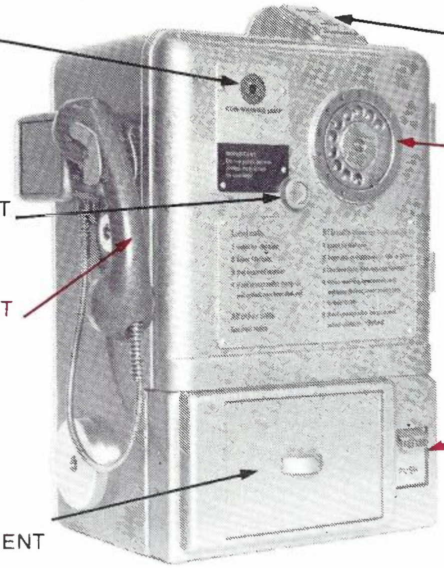
Coin Mechanisms

The CT3 was designed to accept two coin sizes, and is currently fitted to take 10 and 20 cent coins. However, each mechanism is constructed to take only one size coin. Therefore, for any local call tariff change it is necessary to replace a complete coin mechanism. For example, if it was decided to increase the local call fee from 10 cents to 20 cents it would be necessary to effect the costly replacement of the 10 cent mechanism with a 50 cent mechanism. This situation is a reminder that CT3 was introduced in an era when telephone tariffs were expected to remain stable over many years.

Coin mechanisms replacement will not be necessary

Fig. 1 — Aluminium/Glass Cabinet.

Fig. 2 — Wooden Cabinet.



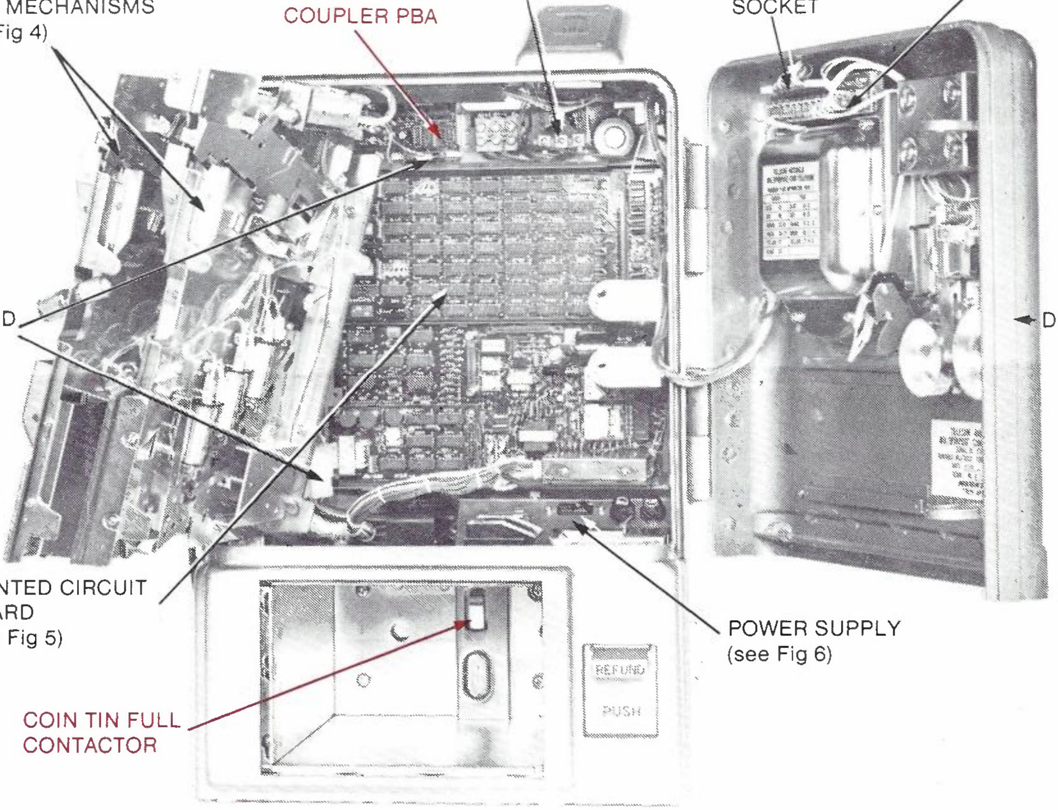


Fig. 3 — CT3 Improved — CT3(I).

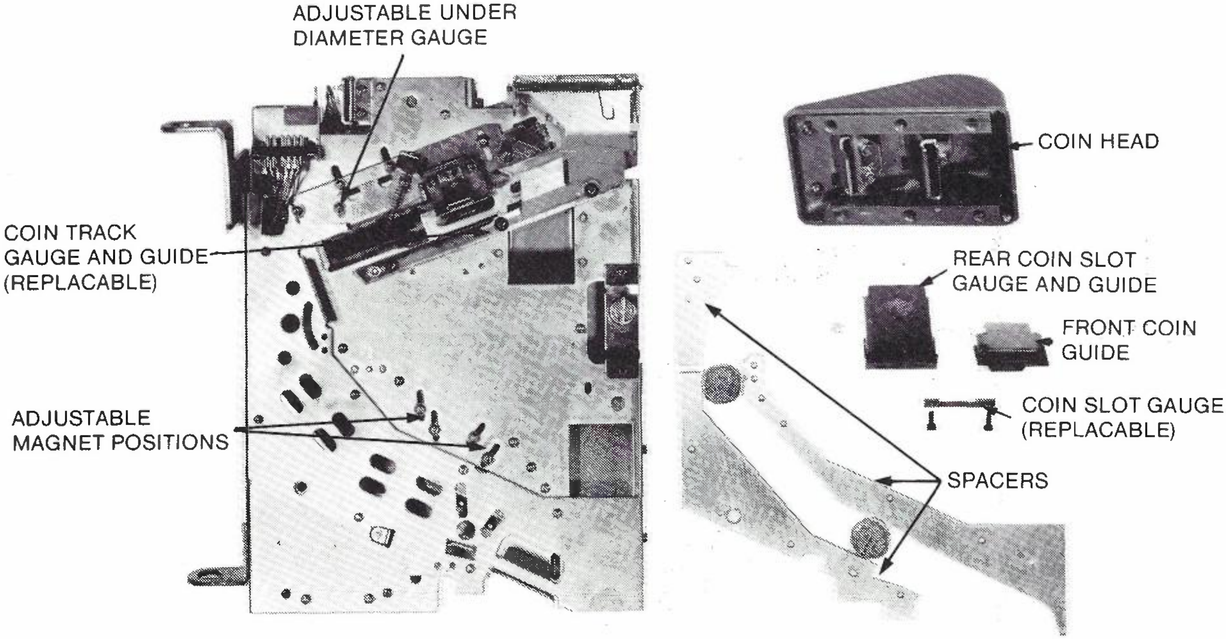


Fig. 4 — Mechanical Adjustments for Tariff Charge.

on CT3(I) since they will be adjustable for all coin sizes from 5 cents to 50 cents. Adjustments will be possible by changing spacers and resetting gauges (**Fig. 4**). The existing 50 cent coin is quite large, and it is expected that any new coin denomination, such as one dollar, would be smaller than the 50 cent coin, and so be accommodated by the proposed mechanism.

Charge Units and Coin Values

The charge unit is the basic debit against money deposited in CT3 for each meter pulse received from the exchange on STD calls. The charge unit is set by fee change strapping plugs on the CT3 circuit board. Currently these are set to charge at 10 cents per meter pulse. Strapping is possible for charging at 4, 5, 6, 7, 8, 10, 12, 14, 15, 16 and 20 cents per meter pulse.

CT3(I) will allow for a much wider range of charge unit settings and will cater for the use of tokens. However, whilst tokens are used in coin telephones in other parts of the world, their use in Australia is not likely in the foreseeable future.

Table 1 shows the wide range of tariff steps offered by CT3(I) in an attempt to meet the effects of inflation in the life of the instrument.

Fig. 5 shows the location of the fee change plugs on the CT3(I) printed board assembly.

Multiple Coin Collection

To further reduce the need for mechanical alterations for tariff changes, CT3(I) allows fee change plug settings for more than one coin to be collected on receipt of a meter pulse. For example, the user inserts one 10c coin at present to make a local call and the fee change plug setting in CT3 causes one 10c coin to be collected on receipt of the answer meter pulse. If the tariff was made 20c for a local call it would be necessary to change a mechanism and gauges in CT3, but in CT3(I) the fee change plugs can be strapped to collect two 10c coins on receipt of the answer meter pulse. This feature also applies to STD calls, and offers a further degree of flexibility in the planning and implementation of future coin telephone tariffing strategies.

Local Call Timing

Telecom has no policy for the introduction of local call timing either for coin telephones or for the normal public exchange telephone service. Nevertheless, it was considered prudent to allow for this eventuality in the CT3(I).

Lowest Denomination Coin or Token	Highest Denomination Coin or Token	Charge Unit
1-99c (in 1c steps)	0-740c (in 10c steps)	0-99c (in 1c steps)

Table 1: CT3(I) Tariff Flexibility

Accordingly, CT3(I) has two sets of fee change plugs **(Fig. 5)**: one set for varying charge units for STD calls, and another set which allows different charge unit settings for timed or untimed local calls. It should be noted that different basic charge unit values can operate concurrently for both local calls and STD calls; for example, the local call charge unit could be 20c and the STD charge unit 12c. This feature, again, allows for a wide flexibility in tariff planning.

If Telecom ever decides to provide local call timing at coin telephones, meter pulses would be generated at the local exchange and sent to the coin telephone. When the type of call (STD or local) is determined by the CT3(I) (see later description of Call Identification Signal), it will charge at the rate set by either the STD or local call fee change plugs. This arrangement will provide another technique to avoid mechanical changes when future local call tariff increases are required. It will allow Telecom to reduce the relatively large fixed steps necessary for coin telephone local calls in the past because of available coin denominations.

NEW AND IMPROVED FACILITIES

Call Identification Signal

To allow CT3(I) to differentiate between local or STD calls, and so set the appropriate charging mode and facilitate adequate Coin Warning Signals, a Call Identification Signal (CIS) will be sent from the exchange on all STD calls. This signal will be applied when sufficient digits have been analysed in the exchange to determine that the call is STD.

On receipt of the CIS signal the instrument will set itself to charge at the rate set by the STD fee change plugs. If no CIS signal is received the instrument will set itself to charge at the local call (timed or untimed) rate.

Coin Warning Signal

On STD calls CT3 has a visual warning lamp which glows when the last coin is collected and flashes when a meter pulse reduces the paid credit time to one metering period.

This Coin Warning Signal (CWS) is intended to give

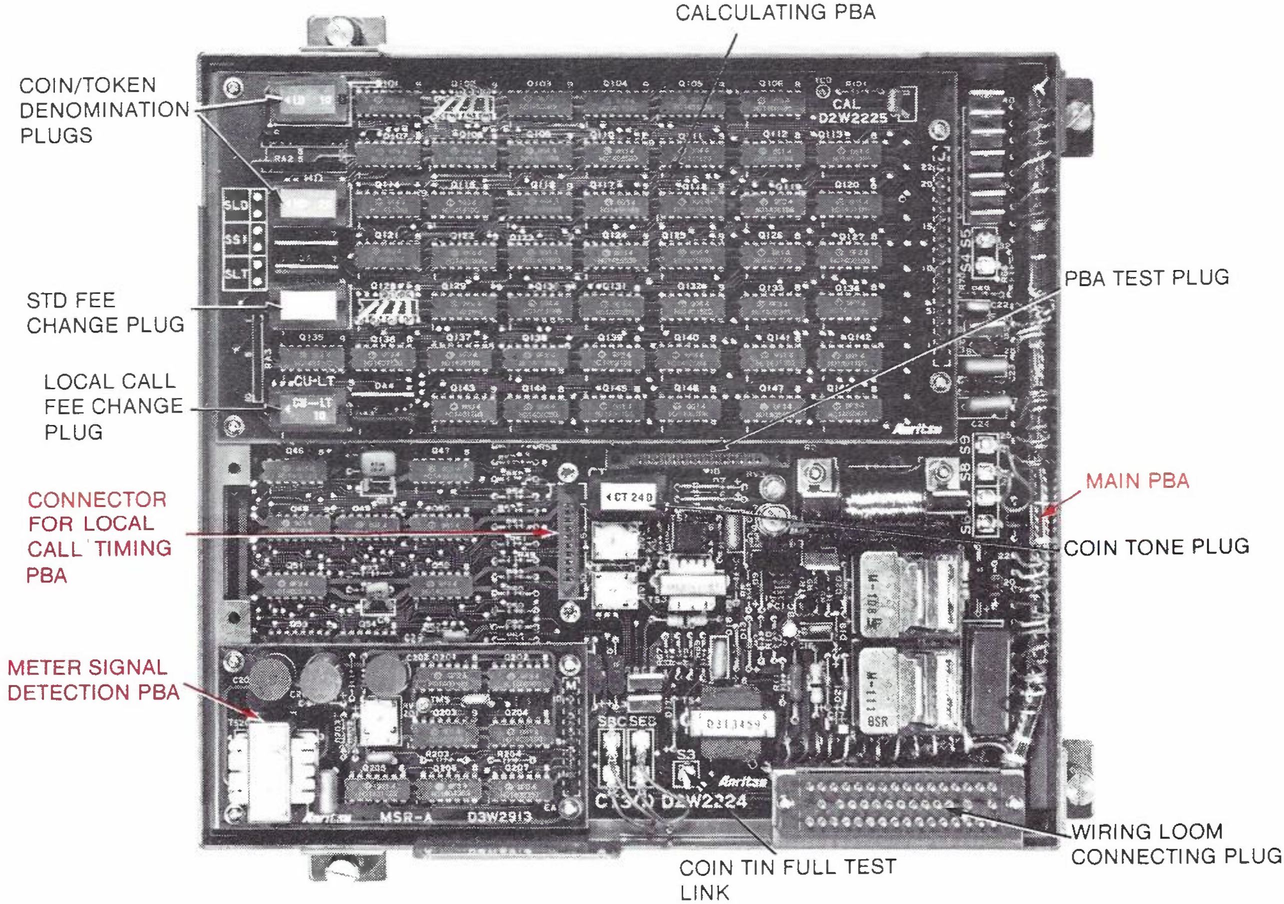


Fig. 5 — Printed Circuit Board Assembly — CT3(I).

sufficient warning to the caller, so that he can insert more coins to extend the call; otherwise, the call is force released when credit expires.

Experience with CT3 has highlighted deficiencies in the CT3 coin warning system:

- The CWS cannot commence until the CT3 knows that the call is STD, and this is known only when a second meter pulse is received. Thus if the user inserts one 10c coin and makes an STD call he gets no CWS before being force released.
- The two CWS lamp states, steady and flashing, are confusing to the average user.
- The CWS can vary in length between 6.0 seconds and 3.75 minutes, depending on the call distance. The user may not receive sufficient warning to insert more coins to extend a long distance call before he is force released, or the CWS is so long that it becomes meaningless.
- Users are not always aware that the CWS lamp is operating, and consequently a call can be force released without the user realising that the credit has expired.

These deficiencies in the CT3 are overcome in CT3(I) as follows:

- The CIS signal allows recognition of STD calls prior to the first meter pulse. Hence, the CWS can be effective from receipt of the first meter pulse.
- Only a flashing lamp condition is used for the CWS. There is no other lamp state.
- A meter period timer checks the time between meter pulses. If the time between pulses is more than 10 seconds the CWS (flashing lamp) is operated when credit is reduced to less than 2 charge units. If the time between meter pulses is less than 10 seconds the CWS operates when credit is reduced to less than 5 charge units.
- A small loudspeaker **(Fig. 6)** mounted inside the CT3(I) case emits a 500 hertz tone for a period of 500 milliseconds at the start of each CWS to alert the user to insert more coins if the call is to be extended.

Collect Button

Both CT3 and CT3(I) allow users to make operator assisted calls. Coins are inserted under instruction from the operator and tones sent forward from the telephone allow the operator to count the money deposited. When the required amount is deposited the operator instructs the user to press the coin collect button.

The coins drop to the coin tin and a collect tone is sent to the operator. On receipt of this tone the operator connects the call through.

In the older type of coin telephones it was necessary to operate the collect button on local calls when the called party answered. Unfortunately, many users carried this practice of pressing the collect button on answer to local and STD calls from CT3. If the user presses the collect button of a CT3 at answer, but before receipt of the answer meter pulse, the call will be force released because no coins will be held in the mechanisms when the answer meter pulse is received. In addition, the user loses all coins deposited in the instrument, which is especially annoying if a number of coins have been inserted for an STD call.

To overcome this misoperation, a dial pulse analyser in

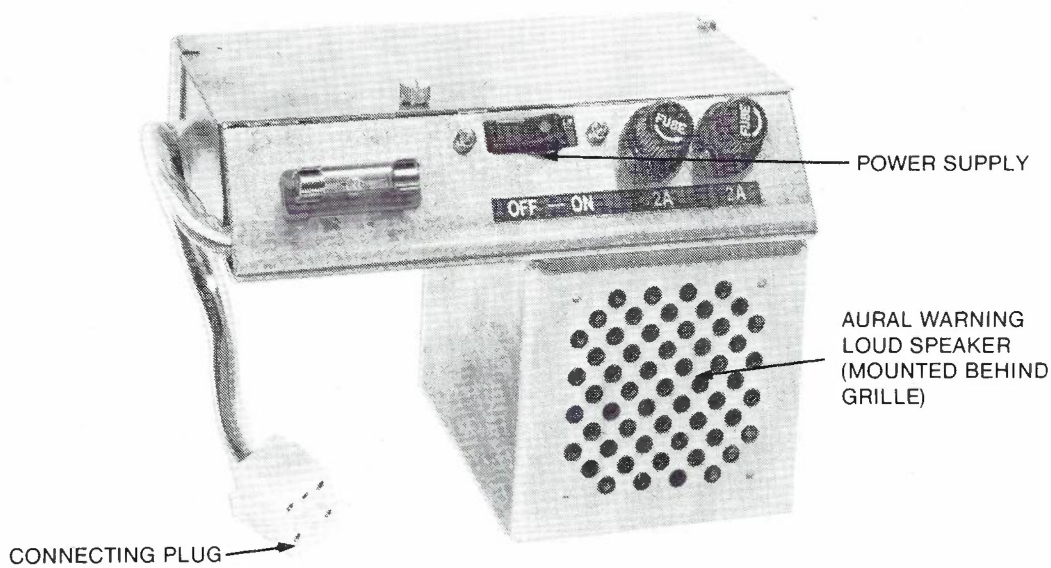


Fig. 6 — Power Supply and Aural Warning Module.

CT3(I) checks that an operator code (01) is dialled before allowing the collect button to be effective. This analyser facility can be strapped out in the few instances where CT3(I) is connected to exchanges with operator prefixes other than 01, and in these instances the collect button will be effective only until CIS or an answer meter pulse is received.

Hearing Aid Coupler

To cater for people who use hearing aids a small amplifier **(Fig. 3)** will receive the incoming speech signals from across the receiver and drive a separate coupler coil in the handset. The coupler coil and amplifier were designed by the Telecom Research Laboratories to comply with the National Acoustics Laboratories recommended field strength for coupling into hearing aids. Direct connection of the coupler coil to the receiver transducer might have been possible if normal telephone circuitry was in use. However, in CT3 and CT3(I) the receiver and transmitter transducer are both receiver capsules 4T which have been decoupled from the telephone circuit via transformers to overcome certain fraudulent manipulation. In addition, the proposed use of a metal handset in CT3(I) would affect the field strength available to the hearing aid. To overcome these factors, the separate amplifier was designed to drive the coupler coil in the handset.

Coin Tin Full Detection and Spreaders

During peaks in usage, such as at holiday resorts or busy locations, the coin tins often may be filled to capacity. When this occurs in CT3 the coins fill up back through the openings in the coin tin into the coin mechanisms. The combination of full coin tin, coins, and telephone case cause a jam which prevents the coin tin being removed from the telephone.

The CT3(I) coin tin is designed so that if the tin is filled to within 50 coins of its maximum capacity, this level is detected by an electrical contactor in the coin tin **(Fig. 7)** and the instrument is set so that subsequent users have their coins refunded.

Detection of the coin tin full condition will not interrupt a call in progress. When the tin is cleared the instrument resets itself.

With earlier coin tins it was noticed that coins tended to form in a pyramid and much of the coin tin capacity was wasted. Metal wings or "spreaders" have now been added to the coin tin lid **(Fig. 7)** and these deflect coins as they enter the tin and spread the coins more evenly within the tin, thereby increasing the effective capacity of the tin.

It is of interest to note that the problem of coin-tin-full led to suggestions that the size of the coin tin should be increased. However, this suggestion overlooked the fact that tins full of coins weigh some 12kg, which is the maximum that a clearance officer can be expected to handle.

High Frequency Metering

CT3(I) will be fitted to receive the normal 50 hertz longitudinal metering signals currently used for CT3. Provision has been made in CT3(I) to change over the plug-in 50 hertz meter signal detector **(Fig. 5)** to a high frequency transverse meter signal detector if Telecom should decide to change to this system of metering.

MF Dialling

CT3(I) will be supplied initially with a rotary dial. Allowance has been made, however, for a dual tone multifrequency (DTMF) dial to be connected to the circuit of CT3(I); suitable connecting points have been brought out and located inside the door near the dial location **(Fig. 3)**.

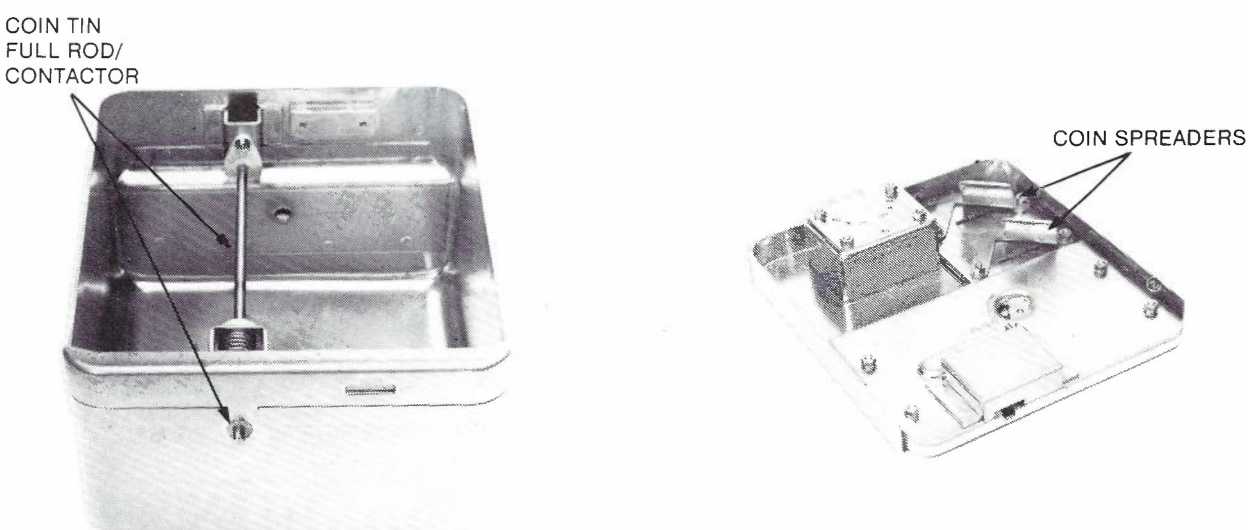


Fig. 7 — **Coin Tin Base and Lid.**

Identification Tone

A major reason preventing the use of coin telephones for the receipt of incoming calls is that such calls could be used to obtain free "reverse charge" calls. CT3(I) will provide an identification tone on incoming calls thus indicating to an operator not to agree to reverse charges. This facility will therefore permit the use of coin telephones for incoming calls. Telecom has not yet decided to utilise this facility.

Wiring

For ease of maintenance all connections to the main wiring form are by plug and socket. This allows removal of all modules and sub-assemblies such as the power supply, mechanism, door and coupler amplifier, etc., without the need to unsolder any wiring **(Fig. 3)**.

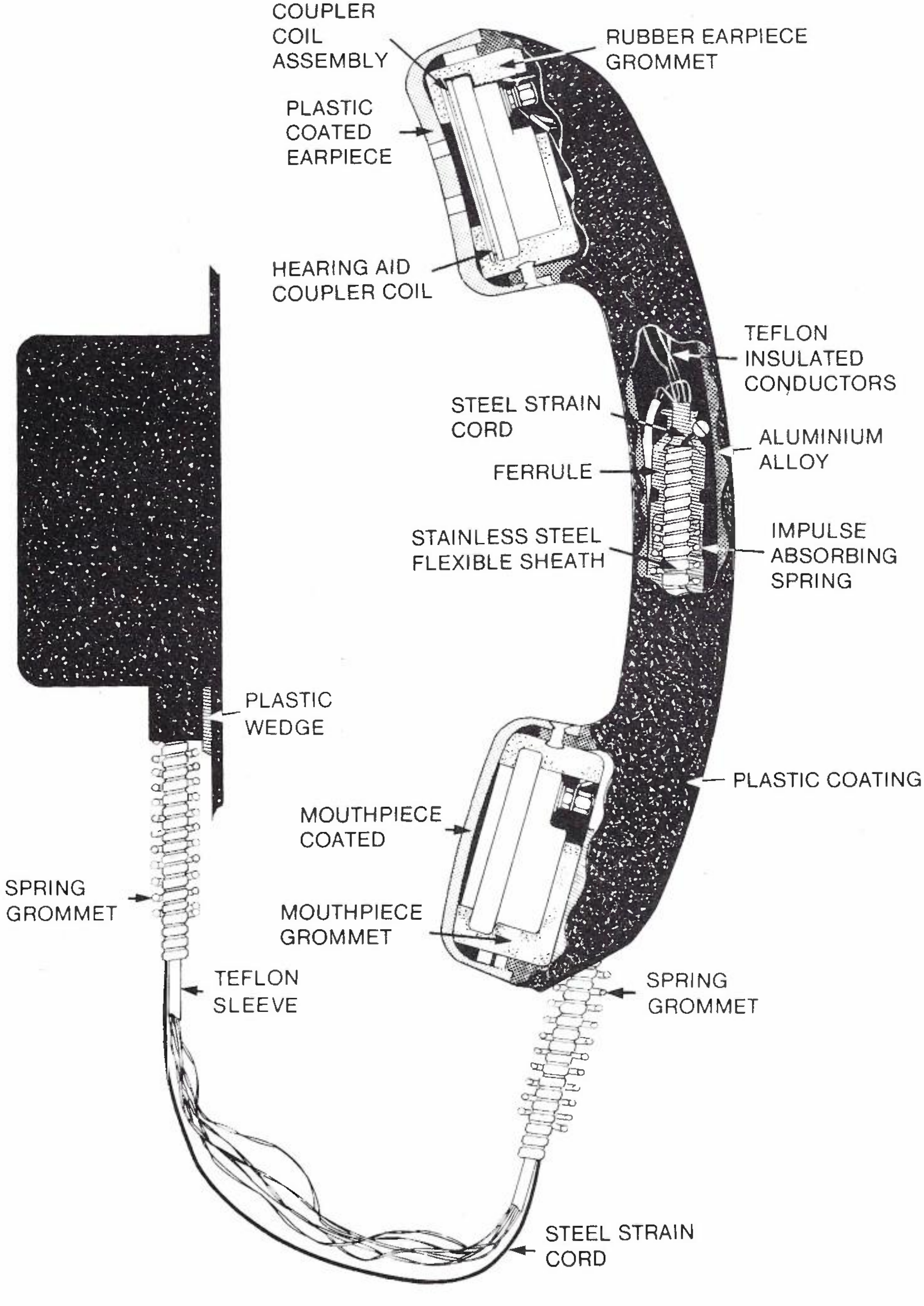


Fig. 8 — HCC 11 Handset.

VANDALISM AND FRAUDULENT USE

The parts most vandalised in CT3 have been the plastic dial, the handset and cord. In addition several techniques of fraudulent manipulation to obtain free calls have been encountered.

Dial

The CT3(I) will be fitted with the same dial mechanism as CT3 but all external parts will be made of stainless steel to resist burning from cigarettes and gas lighters, and also to minimize breakage.

Handset and Cord

A new handset (HCC-11), which has been jointly designed by Telecom and STC Pty Ltd, will be fitted to CT3(I). This handset **(Fig. 8)** is constructed of a plastic coated aluminium alloy to resist smashing, burning and cutting. The connecting cord to the instrument is made up of teflon insulated conductors to resist heat, and an outer stainless steel flexible sheath to resist cutting and burning. The cord also incorporates a steel strain cord connected to an impulse absorbing spring. The transmitter and receiver capsules are housed in rubber to overcome mechanical shock from abuse of the handset.

These unique measures are an indication of the importance placed by Telecom on minimizing the effects of vandalism on and abuse of the handset.

Earth Monitor

Telecom currently uses the 50 hertz system of metering over the subscriber's line, requiring an earth return to the exchange. Considerable effort is expended at each coin telephone installation to provide a mechanically secure earth that cannot be interfered with.

An earth monitor in the CT3(I) circuit will disconnect the call if during progress of the call the earth return circuit is interrupted. Interruptions due to fault conditions will not prevent subsequent calls to non-chargeable numbers such as emergency.

Meter Signal Monitor

A basic method of fraudulent use would be to prevent meter signals reaching the telephone, thereby enabling calls to proceed without the collection of coins. To overcome this possibility a monitor in the CT3(I) circuit checks for a 50 hertz meter signal after the answer reversal is received. This monitor checks for interference with the 50 hertz signals or failure of the exchange to send out these signals. Metered calls are disconnected if a 50 hertz meter signal is not received. Non-chargeable calls to emergency, operators, etc., are not affected.

Refund Chute

There has been a widespread practice in all coin telephones for paper or other objects to be forced up the refund chute to block refunded coins. To prevent this practice the refund chute of CT3(I) has baffles built in and the opening flap is designed to block the entry to objects being pushed up the chute. A novel practice for blocking the refund is to inflate a balloon in the refund chute using a drinking straw and a rubber band to seal the balloon. The CT3(I) refund has two sharp spikes built in to burst balloons or other inflatable objects.

Other Features

There are several other features included in the design to prevent people manipulating the CT3(I) to make free calls or steal money but these cannot be discussed in this article. However, bona-fide enquiries for further details can be made to the author.

CONCLUSION

Coin telephones are perhaps the most vulnerable of Telecom's equipment:

- They are used and abused by a public who are generally quick to criticise but slow to report faults.
- They are exposed to extremes of climatic environments and operational conditions.
- They attract vandals, thieves, and people who manipulate them to obtain free calls.

Whilst every effort has been made to design CT3(I) to resist the common forms of vandalism, theft, and fraudulent manipulation, it would be expensive to make instruments safe from all forms of attack especially where workshop tools are used.

Notwithstanding the considerable forces determined to abuse and defeat coin telephones, Telecom is pleased that CT3 and CT3(I) will provide the normal user in Australia with a much more reliable service than has been possible previously.

Operations and Maintenance Facilities Provided by ARE 11

R. L. ORTON, Grad. I.E. Aust, and J. EVERS.

Following the installation and evaluation of the ARE 11 field trial exchanges an improved version of the ARE 11 was developed by L. M. Ericsson. The new version, ARE 11, stage 2, provides enhanced operating and maintenance facilities.

The original version of ARE 11 (Stage 1) was first introduced into the network in 1976 when the first of two field trial exchanges was placed in service at Elsternwick, Victoria. See Telecommunication Journal of Australia Vol. 27 No. 2 1977, page 110. The second field trial exchange at Salisbury, South Australia, was cutover early in 1977. See Telecommunication Journal of Australia Vol. 28 No. 1 1978, page 45.

Experience gained from operating these field trial exchanges indicated that the operations and maintenance facilities could be enhanced and modified to better suit Telecom Australia's plans for utilising ARE 11 in the network. In response to representations from Telecom and other customers, the contractor, L. M. Ericsson, upgraded the Stage 1 design to develop ARE 11 Stage 2. All ARE 11 installations in Australia subsequent to the two field trial exchanges are the Stage 2 version.

ARE 11 is being installed at two levels of operation known as Level 3 and Level 4. Generally ARF exchanges converted to ARE 11 will operate as Level 3 exchanges, i.e. processor control of registers and originating group selector with MFC controlled subscriber and incoming group selector stages. New ARE 11 exchanges will operate as Level 4, i.e. all major switching stages directly controlled by the Traffic Control Processors (TCP). To enable a uniform maintenance approach to be adopted the operations and maintenance facilities must be similar for both Level 3 and Level 4 exchanges.

The major characteristics of ARE 11 Stage 2 are:

- A New Operations and Maintenance Processor Operating System (OMPOS 2). The OMP installed in the field trial exchanges had a maximum capacity of 48 programs and this capacity severely limited the introduction of new facilities. The new OMP software known as OMPOS 2 has a maximum capacity of 128 programs. The programs are divided into operating programs and application programs. The latter provide the majority of the supervisory and test functions.
- Expanded Operations and Maintenance Facilities — The Stage 2 version of ARE 11 provides improved ANA 30 supervision and includes supervision of the MFC crossbar equipment. Network supervision facilities have also been added together with the capability for the OMP to interface Telecom's existing ADX network.

MAINTENANCE FEATURES OF ARE 11 EXCHANGES

ARE 11 being an SPC system, contains several features that have an impact on the maintenance of the equipment. These features make the exchange easier to maintain and suitable for operation and maintenance from a remote location.

- All contact with the intelligence of the system is via an input/output terminal such as visual display terminal or a teletype. The system is an interrogatory system meaning that information can be stored by the system and unloaded on command from an input/output terminal. This avoids large amounts of data being produced unnecessarily.
- The system exhibits high reliability. This results from the modular structure of both the hardware and the software and leads to fewer faults. All central devices are duplicated so that a single fault will not cause significant loss of traffic.
- Fault finding in ANA 30 equipment and parts of the crossbar is simplified for the majority of fault situations. Standard inbuilt supervisory aids are supplemented by fault diagnostic programs and manuals for fault location of ANA 30 faults. Corrective action after a fault has been located is achieved by replacement of the module (e.g. Printed Board Assembly).
- **Table 1** lists the main ARF maintenance facilities and their equivalent ARE 11 (OMPOS 2) facility. A full list of ARE 11 (OMPOS 2) maintenance facilities is given in the next section.

ARF (WITH ADR)	ARE 11 (OMPOS 2)
DL alarm (Service alarm) for groups of equipment of the same type i.e., Reg-LM(LP) KSR, SSM, CD-KM and Reg-I.	Fault ratio supervision per individual item of equipment STU-L, STU-I, KSR, SSM and CD-KM.
Marker disturbance data for SLM O/G and I/C, GUVM and GIVM output spontaneously from ADR via the ADX network to the mini computer sorting centre.	Marker disturbance reporting for SLMO/G and I/C, GUVM AND GIVM when the equipment type is test marked. The disturbance data is output via on OMP I/O port to a nominated, I/O terminal.
Alarm Transmission	Alarm Transmission
ADR transmits a maximum of 180 alarms to an alarm attention centre via ADX. The alarms can be re-directed to other alarm centres by a command message to the ADR.	OMP transmits a maximum of 80 alarms to alarm attention centres via ADX. The alarms can be re-directed to other alarm centres by up to three time controls per 24 hours, and by command to OMP.
Urgent alarms initiate alarm transmission. Non urgent alarms are only transmitted when an urgent alarm occurs.	Urgent alarms initiate alarm transmission. Non urgent alarms are only transmitted when an urgent alarm occurs.
Permanent Meters for recording individual equipment seizures and faults etc. on SLM I/C and O/G, GUVM, GIVM, CD-KM, SSM, KSR, RSM-1, AN-REG, REG-H4, PBX, RKR, DS and AN-KS.	
Resettable Meters for recording seizures and or faults etc. on RSM-I, REG-H4, REG-LP, REG-LM, SSM and REG-I.	Software counters for connection to individual SLM I/C or O/G, GUVM, GIVM RSM, CD-KM, SSM and KS for recording seizures.
Master Service Alarm message is transmitted by the ADR when ten non action messages from a number of markers of a certain type, (or all marker types) in a specified time (nominally 3 minutes) have been sent by the ADR.	This facility not required in ARE 11 as each marker is individually supervised by fault ratio supervision facility.
Command control of non-switching functions via the ADX.	Command control of non-switching functions via the I/O man machine communications data links.
ADR Blocked route supervision using route alarm relay sets and alarm and blocked route relay sets will supervise a maximum of 100 route alarms.	Blocked route supervision using ANA 30 equipment and alarm and blocked route relay set will supervise a maximum of 128 route alarms.
RKR ADR Supervised.	OMP Supervised
RKR Line Leakage Test Meter Wire Test & Network Call Failure Supervision.	Line Leakage Test Meter Wire Test & Network Call Failure Supervision.
	An alarm is generated if the number of detected Meter Wire or Line Leakage test failures exceeds pre-determined values.
TRT Facilities	TRT Facilities Remote TRT facility if provided.
Subs Apparatus and Line Tester (SALT) Accessed by dialling 199.	Subs Apparatus and Line Tester (SALT) The same as for ARF.
REG-LM Manual Register Tester	Not used in ARE 11. This function performed by the ARE 11 AET and test data.
FIR-P (SNR-P)	FIR-P (SNR-P) The same as for ARF
SR Tester	Not used in ARE 11
Call Event & Meter Pulse Recorder	Call Event & Meter Pulse Recorder. The same as for ARF.
Test Call Answer Relay Set	Test Call Answer Relay Set. The same as for ARF.
Tone Answer Relay Set	Tone Answer Relay Set. The same as for ARF.

Table 1 — ARF Maintenance Facilities and the Equivalent ARE-11/2 Facility.

INBUILT SYSTEM MAINTENANCE FACILITIES

ARE 11 contains a substantial number of inbuilt operations and maintenance facilities that are available to maintenance staff. **Fig. 1** depicts how the following facilities relate to the ARE 11 exchange equipment.

a. Man Machine Communication — Interrogation of the ANA 30 component of the system is provided via standard input output terminals. A system command language is used for all man machine communication. Terminals may be categorised to define which operations may be performed from the terminal.

b. Disturbance Ratio Supervision of ANA 30 Devices — Disturbance supervision is performed for individual distributed devices or functions. A software counter is incremented by a pre-selected number for each disturbance (i.e. device seized but the call attempt failed) and decremented by one for each successful seizure. If the counter overflows an alarm is generated. In addition to supervision of distributed devices STU, KMK, and KME, outgoing routes and PBX equipment (Level 4 only) are also supervised.

c. Test Marking of ANA 30 Devices — If a device is suspected of being faulty, it is possible to test mark that device by command so that whenever a call using that device fails, data describing that call attempt is printed out on a nominated terminal. Devices that can be test marked are STUs, KMK, and KME.

d. Traffic Measurement of ANA 30 Devices — Traffic data can be collected from the following devices, STUs, KS, KMK and KME. Traffic Measurement by OMP of TCP controlled markers is achieved by reading the traffic carried by the KME associated with each Marker. Traffic Measurement of MFC controlled markers (Level 3 only) is also achieved by OMP reading the traffic carried by the KMEs which interface the MFC controlled markers to the ANA 30 equipment for the purpose of MFC marker supervision by OMP. The traffic information is collected over either a 15 or 60 minute period and the results printed out on a nominated terminal.

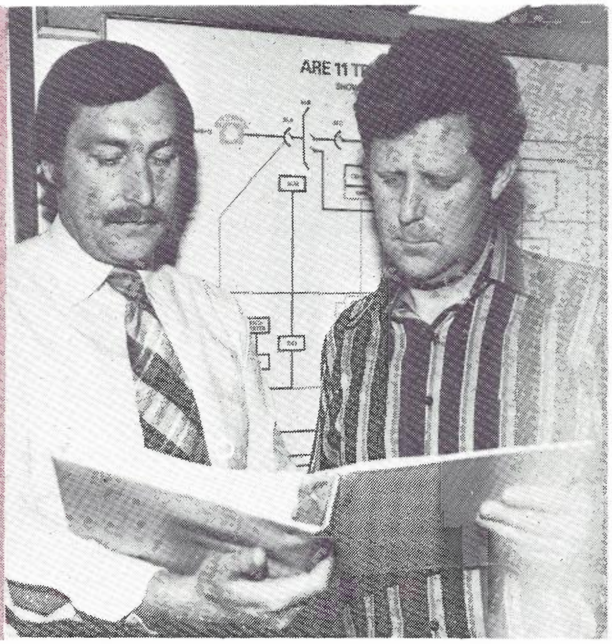
e. Spontaneous Transmission of Alarms and Data via ADX — Selected alarms and data are spontaneously transmitted via the ADX interface to the normal ADX destinations. This transmission includes selected equipment and non-equipment alarms, network call failure data and automatic service assessment data.

f. Crossbar Marker Disturbance Recording — To enable crossbar faults to be detected, data relating to key relays in the crossbar marker is collected for failed calls on GVM, RSM-I, SLM O/G, SLM I/C and CD-KM (Level 4 only). This facility is enabled by a command from the Input/Output (I/O) terminal. The marker disturbance information for a specified marker type is ordered to be printed out on a nominated terminal by a command. If marker disturbance information for a particular marker fault type is only required this can be specified also.

g. Blocking Supervision of ANA 30 Distributed Devices and Routes — A Blocking supervision is performed for STUs, KMK, KME, and routes. The OMP periodically scans devices and routes and collates the number of devices or circuits which are inaccessible for traffic. A non-urgent blocking alarm is generated by OMP when a device or junction is blocked. If the total exceeds preset limits an urgent blocking alarm is generated.

BOB ORTON joined the PMG's Department as a Technician in Training in 1958. In 1969 he completed an engineering diploma at the Royal Melbourne Institute of Technology. He worked in Victoria as an Engineer on exchange installation before joining Headquarters in 1975. After 3 years in the Switching Design Branch he joined Network Performance and Operations Branch in 1978. He is currently Section Manager of the Exchange Switching Service Section of Network Performance and Operations Sub Division.

JOHN EVERS joined the PMG's Department as a Technician in Training in 1957. He worked in metropolitan exchange maintenance in Victoria before joining Network Performance and Operations Branch, Headquarters in 1972. He is currently a Senior Technical Officer and has been associated with the ARE 11 project since 1974.



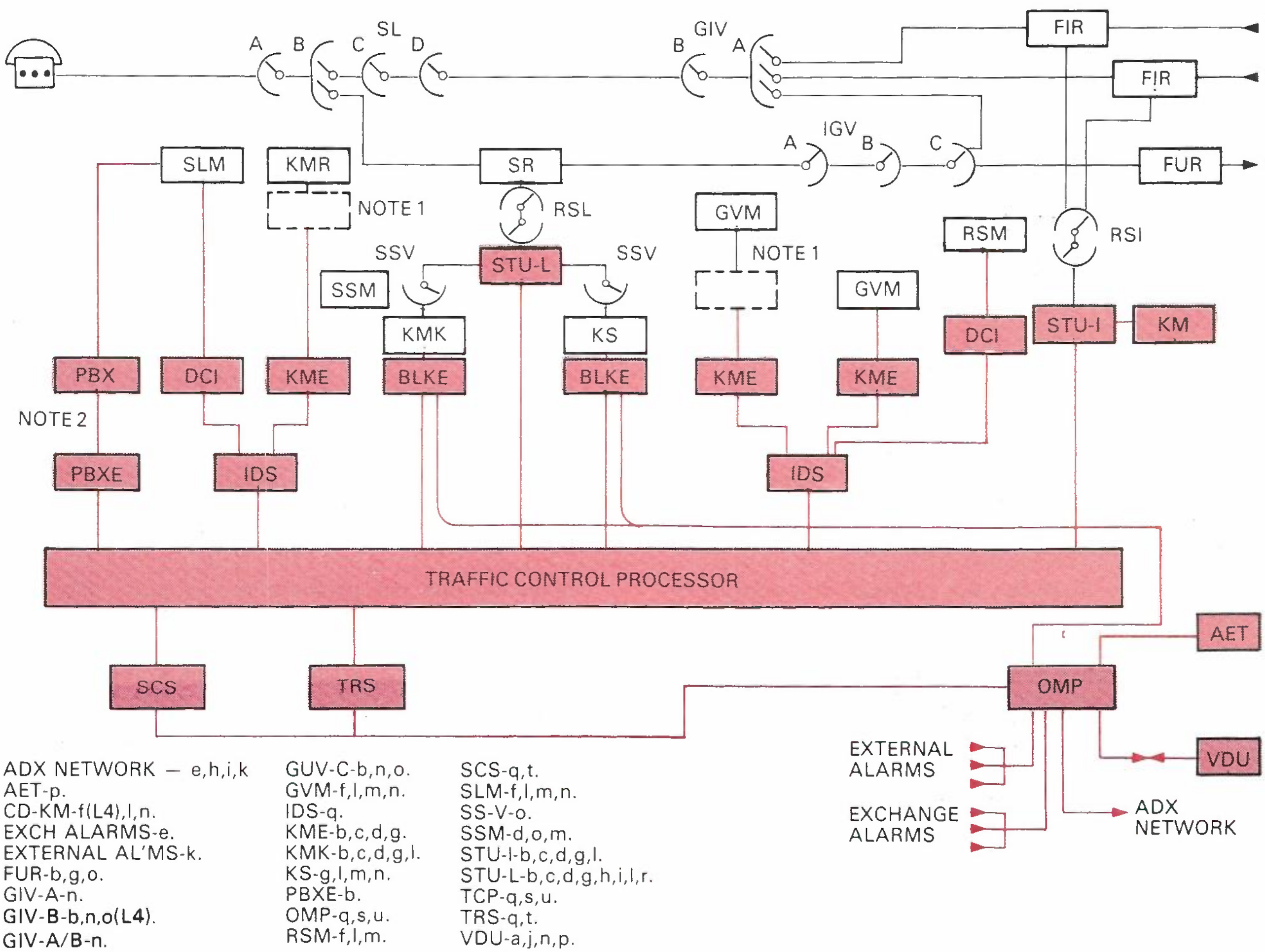
h. Network Call Failure Supervision — This facility is used to detect network fault conditions. A sample of calls are monitored and details of any calls that do not mature due to network congestion or equipment failure are transmitted via the ADX network to a central point for analysis.

i. Automatic Service Assessment — Certain STU-Ls in an exchange can be nominated to provide service assessment data. The total number of calls, the number of unsuccessful calls and the congestion level is recorded by the OMP. When the required number of calls are supervised the data is automatically output by OMP via the ADX network to the Network Performance & Analysis Centre (NPAC) or can be output via ADX network to the NPAC by command from an I/O device over an OMP I/O data link. The NPAC can interrogate the current service assessment data any number of times during a service assessment period.

j. Command Control of Non-Switching Functions — Commands are provided in the system to enable remote control of certain non-switching functions such as reset high/low volts alarm, ring machine control and gas pressure alarm reset.

k. Reception and Transmission of Non-Switching Alarms — Non-Switching (external) alarms may be connected to the system for supervision and transmission via the ADX link.

i. Seizure counting for ANA 30 and Crossbar Equipment — A maximum of 64 software counters for ANA 30 equipment and 16 for Crossbar equipment are



1. FOR EXCHANGES WITH MFC, GIV AND SL STAGES, A KMR-E INTERFACE RELAY SET IS USED BETWEEN THE KMR AND KME.
2. ANA-30 PBX EQUIPMENT IS ONLY PROVIDED WITH DIRECT CONTROLLED SL STAGES.

Fig. 1 — ARE 11 Operation and Maintenance Facilities.

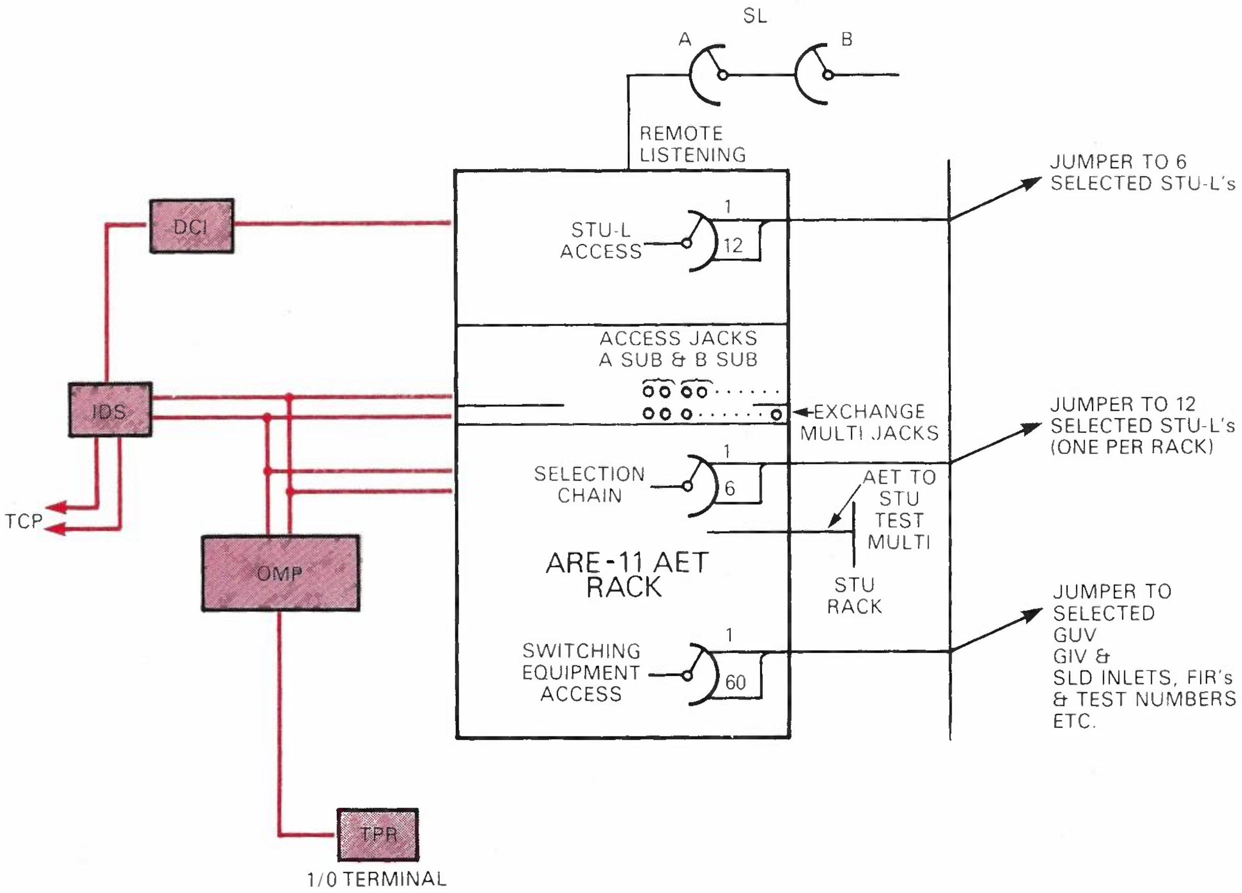


Fig. 2 — ARE-11 AET Connection to Equipment

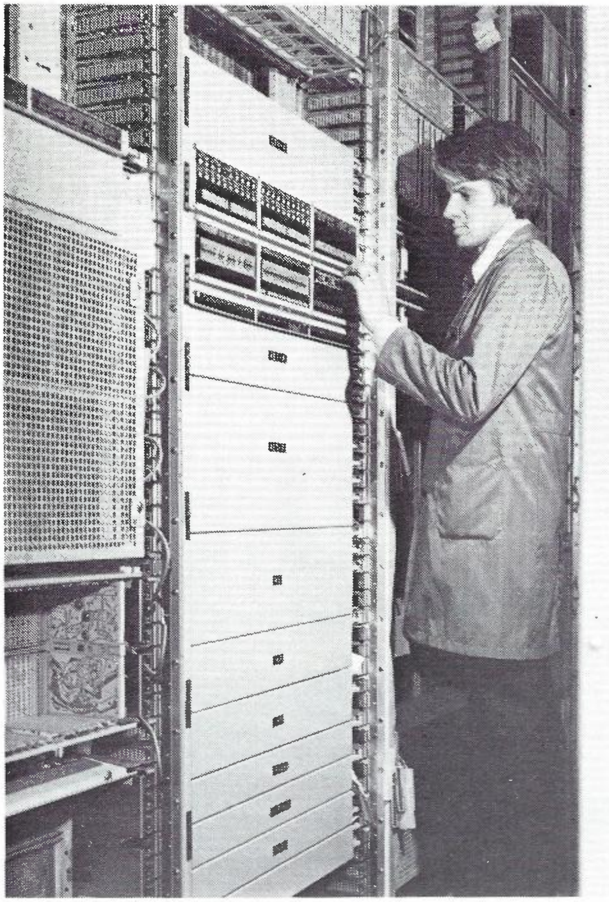
provided by OMP for the purpose of recording individual seizures per item of equipment. The equipment types involved are — STU, KMK, KS, SLM O/G, SLM I/C, RSM-I, GVM and CD-KM. Commands are available to allocate the individual software counters and read or reset the counters to zero.

m. Disturbance Ratio Supervision of Crossbar Equipment — Disturbance ratio supervision of crossbar equipment is performed by OMP in a similar manner to that of ANA 30 distributed devices by relating successful calls to unsuccessful calls. Whenever the rate exceeds the preset alarm threshold an alarm is generated. The alarm threshold value can be varied by command from an I/O device to OMP via an OMP I/O data link. The equipment types supervised are SLM O/G, SLM I/C, GVM, RSM-I, SSM and KS.

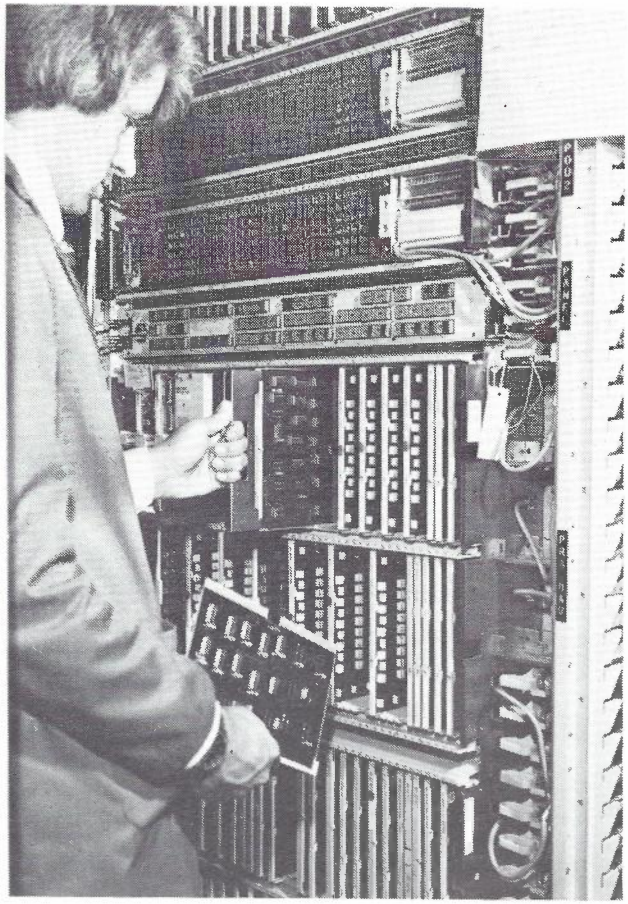
n. Crossbar Equipment Remote Blocking and Supervision — Commands are available in the system to enable remote blocking of the following crossbar equipment: SLM O/G, SLM I/C, GVM, GVA/B, GVC, CD-KM, CD-XY and KS. The OMP supervises the state of the equipment and will generate two types of blocking supervision alarm. One type of alarm e.g. 01, is generated when an item of equipment is blocked. The other alarm e.g. A1, is generated when a preset limit is exceeded.

o. Remote Directed Selection of SS and GV Outlets — The facility exists to remotely direct test traffic via nominated SS and GV stage outlets. For level 3 exchanges directed selection cannot be provided for GIV outlets.

p. ARE-11 AET — An OMP controlled Automatic Exchange Tester (AET) is included in the ARE-11 system. The AET is rack mounted and largely consists of the ARF trolley mounted AET relay sets. A maximum of two OMP controlled AETs can be operated simultaneously within a processor group. The AETs functions can be controlled remotely by command or manually on site. A diagram showing the ARE-11, AET access and control connections is shown in **Fig. 2.** Compared with the ARF AET some of the main additional functions of the ARE-11 rack mounted AET



View of ARE 11 Rack Mounted AET



Most Corrective Action for ANA-30 Faults is by Replacement of the Printed Board Assembly.

are listed below:

- — Connection of the AET for test call purposes, either from a remote location or locally, to pre-selected inlets of the GUV, GIV and SLD switching stages and to pre-selected STUs, FIRs, FURs, SRs and subscribers' numbers etc., made by command via the I/O system.
- — Output of test call data can be made to an I/O device via the OMP I/O system.
- — Monitoring of AET speech wires from a remote location by command via the I/O system.
- — Connection to any subscriber's number for the purpose of originating test calls, by use of commands over the OMP I/O system from a remote location.
- — Performance of functional tests on STU-L, STU-I, KMK and KSR/T hardware on site or remotely.

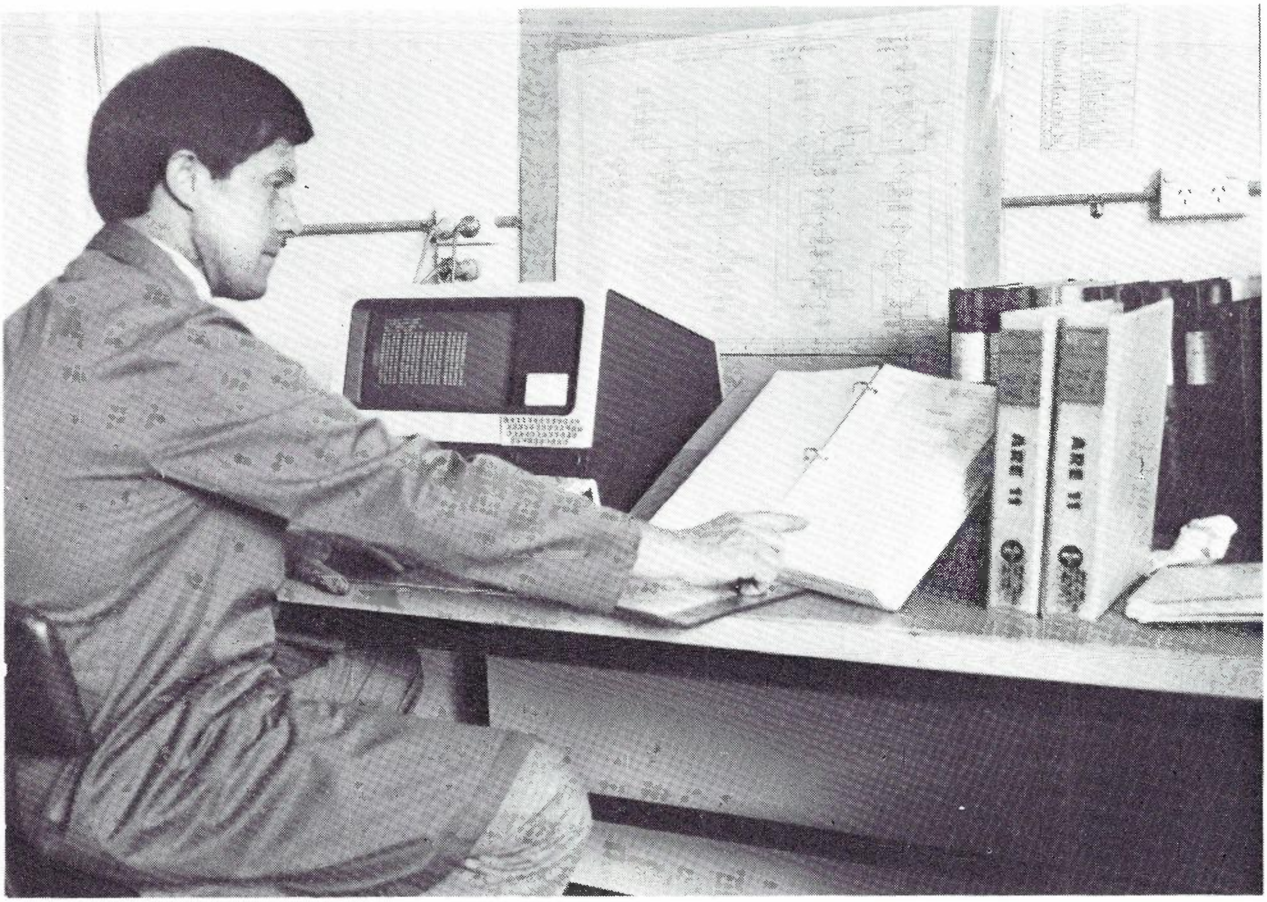
q. Supervision of Processors and Central Devices — Central devices (TRS, SCS, MUX and IDS) are duplicated for reliability and their operation is continually supervised by the OMP. If a fault is detected in a device it is blocked and the standby device is made executive. If a fault is detected in a TCP the TCP is blocked and TCP switchover is initiated and an alarm generated.

Disturbance ratio supervision of the IDS is performed by the OMP in a similar way to that for ANA 30 distributed devices. An alarm is generated if the IDS disturbance rate exceeds a preset limit.

r. Meter Wire and Line Leakage Test of Subscribers' Lines — A maximum of two Meter Wire and Line Leakage test units are provided per processor group for testing subscribers' line insulation and meter wire, when the subscribers' telephone handset is lifted to make an outgoing call.

The tests are performed if the test circuits are free each time an STU marked for that function is seized. It is possible to test mark all STUs for this function.

OMP supervised fault rate supervision is applied separately to Meter wire and subscribers' Line Leakage faults. By relating successful tests to unsuccessful tests an alarm will be generated whenever the rate exceeds a preset alarm threshold value.



Contact with the System is Via an Input/Output Terminal Using Standard Procedures

The subscribers' identification and exchange switching equipment details are recorded in OMP for each unsuccessful test. The failed test data can be output to an I/O device by commanding it via the OMP I/O system.

s. Test Programs for Testing Processors — Test programs CD1-4 are provided for fault diagnosis of the CPU of TCPs and OMP. These fault diagnostic programs are stored off line on punched paper tape and have to be loaded into the program store in place of resident programs when used. Control of the test programs is from the "test panel" on the processor rack and the processor is out of service while the test programs are used.

t. Test Programs for Testing Central Stores — Automatic test programs CT1-4 are provided for testing Central Stores i.e. SCS and TRS. The Central Stores are tested in the standby state and the programs are resident in OMP program store. Control of the CT1-4 test programs is by command into OMP.

u. Continuous Parity Check of Program Stores — Supervision programs are resident in OMP and TCPs that regularly do a check sum of all their program listing values in the program stores and compares the sum total with a previous sum total. If a discrepancy exists an alarm is given and in the case of TCP it is blocked.

STORAGE AND LOADING/UNLOADING OF ARE 11 EXCHANGE DATA

The input/output system requirements for ARE-11 exchanges comprise all aspects associated with the remote and local operation of these exchanges. This includes man-machine interactive communication using commands to control and supervise the operation of the ANA 30 processor and also the transfer of data between the processor and a terminal device for loading program store and for loading and unloading of central store data. The OMP processor may be accessed either from a terminal device located locally at the exchange or remotely via a suitable modem link.

The method of storage and loading/unloading of central stores data for ARE-11 in Australia is a local development and differs from the original method which uses punched paper tape and the paper tape reader.

The Australian development uses a Mini Cartridge tape for the storage and loading/unloading of central stores data. The Mini Cartridge Tape is used with the Hewlett Packard 2645A Visual Display Unit.

By using the Mini Cartridge Tape the rate of data transfer can be increased to 1200 baud compared with 110 baud for the Punched Paper Tape and Paper Tape Reader. It takes approximately 5 minutes to load TRS from the Mini Cartridge Tape and 50 minutes from Punched Paper Tape.

The capacity of the Mini Cartridge Tape is such that it can store TRS data for a 10,000 line exchange, and can easily store the SCS data for a 10,000 line exchange.

Punched Paper Tape is still used for storage and loading of Program data in TCP and OMP.

Loading of Program data is performed on site by assembling the Punched Paper Tape containing the programs in the Paper Tape Reader, connecting the Paper Tape Reader to the Program Loading Interface (PLI) on the TEI shelf of the APN rack, and by press button operation on the required APN rack Test Panel selection of the TCPs or OMP receiving the Program data is made.

CONCLUSION

ARE 11 Stage 2 is a modern SPC system which has been developed with good operations and maintenance facilities some of which are standard and some of which have been developed specifically for Australia. ARE 11 introduces new technology into the local switching area and provides the opportunity for Telecom to improve the efficiency of telephone exchange operations work.

Obituary — V. J. White, B.Sc., B.A.

Readers will be sad to learn of the passing of Vern White, who was Editor-in-Chief of this Journal from 1964 to 1972, and an editor from 1959 to 1961. He also was the founder of Telecom's house magazine for lines staff, "On the Line".

Vern held degrees in both Science and Psychology from the University of Western Australia. After several years as an engineer in the PMG's Department in that State he came to the Headquarters Lines Branch, where he applied his knowledge of human and engineering factors to the development of improved staff training and installation work practices.

In 1972 Vern took up a position as Assistant Secretary in what is now the Department of Employment and Youth Affairs. Here he was engaged in developing industrial training and employment policies. Vern was serving as First Assistant Secretary in that Department when he was invalided because of the illness from which he died recently at the age of 56.

Test Console for Customer Fault Despatch Centres

TREVOR S. MAY M.I.E. Aust., B.Tech (Electronic) — Adelaide

Customer Service line testing facilities have always been and will continue to be essential to the process of attending to customer service faults. The APO Exchange Test Desk has until recently been the standard means of providing these facilities, but with the advent in metropolitan areas of centralised Fault Despatch Centres (FDC's) a number of specialised test desks have been developed for this application. This article briefly describes a test console which has been developed to meet the requirements of a modern FDC pending the introduction of a new generation remotely controlled test network.

BACKGROUND TO DEVELOPMENT OF CONSOLE

In November 1978 two of Adelaide's three Metropolitan Fault Despatch Centres (FDCs) were relocated from telephone exchange buildings to new accommodation specifically designed for FDC operation, both present and for the foreseeable future. Design considerations included the proposed national introduction to metropolitan FDCs of LEOPARD (Local Engineering Operations Processing and Analysis of Recorded Data), a computer based management and information system in which customers' master card records will be held in the system's data base and the majority of functions in an FDC will be performed and managed using information displayed on visual display units (VDUs). Also relevant is the future implementation of SULTAN (Subscribers' Universal Line Testing Access Network) which will interwork with LEOPARD and provide a centralised test access network based on the use of remotely controlled robot testers in terminal exchanges and a new form of test console for FDCs.

A significant factor in the effectiveness of the new locations was the choice of a test desk which provided the necessary FDC testing and service facilities, was suitable for use in conjunction with VDUs and which would facilitate the eventual implementation of SULTAN without major disruption to the Centre. Existing test desk designs were considered including that discussed in a previous Telecommunications Journal of Australia article on 'Melbourne Test and Fault Despatch Centres' (Vol. 21 No. 2; p.178), however, because of the limitations of their physical design or available facilities none provided the flexibility required for these new Centres. Therefore, after consideration of the relevant technical and economic factors, it was decided that the development of a new test desk for these applications was justified.

Design and development was undertaken by engineers of the Adelaide Central Metropolitan Engineering Section and 12 units were constructed in the Adelaide Telecom Workshops.

DESIGN GUIDELINES

The basic concept for the new test desk which would best meet the present needs of an FDC and which would provide future flexibility most economically was that of a desk top console. The main design guidelines which were, for the most part, successfully applied in its development are summarised below:

- A compact, mobile, desk top console suitable for operation in conjunction with a VDU;
- Associated cabling, fixtures and furniture minimised to reduce the costs of installation and later changes in the FDC;
- Standard line testing and service facilities to be provided and improved or streamlined where practical;
- A number of new facilities and improvements which had been found from operating experience to be desirable to be incorporated in the design if possible;
- The interface with the test network to be standard to permit possible use of the consoles elsewhere;
- Construction to be simple and facilitate maintenance or modification and make use of readily available components;
- Appearance to be as modern and aesthetic as practical and in keeping with the open space layout of the new localities.

In the early design stages full scale models were constructed to evaluate the ergonomics and other relative merits of alternative physical formats. FDC personnel and test desk operators were consulted at this time and contributed numerous ideas and criticisms which were taken into account. In the final development stage a working prototype was constructed for testing and refinement of circuit and mechanical designs.

FINAL CONFIGURATION

A test console is shown in **Fig. 1** with its two flexible cables for connection to the floor mounted connector sockets which are cabled to the associated equipment and relay set rack. Two metres of flexible cable are provided so the console can be positioned on a table to suit the operator and to accommodate a VDU or other equipment.

The keys used, including the line test keys which provide the standard line testing facilities in a new streamlined format, are a push button, self illuminating type. **Fig. 2** shows the keyshelf layout and the various facilities provided.

The configuration of a test console and the associated cabling and equipment for the application at each of the two Adelaide FDCs where six consoles were installed is shown in **Fig. 3**. The following are brief descriptions of the major facilities.

Line Test Keys

The standard set of line test keys has been replaced in the console by the row of 17 magnetically interlocked, mutually releasing press button keys each of which provides a test or function according to its designation.

Fig. 1 — The Test Console with Connecting Cables and Operator's Headset.

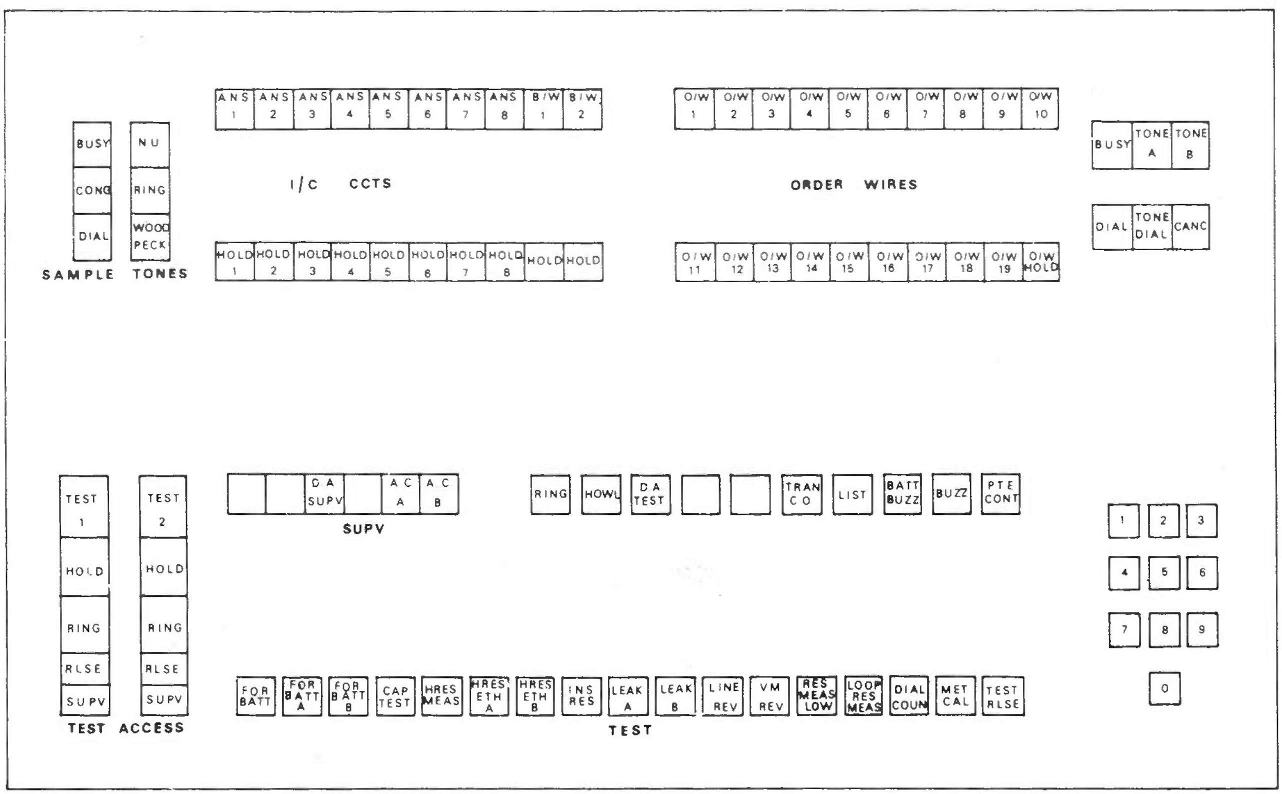


Fig. 2 — Keyshelf Layout.

The full range of line tests can be performed sequentially or individually by single operations except where a resistance measurement scale change or voltmeter reversal is required in which case an additional key operation is required.

Line Test Facilities

Foreign Battery: Wire to wire 'A' and 'B' legs to earth 0-80v range.

Resistance Measurement: Wire to wire: 'A' and 'B' legs to earth. 3 ranges.

- 'High': Mid scale 200k ohms (80v)
- 'Low': Mid scale 5k ohms (48v)
- 'Loop': 0 - 2k ohms. (24v bridge circuit)

Leakage: Wire to wire, 'A' and 'B' legs to earth. Mid scale 5M ohms (250v)

Capacitance Test: Automatic line reversals applied at approximately 1Hz with 48v battery.

Dial Count: A direct readout of the test digits dialled on the console's 9-digit dialled number display.

Ring: Continuous ringer via series supervisory relay and supervisory lamp.

Howler: Standard gliding tone howler with automatic key reset when the loop is removed from the line.

Transmitter Cut-Off Key: Opens the operator's transmitter circuit. Switches series capacitance between the operator's circuit and the line under test.

Listen Key: Connects the operator's circuit across the line under test.

Batt/Buzz Key: Connects 100v speaking battery to the test circuit via a supervisory relay, a contact of which operates a buzzer in the console if required.

Private Control Key: Provides the standard private control functions.

Meter: 400 uA f.s.d. (1500 ohms)

Calibration: The loop resistance measurement scale can be calibrated using a three turn potentio-meter on the front panel.

At both the Adelaide FDCs the test junctions are built out to 2000 ohms and the meter circuits in the test consoles compensated accordingly so that all resistance measurements can be read direct from the meter except in those few cases where the test junction resistance normally exceeds 2000 ohms.

Test Access Circuits

Two test access circuits are provided on each console and have 'Hold', 'Hold Supervisory', 'Interrupted Ring', and 'Automatic Ring Trip' facilities. The circuits can be exclusive to each console or commoned to other consoles as required. In the South Australian application, test access switching is via a Queensland designed ARF 2/160 crossbar GV stage with a standard 4-wire test and operate pair interface and an automatic 'Doesn't Answer' (DA) test facility provided for Service Assistance Operators and also used on the test consoles at the cost of an additional two wires to the interface FIR relay set.

The 'Dial' key, operated for dialling on a test access circuit, is automatically released on connection to the called line via an additional wire from the interface relay set. A further single wire connection to the interface relay set to extend the 'private' wire ('C' lead) of the test access operate circuit is required for a busy indication on commoned test access circuits.

Incoming Trunk Circuits

Eight incoming trunk circuits with flashing lamp call indication, ring trip on connection, hold facilities and caller controlled key release can be commoned to each console.

TREVOR MAY joined the APO in 1963 as a Technician-in-Training. In 1968 he became a Trainee Engineer graduating from the University of Adelaide in 1971 with a Bachelor of Technology degree in Electronic Engineering. He was appointed to Darwin as Engineer Class 1 and in 1973 transferred to Cairns, Queensland, as Engineer Class 2 where he worked for almost four years. In 1977 he returned to Adelaide and was involved in the relocation of two metropolitan Fault Despatch Centres. He is now the South Australian co-ordinator of the national LEOPARD project for the computerisation of FDC Customer Service records.

Order Wire Circuits

Up to 19 order wire circuits with flashing call lamp indication can be commoned to each console. A 'Hold' key is provided to isolate any answered order wire without having to release it.

Bothway Lines

Two bothway exchange lines with hold facilities are provided on each console, one exclusive and the other shared with other consoles in the FDC.

Robot Tester Access

Provision is made for the use of remotely controlled automatic line test relay sets (SNR-P) which are installed in some remote terminal exchanges and are accessed via the normal exchange switching network. The 'Tone Dial' key provides tone dialling into these robot testers which are then controlled by the Tone 'A' and Tone 'B' keys.

Dialled Number Display

This is a 9-digit display which reads out numbers dialled from the test console's bothway line circuits, test access circuits, tone dial circuit and the results of a dial count test. The display is normally blank, clearing automatically when one of the above circuits is engaged or it may be reset manually by a press button adjacent to it.

Time Display

Each console has a 4-digit, 12 hour, hours and minutes time of day readout which is derived from a binary coded decimal signal from the SA Telecom time service. The display is updated every 60 seconds and self adjusts to the correct time when the console power is switched on.

Operator's Circuit

The test console operator's circuit is based on the standard light-weight headset and the pushbutton dial used in the Touchphone 10. The transmitted and received voice levels can be independently amplified under the control of two sliding potentiometers on the front panel.

Sample Tones

The provision of standard service tones for demonstration to customers was considered to be a worthwhile facility for FDCs and has been provided via the sample tone keys. The volume of these tones can be amplified using the third sliding potentiometer on the front panel.

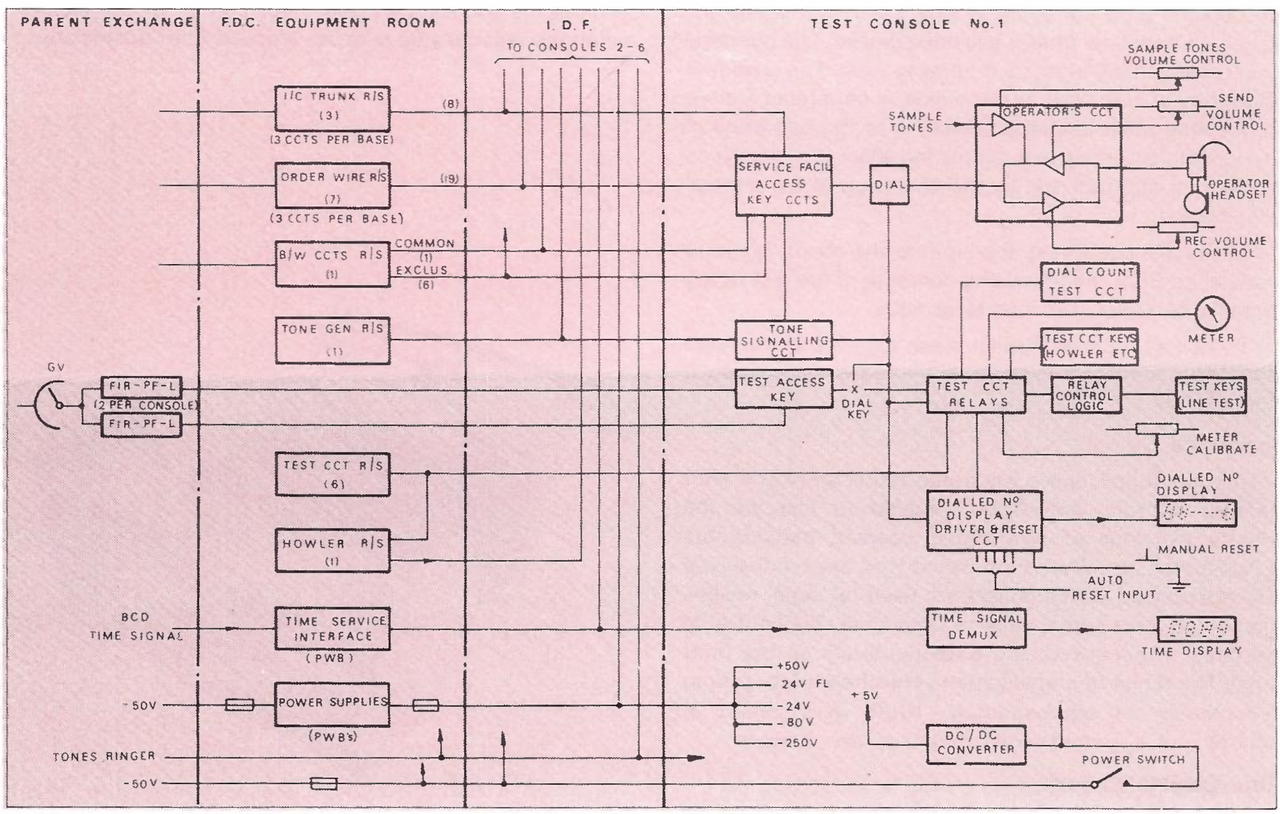


Fig. 3 — Console and Associated Equipment Block Diagram.

'Woodpecker' cable identification tone was included because of customer complaints generated by its induction through cables in which it is being used by Telecom lines staff.

CIRCUIT OPERATION OF NEW FACILITIES

The service facility relay sets, their associated key circuits and the test circuit relay set are conventional in design having been largely adapted from circuits used elsewhere and therefore are not described in detail. However those circuits which are new to test desk design are described briefly with the aid of **Fig. 3**.

Line Test Circuit

The conventional set of test desk keys has been replaced with a set of miniature relays which perform the same function. These relays are operated in the combination required for the various line tests by a logic circuit under the control of the 17 test keys. The test keys are magnetically interlocked via simple diode logic such that they are mutually releasing except for those tests where the operation of an additional key may be required to modify the test circuit. The test circuit relays and relay control logic are mounted on printed wiring boards.

Dialled Number Display Circuits

This circuit counts and stores up to nine digits displaying these on a 9-digit seven segment multiplexed display. The input to the display is taken from the push button dial impulsing contacts and each series of impulses making up a dialled digit are counted with each digit being displayed immediately after it has been dialled. The counting circuit resets itself after each impulse train. The display is cleared by a 'one shot' pulse which is generated from a monostable reset circuit in response to the operation of any key which engages a circuit for which the display is required, or alternatively, by the operation of the manual reset button.

For the dial count test, the input to the counting circuit is switched from the impulsing contacts of the dial to the contacts of a dial test impulsing relay.

The dialled number display driver circuit and the reset circuit are mounted on individual printed wiring boards in the console.

Operator's Circuit

This circuit uses three integrated circuit amplifiers with buffered outputs individually coupled to line via the primary windings of two hybrid coupled transformers with a matching network similar to that used in the type 804 telephone. The amplifiers are used for send, receive and sample tone signal amplification under the control of the three respective sliding potentiometers on the front panel. The range of amplification varies from unity gain to a maximum of approximately 10dB. This circuit is mounted on a printed wiring board in the console.

Time Display Circuit

A binary coded decimal (BCD) time service signal from the SA Telecom Time Service Laboratory is connected via a cable pair feed to an interface circuit consisting of an opto-isolator and buffer amplifier-splitter from which an output for each test console is derived. This output is cabled to a buffer amplifier in each console where it is 'cleaned' before it is input to a de-multiplexing circuit.

The de-multiplexer has a 28 bit output and performs a series to parallel data conversion for 50 baud data streams, and it is used in the SA Time and Frequency Standard system to de-multiplex the binary and BCD time information of which only the hours and minutes are displayed in this application. The de-multiplexing circuit is mounted on a printed wiring board in the console.

CONSTRUCTION

The mechanical construction and layout of the test console can be seen in **Fig. 4**. The chassis, front panel, top and rear covers are made from steel and painted in a light stipple finished, 'Telecom Brown' enamel. The front panel cover is aluminium, anodised by a special process to give a durable, attractive, non-reflective light bronze finish. The meter is shrouded to eliminate reflections from its face.

The various printed wiring boards are mounted in a frame from which they can be unplugged for maintenance. Relays and other components are mounted on a modified relay mounting frame.

The front panel can be opened or the rear panel removed separately, and with the top panel also removed easy access is possible to all the internal components. The flexible connecting cables need only be disconnected when the test console is to be removed from the locality.

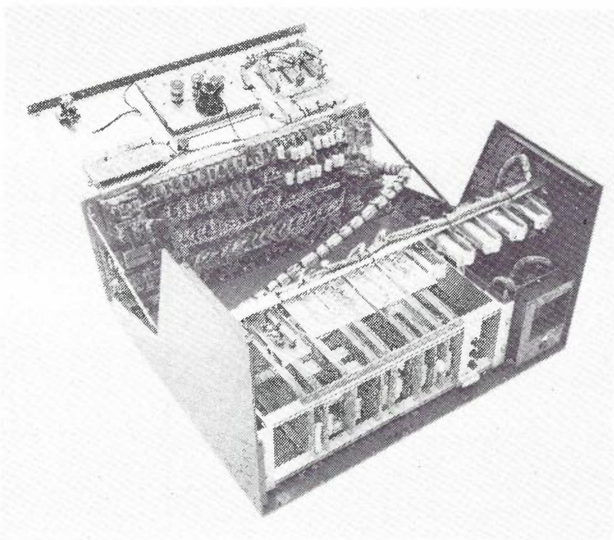


Fig. 4 — Console Interior and Construction.

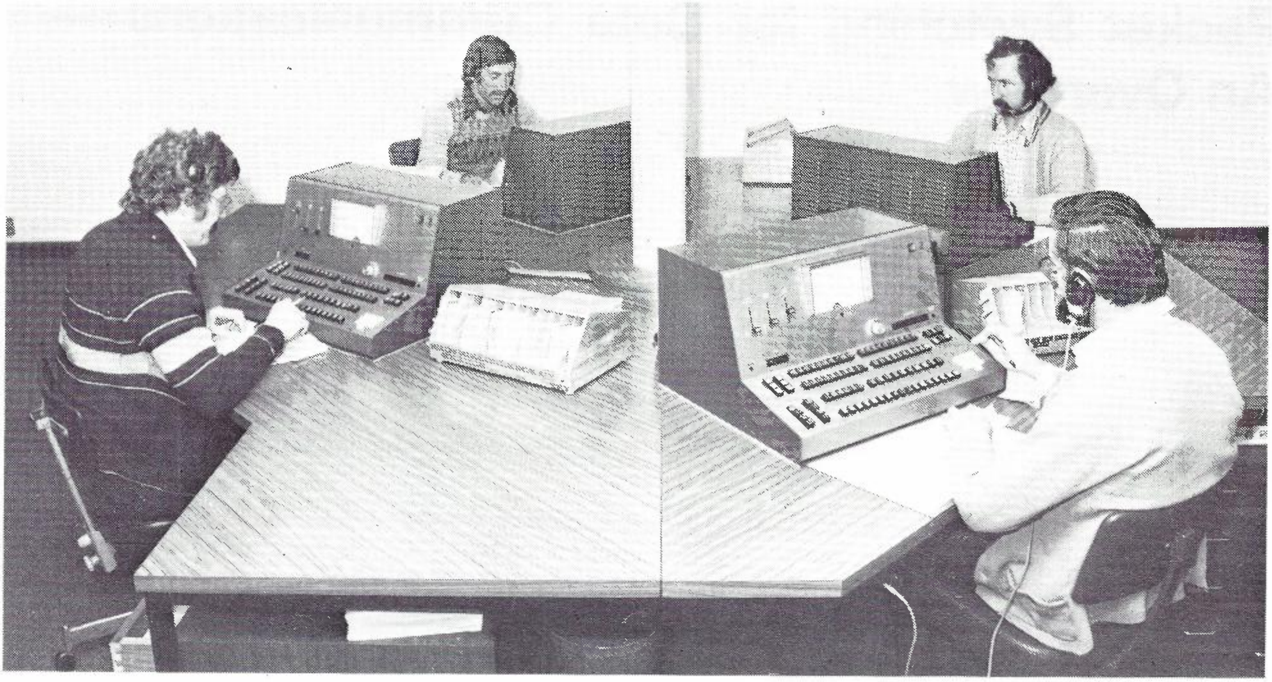


Fig. 5 — Consoles in use at Fault Despatch Centre.

APPLICATIONS

The test console has been designed primarily for use in an FDC and would be most effectively utilised in a new or renovated Centre where flexibility for the future should now be a significant design consideration. The service facilities provided can be modified by appropriate changes to the respective relay sets and key circuits if required, enabling the console to be adapted for other applications in which its compactness and mobility would be an advantage.

The basic test access interface is a standard 4-wire loop signalling test circuit and therefore is compatible with most existing test switching networks. The 'DA' test and dial key release facilities provided in the South Australian application by the additional test circuit interface wiring are desirable in an FDC application but are not essential to the operation of the console.

Fig. 5 shows test consoles in use at the Adelaide Metropolitan South FDC, which has been designed for the introduction of LEOPARD and for which a VDU will be situated alongside each console.

FIELD EXPERIENCE

The test consoles were put into service in November 1978 and since then they have performed satisfactorily and have been well received by operating and supervisory staff in the FDCs. Operators required approximately one hour's familiarisation training and, after some initial adjustment to the new line testing procedure, the introduction of the consoles went smoothly. A detailed assessment of the effectiveness of the various new facilities and operational improvements has not yet been possible. However, general observation and the comments of FDC supervisory staff indicate that the new design has been effective in streamlining and simplifying testing procedures.

A major objective of the new console of allowing future flexibility in the design of the FDCs has been achieved with the Adelaide South FDC test positions being set out as shown in Fig. 5, and with the Adelaide Central FDC using a conveyor belt for distribution of customer fault reports. Both localities are set out on an open space office layout with modern furnishings and decor and will be able to accommodate the introduction of LEOPARD and later, SULTAN with a minimum of rearrangement.

In the context of existing test desk designs this new test console is seen as a useful addition to the inventory of this type of equipment, filling the need for a format which can effectively interface with the introduction of computer based operation and, eventually, a new generation of test equipment.

Packet Switching for Data Communications — An Overview

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Packet switching is gaining increasing acceptance as a method of providing switched data transmission services. This paper presents a brief overview of the history and development of packet switching, the operation of a packet network, the relevant international standards, a summary of the applications well served by packet switching and the expected developments that secure the future of packet switching as an enduring technology.

Packet switching is gaining increasing acceptance as one of the most suitable methods of providing public and private switched networks for data transmission. By 1982 close to 20 packet networks will be in operation in Europe, North America and Japan, indicating the commitment by Administrations and Value Added Carriers to this new technology. This paper summarises the overview section of a packet switching seminar presented by members of the Data and Telegraph Planning Branch of Headquarters in May 1979 (Ref. 1).

BACKGROUND

By the 1960s computers entered the second generation era. Computer power and reliability increased, and the unit cost of computer processing had started out on its long decline that shows no sign of slackening even today. It was about this time that the immense economic and operational advantages of combining data processing with communications technology for the purpose of providing instant access and updating of volatile data bases became evident — special purpose data networks for airline reservations and banking applications made their first appearance. Time sharing computer services also started to provide access to their computer centres from greater and greater distances, often through special private communication networks. With the overwhelming success of these applications a new range of services emerged as candidates for computer communications. These new areas of potential business activity crystallized the need for interconnection of widespread, diverse data processing equipment and for the interconnection of the already existing special purpose networks. The solution to this communications problem was seen in switched data networks with public access.

SWITCHED DATA NETWORKS

Three types of data switching techniques are available to provide on-demand interconnection.

- message switching
- circuit switching
- packet switching.

Although message switching is a long established technique which pre-dates computer technology, the performance characteristics of the service do not meet the objectives of most computer communications applications. As for choosing between circuit and packet switching, considerable debate has taken place over the merits of the two techniques to decide which is better. The debate will probably never be settled conclusively. The emerging view is that more applications are better served by packet networks than by circuit switched networks. Technological developments may obviate the need for a conclusive answer — some networks which provide packet and circuit switched service on the same equipment are already in operation. **Table 1** compares the major characteristics of circuit, packet and message switching.

THE DEFINITION OF PACKET SWITCHING

Packet switching is the technique of data communication by transmitting the information between source and destination in segments of a convenient size, called packets, without reserving a physical circuit. It is a special case of message switching, with the aim of reducing the time taken to transport the message segments from source to destination to 1/3 of a second or less. Thus, to the user, the connection has the appearance of a direct one. The objectives of short transport time and appearance of a direct connection are dictated by the need to make the network suitable for interactive working.

TABLE 1 — MAIN CHARACTERISTICS OF CIRCUIT, MESSAGE AND PACKET SWITCHING

Circuit Switching	Message Switching	Packet Switching
The equivalent of a wire circuit connects the communicating parties	No direct electrical connection	No direct electrical connection
Real time or conversational interaction between the parties is possible	Too slow for real time or conversational interaction	Fast enough for real time or conversational interaction
Messages are not stored	Messages are stored until delivery and filed for later retrieval	Messages are stored until delivery but not filed
Designed to handle long continuous transmissions	Designed to relay messages	Designed to handle bursts of data
The switched path is established for the entire conversation	The route is established for each individual message	The route may be established for the entire conversation or may be established dynamically for each packet
There is a time delay in setting up a call then negligible transmission delay	Substantial delay in message delivery	Negligible delay in setting up the call. Delay of usually a fraction of a second in packet delivery
Busy signal indication if called party is occupied	No busy signal if called party occupied. Delivery held up until called party becomes available	Call rejected if called party is unavailable. Undeliverable packets returned to sender
Increased incidence of blocking on overload, indicated to the caller by network busy signal. No effect on transmission once the connection is made	Increased delivery delay on overload	Increasing (but still short) delivery delay on overload. Blocking when saturation is reached
Large electromechanical or electronic switching offices	Complex switching equipment with storage and filing facilities	Small switching computers with no filing facilities
Protection against loss of messages is the user's responsibility	Elaborate procedures are used to prevent loss of messages. The responsibility of the network for the message is emphasised	Some protection against loss of packets. End user protocols can be used because conversational interaction is possible
Any length of transmission is permitted	Lengthy messages can be transmitted directly. Very long messages must be divided by the user	Long transmissions are chopped into short packets
The network cannot perform speed or code conversation	Speed and code conversion is available	Speed and code conversion is often used
Does not permit delayed delivery	Delayed delivery if the recipient is unavailable	Delayed delivery not available without special network facility
Point to point transmission	Permits broadcast and multi-address messages	Does not permit broadcast or multiaddress messages without special network facility
Fixed bandwidth transmission	User's bandwidth is determined by priority	Users employ small or large bandwidth according to need
Economical for low traffic volumes if the public telephone network is used	Economical with moderate traffic volumes	High total traffic volume needed for economic justification

HISTORY OF PACKET SWITCHING

Early Theoretical Studies

The history of packet switching goes back to the early sixties when a study was prepared by the Rand Corporation for an integrated, secure and fully survivable network for data and voice communications. Although the economics for the type of network envisaged showed a packet network to be superior, no action was taken to realise it and the report sat largely ignored for many years. At about the same time the Advanced Research Projects Agency (ARPA) in the United States also studied the feasibility of providing a packet based network for time sharing computer access. Again, no actual network development took place.

Experimental Networks

The first experimental networks to demonstrate technical feasibility appeared during the late sixties. The first and most famous of these, ARPANET, provided a wealth of information and quickly proved that dynamic allocation techniques can be made to work. The National

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FRANK WION joined the PMG's Department in 1951 as a cadet engineer. After graduation he worked in the Research Laboratories, mainly on electronic switching. In 1967 he transferred to the Victorian Engineering Planning Branch, where he worked on exchange and network planning. In 1974 he joined the National Telecom Planning (NTP) Branch, Headquarters, working with the team which produced the 'Telecom 2000' report. In 1976 he became the Manager of NTP Branch and in early 1978, Superintending Engineer of the Data and Telegraph Planning Branch. Since January 1980, he has been Superintending Engineer, Data Services No. 1 Branch.

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Physical Laboratory in Britain, Tymnet in the US and Cyclades in France were to follow, demonstrating packet switching as a technically viable alternative to circuit switching.

Public Networks

The packet switching technique has been adopted by many common carriers and PTTs in recent years in their implementation of public switched data networks. Up to May 1979 the following public packet switched networks were in operation:

- Telenet (USA)
- Tymnet (USA)
- Graphnet (USA)
- Datapac (Canada)
- Infoswitch (Canada)
- RETD (Spain)
- Transpac (France).

These public and other pioneering community packet switched networks have demonstrated that packet switched data communications services are suitable for most teleprocessing applications, but particularly in the following areas:

- where a large number of users transmit small volumes of data over long distances
- where a large number of widely dispersed terminals access a host computer in interactive mode with long pauses between accesses
- where communications between terminals with incompatible characteristics (speed, code, protocols, etc.) are required
- where terminals need to access more than one host.

STRUCTURE AND OPERATION OF A PACKET NETWORK — A SIMPLIFIED VIEW

A packet switched network consists of switching computers, interconnected by high capacity links. Connected to the switching nodes via network access circuits are computers and terminals. (See **Fig. 1**.)

The majority of teleprocessing applications are characterised by low average, but high peak data rate. This is because the speed of the line over which communications take place is dictated by response time, not traffic volume considerations. Thus line utilisations as low as a few percent are quite common. In a packet network many terminals share use of the internode link. Each user gains access to the entire link capacity, but only for the time required to transmit one message segment. Thus occupancy is raised to an acceptable level while maintaining good response time. This mode of operation contrasts with circuit switching, where the link capacity is subdivided into fixed segments, with each call gaining exclusive access to one of the segments for the entire duration of the call.

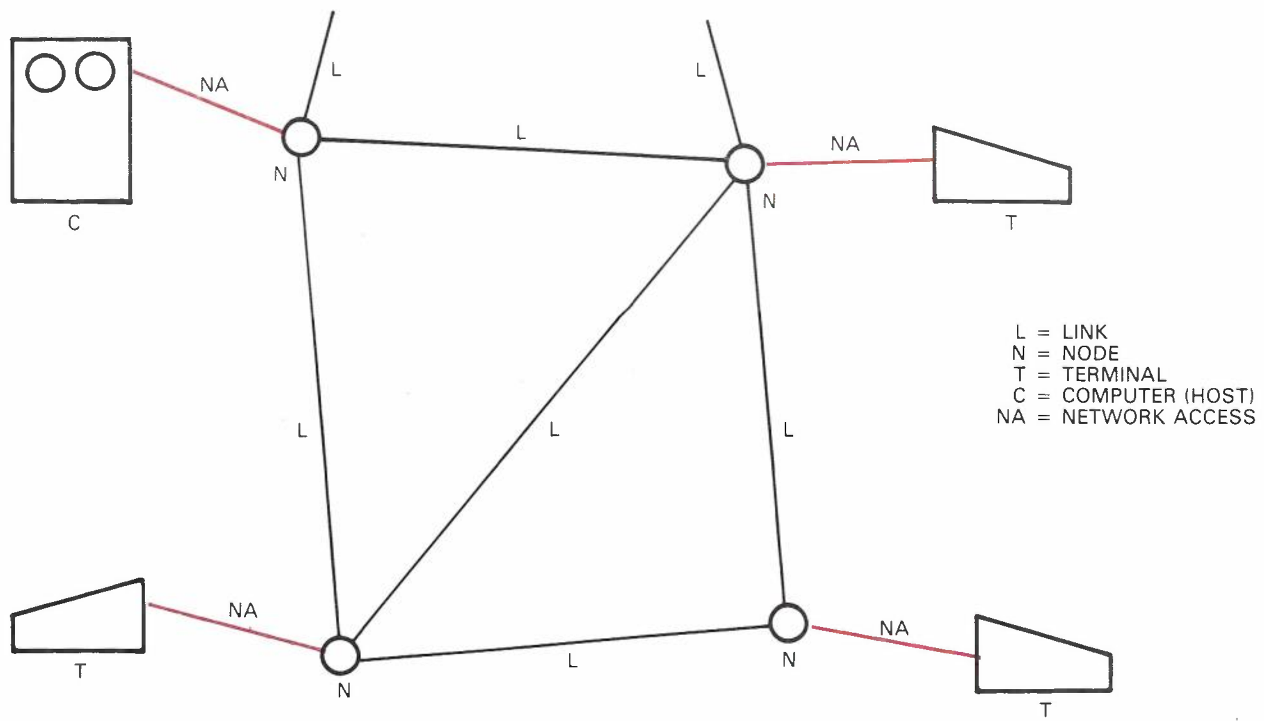

Fig. 1 — Example of a Packet Network Configuration.

Two methods of operation have been proposed for packet switching. In datagram operation each packet is fully addressed and finds its destination independently of other packets from the same message. In virtual circuit operation a call request sets up a path from source to destination and all packets of the message follow this pre-arranged path without a need for full addressing.

Most packet networks operate on the virtual call-virtual circuit principle; the only method standardized by CCITT so far. A virtual call consists of three phases.

Call Establishment

The user indicates to the network the required destination. The network arranges information at every node concerned to direct the passage of packets between source and destination and alerts the destination to receive incoming traffic. If the destination is free and the call is accepted, preparation of the path between the parties (the virtual circuit) is completed and the caller is advised of acceptance of the call.

Data Transfer

The data to be sent enters the network in segments called packets. The segmenting of messages, referred to as packetisation, may be performed by the customer or by the network interface. Packet size is typically 128 characters maximum. Each packet contains control information as well as user data to ensure error-free orderly delivery. The packets are queued for transmission on the appropriate link. Packets received at the next node are checked for correctness. Queueing and transmission are repeated at each node until the destination is reached. Usually the processing, queueing and transit delays are kept to a total of about 300 ms for passage of a packet from source to destination.

Call Clearing

The clearing signal is acknowledged. The other party is advised of clearing the call. All routing information pertaining to the call is discarded.

STANDARDS

The importance of standards applying to data communications cannot be overstated. While in human communication if one masters the art of using a telephone dial and perhaps the interpretation of some of the network tone signals, communication over the path established is almost assured — the occasional "what was that again" or "what did you mean by that" is all that is required to eliminate errors and ambiguities. Computers — as we know them today — cannot do that. Procedures must be designed to cover all possible situations in great detail; one can no longer rely on the redundancy, resourcefulness and robustness of natural languages.

The two most important pressures to establish standards for packet communications stemmed from the need to facilitate interconnection of the established and emerging networks and the potential of IBM's SBS/-SNA/SDLC* combination becoming a defacto standard of the communications industry; with the consequent relegation of Administrations to be providers of "wires" rather than communications services.

In the early seventies CCITT started studies to establish packet switching standards, culminating in the ac-

* Satellite Business Systems/Systems Network Architecture/Synchronous Data Link Control will form the most complete computer communications system ever offered by a computer manufacturer. It encompasses transmission facilities, network building principles and interchange protocols.

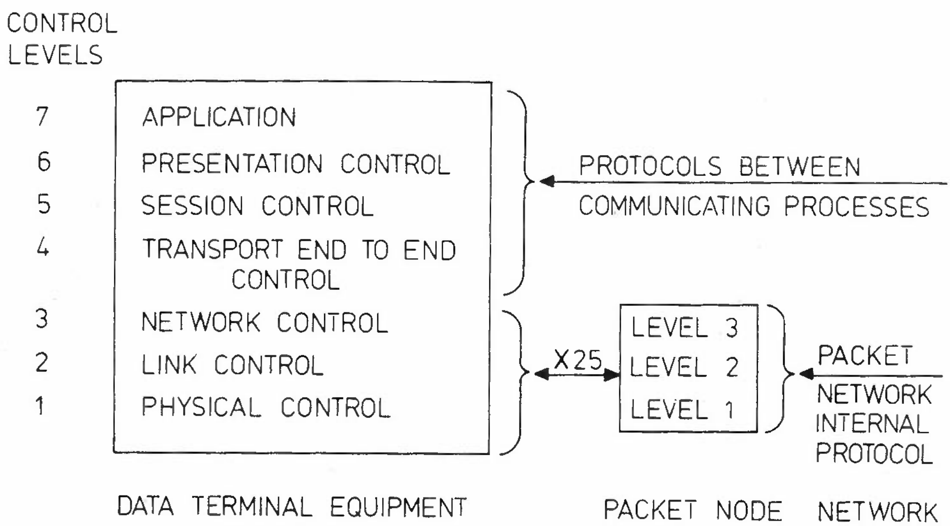

Fig. 2 — X25 and its Relation to the ISO Network Architecture Model.

ceptance of Recommendation X25 in 1976. This Recommendation is particularly important because it goes quite some way towards solving a user's problems in wanting to exchange data, rather than just solving his problem of establishing a communications path. To return to the telephone analogy, it is no use to establish the speech path if the two parties don't speak the same language — X25 provides not only a communications path but elements of a data interchange language.

The International Standards Organisation recently introduced a provisional architecture model to provide for open-system interconnection. It defines seven control levels and should permit full communication of intelligible information between processes once the standards are defined (see **Fig. 2**). X25 defines an "interface protocol" — a set of rules and procedures to allow orderly, secure and error free interchange of information between the user and the network. It refers to other standards as well in specifying the three lowest levels of control, the network interface characteristics. Each level is made as independent of the others as possible to facilitate ease of definition, modification, extension and error free realisation. The three levels concern electrical interface conditions, the rules for the efficient, fast and error free interchange of an arbitrary bit-string over the interface, and the rules for the establishment, supervision and disconnection of a virtual call.

Great interest has been generated by X25, most of the existing packet networks offer it as the standard interface. All planned public packet networks will offer the X25 protocol. Response from computer manufacturers has indicated support — IBM and DEC, the giants of mainframe and minicomputer industries, are offering X25 compatible hardware and software in several countries.

NETWORK INTERFACE AND HOST/TERMINAL SUPPORT

The types of terminal and host which can be connected to a packet switched network are constrained by the network interface standards adopted for the particular network. The interface in this case covers not only physical and electrical characteristics, but also link control procedures, signalling and data transfer procedures.

It is possible to provide terminal access to the packet switched network via a:

- public switched telephone network
- digital leased circuit network (such as Digital Data Network DDN)
- modem based analogue leased line
- telex network
- circuit switched data network.

Host computer access to a network is usually provided by digital or analogue leased lines.

The current relevant CCITT Recommendations applicable to packet switching are X3, X28, X29, X25 and X75. Basically X3, X28 and X29 cover the network interfaces with asynchronous terminals which operate in character mode. X25 defines the interface between packet mode terminals and the network. X75 specifies the interface between packet switched networks on international circuits.

At present no CCITT Recommendation covers interfaces between non-packet mode synchronous terminals and a packet switched network, but some networks do provide support for some types of synchronous terminals from the major suppliers.

NETWORK AND USER FACILITIES

Facilities provided by public packet switched data networks vary between networks due to different market requirements. The typical facilities offered are:

- virtual call
- permanent virtual circuit
- closed user group
- call barring (incoming or outgoing)
- reverse charging acceptance
- caller identification
- direct call
- abbreviated addressing
- priority calls
- speed/code/protocol conversion
- selection of data throughput class
- user selectable functions.

Virtual call is a user facility in which call set-up is necessary to establish a logical association, a virtual circuit, between a source and destination for data transfer. Upon completion of data transfer this logical association is terminated. Permanent virtual circuit is a facility in which a permanent association exists between the source and destination, i.e. there are no call set-up and call clearing phases. From the user's viewpoint a permanent virtual circuit is similar to a point-to-point leased circuit service. With some networks a permanent virtual circuit may be provided on a part-time basis.

Many of the facilities such as closed user group, call barring, reverse charging acceptance, caller identification, etc. are assigned at the time of connection to the network. User selectable functions as described in CCITT Recommendations X3, X28 and X29 are assigned on per call basis.

APPLICATIONS

Current applications on established public packet switched networks include:

- time sharing and other types of resource sharing
- access to data bases and information services
- credit checking
- remote job entry
- travel reservation
- order entry, stock control, goods handling, management information.

Intended and possible future applications include:

- electronic payment systems/electronic funds transfers system
- remote maintenance of computers and terminals

- interconnecting of research institutions' computer systems
- monitoring systems, e.g. environment, road traffic
- electronic mail/text communications/teletex
- facsimile
- file transfer
- alarm and protection.

The characteristics of data traffics resulting from different applications vary greatly. They also place different requirements on network performance characteristics and facilities.

In time sharing applications, for example, data is generated in bursts in both directions with relatively long pauses between accesses. Since no physical circuit is reserved exclusively between terminal and computer for the duration of a computing session, transmission capacity not required during transmission pauses is shared by other users.

Time sharing traffic currently represents the most significant portion of total network load of Telenet and Tymnet.

Credit checking and travel reservation applications generate data of small volume per access and accesses are frequent. Response time must be short. In addition there is the requirement of accessing a number of host computers from one terminal. These applications undoubtedly require switched data services and packet switching is ideally suited to handling data traffic of this type. It is predicted that these applications will constitute a major network load of public packet switched data networks in North America in the near future. The speed of market penetration will to a large extent depend on the availability of suitable terminals from manufacturers.

ATTRACTIVE FEATURES OF PACKET SWITCHING

High Performance

The arrangement of switching computers and high data rate links ensures a fast response time. High peak data rate is made available to the users by allocating the full transmission capacity of links for the duration of packet transfer. The built-in error checking and correction procedure ensures excellent bit error performance, usually in the order of 1 in 10^{11}.

Connection of Dissimilar Devices

The basic store and forward mechanism of packet switching is inherently suitable to perform the code, speed and protocol conversion necessary for successful interconnection of users with dissimilar equipment.

Good Utilisation of Transmission Resources

The shared use of wideband links allows improvements in the low line utilisation inherent in serving low average data rate applications where line speeds are dictated by response time considerations. The multiple use principle employed on links may also be extended to sharing the network access links between simultaneously operating applications in the computers connected to the network.

Tariff Flexibility

In addition to the normally available usage measures of number of calls, call duration, time of day and distance, the additional measures of volume and data rate enables setting of tariffs designed to attract most potential markets.

The tariff structure of a typical packet network is made up of the following components:

- connection fee
- access charge
- usage charge
- charge for special facilities.

The connection fee is a once-only charge dependent on the class of service required and sometimes on the distance of the data terminal equipment from the nominal access point to the network.

The access charge is a monthly rental for permanently connected subscribers, dependent on the class of service and possibly on the distance to the access point. For subscribers connected via the telephone, telex or public circuit switched data network it depends on access duration.

The usage charge depends on one or more of the following parameters:

- volume of data sent
- duration of the virtual call
- a charge per virtual circuit allocation
- distance involved
- time of day and week
- facilities used
- volume discount (applies only to certain part of the overall charge).

Ease of Realisation

Because packet switching uses mini or micro computers, and many of the software techniques developed for general teleprocessing applications, some of the development costs for these items need not be expended. This was particularly true in the early days of packet switching when users built their own networks using equipment that could be obtained readily. However, even off-the-shelf packet switching systems benefit from the low cost of mini and microcomputers available from commercial sources.

DISADVANTAGES AND LIMITATIONS

To present a balanced picture, it is also necessary to mention the limitations and disadvantages of packet switching voiced by its critics. A great many of these relate to implementation difficulties as experienced today rather than fundamentally to the packet switching technique. It is confidently expected that as standards and equipment develop over the next two to three years these will be resolved satisfactorily. Concerns of this type centre on:

- the apparent variations evident between different implementations of X25 and related standards

- the lack of a CCITT standard for simple synchronous terminals, for example for devices employing binary synchronous communication (BSC) procedures
- the scarcity of program packages to interface computers to X25 networks
- the limited range of interfaces available from packet networks to interface specific devices or computer manufacturers' proprietary communications packages
- the cost incurred both in terms of expenditure on equipment and manpower to convert to, or base a new application on, a packet network.

Other reservations expressed relate fundamentally to the technique of packet switching or to the X25 standard:

- the transit delay introduced by packet switching over and above the propagation delays incurred in the transmission medium may prevent interactive working
- the overhead introduced by the packet and link control information transmitted along with user data jeopardises efficiency
- the procedure of setting up links and virtual circuits before actual useful data exchange can take place is too cumbersome
- the attractiveness of untimed local telephone calls for data transmission as an alternative to packet switching.

The transit delay incurred depends on the engineering of networks and network components, therefore they are under the control of the system designers. The last mentioned three items are already receiving close attention by CCITT and system implementers. Overheads will be reduced significantly by new procedures such as user selected packet size, fast select, fast transmit, etc.

The best indication of the success of packet switching is demonstrated by the confidence with which value added carriers and administrations are implementing packet networks.

THE FUTURE OF PACKET SWITCHING

New networks will commence operation in the next 2-3 years in the USA, Japan, W. Germany, United Kingdom, Nordic countries, Netherlands, Italy and Belgium. It is also proposed to introduce links between the many packet networks that will be in operation by the early eighties, making international and intercontinental working a reality.

Most significant is the commitment by the major US carrier, AT&T, to packet switching. Their proposed Advanced Communications System (ACS) confers a degree of acceptance on packet switching as a mature communication technology. This is also reinforced by the decision to establish packet networks in countries already operating circuit switched data networks, e.g. Germany and the Nordic countries.

Technological developments will continue to have a large impact on packet switching. Higher capacity links will further reduce transit time, high data rate applications such as Remote Job Entry and file transfer will become commonplace. Radio based local distribution systems will open the door to mobile and personal packet terminals for business and home use.

A final point about packet switching is that it might become important in voice switching as well as in data. Some recent overseas studies have claimed to show that packet switching is the best available technology for switching voice traffic. This is because of the advantage which can be taken of the naturally occurring pauses in normal speech. The suggestion is that when integrated voice/data networks appear, they will be packet switched.

Late in 1979 Telecom announced an intention to establish a packet switching network by 1982. A schedule and functional specification is now under preparation by the Product Engineering Group — Packet Switching of the newly created Data Services Sub-division. It is expected that following the normal tendering procedure, equipment will be selected for an Australian packet switching network in 1980/81.

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Route Planning Rules for Primary PCM

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Like many planning problems, the design of PCM route planning rules is an exercise in engineering judgment. There is undoubtedly a "right" solution, but it cannot be identified with certainty until it is much too late to matter. However, the potential gains — or losses — are such that the continuing effort to get as near as possible to the correct solution is well worth while.

Planning considerations for PCM systems were discussed in a previous issue of this Journal (Volume 28, No 2, 1978). Once it has been decided to introduce primary PCM in a given area, the next stage is the design of the route layouts, in particular the number and position of the repeaters. This stage has become known as route planning.

The practice of placing a repeater at every exchange on a PCM route, which is generally used overseas, has also been adopted for Australia. The main advantage is that this practice allows flexibility in the network to accommodate alterations — this will certainly be needed during the introduction of digital switching. The consequence for route planning is that each route between successive exchanges (called a span) can be considered separately.

The layout for each span must not be designed for immediate needs alone, but to accommodate all the PCM systems which will ever be required on the cable used. The reason is that once housings are installed upon a given cable, its ultimate PCM capacity (or penetration) has been effectively fixed. If the penetration limit is reached prematurely, it would not be worthwhile to re-engineer the cable, by then carrying a large number of working systems.

On current forecasts, there seems little chance that either optical fibres or special cables will ever be competitive with already installed VF cables, as bearers for primary PCM systems. This suggests that PCM installations on VF cable will continue well beyond the year 2000, though the repeater positions on most cables will have been fixed much earlier, perhaps by 1990.

Unfortunately, the crosstalk performance of VF cable, which sets the limit to PCM penetration, is very variable in the frequency range used for primary PCM. It is not practicable to measure this performance before housings are installed, so that route planning must be based on statistical predictions derived from large amounts of crosstalk data.

The difficulty of this problem may be gauged from the fact that the classical paper on PCM route planning was written by Cravis and Crater in 1962 (B.S.T.J. March 1963). Despite many efforts by workers in a number of countries, no definitive paper has yet been written. Significant contributions in this area have been made by Transmission Systems Branch (now Transmission Branch) in the Telecom Research Department; in particular the crosstalk computer program, designed by Dr A. J. Gibbs, on which the present route planning rules are largely based.

Given all the uncertainties and difficulties in this area, it is reasonable to ask why Telecom should not simply adopt one of the planning rules used overseas, some of which are well tested in the field. One reason is that these rules vary widely — probably because they have developed to suit national network characteristics and working practices. Another is that most overseas rules are conservative, which is appropriate in the early stages of PCM development, but can become expensive when the PCM network grows to the size expected in Australia.

Because of Australia's late entry to the PCM field, the probable course of PCM development can be more clearly seen. It should be possible to turn this to account, by developing more efficient route planning rules than would have been possible earlier. Cost studies indicate that the expense of developing and administering such rules may be repaid up to ten times over, which makes the development a good investment by any standards.

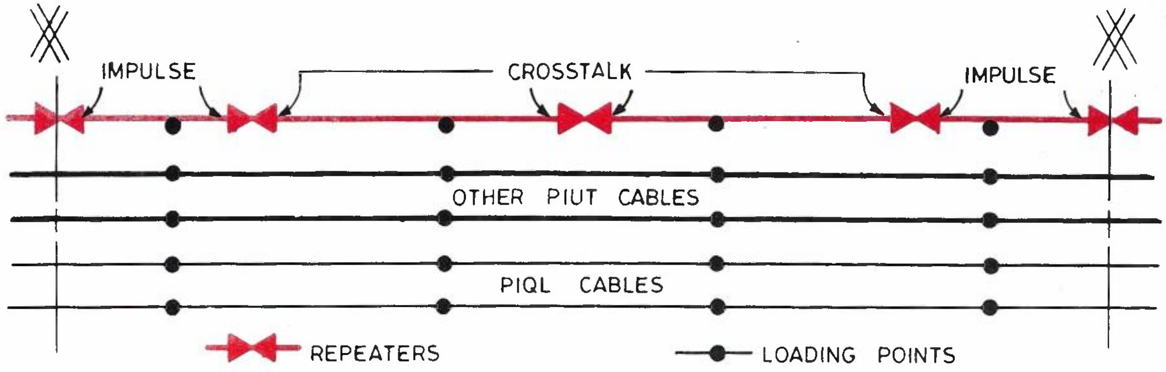


Fig. 1 — Typical Junction Span

SPAN LAYOUT

The basic problem is illustrated by **Fig 1** which shows a typical span. If the repeater sections are made short enough, almost perfect performance for all systems can be guaranteed; but the cost will be high, because in most cases too many repeaters will be used. If the repeater sections are stretched too far, to reduce costs, the final network cost will again be increased, because too many spans will fail to provide the PCM capacity eventually required. Somewhere between these two extremes there is obviously an optimum solution.

In the present analogue network, the noise at the input of the exchange regenerators is mainly impulse noise, from signalling pulses on the VF pairs in the cable. The exchange repeater sections are shortened to retain an acceptable error performance, which means that crosstalk noise in these sections is negligible, and hence the noise level in these sections is independent of the number of PCM systems in the cable.

In the remaining repeater sections, the dominant noise at the regenerator inputs is crosstalk from the other PCM systems. This noise increases as the number of systems on the cable rises, and eventually sets the limit to PCM penetration on the cable. In any given span, the penetration limit depends upon the repeater spacings and the cable crosstalk characteristics.

Most spans will have more than one cable suitable for use as a PCM bearer, as indicated in Fig 1. This allows some elasticity in design, because the layout for the second and subsequent cables need not be fixed until the first is filled — which may take 5-10 years. By this time, more accurate forecasts of future demand will be available, and the route plan for the second cable can be adjusted accordingly; and so on. Fortunately, this elasticity will be greatest on the largest routes, which are also those on which mistakes would be the most expensive.

IMPULSE NOISE

Considerable progress has been made towards understanding the mechanism of this type of interference. Its main feature is that it is extremely sporadic, which makes its level hard to define. Concepts such as bit error rate, which are useful to define crosstalk levels are meaningless when applied to impulse noise. Studies have shown that the worst effect is always at the exchange regenerator: the effect at the far end of the first section is less, and at all other regenerator inputs it is negligible, provided that the first repeater is beyond the first loading point from the exchange.

The short end sections defined by the current route planning rules are expected to provide adequate control of impulse noise for telephone service over PCM systems. However, this may not be good enough for data traffic, though standards for this service have yet to be established. Accordingly, it is proposed to condition routes for data traffic, when required, by barring dc signalling on the most closely coupled pairs, or by filtering the signalling pulses when barring is not practicable. This will be less expensive, and more effective, than further shortening of the end sections.

Because of the short spans typical of the junction network, considerable savings would be possible if the end sections could be full length, with impulse noise controlled entirely by conditioning. However, it appears unlikely that the conditioning could then be effective enough for data traffic, except at prohibitive cost.

CROSSTALK

Except in exchange sections, the noise at the input of a PCM regenerator is almost entirely due to crosstalk from other PCM systems in the cable. There are three forms of crosstalk — near-end (NEXT), far-end (FEXT) and third circuit (3CXT). In the large PIUT cables which are the most common PCM bearers, 3CXT is the dominant form, with NEXT a close second. In PIQL cables NEXT is dominant. FEXT is almost always insignificant.

All forms of crosstalk are very variable, both within a cable and between different cables. As a result, the permissible section loss, calculated from data for nominally identical cables, may vary by 10 dB or more (**Fig 2**). Consequently, the most realistic representation of cable performance is a graph of the failure probability P_f, against section loss (or length). P_f is the probability that a section of a given length will not meet the performance criterion, for a given penetration — usually 12%. The performance criterion chosen is an error rate of $1/10^7$ for the worst pair: it is not critical, because of the pronounced threshold effect in PCM systems. A typical P_f graph is shown as **Fig 3**.

Unfortunately, graphs such as Fig 3 cannot yet be drawn with the accuracy required for the final route planning rules. The main reasons are —

- Large quantities of crosstalk data are needed. The only practicable way to obtain this data is by crosstalk measurements at all newly installed PCM housings, which provide free access to cable pairs. However, cross talk data for each type of cable then accumulates only as fast as housings are installed.
- With conventional pair to pair measurements there are practical limits on the number of measurements at each housing: the present standard is 2 x 72 NEXT + 2 x 72 3CXT, a total of 288, which leaves a significant sampling error in the results.
- At present, there are significant differences between the noise margins derived from the crosstalk measurements, via the computer program, and those

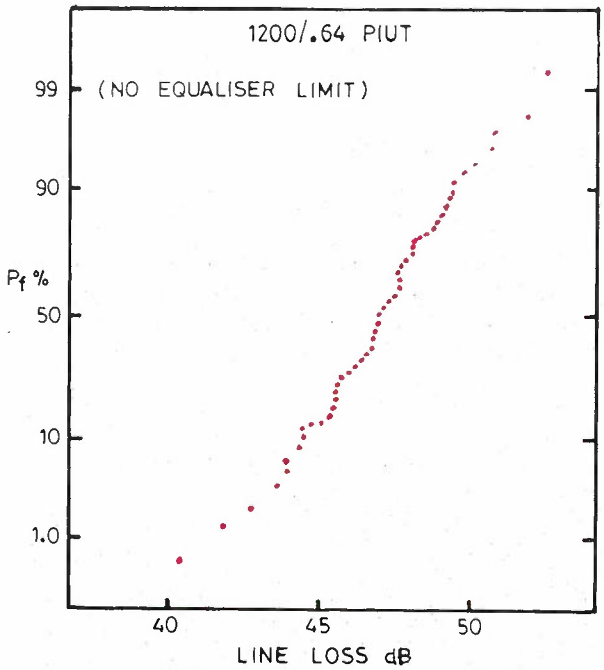
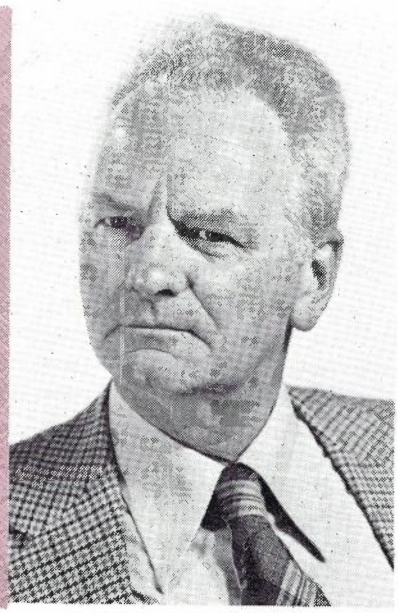


Fig. 2 — Cable End P_f.

measured by the barrage test equipment (which simulates the working case). It may be some time

MICHAEL JINMAN was born and educated in the UK, and graduated in 1953 with first class honours in electrical engineering. He then worked in the research and development laboratories of two large and one small UK companies, mainly on the design of microwave components and systems. Seven patents were filed during this period, in several different fields. In 1971 he joined the Australian Post Office, in the Long Line Equipment Branch at Headquarters. In 1975 he was appointed to the new Transmission Network Design Branch of Telecom Australia, and began the exploratory work on primary PCM transmission which led, eventually, to the formulation of the route planning rules.



before the reason for these differences can be established and corrected. Several other corrections are being held back, to preserve a safety margin, until this is done.

It is hoped to eliminate most of these problems by adapting the barrage test equipment to cable characterisation, using a technique devised by Transmission Branch, Research Department. This equipment would, in effect, make 5184 crosstalk measurements at each housing, virtually eliminating sampling errors: the results would not need processing, so that the computer program would be no longer needed. However, direct characterisation by this means is not likely to be fully available before 1981.

Naturally, PCM installations cannot wait upon the establishment of final route planning rules. Consequently, for the early stages, conservative rules based on what data is available, plus a fair amount of educated judgment, must be used. As data accumulates, and techniques are refined, the rules can be made progressively more accurate. Eventually, a point will be reached beyond which no further improvements are worthwhile, either because their effect would be small, or because most spans of a given cable type are already committed. It seems likely that this point will be reached, for most cable types, between 1985 and 1990.

PAIR SELECTION

In contrast to the above, there is little uncertainty as to the best pair selection for PCM systems. NEXT is always either the dominant crosstalk class, or close to it, while 3CXT is little affected by pair selection, and FEXT is negligible. Thus pair selections are simply designed to minimise NEXT, which roughly means that go and return pairs are kept as far apart as practicable.

In general, FDM carrier systems should not be operated in cables used for PCM. Most other services will cause no problems, though high speed data pairs should be kept away from PCM pairs where possible.

ECONOMICS

The economic justification for primary PCM on VF cable pairs is likely to vary widely during its life. In the present analogue network, PCM "proves in" only for the longer junction circuits. However, as digital switching is introduced, the range of applications for PCM will increase rapidly, because multiplex equipment is not needed at the interface between a PCM system and a digital switch block. In an all-digital network, PCM systems "prove in" for any junction length.

This effect is anticipated in the growth scenario used for economic calculations **(Fig 4)** which is in general agreement with other current forecasts. Detail differences are not important here because the conclusions reached are not sensitive to quite large changes in the scenario. The time scale extends to the year 2000 only, because forecasting still further ahead is very uncertain — as may be seen by comparing the outlook in 1960 with the position today.

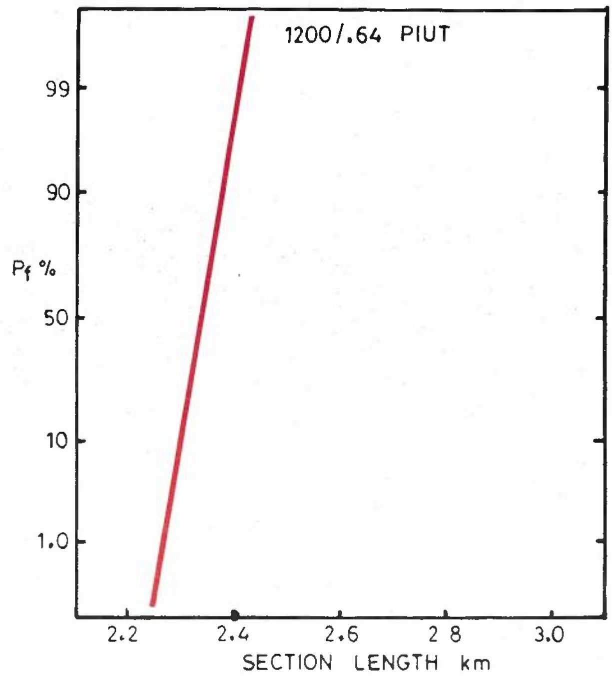


Fig. 3 — Cable Section P_f.

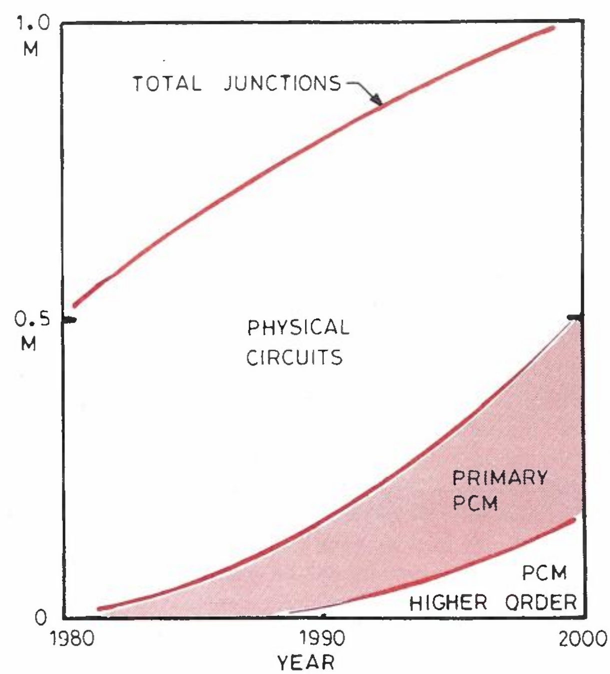


Fig. 4 — Junction Network Growth

Using this scenario, and a network model, the overall cost of PCM line equipment to the year 2000, using different route planning rules, can be calculated, with the results shown in **Fig 5**. Although this figure may not be accurate, because of the many assumptions involved, it is very useful to assess whether any particular change is worthwhile. For example, taking loading point location of all repeaters as a reference (point LP) it may be seen that the present rule will be about $8 million cheaper, at 1979 prices. As the broken line suggests, this saving is due about equally to longer end sections (impulse noise controlled) and longer centre sections (crosstalk controlled). The curve also suggests that still further savings are possible: However, there are other factors to consider, as discussed below.

STRATEGY

As already mentioned, forecasting more than 20 years ahead is a very dubious exercise. However, the modern PIUT cables which make up about half the present junction network are expected to remain serviceable for PCM until 2020 or 2030 at least, and there is no present reason to suppose that they will not be used. Thus, although the route planning rules are based mainly on the expected growth for the next 20 years, it is desirable to give some thought to what may happen if PCM on VF cables continues to be used after this period (or if the need for primary PCM is greater than shown in the scenario.)

The diagram shown in **Fig 6** was drawn for this purpose. It shows the expected proportion of spans reaching their penetration limit, at different penetration levels, using the present design rules: also, the penetration ranges expected at different stages of development, and their nominal (and earliest) dates. It is clear from this diagram that the present rules will allow for double the nominal 2000 penetration without serious difficulty, but not for very much more.

It should be noted that, although the rules are based on a nominal penetration of 12%, most spans will allow much higher penetrations. One reason is that, because of the short span lengths in the junction network, the specified maximum section length is approached only occasionally. The other reason is that the rules are based on a low maximum P_f, which means that most cables will allow a higher penetration, even at the maximum section length.

In the worst case, the PCM capacity of the present cable network will begin to be exhausted about the year 2000. However, by this time optical fibre cables (or some other new bearer) will almost certainly be the established mode. If new bearers have to be laid after this change in technology, the penalty will be much less than before it, when already obsolescent metal cables would have to be used. It appears, therefore, that Fig 6 strikes a reasonable balance between present and future needs.

In the more immediate future, Fig 6 indicates that there should be very few problems due to excessive crosstalk until 1990 at the earliest. Later on, penetration

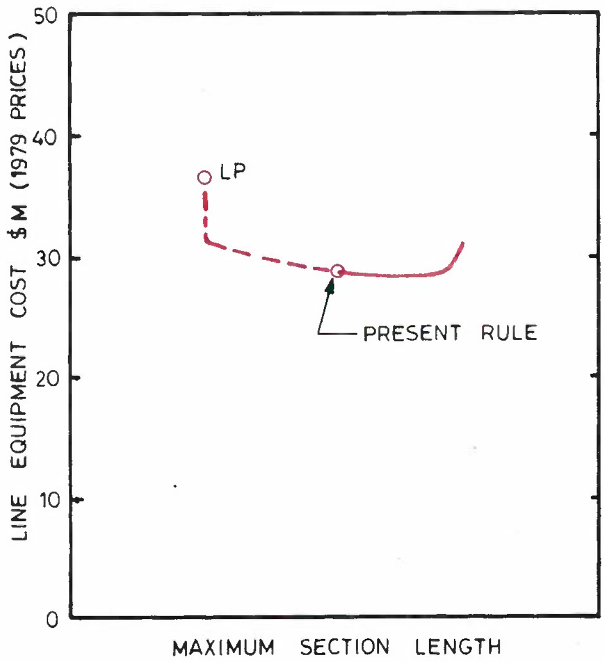


Fig. 5 — Cost Comparisons

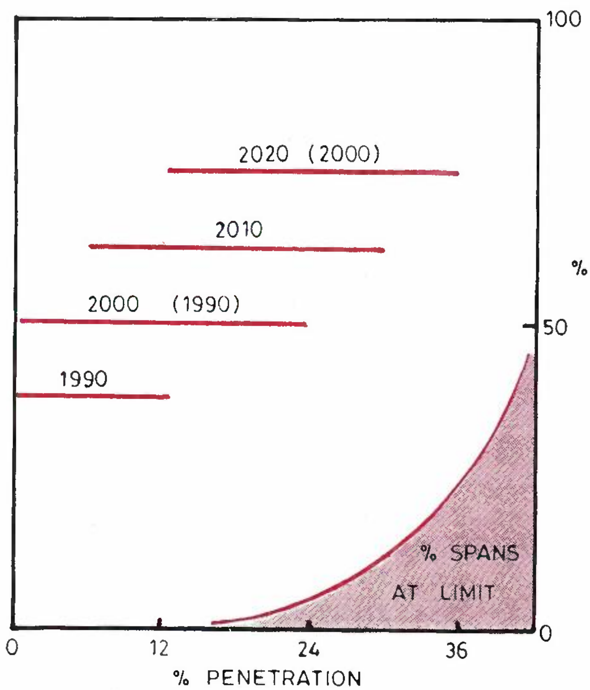


Fig. 6 — Penetration Limits and Ranges.

limits will be met more frequently, and barrage testing will be needed to give advance warning of these limits, so that planning changes can be made in good time.

PHILOSOPHY

This seems a good heading for some issues which are not technical, but are equally important in shaping the final result. Like many planning problems, the design of route planning rules is as much art as science, because the best solution can only be a matter of opinion, within certain limits. The designer's task is to identify these limits, and then use his judgement to choose a course between them. The choice will inevitably involve a series of compromises between conflicting interests, which may be in different fields.

It may be noted that there are no "soft options" in this choice, assuming that the real aim is to contain costs. In the long run, either timidity or rashness will equally prove expensive: indeed, the latter may be preferable, because errors in this direction are more likely to be discovered and corrected before any serious harm is done.

The basic purpose of the route planning rules is to ensure that the primary PCM network is established as cheaply as possible, without compromising on performance. However, economic comparisons seldom include all relevant factors, usually because they cannot be quantified. At present there is a healthy distrust of narrow economic comparisons, because they frequently ignore both social consequences and longer term economic effects. Fortunately, in this case, these aspects also are favourable: the type of planning rules described will tend to retain employment and expertise, as well as capital, in Australia.

CONCLUSIONS

The overall argument can be divided conveniently into impulse noise and crosstalk areas. Impulse noise problems are likely to occur from time to time, because any final solution so far proposed would be too expensive. The objective of the route planning rules is to keep, such problems within manageable proportions and to provide techniques to resolve them when they do arise.

Crosstalk problems are unlikely in the near future, with the planning rules now adopted. The present rules are largely a compromise between the medium term economics of the network, as illustrated by Fig. 5, the longer term requirements for PCM capacity, shown in Fig. 6, and the need to preserve some temporary margin to cover present uncertainties in calculations and data. (In all calculations a separate safety margin of 3 dB is included, to cover performance degradations in service, of bearers or equipment). By the time that crosstalk limits become a significant problem, alternative bearers should be available to accommodate further growth without serious economic penalty.

Development and adjustment of the route planning rules are expected to continue for several more years at least, while data and experience accumulate and techniques improve. At the same time, the uncommitted proportion of the final PCM network will gradually diminish, as will the effectiveness of further changes in the rules. Eventually, this process will set a natural limit on further development, possibly about 1990. However, there are good reasons to expect that final route planning rules can be set much earlier than this, using the new techniques now being developed.

VDU/TRESS System

G. MASSIH B.Sc, Hon (Electronics)

This paper outlines briefly the developments of the Public Telegram Service in Australia and its evolution to the present system known as TRESS (Transmitter Reperforator Switching System).

A further development — VDU/TRESS — has recently been introduced following successful field trials. VDU/TRESS is a new phonogram input system aimed at cost reduction and increased efficiency through the use of new input equipment (VDU) and a more effective utilisation of staff.

The TRESS system currently operating for public telegram traffic has become financially unattractive, mainly because of the number of manual operations involved, and is subject to a declining traffic level due to the penetration of telex and the increasing usage by the public of the telephone STD network. (Table 1 depicts the fall in public telegram traffic since 1950). It is clear that the financial liability will become greater if present operating methods are maintained. To overcome deficiencies of the TRESS system operations to some degree, Telecom Australia has embarked on a short-term modernization and loss reduction programme. The TRESS/VDU system described in this paper is one method of improving public telegram operations being implemented to this end.

AN HISTORICAL PERSPECTIVE

A morse circuit was first established between Melbourne and Williamstown in Victoria in 1854.

Interstate telegraph communication began between Melbourne and Adelaide in July, 1858 and three months later between Sydney and Melbourne.

1877 saw the opening of the coastal link between Adelaide and Perth. Melbourne was connected to Tasmania by means of submarine cable from Flinders to Low Head around 1869.

The year 1872 saw two notable telegraph achievements: the first overseas submarine cable linking Australia with Europe, and the renowned overland telegraph circuit between Port Augusta and Darwin. These two links provided the Eastern States of Australia with direct overseas communication facilities.

The installation of the first supra-acoustic telegraph carrier system in Australia between Sydney and Melbourne in February, 1927, marked the introduction of one of the most outstanding developments in the improvement of our telegraph service.

With the development of Voice Frequency Carrier systems, action was taken to replace the earlier supra-acoustic system. The first telegraph service of this kind was brought into operation between Sydney and Tamworth in November 1935, and since that date there has been considerable expansion of the voice frequency carrier network in each State.

The first telegraph equipment used in Australia comprised a morse key, relay and register at each telegraph office. This service was later modified by replacement of the register with a morse sounder.

With this system, it was necessary for all telegrams between Melbourne and Sydney to be re-transmitted manually at Albury, all telegrams between Sydney and Brisbane to be re-transmitted at Tenterfield, while Melbourne-Adelaide and Adelaide-Perth messages were manually re-transmitted at Mount Gambier and Eucla, respectively. The introduction of electromechanical repeaters was an important development — as their installation eliminated the need for manual re-transmission at repeating centres.

Direct teleprinter working between individual centres was replaced in 1959 with the TRESS system.

The morse system virtually disappeared from the Australian scene in December 1962.

By Type (a)

Year ended 30 June	Ordinary(b)	Urgent	Press	Letter-grams	Meteoro-logical	Service	Total Telegrams
1950	28,892,425	1,988,987	287,410	97,237	3,434,606	785,013	35,485,678
1960	16,976,993	665,716	143,523	93,427	842,522	653,634	19,375,815
1970	18,216,855	453,749	63,311	32,106	1,039,952	753,993	20,559,966
1974	15,663,631	467,234	14,051(c)	18,185	1,004,497	834,042	18,001,640
1975	13,774,893	355,277	Nil	23,053	1,065,143	874,666	16,093,032
1978	7,775,779	164,497	Nil	18,916	635,598	371,252	8,966,042
1979	6,024,376	184,934	Nil	6,688	534,482	324,286	7,074,766

By States (a)

Year ended 30 June	NSW	VIC	QLD	SA	WA	TAS	AUSTRALIA
1950	13,126,824	8,029,609	5,980,781	3,917,849	3,478,670	951,945	35,485,678
1960	7,094,935	4,397,355	3,834,306	1,745,327	1,767,586	536,306	19,375,815
1970	7,013,849	3,909,064	4,464,866	2,142,959	2,486,864	542,364	20,559,966
1974	6,200,991	3,338,771	4,009,488	1,968,415	2,034,714	449,261	18,001,640
1975	5,538,671	3,014,546	3,459,333	1,751,083	1,926,285	403,114	16,093,032
1978	3,291,763	1,773,970	1,689,257	870,358	1,021,214	219,480	8,966,042

(a) Includes only those telegrams originating and terminating within Australia.
(b) Includes radiograms.
(c) Press Rate discontinued 1 October 1973.

Table 1 — Telegraph Traffic

GEORGE MASSIH was born in Tehran, Iran. He received the B.S. Hon. degree in Electronics from Salford University in U.K. From 1967 to 1972 he was engaged in computer design work with International Computers Limited in U.K. In August 1972 he joined the Postmaster General's Department. His principal work has been in the field of Telegraph and Data Control equipment design.

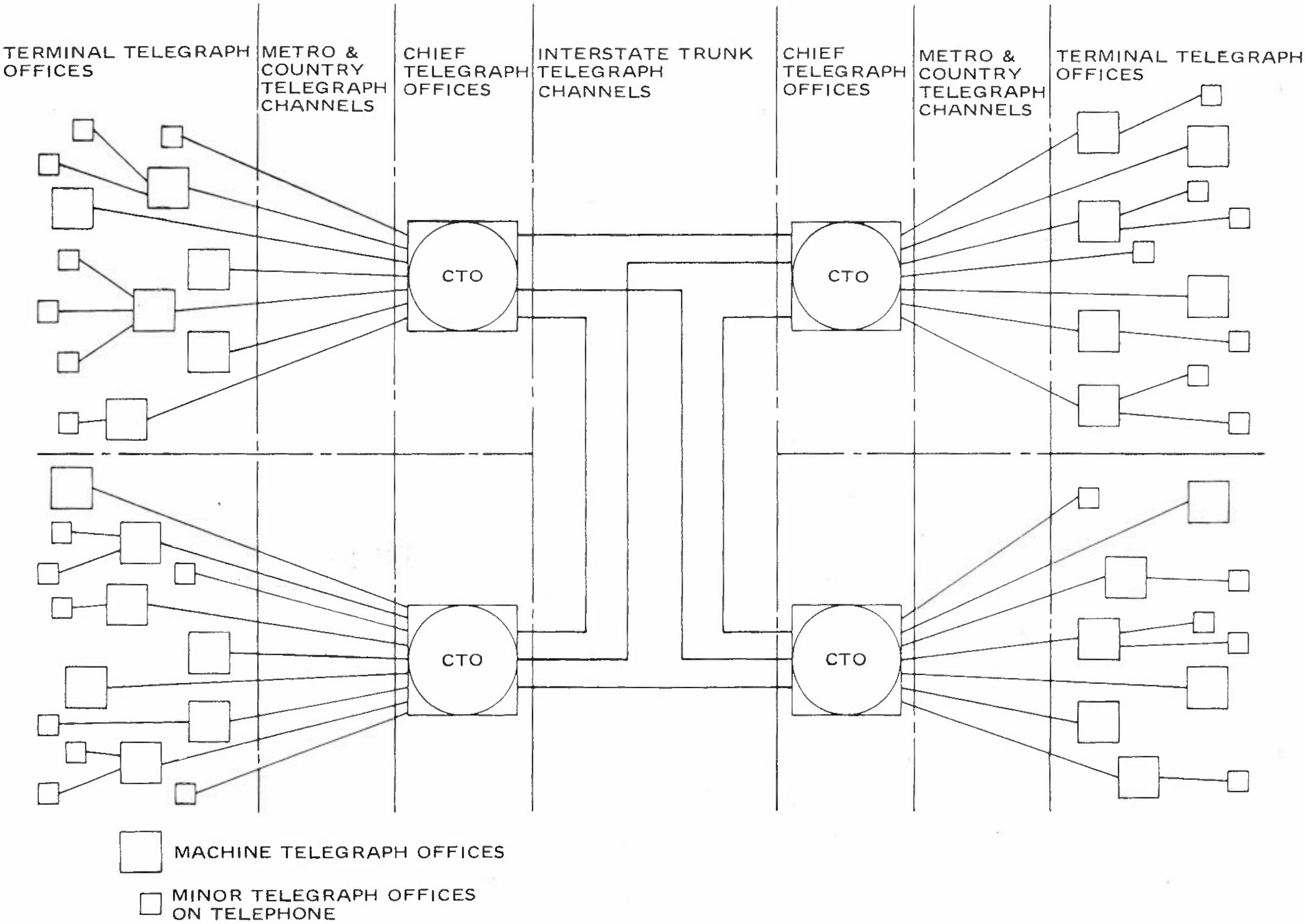


Fig. 1 — Tress Network

THE TRESS SYSTEM

TRESS is a message switching system using a paper tape store and electromechanical switching. There is no direct transmission connection between the sending and receiving offices such as is established in a telephone or telex call. All messages into the system are stored on perforated tape at the Chief Telegraph Office (CTO) and forwarded to nominated destination post office or printergram terminals when switching equipment, links and receiving channels are available for transmission.

Generally, messages are switched at only one or two switching centres in passing from originating to destination offices, intrastate messages being switched once and interstate messages twice.
Fig. 1 is a block diagram of the TRESS network.

Methods of Message Lodgement

Messages (Telegrams) may be lodged for transmission through the system by means of each of the following three methods:

- By filling a form at the local post office and handing it over the counter. Payment is made at the same time as lodgement.
- By telephone, direct to an operator at a phonogram centre at the Chief Telegraph Office (CTO). Accounting is done via the telephone billing system.
- By telex, direct to terminals located in each CTO. Accounting is done via the telex billing system.

The telegraph network over which these telegrams are sent is called TRESS (Teleprinter Reperforator Switching System).

INTRODUCTION OF VDUs IN THE PHONOGRAM CENTRES

The TRESS Network is a relatively efficient method of switching telegram traffic between outstations. However, procedures relating to injection of messages into the system involve time consuming and labour intensive operations. In brief the process is as follows:

The Phonogram operator records and edits the message on a typewriter. After word counting and calculation of charges, the message is sent to the TRESS Send area. An assistant sorts the telegram according to its destination, prefixes it with a TRESS destination and places it on a TRESS Send position. At the TRESS Send position, a Telegraphist prepares the message on perforated papertape with a keyboard perforator and feeds the tape into a transmitter which is under the control of the TRESS switching equipment.

As part of the cost reduction programme in the Public Telegram Service, a limited trial, using the VDUs on phonogram inputs as a means of accepting telephone originated telegrams and transmitting them directly through the system, was successfully completed in Adelaide, South Australia.

Following encouraging results from the trial it was recommended to extend the installation of VDUs to a total of eight units in each mainland capital city.

Currently an improved version of the trial system called VDU/TRESS System is in service in all mainland States.

Advantages evident from the introduction of VDUs in the phonogram centres are:

- Direct entry of phonogram messages into the TRESS network.
- Marked improvement in the overall message handling efficiency and the message transit time.
- Automatic Word Counting and Charging.
- Optimum Operator/Machine environment.

VDU/TRESS SYSTEM CONFIGURATION

A complete system consists of:

- A bank of eight Visual Display Units.
- An Operator Control Unit per VDU position.
- Two Controllers.
- Two Terminet T.300 monitor teleprinters.
- Two Buffer Stores.
- Two TRESS interface units.
- One error dump and retransmit system.
- One Supervisors Control Panel.

For details see block diagram of **Fig. 2.**

HOW IT WORKS

The subscriber can telephone directly to an operator at a phonogram centre.

The Phonogram Operator via the VDU keyboard enters the message on the VDU screen while the message is being received via phone from the subscriber. When the call is completed the operator is required to charge and transmit the message into the system by pressing a transmit button.

The message is transmitted at 300 Baud from the VDU position into the controller where code conversion and speed change takes place. Then information at 50 Baud is transmitted into the TRESS switching equipment via an interface.

In the following paragraphs, operation of each unit is described in more detail.

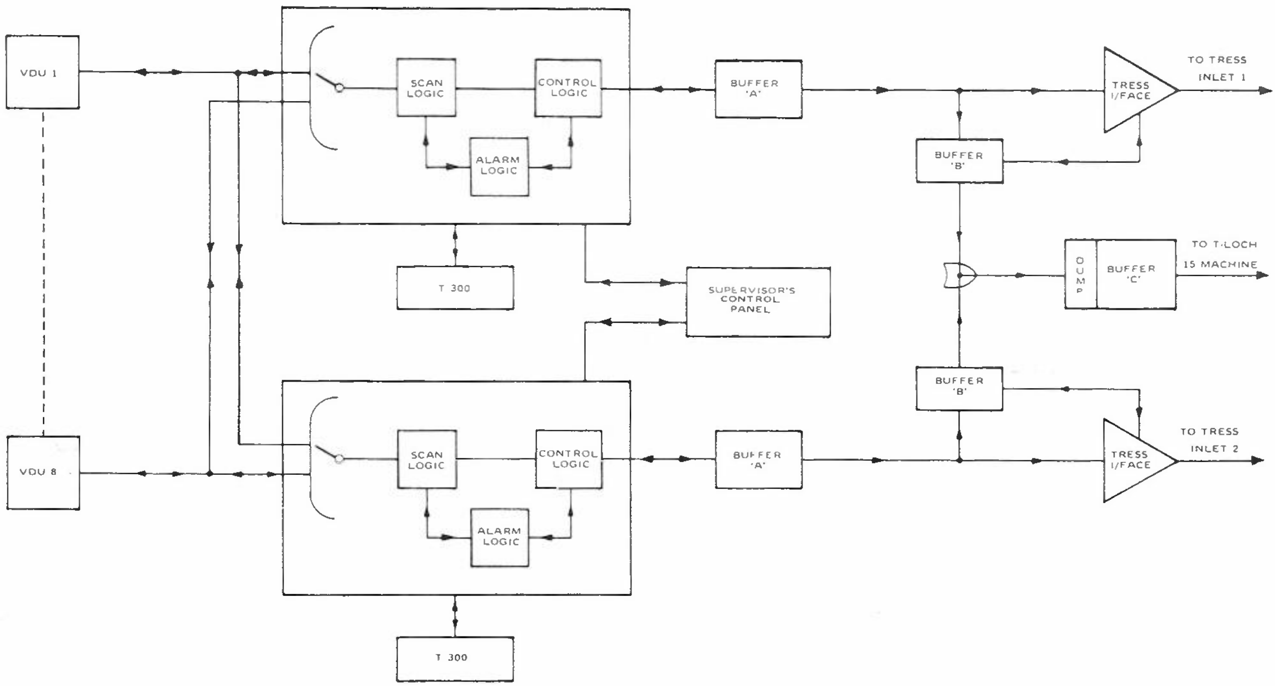


Fig. 2 — System Block Diagram

Visual Display Units (VDUs)

The VDUs are located in the phonogram operating area and provide facilities for the operator to record, correct, and transmit messages. Each VDU is selected on a cyclic basis by either of the two Controllers. The number of VDUs can be varied between two (2) and eight (8) by strapping.

Operator Control Unit

An Operator Control Unit is associated with each VDU position to provide indicators to alert the operator of the following conditions:

- Controller busy.
- Controller servicing VDU.
- Repeat transmission required.

The unit also provides a lamp test facility.

Controllers

Two Controllers are provided per eight VDUs to safeguard the service availability. The two Controllers work independently enabling simultaneous servicing of two VDUs. If one Controller fails, the other Controller will carry on servicing all VDUs sequentially.

The Controllers are designed to perform the following functions:

- Scan bank of VDUs on a cyclic basis and select the next VDU which is ready to transmit.
- Control the transmission of data from the VDU to the Buffer Store and initiate the simultaneous transmission to the Terminet T.300 monitor teleprinter.
- Recognise and check the Control Characters — Start of Header (SOH), Start of Message (SOM), Channel Sequence Number (CSN), and End of Message (EOM). And if any of these characters are missing a "Repeat" Alarm is initiated to enable the operator to edit and/or retransmit the message.
- When a "Repeat" Alarm is initiated, the connection with the VDU will be maintained until the retransmission occurs. If the retransmitted message is not acceptable to the Controller, connection to the VDU is still maintained and an Emergency Alarm operates on the Supervisors Control Panel.
- Suppress all information prior to SOM from the Buffer Store.
- Convert all characters following and including SOH from Alphabet No. 5 to Alphabet No. 2.
- Provide automatic insertion of Channel Sequence Number groups comprising three alpha and three numeric characters and increment by one the CSN groups for each message transmitted including repeated messages.
- Provide facility of presetting the CSN to any number between 001 and 999.
- Check the progress of messages at various stages through the system and generate alarms for fault conditions detected.
- On detection of Control Character or data transfer faults in the VDU/Controller a second check comparison procedure is automatically initiated to ensure efficient fault location in the system.

Terminet T.300 Monitor Teleprinter

Two receive only machines with pagewinders (one per Controller) are connected in parallel with the Controllers and receive a complete printout of all messages and their associated headers from the VDUs to provide a hard copy for record and accounting purposes. Supervisory alarms for "paper out" and "T.300 not ready" are provided and extended to the Controller equipment and the Supervisors Control Panel.

The Buffer Stores

The Buffer Store is based on the dynamic shift register principle which is used as the storage device. It operates on a "first in first out" basis so that the first character fed to the output device is the first character fed into the store by the input device.

The Buffer Store consists of two inter-connected buffers, "A", and "B", which function in the following manner. Buffer A is a destructive read out (DRO) device which stores data from the VDU/Controller and destructs as it reads out to both Buffer B and the TRESS interface.

Buffer B is a non destructive read out (NDRO) device and ensures that the data is not destroyed until the end of message sequence, Fig. Z.LTRS, has been transmitted to TRESS.

The Buffer Store provides a 50 baud output to TRESS and interacts with the line interface to control this output in response to incoming TRESS signals.

Stored data in the buffers is protected from short-term power failures by an uninterrupted power supply which also acts as a filter and maintains constant frequency.

Alarm indicators associated with the Buffer "A" store of each Controller are extended to the Supervisors Control Panel.

TRESS Interface

The TRESS interface automatically controls the transfer of data from the Buffer "A" store to TRESS.

The main functions of the interface unit are:

- Convert serial data to parallel data.
- Convert logic level to 50 volt telegraph level and vice-versa.
- Control the error dump system.
- Monitor for EOA, EOM and CID format characters.
- Monitor all incoming and outgoing control signals between TRESS and the interface.
- Clear the TRESS connection when timeout occurs due to "Held on Start", "Busy", "Number Bulletin Printer" or "Progress" alarms and transmit complete message to the error dump position.
- Switch the complete message to the error dump position immediately when an "intercept" condition is detected.
- Extend the TRESS indicators and interface faulty alarms to the Supervisors Control Panel.

Error Dump and Retransmit System

When a message is being transmitted from the Buffer "A"s to the TRESS interface it is also stored in the Buffer "B"s until the Fig. Z, LTRS, characters have been transmitted and accepted by the TRESS equipment as being correct.

Rejected messages requiring manual assistance due to invalid formats, intercepts, timeouts, and similar errors are detected and transmitted from the Buffer "B"s in the Controllers to a Buffer C which receives the messages on a cyclic basis and transfers the data at 50 bauds to the error dump positions which consist of one or more T.LOCH 15 machines located in the TRESS reperforator section.

Supervisors Control Panel

The Supervisors Control Panel is located on the rear of the equipment console and is associated with the VDU controller to indicate the status of the equipment and provide necessary controls.

THE TRIAL RESULTS

The Trial has shown that:

- VDU/TRESS is a practical method of operation.
- VDU can be a valuable adjunct to reduce labour-intensive areas of the public telegram system.
- Further improvement in attaining satisfactory operator outputs and message security, which requires little additional development/installation cost, is feasible.

In Brief

Revision of Part 9 of Standard on Graphic Symbols for Electrotechnology

The Standards Association of Australia has recently published a revision of the standard of graphical symbols for electrotechnology, Part 9, binary logic elements.

The purpose of the standard is to establish a system of graphical symbols for use in the preparation of logic diagrams representing logic functions implemented with binary (two-state) devices. The system is designed to enable the user to readily read and understand the function of the logic without requiring a specific knowledge of the technology of the device represented in the diagram or how the system is to be realised.

In its format, terminology and general treatment of the subject, the standard is consistent with the recommendation of the International Electrotechnical Commission as published in Publications 117-15, 15A, 15B and 15C. The International system, however, uses only block symbols. For purposes which require distinctive symbols for optimum usage, the decision has been made to supplement this system with distinctive symbols as used in the 1971 version for certain basic functions in a similar manner to the relevant American standard.

In the 1971 version of the standard, only positive logic was acknowledged as necessary to describe any pure logic function. The present standard complies with the International concept of mixed logic. This merely assumes that either a positive logic convention or a negative logic convention may be used to describe a function. A dual system is then described involving the basic convention, state or polarity indicators, which is called mixed logic. It is considered that no problems should arise provided that the logic convention being used is suitably identified.

Copies of AS 1102 ($9.20) may be obtained from the offices of the Association in all State capitals and Newcastle. (Postage and handling $1.00 extra.)

New Standard for Disturbances in Mains Supply Networks partly based on International Recommendations

The Association has recently published a new Australian standard (in two parts) on disturbances in electrical supply networks to provide guidance for the supply authorities, the manufacturers and the users of electrical appliances and equipment.

Part 1 of the standard (AS 2279) deals with semiconductor controlled domestic appliances with ratings not exceeding 3.6 kVA and its purpose is to specify limiting values of harmonic content produced by an electrical appliance when tested under specific conditions. Reference impedance networks and values for the relevant reference impedances are specified along with practical methods of test and calculation, while guidance is provided on the implementation of the requirements.

The preparation of Part 1 was based on the recommendations of the International Electrotechnical Commission and has been adopted to suit conditions peculiar to Australian distribution systems.

Part 2 deals with electrical equipment intended for industrial, professional and commercial purposes and household appliances rated above 3.6 kVA. It provides guidance on the maximum size of harmonic producing equipment that may be supplied from high or low voltage electricity supply systems and on the limits of harmonic voltage which may be caused at the point of common coupling.

Copies of AS 2279 Parts 1 and 2 ($6.00) may be obtained from the offices of the Association in all State capitals and Newcastle. (Postage and handling 80 cents extra.)

The Development of Cellular Plastics Insulated, Filled Cable

R. J. LEWIS, ARMIT

Following the successful development of filled cable overseas, Telecom Australia has developed and introduced a range of small size (up to 100 pairs) cellular plastics insulated filled cable, suitable for Australian environmental and manufacturing conditions. A very extensive developmental programme including contract work costing $473,000 by an Australian and a Japanese cable manufacturer, was undertaken by Telecom. The cable has been designed for direct burial in the rural section in the network, and uses copper conductors, cellular plastics insulation, a proprietary petroleum jelly filling compound, paper core wrap and a moisture barrier sheath. The more important design considerations for filled cable are described together with a summary of the electrical and transmission properties. The article also includes short sections on manufacturing, costs and installation practices; it concludes with a preview of likely future developments.

The term filled cable is used to describe a plastics insulated cable that includes a jelly like filling compound in the core, to fill as far as practicable the space normally occupied by air. **Fig. 1** shows the cross-section of Telecom's current design of filled cable. The purpose of the filling compound is to prevent the entry of water into the cable at joints or through holes that may occur in the sheath. The entry of water into the core of a plastics insulated cable has at least two undesirable effects. It increases the mutual capacitance of the cable and consequently the attenuation; it also ultimately finds insulation defects causing low insulation resistance to earth faults and eventually open circuit faults due to corrosion. These faults are often remote from the site of the sheath damage, which separates the cause and effect with substantial maintenance cost penalties. The introduction of a filling compound into the core has important immediate and long term electrical consequences for the cable and also has long term physical compatibility implications for other cable components. The immediate electrical consequence is an increase in mutual capacitance of about 20% which must be offset by increased insulation thickness or a reduction of insulation permittivity by using a cellular form, if the attenuation of the cable is to remain unaltered. The long term consequences are due to absorption of the filling compound by the insulation.

Following a very extensive developmental programme, Telecom Australia introduced a range of small size (up to 100 pairs) cellular plastics insulated filled cable during 1978, for extensive field trials in the rural section of the network. These trials were successful and routine use started during 1979.

HISTORY

Filled cable was developed in the United Kingdom and introduced into the British Post Office (BPO) network in 1964. The BPO, in common with other administrations using small size unfilled plastics cables, was experiencing a severe problem with water logged cables, and adopted the then novel concept of a filled cable to solve their problem. Initially, two types of cable were used; one with discrete water blocks 20m apart and the other with continuous filling. The latter proved to be more effective and by 1968 installation of cable with discrete water blocks had ceased.

Telecom Australia was also experiencing similar problems with water logged cable during the late 1950's and early 1960's but tackled the problem in another way. Telecom's approach included the following improvements to both their unfilled plastics cable and associated installation practices.

- A reduction in the incidence of insulation faults.
- Installation of cable in PVC pipe in urban areas.
- The use of nylon jacketed cable in areas of insect or termite attack.
- Improved jointing practices.

These approaches met with a good deal of success and reduced the need to develop a filled cable suitable for use under Australian conditions. In addition, Telecom Australia HQ considered that although the concept of a filled cable was sound, the use of petroleum jelly and polyethylene, two fundamentally incompatible materials, as filler and insulant respectively was not sound.

It was expected that new designs would emerge and in view of the success achieved with unfilled plastic cable, it would be preferable to wait for the next generation of filled cable.

By the late 1960's adequately compatible combinations of petroleum jelly based fillers and polyethylene insulants were becoming available and it was clear that the polyethylene/petroleum jelly (PE/PJ) design was meeting with considerable success and acceptance around the world. Although the general PE/PJ design was widely accepted a multiplicity of detailed design features existed. These included:

- Copper and aluminium conductors.
- Solid and cellular insulation.
- High density (HDPE) and medium density polyethylene (MDPE) and polypropylene insulation (PP).
- A wide range of fillers, generally PJ based but including additives such as polyisobutylene, low molecular weight polyethylene and a variety of stabilising systems.
- A wide range of sheath types including plain polyethylene, bonded and unbonded aluminium screens, corrugated and uncorrugated screens.

It was clear that a great deal of work would be required to develop a design fully suitable for manufacture and use in Australia.

The work was clearly beyond the capacity of resources available within Telecom, and in 1971 a schedule was issued that invited tenders for an extensive range of tests that started with tests on individual cable components and finished with tests on drums of cable. Two tenders were received, one from Australian cable manufacturer Austral Standard Cables who have strong affiliations with British Insulated Calendar Cables (BICC) of the UK, the inventors of filled cable, and the other from Sumitomo Electric Industries a large Japanese cable manufacturer. It was decided that the most satisfactory arrangement would be to let two contracts and divide the materials to be tested between the two contractors, with a small

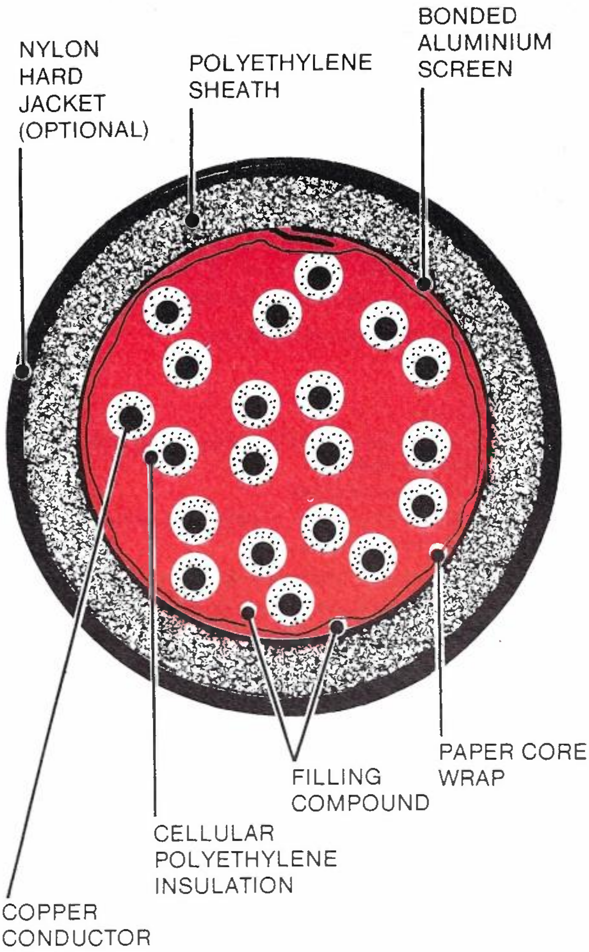
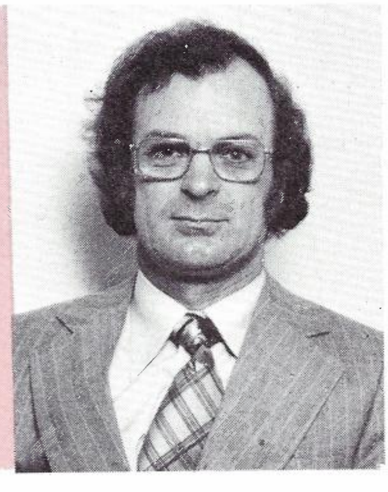


Fig. 1 — Cross-section of Filled Cable

BOB LEWIS worked as a Technician and Senior Technician on the installation of transmission and switching equipment for a short period, before attending the Royal Melbourne Institute of Technology (RMIT). He obtained a Diploma of Communication Engineering from RMIT in 1959 and spent the next seven years as project engineer on the installation of major cables; this was followed by five years as an area engineer responsible for the installation and maintenance of external plant. In 1972 he joined the Headquarters staff of Telecom Australia where he worked for six years as Senior Engineer, Cable Design. He is currently Engineer Class 4 (Construction) in the Installation Engineering Section of Lines Construction Branch at Headquarters.



overlap to allow for cross reference between the two contracts. This arrangement allowed Telecom to benefit from the accumulated knowledge of two experienced overseas manufacturers of filled cable and also to obtain early warning of any manufacturing problems peculiar to Australian conditions. Before contracts were let extensive negotiations were conducted with both companies to develop detailed test programmes, and to select promising materials for inclusion in the test programmes. The programmes each consisted of three stages and were similar but not identical. The three stages were:

(1) Tests on individual cable components:
Conductors
Insulation
Filling compound
Preliminary compatibility tests between insulants and fillers.
(2) Final compatibility tests.
Initial tests on cable samples.
(3) Final physical, electrical and transmission tests on cable samples and drums of cable.

A reduced number of materials was used in each successive stage. The contents of the test programme and the sequence of the tests are shown in more detail in **Fig. 2**. The data obtained from these contracts was used to write Telecom Australia's specifications for cellular plastics insulated filled unit twin (CPFUT) cable and cellular plastics insulated lead-in (CPFLI) cable.

The initial cable was designed for direct burial in rural areas and is of the following general design:

Conductors — Copper. Aluminium is currently more expensive in this cable design.

Insulation — High Density Polyethylene (HDPE) 35% blown. 35% expansion allows cables to be manufactured with approximately the same diameter as equivalent solid insulation air core cables. HDPE was chosen because of its good compatibility with fillers and general robustness. Two MDPE compounds have since been approved for use in filled cable.

Filling Compound — A proprietary petroleum jelly with a congealing point of 83°C, chosen primarily because of its high congealing point and good compatibility.

Core Wrap — Paper Tape. Paper is cheaper than other core wrap materials and performed well in water infiltration and core to screen breakdown voltage tests.

Core Construction — Unit Twin. Chosen for crosstalk and manufacturing reasons.

Sheath — Moisture Barrier. The use of a moisture barrier sheath rather than plain polyethylene is justified in most rural applications by the total benefits derived from increased resistance to lightning damage, elimination of possible filler/sheath incompatibility problems and high frequency screening. A bonded rather than unbonded form of screen was chosen because of its good bending properties and because it facilitates connection to the thin aluminium foil.

The two pair lead-in design is similar except that the two pairs are in quad formation, the only practical way to manufacture 2 pair cable, and there is no screen. The screen was not provided because other studies have indicated that the extension of a remote earth into a customer's premises, can present a hazard to the customer under certain conditions. In addition, it was considered to be very doubtful whether a bonded moisture barrier sheath could be economically manufactured in such a small diameter.

FILLING COMPOUNDS

The properties required of a filling compound are many and some tend to be conflicting. It must form a waterproof seal with other cable components and yet it

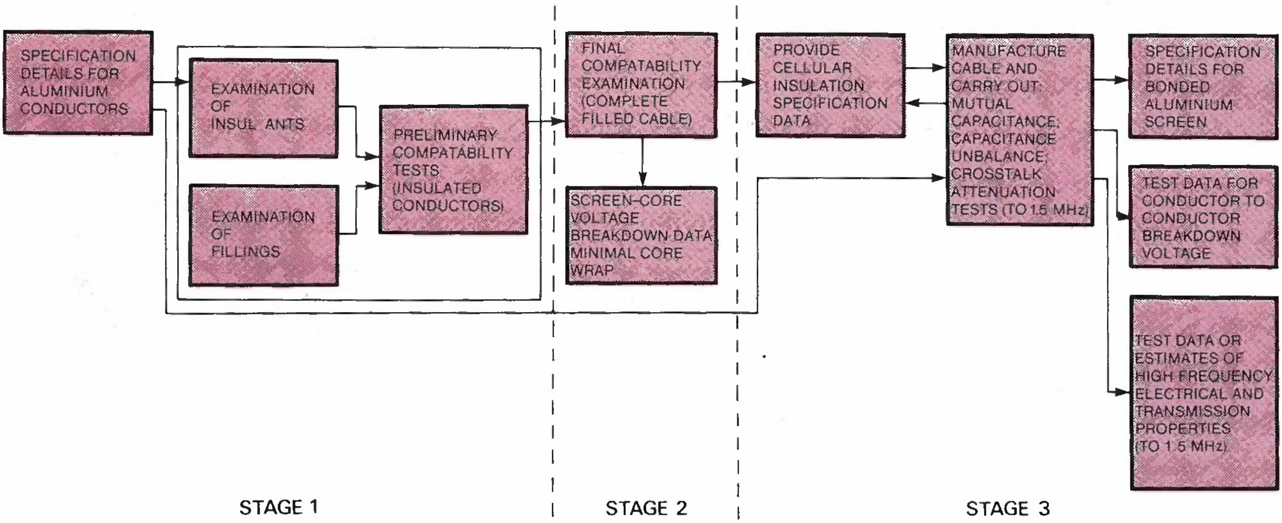


Fig. 2 — Filled Cable Developmental Contract

must also wipe off satisfactorily, it must not be unduly messy to work with and of course, not present any dermatitic hazard. Its presence must not interfere with the identification of cable conductors by colour. The compound must perform satisfactorily over a range of temperatures, not flowing or separating into its components at high temperatures and not making the cable too stiff to handle at low temperatures. The flash point should be acceptable and it should not cause corrosion of either copper or aluminium. Although it is not the primary insulation it must have good electrical properties both before and after contact with water. It must be compatible with other cable components over the 20-30 year expected life of the cable. Finally the cost and manufacturing properties must be acceptable.

Petroleum jelly consisting of a microcrystalline paraffin wax and mineral oil is the basis of most filling compounds. Some filling compounds include low molecular weight polyethylene or a higher melting point wax to raise the drop point of the filler and polyisobutylene is sometimes added to increase its tackiness.

Full laboratory evaluation of a filling compound requires three stages of testing comprising: tests on the filler itself, compatibility tests with other cable components and performance tests on complete cable specimens. The tests listed in Table 1 are considered suitable for the first stage of evaluation and the test results shown are for a petroleum jelly type of filler suitable for use under Australian climatic conditions.

Test	Test Result
General Purity (soxhlet extractor, toluene solvent)	No foreign material
Colour (effect on colours of insulated conductors)	Amber, satisfactory
Handling (subjective assessment of wiping, tackiness etc.)	satisfactory
Stability:	
Loss by evaporation 60°C	0%
Oil separation 60°C	6%
Congealing point (ASTM D938)	82°C
Cone penetration 0°C	26 (tenth of mm)
(ASTM D937) 23°C	42 (tenth of mm)
Flash Point (ASTM D92)	270°C
Volume Resistivity 100°C	7.7×10^{10} Ω m
Permittivity 1 kHz, 23°C	2.19
Dissipation factor 1 MHz, 23°C	7×10^{-3}
Effect of moisture on Permittivity	2.26
Dissipation Factor (12mm thick blocks immersed in water at 23°C for seven days.)	8.5×10^{-3}
Corrosion test (Sheets of polished aluminium and copper immersed in filler for 14 days at 80°C and then examined).	Copper — very slightly tarnished. Aluminium — not tarnished

Table 1 — Filling Compound Tests.

The effectiveness of the filling compound in a filled cable may be checked by subjecting a 1m cable specimen to a 1m head of water applied to the full cross-section of the cable end for 14 days. Tests of this type have shown that cables can be manufactured with no leakage through the core but that for moisture barrier sheathed cables it is very difficult to avoid leakage between the core and sheath, particularly along the overlap of the aluminium/polyethylene laminate tape. Water infiltration between the core and screen will not significantly degrade the transmission performance of the cable but it is considered undesirable because of possible corrosion of the screen and water entry to joints.

A more direct check on the effectiveness of the filler is to immerse specimens of cable with a damaged sheath in water and monitor the electrical properties. Tests have been made on 50m lengths of cable with 1% of the sheath removed by holes approximately 5mm x 10mm. The cable was immersed in water for eight weeks and the mutual capacitance and conductance monitored. Typical tests results obtained were a mutual capacitance increase of 5-10% over the eight week period.

The increase in conductance was in the range 150-250% but was considered satisfactory because of the very minor influence on the transmission characteristics of the cable.

INSULANTS

The oxidative stability of conductor insulation in a jointing enclosure that is exposed to direct sunlight is very important as oxidation leads to a reduction in elongation, and possibly cracking of the insulation.

Oxidative stability is a function of the base polymer and the stabilising system that has been added to the polymer. The requirement for a filled cable can be more critical than for an unfilled cable as the filling compound may leach some of the stabiliser out of the polymer before the cable has the sheath removed, and the insulated conductors exposed to the air at a jointing or terminating point.

The cellular insulation used in Telecom's filled cable design is approximately 35% blown so that the cable diameter can be approximately the same as equivalent solid insulation air core cable (See **Fig. 3**). This form of plastics insulation is not as robust as solid plastics and resistance to compression and abrasion tests are required in the design stage to determine whether the insulation will be mechanically satisfactory for manufacturing and field handling. Tests have shown that cellular HDPE and PP insulation require a compressive load about 50% greater than for cellular MDPE to cause contact between two twisted conductors. Abrasion resistance tests using insulated conductors slung over a

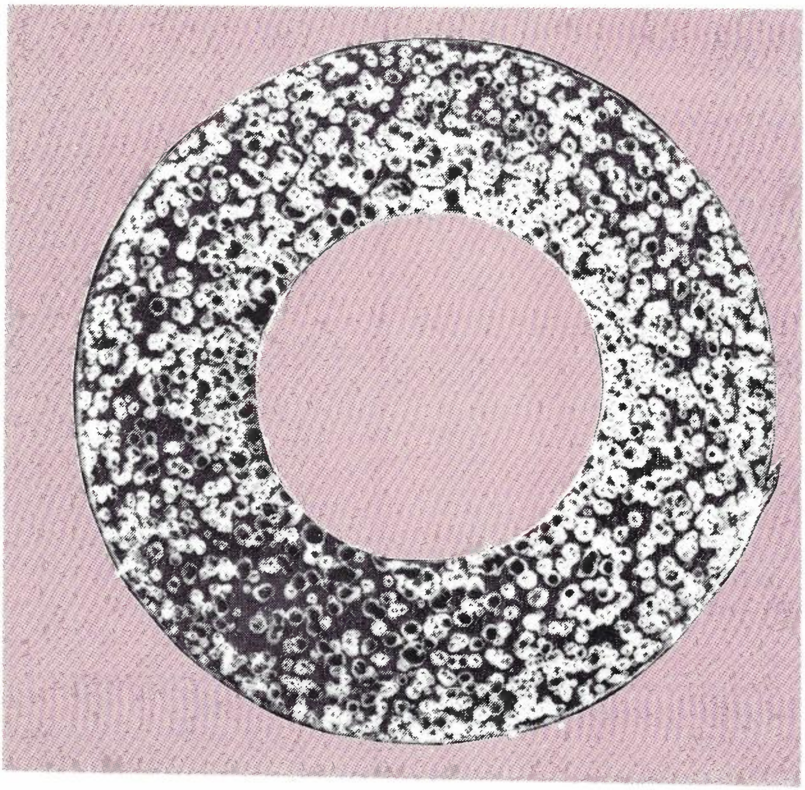


Fig. 3 — Cross-section of Cellular Plastics Insulated Conductor

rotating piano wire cage have given the following results:

MDPE (35% blown) — 2 revolutions to failure

MDPE (solid) — 16 revolutions to failure

HDPE (35% blown) — 57 revolutions to failure

HDPE (solid) — > 1000 revolutions to failure

COMPATIBILITY

All cable components must of course be compatible but the combinations of prime importance are insulation/filler and sheath/filler. Potential problems associated with the latter may be avoided by the use of a bonded moisture barrier sheath to separate the polyethylene sheath from the filler. For the insulant/filler combination it is the insulant that may be detrimentally affected by the filler. This can happen in at least three ways; the oxidative stability of the insulation may be reduced due to stabiliser being leached out of the insulation by the filler, absorption of filler by the insulation may degrade its mechanical properties and change the electrical properties of the cable.

The effect of the filler on oxidative stability may be examined by first ageing insulated conductors in filling compound and then ageing in air. Control samples that have been air aged for the whole period will also be required. **Fig. 4** shows the result obtained for all combinations of four fillers and six insulants where the ageing in filler was for eight weeks at 70°C and subsequent air ageing at 105°C.

These results also reflect changes in the mechanical properties of the insulation due to filler absorption, because the test method used to determine failure was to wind aged insulated conductor specimens on a mandrel of the same diameter as the insulated conductor. Failure was said to have occurred when the insulation cracked during or soon after winding on the mandrel.

Insulants 1, 2, 4 and 6 were different MDPEs and 3 and 5 were HDPEs. All fillers were basically petroleum jelly compounds but filler 2 included a proportion of a thixotropic agent, and filler 4 included a proportion of low molecular weight polyethylene to raise the drop point. The dotted line shown as filler 0 is for the control specimens aged in air. 42 days at 105°C is considered to be approximately equivalent to 20 years at 30°C.

Alternatively the effect of the filler on oxidative stability may be examined by performing tensile strength and elongation measurements on insulation samples after they have been aged in filler and then aged in air.

The effect of filler absorption on the physical properties of insulation can be quite varied as illustrated by the following test report on insulation specimens that had been aged in filling compound for 8 weeks at 70°C:

"Absorption: The absorption of filler by the HDPE was only slightly less than that by the MDPE for solid insulation, but absorption by 35% blown cellular MDPE was about twice that of the HDPE.

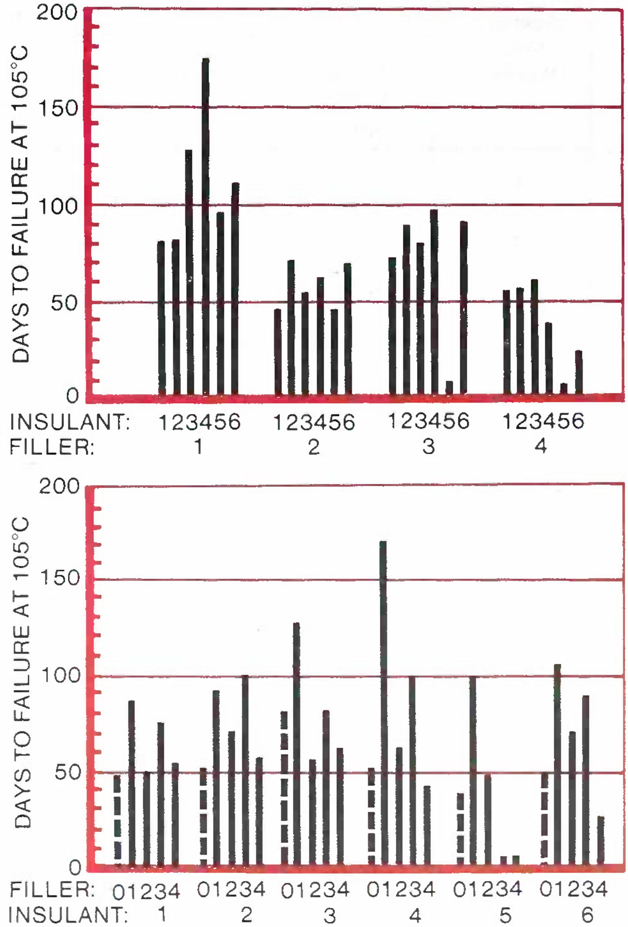


Fig. 4 — Oxidative Stability of Cellular Insulation Aged in Filler for Eight Weeks at 70°C.

Tensile strength, at yield and break, and elongation at break: The tensile strength of the HDPE increased by approximately 12% after immersion in filler compound whilst the tensile strength of the MDPE decreased by about 15%. The yield strength of both compounds increased after immersion; by approximately 25% for the MDPE and 12% for the HDPE.

The elongation at break of the solid HDPE increased by about 10% whilst that of the solid MDPE decreased by about 15%. In the 35% blown form, the elongation of the HDPE decreased by about 70% whilst the average decrease for the MDPE was about 65%. There was a wide spread of results for the MDPE with values at low at 5% of the original elongation being recorded. This was considered to be one of the most serious weaknesses of the MDPE compound."

Table 2 shows the degradation of the physical properties of the sheath of three sizes of cable aged at 75°C. In each case the sheath was low density polyethylene one side of which was in direct contact with the filler. These results clearly show that the degradation was a function of the quantity of filler available. Grades of sheathing

Ageing Time Weeks	100 pair, 0.4mm		30 pair, 0.4mm		10 pair, 0.4mm	
	Break Stress (MPa)	Elongation at Break (%)	Break Stress (MPa)	Elongation at Break (%)	Break Stress (MPa)	Elongation at Break (%)
0	12.25	525	10.60	460	10.41	568
2	9.04	112	7.58	150	8.03	449
4	8.23	97	7.96	128	8.61	472
8	9.07	93	7.74	141	9.31	537
12	8.35	76	7.70	109	8.33	490

Table 2 — Physical Properties of Polyethylene Sheath of Cable Aged for 12 weeks at 75°C

polyethylene approved for use in Telecom's cables do not degrade as much as this material.

Absorption of filler by solid insulation will cause swelling and the absorption of filler by cellular insulation will cause swelling and possibly cell filling. Swelling will reduce the mutual capacitance while cell filling will increase the mutual capacitance. Accelerated ageing tests on cable with solid HDPE insulation at 70°C show a continuing drop in mutual capacitance amounting to about 2.5% after 300 days. For cellular HDPE insulation the mutual capacitance initially falls by about 1%, but by 300 days at 70°C it has returned to the original value and is rising quite steeply. 300 days at 70°C is considered to be approximately equivalent to 25 years at 20°C. Expert opinion is divided on whether cell filling occurs below a certain temperature and there is some doubt that any cell filling will take place at ground temperatures encountered in Australia.

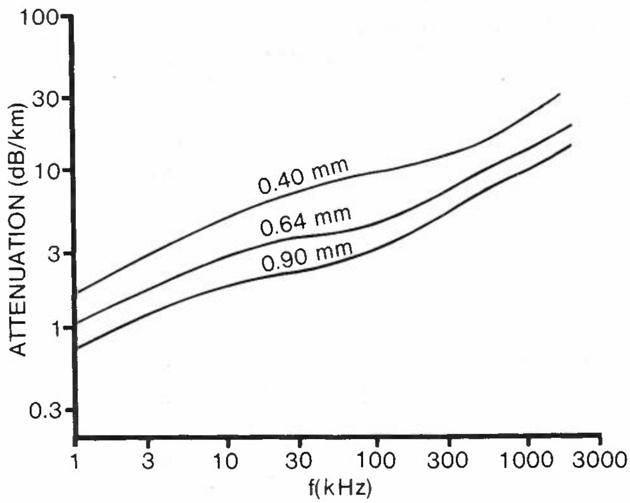


Fig. 5 — High Frequency Attenuation 0.40, 0.64 and 0.90mm Filled Cable

TRANSMISSION, CROSSTALK AND ELECTRICAL PROPERTIES

Transmission: As Telecom's filled cable is manufactured with the same gauge copper conductors and the same mutual capacitance as equivalent unfilled solid plastics insulated cable the voice frequency attenuation is the same for both types of cable. Measurements have been made up to 3 MHz which showed predictable changes in primary and secondary parameters with frequency, and confirmed that neither the filling compound nor residue from the blowing agent used had degraded the high frequency performance of the cable. **Fig. 5** shows the attenuation versus frequency characteristics obtained from measurements made on 0.40mm, 0.64mm and 0.90mm cables.

Crosstalk: The capacitance unbalance design objective for Telecom's filled cable was to meet the limits set for small size unfilled plastics cable. Tests on drums of filled cable indicated that the pair to pair unbalance limits could be met comfortably and that similar results to unfilled cable could be expected. The side to earth capacitance unbalance results were somewhat worse than would be expected for an unfilled cable; subsequent investigation revealed that this is a predictable effect inherent in filled cable. The results obtained from Crosstalk measurements on 1 km drums of cable carried out at 1 MHz are shown in Table 3.

Breakdown Voltage: As Telecom's filled cable is initially intended for directly buried rural use, the lightning performance and consequently the screen to core breakdown voltage is very important. Results obtained during the test program for three types of core wrap showed that paper performed better than the other more expensive core wraps tested; a summary of the results obtained from tests on 1m samples is contained in Table 4. The tests also confirmed the prediction that most failures would occur at the end of the sheath where there is an electrical potential stress concentration associated with the end of the aluminium screen.

Crosstalk Average / worst — Cable	Within Unit		Between Adjacent Units		One Unit Separation	
	NEXT (dB)	FEXT (dB)	NEXT (dB)	FEXT (dB)	NEXT (dB)	FEXT (dB)
10/0.40mm	67.1 49.6	64.9 49.8				
50/0.64mm	69.7 50.8	65.7 38.7	68.8 53.4	67.4 41.9	81.2 60.0	76.5 52.7
10/0.90mm	69.5 46.7	67.3 50.7				

Table 3 — Crosstalk Measurements on 1 km Drums of Cable at 1 MHz

When open wire aerial lines are connected to cable, insulation breakdown between conductors is a possible failure mode. The conductor to conductor breakdown voltage for cellular plastics insulated cable is less than for solid plastics insulation of the same thickness and it may be desirable to provide protection at the cable head where cellular insulated cable is used. A summary of the results of conductor to conductor breakdown voltage tests carried out on 10m samples of filled cable is contained in Table 5.

Cable Size / Core Wrap	10/0.4mm Average BD Voltage (kVac)	10/0.9mm Average BD Voltage (kVac)
Paper	6	8.0
Textile	4.25	6.2
Permeable plastic	3.9	6.45

Table 4 — Screen to Core Break-Down Voltage

Conductor Gauge (mm)	Average Breakdown Voltage (kVac)
0.40	3.3
0.90	5.8

Table 5 — Conductor to Conductor Break-down Voltage

MANUFACTURE

The manufacture of filled cable follows the usual cable manufacturing stages of:

- wire drawing
- insulating
- twinning
- unitising
- cabling
- sheathing

The production of the cell structure in the plastics insulation is generally achieved by the chemical decomposition of a blowing agent during extrusion. The blowing agent is usually precompounded into the polymer pellets but it is possible to achieve a similar result by dusting pellets of normal polymer with a blowing agent before they are fed into the extruder.

The control of the degree of blow is very important in achieving the desired mutual capacitance and uniform properties in the cable. Consequently, although the extruders used are of the same general design as extruders used for solid plastics insulation, far more precise control is exercised over extruder temperatures, wire preheat and line speed. In addition, an automatically controlled, variable position water bath is used to quench the expanding insulation and provide fine control of the degree of blow.

An additional process is of course required for filling the cable core. This process takes place between the cabling and sheathing operations and is generally carried out in tandem with the sheathing process. The cable core is fed through a filling tube which contains semi molten filling compound under pressure, prior to the application of the core wrap. A further application of filling compound is made by flooding over the core wrap immediately before the application of the sheath. **Fig. 6** shows the general arrangement of a typical filling and sheathing line.

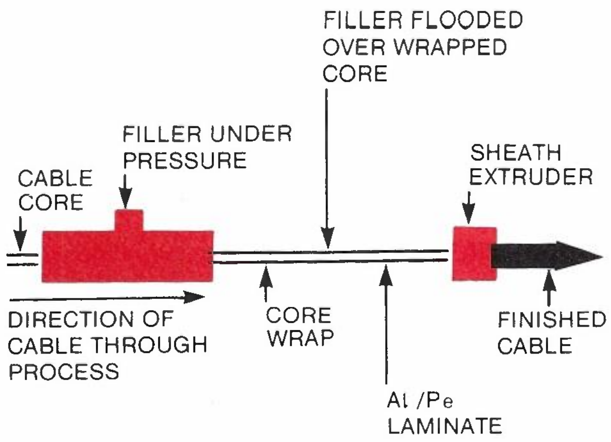


Fig. 6 — Typical Filling and Sheathing Line

COST

Filled cable purchased under the first contracts during 1978 was approximately 45% more expensive than unfilled small size plastics cable (PEIUT); this was due in part to the extensive testing required on these initial contracts. Tendered prices for the second schedule show a substantial reduction, now that it has been possible to reduce the testing required, and manufacturers are more familiar with the processes and are thus able to price more accurately. The cost differential between PEIUT and CPFUT has combined with supply difficulties to limit the penetration of CPFUT in the rural subscriber network; work is in hand at Telecom Headquarters to reduce this cost differential.

Compared with equivalent paper insulated unit twin (PIUT) with an alloy lead plastics jacketed (APJ) sheath, which is used primarily in the minor trunk and junction section of the network, filled cable purchased under the first contracts was approximately 43% less expensive. In addition, to this initial saving, further savings will accrue during the life of the filled cable as a cable pressure alarm system is not required.

INSTALLATION PRACTICES:

Filled cable is heavier and stiffer than its unfilled counterpart due to the filling compound; in Telecom's design the moisture barrier sheath also contributes to the greater stiffness. It is however required to meet the same minimum bending radius of 16D that is specified for unfilled cable. The moisture barrier sheath results in the overall diameter being about 1mm greater than for the same size PEIUT with a plain PE sheath. These characteristics do not require any change in cable ploughing techniques and the same equipment that is used for PEIUT or PIUT cable may be used.

Although cellular polyethylene insulation is less robust than its solid counterpart, (note, however, that cellular HDPE may be more robust than solid MDPE) filled cable can be jointed in openable joint enclosures and above ground jointing posts. It is of course necessary to connect the moisture barrier screens of the cables being jointed and to provide the facility for connection of the screen to earth where required.

FUTURE DEVELOPMENTS

Use of Filled Cables in Urban Distribution Areas.

The initial cable was designed to be suitable for direct burial in rural areas. A less expensive design suitable for use in pipe in urban distribution areas is being considered.

Need for Nylon Jacket.

About 80% of the sheath length of small size plastics cable in 0.64mm and 0.90mm gauges is purchased with a nylon jacket. The cost of unjacketed filled cable is slightly less than jacketed unfilled cable.

There is some evidence that an unjacketed filled cable with a moisture barrier sheath may provide adequate protection against insect and termite attack in areas of low to moderate hazard. Laboratory tests are being set up to determine the resistance of this type of cable to attack and if results are encouraging field trials will be set up.

Evaluation of Lightning Performance

One of the reasons for providing the aluminium moisture barrier screen was to increase the resistance of the cable to lightning damage, compared with a plain polyethylene sheath. Screen to core breakdown voltage tests were conducted as part of the developmental programme; further laboratory tests are now being conducted to assist in determining whether the sheath as currently designed functions effectively in reducing lightning damage to the cable and the equipment and loading coils connected to the cable.

Large Size Filled Cable.

Large size filled cable is currently used by some overseas administrations. The BPO purchased and installed a small quantity but although satisfied with the performance of the cable did not proceed to routine use because of the adverse reaction of cable jointers. The performance of the pressurised main and junction cable network in Australia has been very good and a change to filled cable would not be undertaken until clear economic advantages have been demonstrated and all industrial aspects fully considered. Application in towns where no pressurised network exists e.g. new mining towns, appears particularly attractive.

New Design Concepts.

In recent years a number of fundamentally different new designs have been reported in the world literature. None of these has yet challenged the supremacy of the plastics insulation/petroleum jelly filling design.

CONCLUSION:

Substantial quantities of small size filled cable are now being installed in the rural customer distribution network. The wide scale use of the cable in this application will depend on the relative long term total cost structure of filled cable network compared to unfilled cable networks.

The cable is currently replacing lead alloy sheathed paper insulated minor trunk and junction cable with substantial cost savings.

The considerable cost of the developmental work is considered justified, as it is expected that filled cable will be used extensively, and that the cost penalty of introducing an inadequate design could have been very great. In addition, a greatly increased knowledge of cellular plastics insulation technology has resulted within Telecom Australia, the Australian cable industry and its raw material suppliers. This knowledge is proving to be of great value in the development of other cables based on this technology, particularly large size dry core cellular plastics cable as a replacement for both large size solid plastics insulated and paper insulated cable.

In Brief

New Australian Standard for the Layout of Typebar Typewriter Keyboards will Provide Convenience for Operators

The Standards Association of Australia has published a new standard for the layout of Typebar Typewriter Keyboards — QWERTY — which is intended to introduce characters necessary for the proper and convenient use of the modern metric units as specified in AS 1000, and to establish key positions for these and other characters.

The degree symbol (^{0}) and superscript digits 3 and 2 are among the new symbols introduced and these will enable quantities such as 20 degrees Celsius and 50 cubic millimetres to be typed in proper metric notation: 20^{0} and 50 mm^{3}, respectively.

While the layout of the alphabet and numerals in QWERTY keyboards has been well standardized, the positioning of punctuation marks and graphic symbols has been inconsistent. The new standard defines specific keys for all of these characters.

In preparing this standard, account has been taken of existing Australian and International standards, including the standard for the keyboard layout of data processing equipment which incorporates keyboards. The new typewriter keyboard layout has several key allocations which are common to computer keyboards and should assist operators who are required to alternate between the two keyboards.

Copies of AS 2287-1979 ($2.00) may be obtained from the offices of the Association in the State capitals and Newcastle. (Postage and handling 50 cents extra.)

New Australian Standard for Office Machine Keyboard Layouts

A new Australian standard for the layout of numerals of office machine keyboards has been published by the Standards Association of Australia.

The new standard AS 2250 applies to data processing equipment and all office machines, including calculators. The keys controlling the decimal sign, minus character and 'space' are also covered.

This standard is technically identical to ISO 3791.

Copies of AS 2250 ($3.00) may be obtained from the offices of the Association. (Postage and handling 50 cents extra).

New Guide for use of Sound Measuring Equipment — MP 44

The Standards Association of Australia announces the publication of a new guide which provides basic information and procedures for making objective sound measurements with portable sound level meters.

Guidance is given in this publication on types of sound level meters, types of sounds and how they are identified, measurement techniques and the reporting of the information obtained. It also describes the use of sound level meters under various environmental and physical conditions so that the measurements will provide comparable and reproducible results.

Copies of MP 44 ($6.00) may be obtained from the Association in the State capitals and Newcastle. (Postage and handling 80 cents extra.)

In Brief

New Technology Gets Green Light

In spite of low research and development budgets and geographic isolation from the mainstream of innovative technology advances, Australian expertise continues to confound world scientific communities with the regularity of breakthroughs of global significance.

But whilst some of our successes in fields such as solar energy and air navigation systems receive widespread attention, many leading achievements get little public recognition.

An area where Australian innovation has scored remarkable success is the application of microprocessors. In recent years the Australian electronics industry has led the world in the development of signals communications systems for traffic lights.

The efforts have resulted in worldwide recognition for the system and exports to Holland, Ireland, France, Belgium, Canada and Asia.

The latest overseas contract was for seventy of the new systems worth $3.5 million from a traffic control authority in Kuala Lumpur.

The new series of traffic controllers, designed and manufactured locally contain a microprocessor which dynamically controls and co-ordinates the complex light switching tasks according to traffic flow demand.

The system was first developed to satisfy a tender, issued by the NSW Department of Main Roads back in 1973. Although the tender specified hardwired logic machines an electronics industry submission recommended the revolutionary approach of using a microprocessor controlled by software logic.

The Department's adventurous acceptance of the new technology was partly a response to a pressing shortage of funds for freeways and roadworks, the need to maximise the efficiency of existing arterial roads and to more efficiently improve traffic flow at the most common bottleneck points — street intersections.

Since that decision, according to an electronics industry spokesman, "The NSW DMR has literally moved streets in front of the rest of the world in this field. The feeling is that Australia is a good couple of years ahead of

Assembly of the Mothercard by the Australian Electronics Industry for the Minicomputer of the Australian Designed and Manufactured Traffic Controller, regarded as the most Advanced System of its Kind in the World.

American efforts. Their systems aren't nearly as intelligent as ours which are regarded as the most advanced traffic control systems available in the world."

The microprocessor controlled traffic lights are already in widespread use throughout all Australian states.

An extension of the basic application by the DMR is its implementation of the SCAT system (Sydney Co-ordinated Adaptive Traffic System. This will use over 1000 traffic controller units grouped into eleven zones. Each zone is to be controlled by a regional minicomputer linked directly to the controllers in its zone and itself linked to a central processor. Each of these hierarchical levels is linked to the adjacent level by means of a serial communications network using leased Telecom telephone lines.

This network of distributed intelligence will enable independent control of traffic by the local controller most of the time but with the ability of the master system to act in a supervisory role and, using the communications links, to initiate corrective action where a malfunction has occurred.

This system, in effect, puts intelligent computing power on the street corner. With this capability the local controller will be able to process both supervisory commands and the demands of the traffic.

In carrying out its normal traffic control tasks, the local controllers will also collect information on traffic volume, and data on the space between vehicles.

After processing, the information will be communicated to the master unit. After receiving data from all the controllers in its region the master will programme an overall plan to best satisfy traffic flow to and from adjacent areas and signal each controller accordingly. As far as possible, however, the local controller will decide its own actions in order to minimise local delays.

Heart of this revolutionary approach to traffic control is the unique software to be used to programme the microprocessors. The communications software in the package will allow detailed examination of the operational controller for both diagnostic and control purposes. For example, by comparing the actual vehicle count per unit against a stored mean value the controller will be able to report suspect loop detectors to the control centre within a short time of the fault occurring.

Development of the software was also a joint DMR/electronics industry exercise and is a continuing effort. Research in this area led to the release of a second generation controller earlier this year.

The total concept of computerised traffic control is an age removed from the electro-mechanical controllers still operating in most parts of the world. Constructed from such building blocks as motorised cam switches, timers and relays, each of these older controller units must be manually reset with new instructions to meet changed traffic conditions.

The use of minicomputers communicating with networks of intelligent logic modules means that a local controller's actions can be completely reorganised immediately simply by keying new instructions into the system from a remote video-keyboard terminal.

A further exciting dimension of this network already in practical use, is a terminal mounted in a NSW police helicopter. Hovering above a congested intersection, new instructions can be communicated to the ground controller to help alleviate the problem and ensure the resultant traffic movement continues smoothly through surrounding intersections. With this flexibility chaotic traffic jams can be found and fixed on the spot.

Although the technology was not applied until 1975 when the first local manufactured controller was delivered for field trials, development of the system had been supported since 1972 by a project team of six engineers working on applications research and developing manufacturing techniques.

"The effort has been very good for Australian industry", according to the Chairman of the Australian Telecommunications Development Association, Mr Alan Deegan. "This is the type of technology which is going to impact powerfully on the future direction of this country and transform our lifestyles in the 1980s." "It is already the very essence of modern defence systems for communications and weapons control." "In terms of manufacturing, in a few short years there will be few areas not utilising this technology." "Our desperate need is to develop a continuing self reliance in these fields."

According to the A.T.D.A., traditional company structure and conservative management styles are also impeding Australia's progress into the high technology age and will need to be drastically revamped.

"To handle the new technology requires a total rethink by companies of their management philosophies and by Governments of the types of manufacturing industry they must support in the future", said Deegan.

"This will be necessary also to satisfy overseas prime contractors that local manufacturing has not only the skills, a fact which has long been acknowledged, but that a satisfactory economic climate exists in the local electronics industry which will efficiently support their commitment." "Impressive breakthroughs such as those which now guide our traffic are the lifepulse for a continuing viable electronics industry."

LEDs as Replacement Lamps in Existing Switchboards

I. A. DEW, M.Sc., M.A.I.P. and A. MURFETT B.Sc. (Hons.), Grad. A.I.P.

Incandescent switchboard lamps have remained the preferred source of illumination despite their relatively short service life and high replacement costs. Light emitting diodes as presently produced while offering substantially greater life expectancies cannot compete with the incandescent lamp because of their much lower luminous intensity.

This article makes a critical comparison of the two types of light source and presents evidence to show how the deficiencies of the LED may be overcome. A prototype development of a multichip LED, designed for use as a switchboard lamp is described.

BACKGROUND

Future switchboard equipment will undoubtedly be designed for LED (light emitting diode) lamps. However, existing switchboards use incandescent lamps and lamp failures comprise a significant proportion of the total maintenance cost per switchboard. The cost to replace a switchboard lamp, including transport and overheads, is of the order of $20.

While LED lamps would appear to offer a reliable alternative, the total light emitted from any of the varieties currently available is considered to be too low for use as a direct replacement of existing switchboard lamps. Accordingly a novel LED lamp has been developed by the authors to overcome this disadvantage.

This paper discusses the electrical and optical properties of incandescent and LED lamps and the factors which in general are regarded as affecting their life expectancy. Results of life tests of LED lamps are presented. Finally details of an LED construction adopted to overcome what are seen as the shortcomings of the current LEDs available are presented together with the measurements of luminous intensity made which suggest that an LED lamp as described may be suitable as a direct replacement for the incandescent switchboard lamp.

Optical Quantities and Units

A brief description of relevant radiometric and photometric quantities and units is contained in the Appendix.

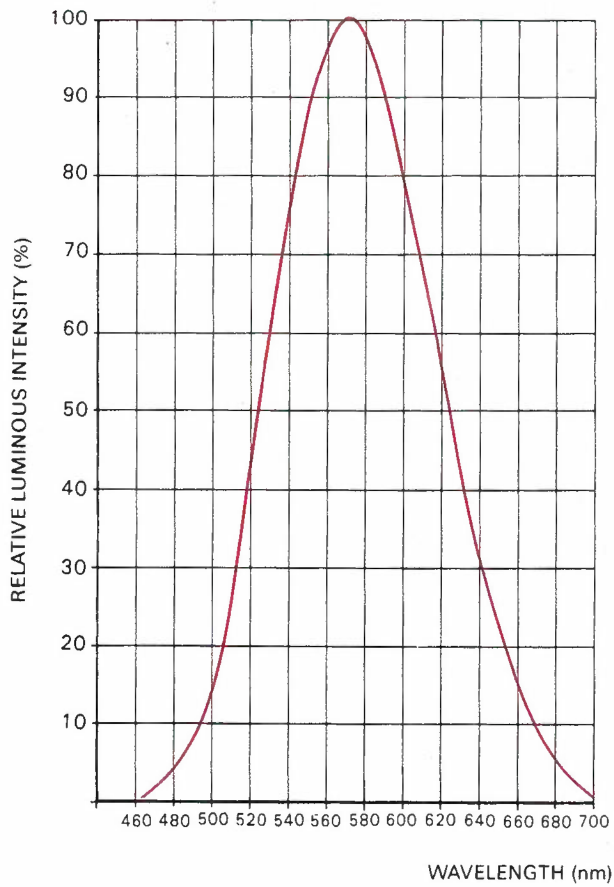


Fig. 1 — **Relative Luminous Intensity of an Incandescent Switchboard Lamp as a Function of Wavelength.**

INCANDESCENT SWITCHBOARD LAMPS

Incandescent Lamps

An incandescent lamp contains a tungsten filament which operates as an essentially black-body radiator at a temperature of 1700-2300 K. Such a high filament temperature (iron melts at 1800 K and boils at 3000 K) is necessary because the luminous efficiency increases and the colour of the emitted light is whiter, with increasing temperature. The upper operating temperature is limited by the melting point of tungsten (3650 K) and more practically, from the viewpoint of lamp life, by evaporation of the filament and consequent deposition of dark deposits on the bulb at somewhat lower temperatures. To operate at around 3000 K a halogen gas is introduced and the bulb made from silica — the 'quartz-halogen' lamp.

Luminous Properties

Traditionally incandescent switchboard lamps have been rated by their total luminous flux which is typically around 1-3 lumens (lm.) The luminous efficiency of incandescent switchboard lamps as a source, and the luminous efficiency of the radiation, is of the order of 1 lm/W. **Fig. 1** shows the relative luminous intensity as a function of wavelength.

As bulb and filament shapes and filament position vary widely the angular distributions of luminous intensity also vary considerably. The relative luminous intensity of one incandescent switchboard lamp in a lampholder as a function of angle is shown in **Fig. 2.** Also shown is the average of the luminous intensities through particular red, green and yellow lamp caps. Maximum luminous intensities of incandescent switchboard lamps are of the order of 200-500 mcd.

Life Expectancy

The life of incandescent switchboard lamps is inversely proportional to about 13th power of operating voltage (Ref. 1). Life testing is often conducted with a voltage of 110% or 120% the nominal operating voltage, giving an

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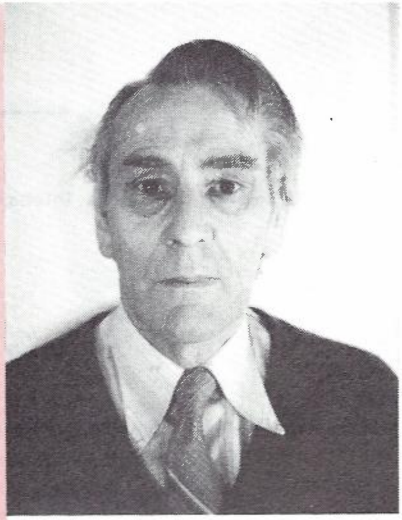
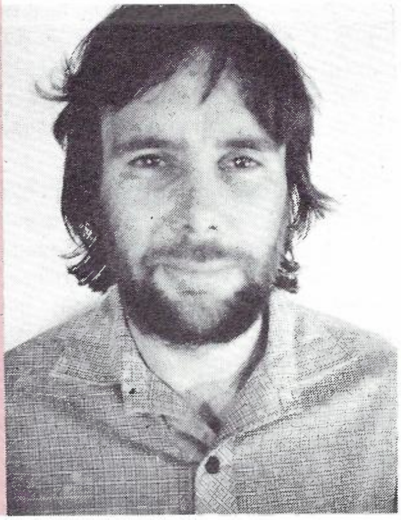
Since joining Telecom he has worked on a number of projects including reed relays for the 10C exchange, Miniswitch for the Minimat PABX and light emitting diodes.

At present he is Section Head of Applied Physics in the Applied Science Branch.



ALAN MURFETT joined Telecom Australia in 1974. Since then he has worked as a physicist in the Physical Science (now Applied Science) Branch of the Research Laboratories. He graduated from La Trobe University with a B.Sc. (Hons) in 1973.



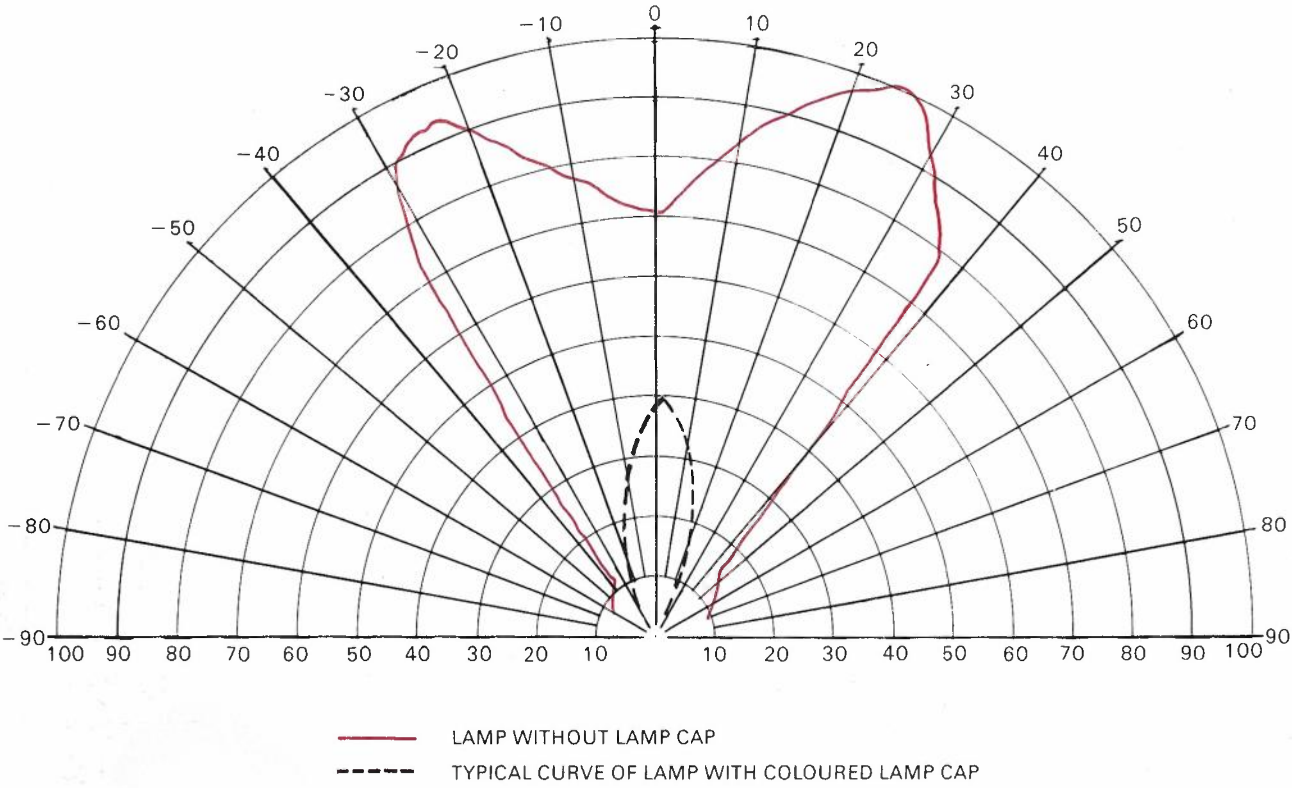


Fig. 2 — Relative Luminous Intensity of an Incandescent Switchboard Lamp in a Lamp Holder with and without Lamp Caps as a Function of Angle.

approximate life reduction factor of 3.5 or 10 respectively. Test experience is that with 20% overvoltage the median life of a batch (time at which 50% have failed) rarely exceeds 1000 h, i.e. anticipated median life at normal operating voltage is generally less than 10 000 h. Lamps used in the Bell system are stated to have a median life expectancy of about 2 years (Ref. 2). During life testing it is not uncommon for lamps to fail within several hundred hours of operation and in some cases failures occur after only several hours operation.

The electrical resistance of a cold tungsten filament is much lower than its operating resistance which causes a switch-on current surge of typically several times the operating current lasting for milliseconds. It is common experience that incandescent globes for household lighting often fail immediately after being turned on. Despite this, life tests on incandescent switchboard lamps (see, for example, Ref. 3) indicate that switching is not a significant factor. It is considered that this is due to different priorities in the balance of luminous efficiency with life for household and switchboard use, a longer life being more important in the latter area. The economics of incandescent lamps is discussed in Ref. 1.

Shock and vibration can cause lamp failures to both operating and non-operating lamps.

Heating Effects

Less than 1% of the radiant flux emitted from a black-body radiator at 2000 K has a wavelength less than 700 nm, i.e. is non-infra red radiation. The percentage for an incandescent lamp is higher, due to greater absorption of the infra red than visible by the glass envelope and the removal of this absorbed radiation by conduction.

A 48V 30 mA incandescent switchboard lamp radiates/dissipates approximately 1.5W of heat. Switchboards are designed to cope with this by allowing suitable clearance between lamps and between each lamp bulb and its lamp cap.

Other Properties

Switchboard lamp filaments are usually single coil or of coiled coil construction. Vibration can cause shorting of adjacent coils and the consequent transient currents appear as noise.

LIGHT EMITTING DIODE (LED) LAMPS

Electroluminescence in Diodes

That visible light could be emitted by diodes has been known since about 1955 (Ref. 4). Early observations were made on reverse biased diodes under avalanche breakdown conditions but the present forward biased diode methods are more efficient.

A brief description of the LED light emission mechanism follows. In semiconductor materials the energies of electrons are confined to certain ranges, those of interest being the valence band and conduction band. In a pure semiconductor electrons cannot exist between these bands and a certain energy is required to transfer an electron from the valence band to the conduction band. The controlled addition of donor atoms (n-type doping) which adds electrons to the conduction band and of acceptor atoms (p-type doping) which adds electron vacancies, known as holes, to the valence band permits the formation of a p-n junction. Such a junction, which allows current flow in only one direction, is the basis of a p-n junction diode. Current conduction near the p-n junction involves recombination of electrons and holes and the energy of recombination can be released as heat (phonons) or radiation (photons). In a LED conditions are optimised for photon emission. The energy of the photon emitted, i.e. its wavelength, is determined by the energy band gap of the semiconductor. The semiconductor materials in currently available LED's are GaAs, GaP and a mixture $GaAs_xP_{1-x}$, in which the As and P concentrations are varied. **Fig 3** shows the energy-momentum (really the wavevector which is related to momentum) diagram of a GaP green LED, emission wavelength 560 nm, and a GaAsP ($GaAs_{0.6}P_{0.4}$) red LED, emission wavelength 650 nm. From the diagram it can also be seen that some recombinations are direct transitions (GaAsP on diagram) and others are indirect transitions (GaP on diagram) requiring an intermediate step so that momentum is conserved.

Detailed descriptions of LED fabrication and the mechanism of light emission may be found by reference to text books or published articles (Ref. 5, Ref. 6).

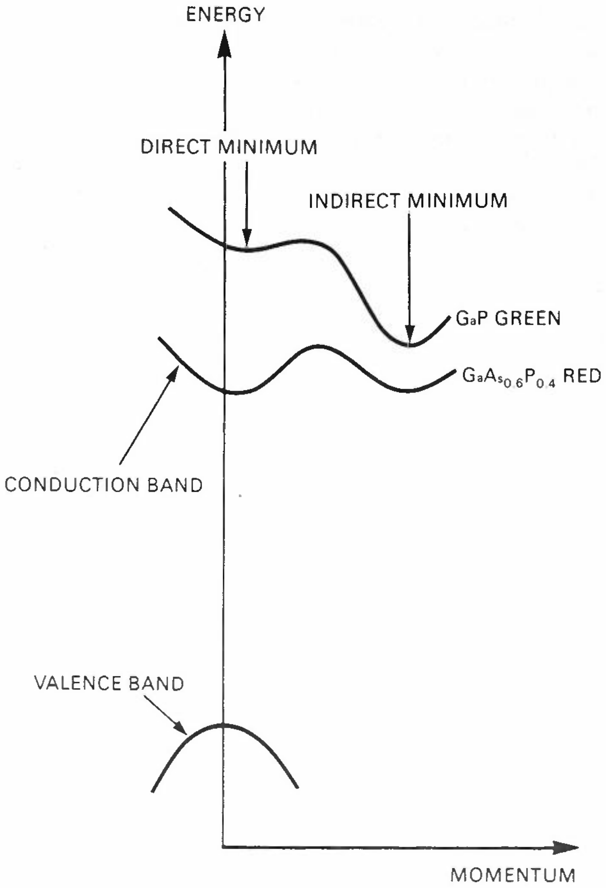


Fig. 3 — Energy Momentum Diagram for Red and Green LEDs (Adapted from Ref. 6).

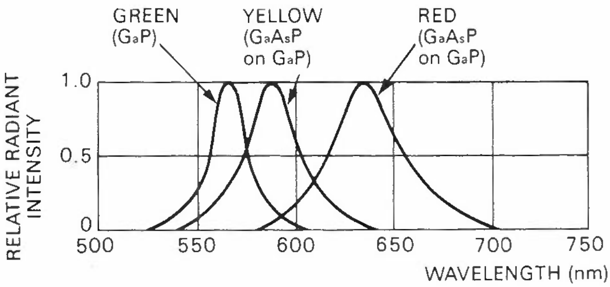


Fig. 4 — Wavelength Distribution of Several Currently Available LEDs.

Luminous Properties

The wavelength distribution of several currently available red, yellow and green LED lamps is shown in **Fig. 4.**

Typical values of the luminous efficiency (total luminous flux emitted per watt of electrical power consumed) for LED lamps as light sources are 100 to 500 m lm/W. **Fig. 5** (see Appendix for discussion) shows that the human eye has a poor response to red light; for example at 650 nm the response is one-tenth of its maximum. Combining Figs. 4 and 5 gives the result that typical ratios of the luminous flux in lumens to radiant flux in watts emitted by different coloured LED's are: red, 135 lm/W; yellow, 540 lm/W; green 640 lm/W (Ref. 6)

Being roughly point sources with spherical symmetry about the forward direction, LED lamps are generally characterised by their maximum luminous intensity and the half angle of the emitted cone of light. The lower limit of the half angle is generally taken as the point where the luminous intensity is 50% of the maximum. The maximum luminous intensities currently available commercially are around 30 millicandela (mcd) for a 10 mA forward current and a half angle of approximately 10°. Half angle is just as important as maximum luminous intensity; for example one LED lamp with a half angle of 12° has a relative luminous intensity of about 5% at 45° off axis, and would hence be unsuitable in applications where off axis visibility is essential. From a construction viewpoint the angular light distribution of a LED lamp is basically controlled by the positioning of the chip in relation to the lens, the lens shape and lens material. As the total luminous flux emitted by a chip is determined by other factors, increasing the half angle decreases the maximum luminous intensity.

Manufacturers have, to date, generally used chips of size 0.3-0.4 mm square and increases in total luminous flux have been achieved by improving chip efficiency. (It should be noted that the chips in LED lamps appear larger due to magnification by the lens).

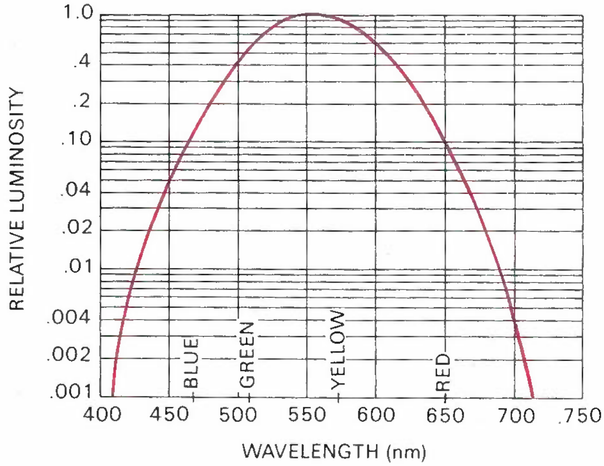


Fig. 5 — CIE Relative Luminosity Function.

Reliability of LEDs

Since there is no known catastrophic failure mechanism for a LED chip operated within its specified temperature and forward current limits, the short term reliability of LEDs is dependent upon the method adopted for mounting and making connections to the chip. Encapsulating resins which cause internal stresses on setting may affect bonding reliability, as may the stress produced by differential expansion of the various components from temperature changes during LED life. It has been observed, however, that the luminous intensity of all LEDs falls rapidly over the first few hours of use. This is illustrated in **Fig. 6** where the averaged relative intensity of a number of red, yellow/amber and green LEDs has been plotted against time. After approximately 250 h the rate of decrease of luminous intensity declines considerably and remains small until the end of the useful life of the LED. The decline to 64% of the initial output in a relatively short period is in marked contrast to filament type lamps which are generally required to drop no more than 15% from their initial values in 850 h. As a matter of convention the end of the useful life is taken to be when the luminous intensity of the light emitted has fallen to one half of its initial value, measured at the first turn-on of the LED. The reason for this early decrease in luminous intensity is not known and as yet no models have been proposed which would lead to an understanding of the phenomenon.

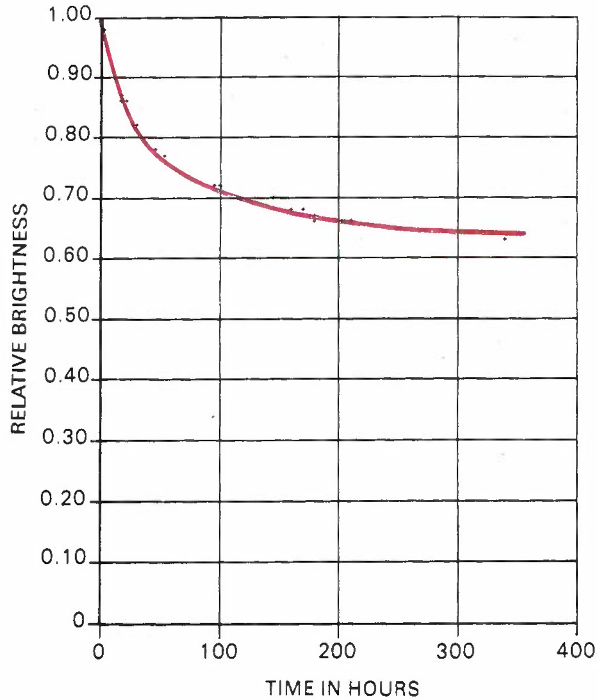


Fig. 6 — Life Test of LEDs. Averaged Figures for 3 Manufacturers and 3 Different Coloured LEDs of Various Brightnesses.

Long term maintenance of the luminous output of the LED chip is dependent upon the regularity of its crystal structure and the relative absence of micro cracks and doping imperfections which can act as electron or hole traps. Growth of such imperfections, due to temperature cycling resulting from operation, will lead over a period of time to diminished luminous output.

While it would appear a simple matter to increase the luminous intensity of an LED lamp simply by increasing the chip area and hence the total luminous flux this approach has not been adopted by manufacturers. From enquiries made by the authors it would appear that the present chip size is regarded as optimum from the manufacturing viewpoint, but it has not been possible to obtain any details of the factors which dictate the choice of chip size. It is thought that a possible explanation may be the difficulty in obtaining an even current distribution in a larger chip without having to sacrifice a proportion of the extra area so obtained to extra conductor tracking on the chip surface.

A review of the results of life testing LED lamps, by Telecom Research Laboratories, begun in 1974, showed that all LEDs tested had a similar pattern of diminution of luminous intensity with operating time. Test results were analysed using a least squares fit to an equation of the form:

$$\frac{I_m}{I_o} = b + c \ln T, \; T \geqslant 1. \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where:

$\frac{I_m}{I_o}$ = the ratio of the measured luminous intensity, I_m, to the measured initial luminous intensity, I_o.

b = constant

c = constant

ln T = natural logarithm of the operating time in hours.

It should be noted that when T = 0 the equation is undefined, and $|c \ln T|$ may be very large when $T < 1$. Since this could lead to calculated values of $I_m > I_o$, which cannot be so, as I_o is the initial measurement, the equation is only valid for $T \geqslant 1$. This results from the use of relative brightness instead of absolute values of luminous intensity. The results of the life tests are set out below.

- TEST 1. Red, yellow/amber and green LEDs obtained from three manufacturers and of various luminous intensities. The lamps were operated on half wave rectified A.C. current having an average value equal to the specified maximum forward current for lamp type. Life testing was conducted at laboratory temperature which approximated 20°C, and the lamps were operated continuously for the duration of the test.

A plot of the results is shown in **Fig. 7a** and analysis showed that:

$$\frac{I_m}{I_o} = 1.04 - 0.07 \ln T$$

Correlation coefficient R = 0.98.
Half-life (calculated) 2.2×10^3h.

- TEST 2. Red LEDs from a single manufacturer with a luminous intensity of 4 mcd. Operated on regulated D.C. at specified maximum forward current, temperature approximately 20°C.

Results of testing are shown in the plot of **Fig. 7b** and analysis showed by:

$$\frac{I_m}{I_o} = 0.98 - 0.02 \ln T$$

Correlation coefficient R = 0.99
Half-life (calculated) 2.0×10^{10}h

- TEST 3. Red LEDs from a single manufacturer with a luminous intensity of 30 mcd. Test conditions the same as for Test 2. The results are plotted in **Fig. 7c**.

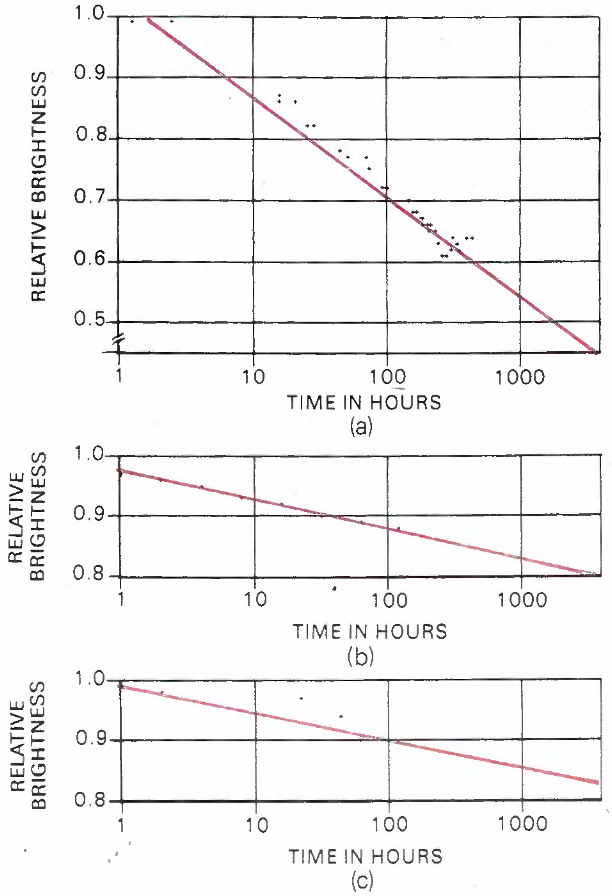


Fig. 7 — Relative Brightness Versus Operating Time:
Curve (a) Results of life testing red, yellow/amber and green LED lamps. The lamps were obtained from three manufacturers and had various luminous intensities. Each lamp was operated from a half wave rectified A.C. supply at an average current equal to its specified maximum current.
Curve (b) Life test results for 4 mcd red LED lamps, operated from a regulated DC supply at specified maximum current. One manufacturer only.
Curve (c) Life test results for 30 mcd red LED lamps, operated from a regulated DC supply at specified maximum current. One manufacturer only.

This test was marred by instrument problems and analysis showed that:

$$\frac{I_m}{I_o} = 1.00 - 0.02 \ln T$$

Correlation coefficient R = 0.88
Half-life (calculated) 2.0×10^{10}h.

The extrapolition for the half-lives quoted assumes that equation (1) is valid over the life time of the LED.

While Tests 2 and 3 were confined to a single manufacturer, Test 1 results show that neither manufacturer nor colour were significant, the correlation coefficient of R = 0.98 showing that the data was a good fit to the expression derived. The much lower half-life figure for the first life test is a reflection of the LED drive conditions, which exceeded the manufacturers specified maximum forward current for LEDs in this life test. This is in direct contrast to the second and third life tests where LED forward current was strictly controlled so as to not exceed the manufacturers specified maximum and the ambient temperature was also strictly controlled.

Comparison with Incandescent Switchboard Lamps

The main reason why LED lamps have not yet been employed as replacement lamps in switchboard applications is that they are not bright enough to provide sufficient contrast relative to their surroundings when used behind existing lamp caps.

The total luminous flux emitted by an incandescent switchboard lamp is of the order of 100 times that of currently available LED lamps. However, LED lamps do have the advantage of controlled angular distribution and of being approximately monochromatic. Thus the wavelength distribution of the light emitted by the LED may be matched to the band-pass of a coloured lens cap so that there will be very small transmission losses. For the incandescent lamp, however, the total luminous flux is reduced by approximately 90% as a consequence of transmission loss in the lens cap, as only a fraction of the light output matches the bandpass of the lens cap material. Since the response of the human eye is approximately logarithmic, the apparent brightness of a coloured lens cap illuminated by an LED is therefore not much less than that observed when illuminated by an incandescent globe. However, since contrast is a linear function the difference in brightness between LEDs and incandescent lamps is sufficient to cause "wash-out" in areas of high ambient brightness.

Other LED shortcomings are:

- The LED forward voltage drop is usually 1.5 - 2.5 V and for operation in a higher voltage system a series voltage dropping resistor or a dc-dc converter is required. The introduction of such a series resistor in a typical 48V system reduces the overall efficiency of the system by a factor of about 20 because of the large power losses due to the series resistor.
  The resistor also dissipates a similar quantity of heat to an incandescent lamp thus requiring replacement LEDs to be as widely spaced as the present incandescent lamps. A second undesirable effect is the reduction in LED brightness caused by operation at temperatures above ambient. Thus it appears worthwhile to investigate the economics and practicalities of using dc-dc converters.

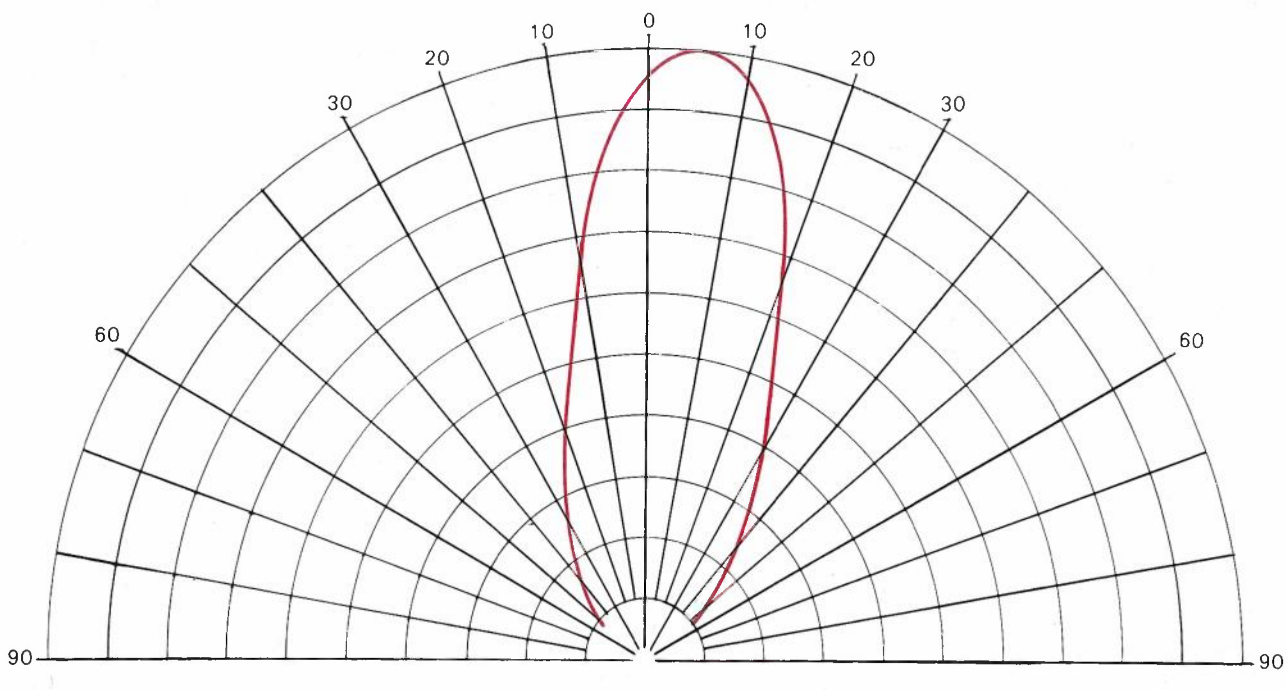


Fig. 8 — Relative Luminous Intensity vs. Angle For 4 Chip LED Lamp (Chips Mounted Together)

- LEDs are polarity conscious. The reverse breakdown voltages of LEDs are usually specified as about 6V and thus a LED switchboard lamp needs to be protected against reverse polarity damage.

On the credit side:

- The luminous flux of a LED is nominally directly proportional to current, whereas the luminous flux of an incandescent switchboard lamp varies as the 3rd to 4th power of operating voltage (or current). Due to the combination of the direct proportionality of light output with forward diode current and the logarithmic response of the human eye LEDs are thus apparently less affected by supply voltage variations.
- LED life appears to be unaffected by vibration and switching surges, unless the surges occur with sufficient frequency to increase the power dissipated by the LED to a figure in excess of the manufacturers' recommendations.
- The decisive advantage of LEDs over incandescent switchboard lamps is their reliability, with a lifetime of the order of 100 000 hours being a reasonable expectation.

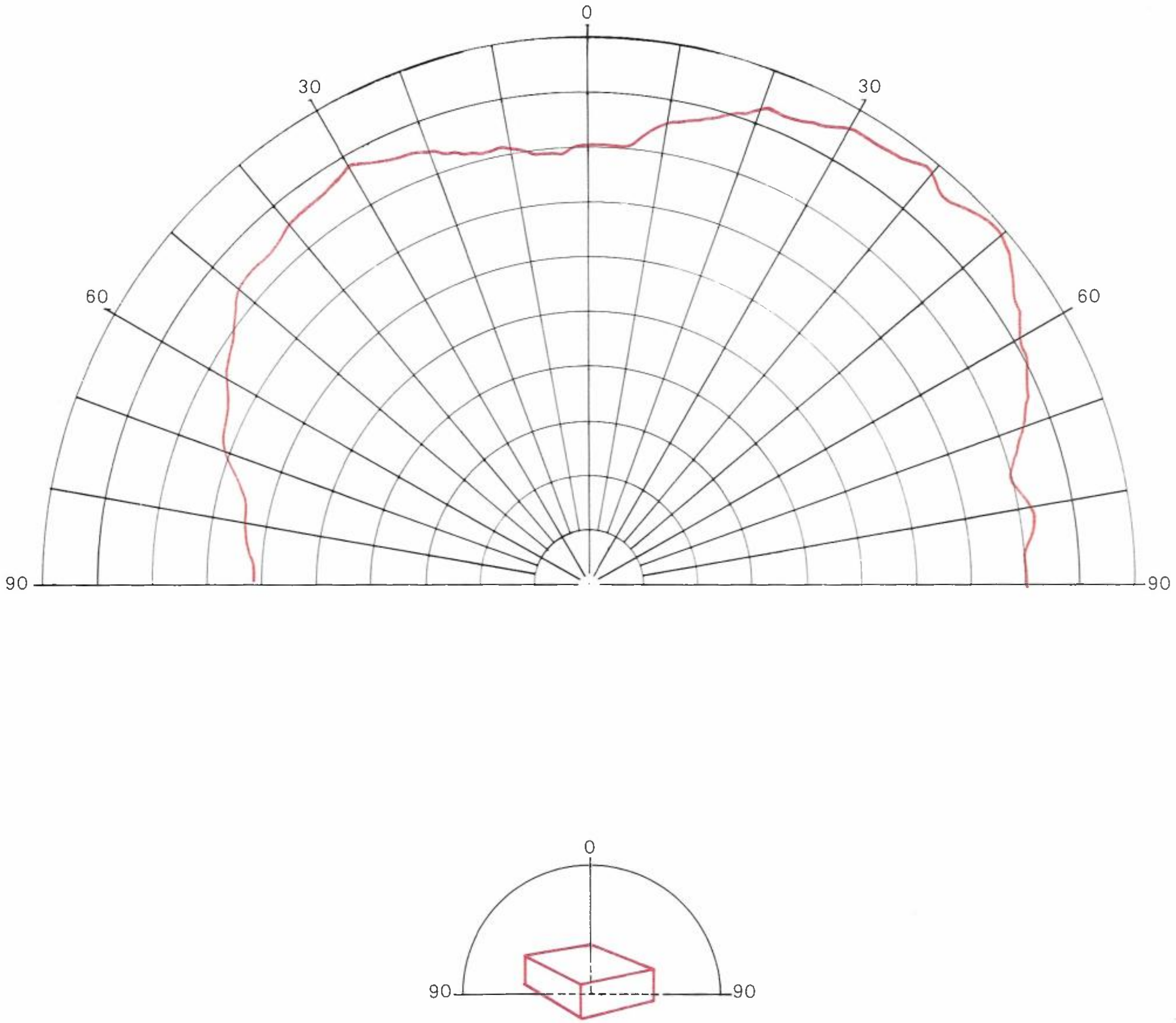


Fig. 9 — Relative Luminous Intensity vs. Angle Across Front Surface of Single LED Chip.

CONSTRUCTION OF MULTIPLE CHIP LED LAMP

Multiple Chip LED Lamp

As a first approximation it could be expected that the total luminous flux of an LED lamp might be increased by using a larger LED chip or incorporating several LED chips. Attempts to procure larger chips from commercial sources were unsuccessful. Subsequently standard sized (0.3 mm square) high efficiency chips were obtained and several unencapsulated multiple chip LED lamps constructed.

Constructional Details and Measurements

A cone of 45° half angle was cut into a 6 mm square brass post to a depth of 2 mm. This was then nickel plated to form a conical reflector. At the apex of the cone

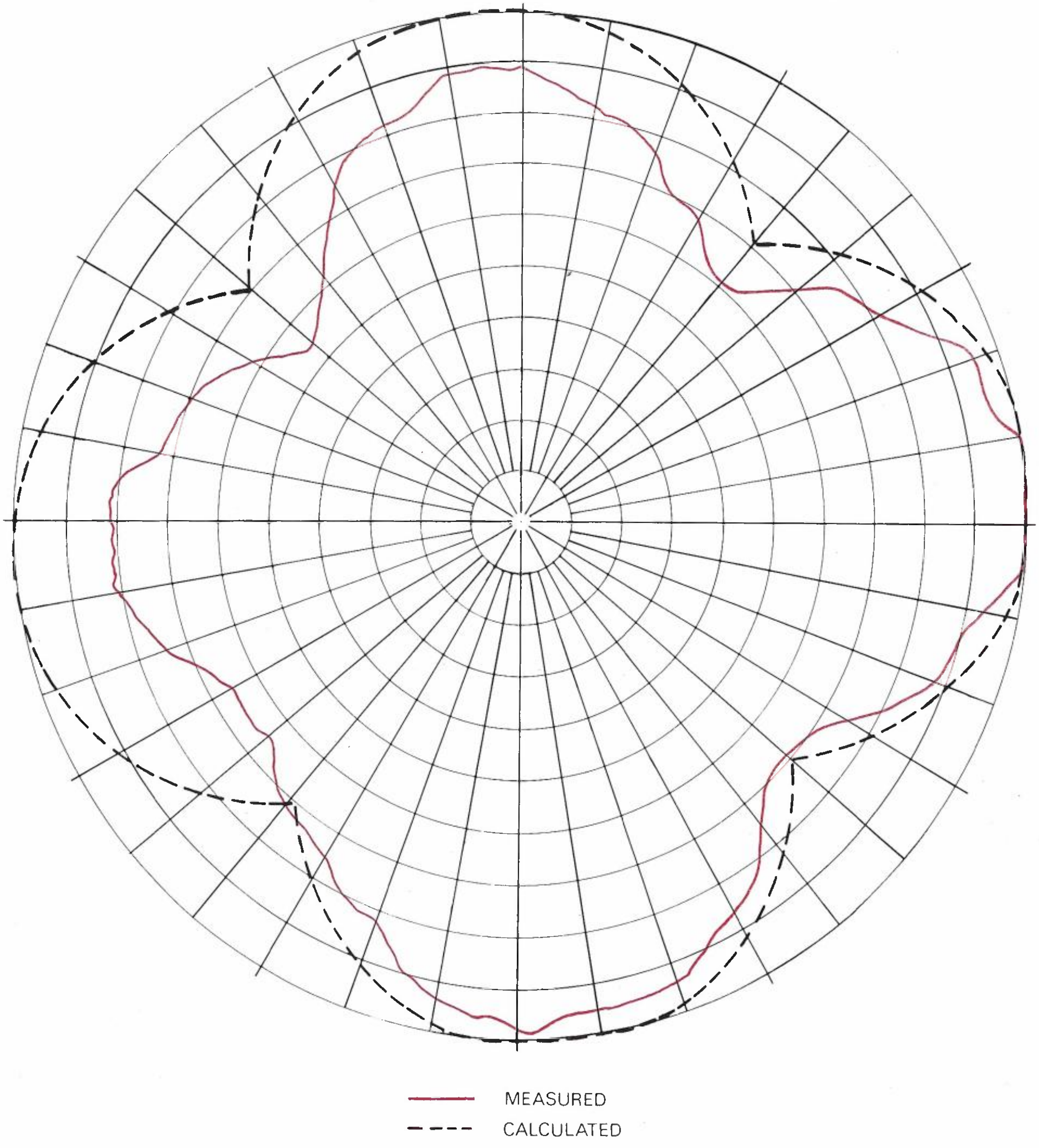


Fig. 10 — Relative Luminous Intensity Around Sides of Single LED Chip.

the cathodes of 4 red LED chips were attached with silver-loaded epoxy resin. The chips were positioned to form a square with a separation between chips of less than 0.1 mm. Each chip had its own thick film current limiting resistor.

When operated with 20 mA flowing in each chip a maximum luminous intensity of 18 mcd with a half angle of 19° was measured. The relative luminous intensity as a function of angle is shown in **Fig. 8**, and from this the total luminous flux was calculated to be 14 mlm.

For comparison a single chip was mounted in an identical post with conical depression. With 20 mA current flowing its maximum luminous intensity was 8.5 mcd, half angle 16° and total luminous flux 4.9 mlm.

It was postulated that the 4 chip device was not 4 times as intense as the equivalent single chip device due to absorption of light emitted from 2 sides of each chip by the adjacent chips. To investigate this the angular output from a single isolated chip was measured and another 4 chip device with each chip in its own cone was constructed.

The single chip was mounted on a narrow post. **Figs. 9 and 10** show the relative luminous intensities as a function of angle across the front surface of the chip and around the sides of the chip respectively. **Fig. 11** also shows the calculated radiation pattern if the sides were Lambertian sources (i.e. the emitted flux varies as cos θ, where θ is the angle from the normal to the surface). The luminous intensities from both the front of the chip and a corner of the sides was approximately 0.5 mcd. **Fig. 11** shows a single chip mounted on a flat surface.

Four yellow LED chips were mounted in 4 separate cones 1 mm deep in a plated brass post. When operated with 20 mA through each chip the maximum luminous intensity was 11 mcd, the half angle 61° and the calculated total luminous flux 31 mlm. **Fig. 12** shows the relative luminous intensity against angle.

Manufacturers information on commercially available LED lamps using the same LED chips indicate that the red chips are 1.2-1.5 times photometrically brighter than the yellow chips.

Evaluation of Multiple Chip LED Lamp

From the manufacturers' data the maximum total luminous flux of a yellow LED lamp using the same chips was calculated to be approximately 7 mlm for a forward current of 10 mA. Assuming the luminous flux is proportional to current then, at 20 mA, four chips can emit 56 mlm. Our result of 31 mlm from the 4 separated chip device is considered satisfactory as it was unencapsulated. The chip material has a refractive index of about 3.4, and at the chip-air interface any rays deviating by more than 17° from the normal are totally internally reflected in accordance with Snell's Law. When encapsulated in a plastic of refractive index 1.5 rays up to 26° from the normal are transmitted. Fresnel loss due to reflection at an encapsulating material-air interface is also less than for a chip-air interface. For normal incidence and small angles of incidence from the normal

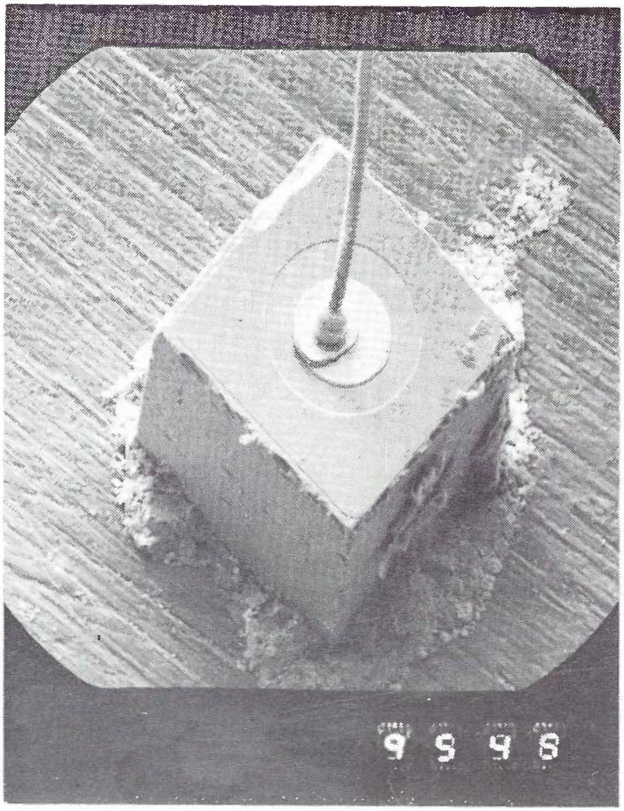


Fig. 11 — **SEM Photograph of Single LED Chip Mounted on Flat Surface.**

the reflection coefficient is given by:

$$r = \left(\frac{n_2 - n_1}{n_2 + n_1}\right)^2$$

where n is the refractive index

At a chip-air interface 70% is transmitted whereas at a chip-encapsulant (n = 1.5) interface 85% is transmitted.

CONCLUSION

Although LED lamps are more reliable than incandescent switchboard lamps, their lower total luminous flux to date has precluded their use as replacement switchboard lamps in existing equipment.

Measurements of single and multichip LED unencapsulated assemblies have shown that the multi-chip assembly radiates proportionally more total luminous flux than does a single chip. It is expected that encapsulation would effect a further improvement favouring the multichip assembly as the high refractive index of the encapsulating resin should reduce present losses due to total internal reflection and scattering. Once a suitable

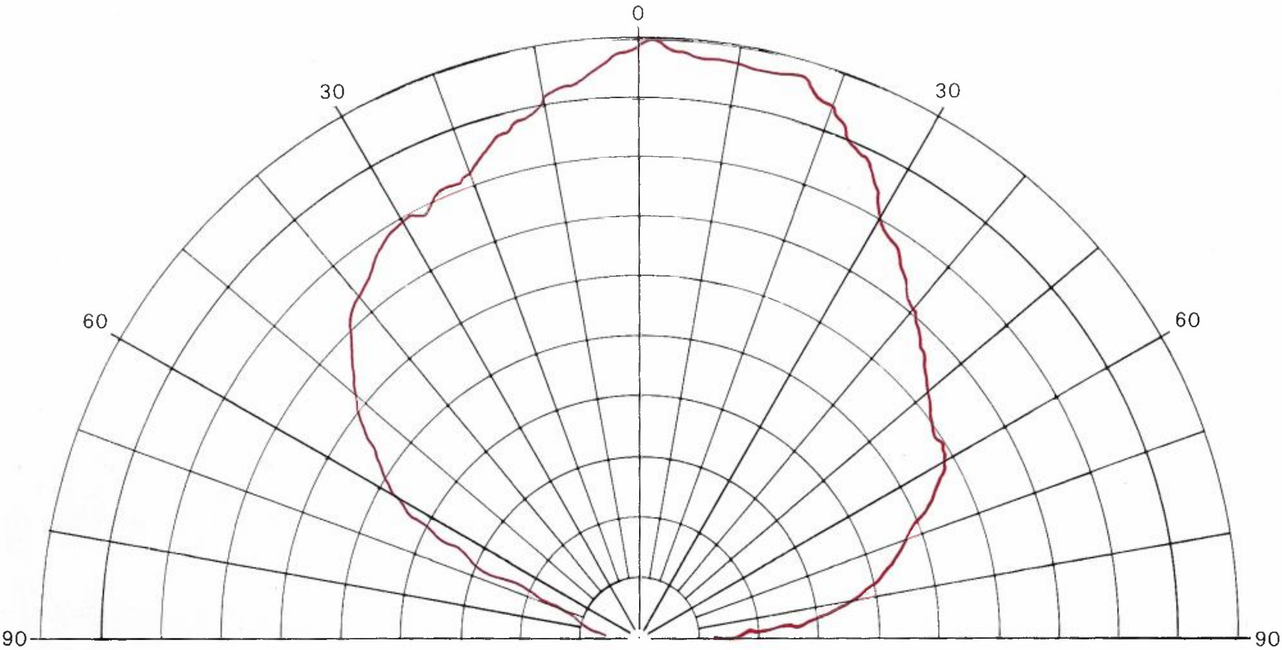


Fig. 12 — Relative Luminous Intensity vs. Angle for 4 Chip LED Lamp (Chips in Separate Reflectors).

envelope and lens shape is determined an increased luminous intensity available over a half angle of the order of 60° should enable construction of a prototype switchboard lamp for evaluation.

To bring this work to a conclusion, work is proceeding on the preparation of a Telecom Australia specification for LED switchboard lamps. It is probable that contracts will subsequently be let for development and manufacture of a product which will be capable of directly replacing existing type filament lamps.

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APPENDIX

Radiometry and photometry

Radiometry is concerned with the measurement of ultraviolet (wavelength less than 400 nm), visible (400-700 nm) and infra red (above 700 nm) radiation, the basic unit of power, or flux as it is called, being the Watt (W). Photometry deals with the measurement of visible light as perceived by the average human eye, the unit of flux being the lumen (lm). Fig 5, the CIE relative luminosity function, relates luminous flux to radiant flux. Peak photopic response is at 555 nm and at this wavelength 1 W of radiant power is the equivalent of 680 lm. For a practical introduction to optical measurements see Refs. 7 and 8.

Total luminous flux

The total luminous flux (lm) of a lamp is a measure of the total light emitted by the lamp.

Luminous intensity

The luminous intensity of a point source is the luminous flux per unit solid angle travelling in a given direction. 1 lm per steradian equals 1 candela (cd).

Luminous efficiency

Two luminous efficiencies need to be defined:

(1) the luminous efficiency of the source — i.e. the total luminous flux emitted per watt of power consumed (lm/W)
(2) the luminous efficiency of the radiation — i.e. the ratio of the luminous flux to the radiant flux of the radiation (lm/W)

Coaxial Cable Impedance Considerations — Manufacture, Testing and Allocation of Tubes and Cables

L. J. HALL, B.E., J. K. LYNCH B.Sc., and R. R. LLOYD, M.Sc.

In order to obtain satisfactory transmission performance on a coaxial line system, reflections on the coaxial tubes must be carefully controlled. The most significant reflections are those occurring between repeaters and the coaxial tubes and those at joints, where coaxial tubes of different end impedances meet. This paper firstly defines end impedance and its measurement, and then indicates the limits required in the impedance matching of end impedances of the coaxial tubes at both joints and repeaters. The measures taken by the manufacturer of coaxial cable to control the end impedances of coaxial tubes are also discussed.

Coaxial cable line systems are an important part of the Australian broadband network. The 2.6/9.5 mm coaxial tube (Reference 1) is used exclusively in this country, although overseas countries make significant use of the 1.2/4.4 mm tube.

Currently, frequency division multiplex (FDM) systems operating up to a frequency of 12MHz (2700 channel) are in use, although 18 MHz (3600 channel) systems are now planned. Many coaxial cable routes are laid out for 60 MHz working (10 800 channel) and digital operation at 140 Mbit/s is a real possibility in the service life of many cables.

For the long routes in Australia, variations from the nominal curve of attenuation versus frequency of installed coaxial tubes must be carefully controlled if equalisation difficulties, leading to noise penalties, are to be minimised. Strict specifications exist on the tolerances allowed in the attenuation of drumlengths of coaxial cable. However, significant equalisation errors may arise due to double reflections of signal energy on a coaxial tube within a minor repeater section. The mismatches of the coaxial tubes with the repeaters, the mismatches between joints in coaxial tubes and the mismatches within tubes interact in pairs to form double reflections. Each double reflection leads to a ripple in the frequency response of the minor repeater section (see Appendix 1 for more detail) and steps must be taken to ensure that the ripples from the many repeater sections on a long route do not add collectively to produce an overall unacceptable response (Reference 2). The double reflections involving the coaxial tube to repeater input and coaxial tube to repeater output occur regularly and would add directly except that the lengths of minor repeater sections are deliberately altered to vary the ripple period, thereby considerably easing the problem of matching the impedances of the repeaters to the coaxial tubes. Other double reflections, such as those involving joints, are also of great significance and these must be controlled by placing appropriate limits on the level of reflections occurring at joints. This is done by limiting the differences in end impedance across joints.

The above discussion indicates that end impedance and its control are very significant factors in the manufacture of coaxial tubes and cables and their laying. End impedance and its method of measurement will now be defined. The significance of the limits on end impedance to cable manufacture are then described together with a discussion of the techniques which the manufacturer uses to control end impedance. Finally, Appendix 2 shows how varying the jointing conditions can alter significantly the required limits on end impedance.

END IMPEDANCE

Definition

When a perfectly uniform coaxial tube is terminated by its characteristic impedance, all the energy in a propagating signal is absorbed by the termination. The characteristic impedance of coaxial tubes used by Telecom Australia is very closely approximated by:-

$$Z_0 = R_\infty + \frac{A}{\sqrt{f}}(1 - j) \text{ ohm} \qquad \ldots\ldots\ldots (1)$$

where R_∞ is the characteristic impedance at infinite frequency, f is the frequency in MHz and A is a constant. The nominal values, for installed cables, of R_∞ and A are 74.4 and 0.915 respectively. Due to manufacturing tolerances (see later), each individual tube has values of R_∞ and A which depart from the nominal values, so that the terminating impedance required for no reflection varies slightly from one tube to the next. In addition, a coaxial tube is not perfectly uniform with length, so that the characteristic impedance varies slightly with length. The terminating impedance required to minimise the reflection of a particular pulse shape is termed the true end impedance for that pulse shape and is not the characteristic impedance averaged over the entire tube length, but is a weighted average, biased towards the end under consideration. The true end impedance is a complex function of frequency and, to simplify matters, is assumed to be of the form of Equation 1 with A equal to 0.915 so that R_∞ only is considered to vary. The modulus of this simplified true end impedance at 2.5 MHz (that is, R_∞ + 0.58 ohm) is the value referred to from this point and in all other Telecom Australia literature as the end impedance, and is a quantity which enables tubes to be graded for their reflection level against a known termination or to enable two tubes to be selected so that the reflection at the joint between the two is minimised. In addition, it can be used as the characteristic impedance of the tube at that end, in design calculations, and as such is often simply referred to as the impedance of the tube at that end.

Measurement

From the above definition, it is seen that the method of determining the end impedance is to find the value of R_∞ such that the function

$$R_\infty + \frac{0.915}{\sqrt{f}}(1 - j) \qquad \ldots\ldots\ldots (2)$$

is the best fit to the curve of the true end impedance versus frequency for the particular pulse shape required. This pulse is selected to contain significantly the range of frequencies which the coaxial line equipment uses. The method is to feed the pulse into the tube and then to balance the true end impedance of the tube against a network with an impedance of the form given in (2) above. **Fig. 1** shows the basic elements of the measurement.

The pulse generator produces a sine-squared pulse of selectable half-amplitude width which is fed into the bridge circuit containing two identical resistors R, the tube under test (which is terminated by a network S2, simulating the true end impedance of the cable at the remote end) and a fourth arm which is the network S1, simulating the true end impedance at the sending end. **Fig 2** shows the pulse echo test set normally used, with **Fig 3** showing the pulse generator, bridge and network S1 in greater detail. Network S2 is identical to S1.

Two methods of measurement are used. The first measures the end impedance at the remote end by adjusting the simulating network S2 to minimise the reflection occurring to the pulse where the tube is terminated by network S2. The process of minimising the reflection is to obtain the "best straight-line match" to the tube by adjusting R_∞ and A (see Equation 1). Making A variable improves the balance obtainable but has negligible effect on the evaluation of the end impedance, so the dial scale for R_∞ assumes A to be 0.915 and consequently adds 0.58 ohm to the value of R_∞ to yield what has been defined above as the end impedance. When R_∞ and A have been adjusted so that the real part of the input impedance of S2 is a very close match to the real part of the true end impedance over the frequency band contained in

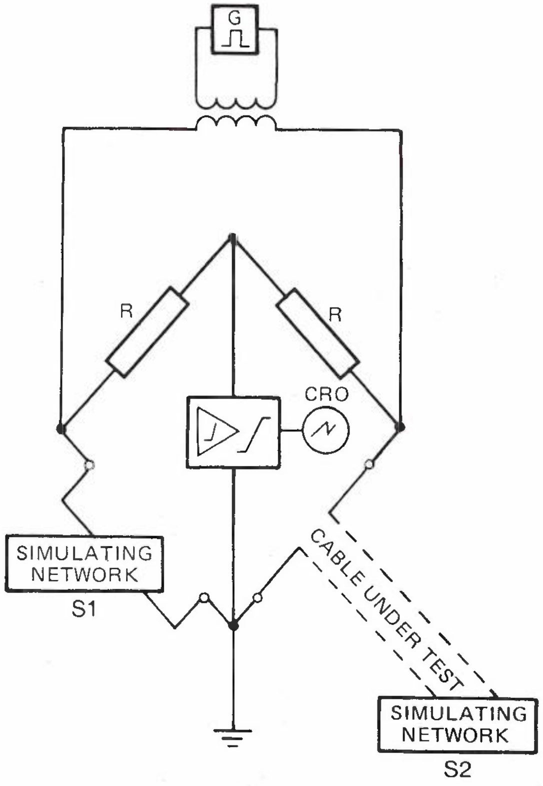


Fig. 1 — Measurement of End Impedance Using Pulse Echo Test

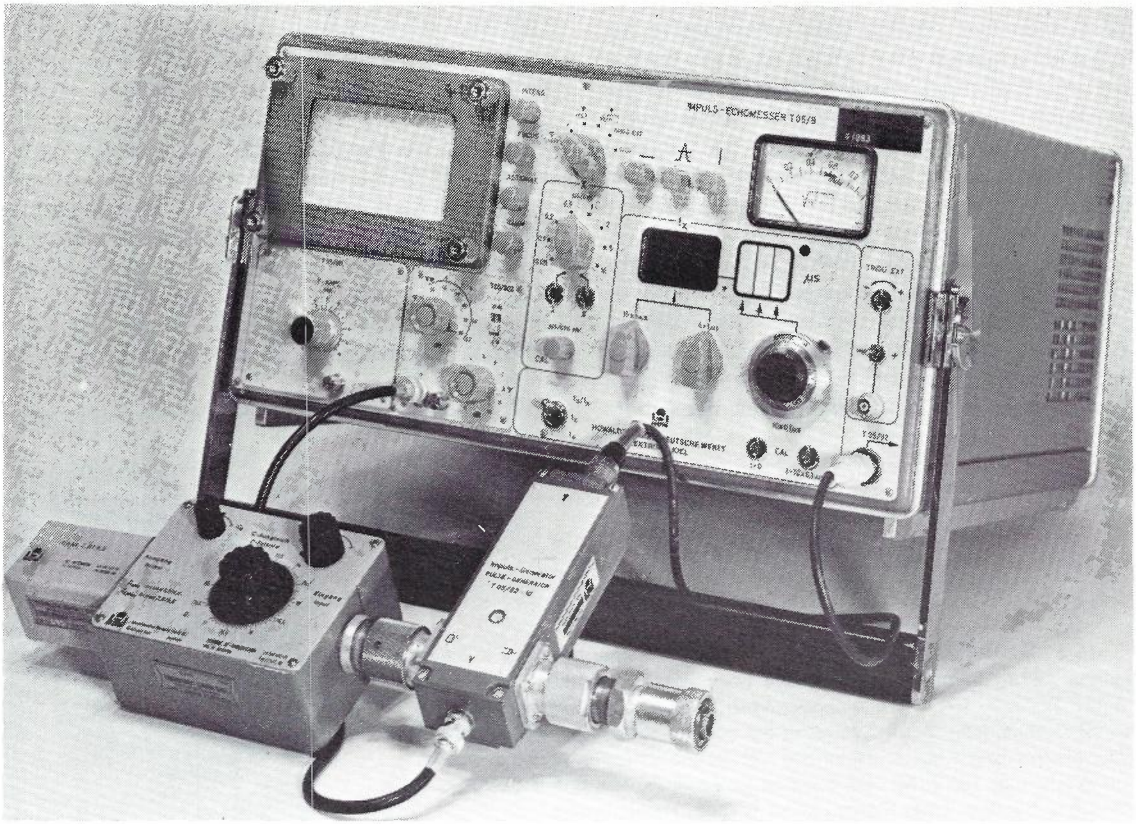


Fig. 2. — Coaxial Cable Pulse Echo Test Set

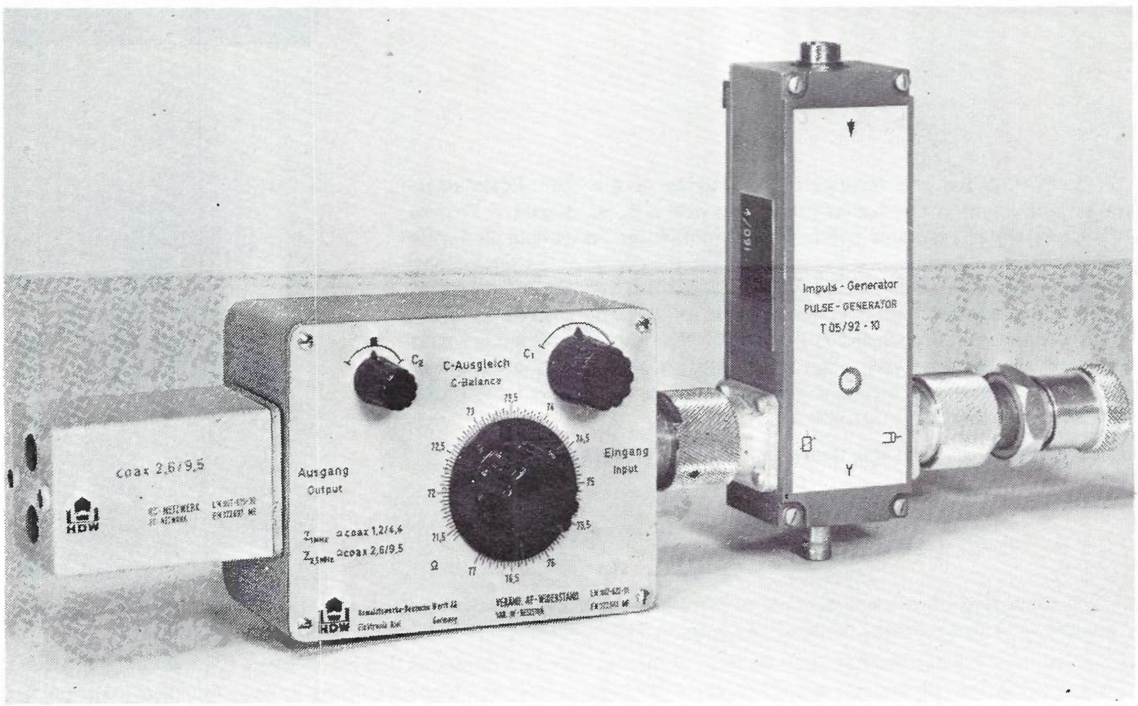
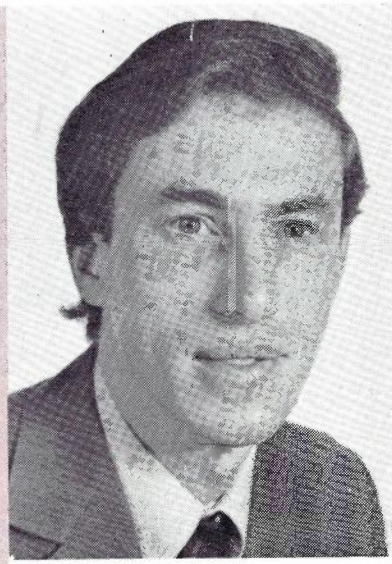


Fig. 3. — Pulse Echo Test Set: Pulse Generator, Bridge and Cable Simulation

the pulse, the residual reflection is approximately capacitive or inductive, coming from reflections in the connectors and residual errors in matching the imaginary part of the true end impedance. As the pulse generator produces unipolar pulses, capacitive or inductive reflections (see Reference 1) produce bipolar or "double-humped" reflections which are easily distinguished from the unipolar or "single-humped" reflections due to resistive mismatches. Achievement of the best approximation to a bipolar reflection is what is meant by the "best straight-line match". This method has proved to be reproducible between different operators and equipment, but it has the disadvantage that the pulse reflected from the termination has suffered the two-way attenuation of the tube under test. This disadvantage becomes more pronounced in testing long drumlengths (2.25 and 1.5 km). The second method overcomes this disadvantage. The end impedance is measured at the pulse sending end by adjusting S1 to minimise the unbalance in the bridge circuit while the pulse generator is "on". It can be shown that when the impedance of S1 is equal to the true end impedance of the tube, then neglecting residual bridge unbalance, there is no output from the bridge during the pulse "on" time. As with the measurement at the remote end, R_∞ and A of S1 are adjusted to minimise the bridge unbalance with emphasis being given to remove the real (the unipolar) component. Again, the end impedance is given by assuming A to be 0.915 and adding 0.58 ohm to R_∞.

The measurement can be conducted with a pulse half-



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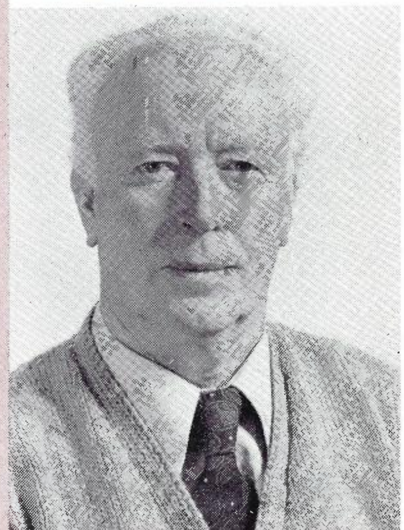

J. K. LYNCH joined the Research Laboratories of the then Postmaster-General's Department in 1944 after graduating with a B. Sc. degree in Physics from the University of Tasmania. While at the Laboratories, he worked on a wide range of problems concerning line transmission and the design of line equipment. From 1944 to 1949, he studied part-time at Melbourne University and passed in Radiophysics and several mathematical subjects. In 1969, he transferred to the now Lines Construction Branch and has worked in the cable design and ordering groups. In recent years he has taken an interest in studies of the Japanese language and has reached a level of being able to make reasonable translations of technical articles written in Japanese.

He has written papers on the transmission characteristics of cables.

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width of either 200 ns, 50 ns or 10 ns. However, the value obtained at 50 ns is taken to be the end impedance for the purpose of characterising the tube.

Limits

When constructing a coaxial cable route, Telecom Australia requires drumlengths of cable which are determined by routing requirements. Consequently, the cable manufacturer is advised of the lengths which are required for the project and the order in which these lengths will be laid, so that it is known in advance which cable ends will be jointed together. Unlike other authorities, for example the British Post Office, Telecom uses numbered tubes, that is tube N in one cable length is jointed to tube N in the next cable length. However, it is the tube position in the laid-up cable which is numbered, not the actual tube itself. Thus the manufacturer effectively numbers a tube when the position which that tube will occupy in the laid-up cable is decided. The significance of this is discussed in the paragraphs which follow.

Present standards of Telecom Australia require that the difference in end impedances across a joint should rarely exceed 0.2 ohm. This result can be achieved by a full analysis similar to that outlined in the Introduction and Appendix 1.

If selection and allocation were not used, all tubes would have to be manufactured to within 0.1 ohm of the nominal end impedance of 75.05 ohm (this value includes an allowance of 0.05 ohm to allow for the slight drop after installation). This degree of tolerance is expensive to achieve, as is evident by the notional cost of Spare Drum Quality Cable which does meet this specification (together with tighter limits on other parameters). Consequently the end impedance tolerance is set at ± 0.3 ohm about nominal with the end impedance mismatch across joints being maintained below 0.2 ohm by selection and allocation, thereby permitting significant economies in manufacture with no effect on transmission.

The manufacturer allocates the drums of uncabled coaxial tube to the appropriate positions on the cable lay-up machine, and thus the appropriate positions within the laid-up cable, with the knowledge of the end impedances of the tubes of the cable end to which this new cable will be jointed. The manufacturer has to allow for the slight reduction in end impedance which occurs due to the slight stretching imposed on the tube by the stranding process, and must prove the selection by measuring the impedances of each end of each cable and entering these on an Allocation Chart, which shows that the 0.2 ohm mismatch limit across each joint will be met.

Appendix 2 details considerations involving the reflections occurring at minor (underground) repeaters and concludes that the end impedance limit of ± 0.3 ohm is appropriate, wherever multi-tube coaxial cable connects to the repeaters by only short lengths of semiflex cable. However, at above-ground repeaters, practical considerations determine that the multi-tube cable be jointed to significant lengths of single tube semi-air-spaced 2.6/9.5 mm coaxial cable. This cable cannot be allocated by the manufacturer and Appendix 2 shows that it, and the tubes in a multi-tube cable at the end which is being terminated, are required to be within ± 0.1 ohm of nominal.

The above discussion applies to a coaxial cable route at initial installation. Spare drumlengths are, of course, kept for emergencies and as the installed position of these drums obviously cannot be predicted, the end impedances of all tubes in such drums are required to be within ± 0.1 ohm of nominal.

Although, on installation, this will not guarantee a mismatch at joints of less than 0.2 ohm, it does guarantee better than 0.4 ohm which is significantly better than the maximum mismatch of 0.6 ohm that would result if only the limit of ± 0.3 ohm on the end impedance were required on spare drumlengths. If a replacement length of cable is required, and if there is sufficient time to have one manufactured, then the end impedances of the tubes, on to which the replacement length will joint, can be determined from the original allocation charts for the project. These values are supplied to the manufacturer as the nominal end impedances for that length (rather than the normal 75.05 ohm) and the tolerance on production becomes ± 0.2 ohm about that nominal, ensuring that the mismatch limit of 0.2 ohm across the joints is maintained.

Future major coaxial cable routes will employ 2.25 kilometre drumlengths, made possible due to the weight saving through the use of the new polyethylene and moisture barrier sheath (PEMB) cable in place of the conventional lead polyethylene sheath (APJ) cable. Investigations are proceeding as to the possibility of replacing the limit of ± 0.3 ohm on the end impedance and the limit of 0.2 ohm on the joint mismatch with a specification of the end impedance, phrased in terms of a mean and standard deviation, which although tighter than the current specification, would dispense with the explicit limit of 0.2 ohm on a joint mismatch. Any tube meeting the new specification will be able to be jointed to any other tube meeting the specification with no allocation chart required. The statistical distribution of the end impedances will, in conjunction with the long drumlengths, ensure a satisfactory final transmission performance.

CABLE MANUFACTURE

Under the current specification, the cable manufacturer allocates the cables to a repeater section in such an order that the criterion of a joint mismatch no greater than 0.2 ohm is satisfied. A repeater section may typically consist of six 750 metre drumlengths, three 1500 metre drumlengths or up to 20 drumlengths for large cables in urban areas. The end impedance of a coaxial tube in a completed cable is affected by every stage of cable manufacture. Indeed, even the specified nominal value of 75.05 ohm allows for a reduction of 0.05 ohm caused by unwinding the cable from the delivery drum and installing it underground. As the impedance of the coaxial tube is controlled at the initial stage of forming the tube in manufacture, the influence of subsequent stages must be determined and minimised, if the final impedance of the cable is to fall within specification. The manufacturing stages can be grouped broadly into three categories: tube forming, cable stranding and cable sheathing. Each stage after the first involves rewinding cable from one drum to another and the resultant slight radial compression of the tubes causes a gradual lowering of their impedance. A change of 0.05 ohm at each stage is not uncommon.

In the manufacturing stage of the coaxial tube, the accurately drawn central copper conductor is fitted with polyethylene spacer discs. A clean untarnished copper tape is formed tightly around the spacers to produce the outer conductor. Finally the tube is lapped with steel and paper tapes. In the second manufacturing stage, the drums, each with a single tube, are loaded on to the stranding machine, together with any drums for pairs or quads also to be included in the cable, and stranded together to form the cable core. The stranding process causes each tube to follow a helical path within the cable, which explains why the tube length is greater than the sheath length by the so-called take-up factor.

At the sheathing stage, the vacuum-dried core receives an impermeable protection layer of either lead or aluminium/polyethylene laminate covered by an extrusion of black polyethylene. In the latter form of protection, the polyethylene layer of the laminate fuses with the black polyethylene to form what is called a moisture barrier sheath (MB). The moisture barrier sheath is suitable for installation in ducts only. However, if a polyethylene sheath is extruded over the core, before application of the moisture barrier sheath to form the polyethylene and moisture barrier sheath (PEMB), the cable is suitable for direct burial by ploughing.

Control of End Impedance

The characteristic impedance of the coaxial tube is determined principally by two factors; firstly, the geometry of the tube, that is the ratio of the inner diameter of the outer conductor to the outer diameter of the centre conductor, and secondly, the effective permittivity of the dielectric determined by the permittivity of the polyethylene spacers and the ratio of their width to that of the air space between them.

The diameter of the inner conductor is determined by the final die through which the wire is drawn. The outer conductor is applied by forming a flat copper tape into a longitudinal tube with edges of the tape abutting. The edges are either crimped or toothed so as to prevent their overlapping and altering the effective tube diameter, thereby forming a stable and precise tube. The internal diameter of the outer conductor is thus influenced by tape width and tape thickness.

The polyethylene spacers may be fitted in one of two ways. The first method uses spacers, punched from a flat extruded strip of polyethylene. These are loaded into a hopper in the tube-forming machine and a slotted revolving wheel takes the spacers one by one from the hopper, slits them by passing them over a fixed knife and places them at 33 mm intervals on the centre conductor. The second method is to injection-mould the spacers onto the centre conductor, moulding up to 14 spacers at any one time. The conductor is then advanced through the machine and another group of spacers moulded. In both processes, the spacing of the discs is set by the mechanism of the machine and is not easily changed. However, the disc thickness is subject to random fluctuation, and, in the first process, it is possible to sort the discs into several groups between the allowed limits of disc thickness. Use of discs from different groups allows a small adjustment of characteristic impedance by varying the effective permittivity.

However, as the effective permittivity cannot be varied significantly, the manufacturer's main control of impedance is by choosing appropriate combinations of wire diameter, tape width and tape thickness. The geometry of the final tube depends on diameter, tape width and thickness, machine tension settings and running speed. As each of these quantities is subject to fluctuation between certain tolerance limits, the manufacturer is able to compensate, for example, for die wear causing an increase in inner conductor diameter, by choosing a slightly wider and/or thinner tape for the outer conductor.

CONCLUSION

This paper has explained the meaning of the term end impedance as applied to coaxial cable and has indicated the significance of end impedance matching to the transmission performance of a coaxial line system. The manufacture of coaxial tubes and cables has been outlined with emphasis on the steps which the manufacturer must take to control the end impedance at both the tube and the completed cable stages. The reasons behind the choice of various limits of end impedance for different jointing conditions are also explained. An indication of future ways of specifying the tolerance of end impedance on coaxial tubes, and hence control of reflections due to mismatches, is given.

Only reflections caused by impedance mismatches between adjacent lengths of coaxial tube (joint mismatches) and between the coaxial tube and a repeater have been considered. However, internal discontinuities in the coaxial tube structure also cause reflections which must be rigorously controlled. The limits applying to these reflections have been determined in conjunction with the limits for the other two sources of reflection to ensure that the overall reflection process on the complete system remains within the tight limits necessary for high quality transmission.

REFERENCES

1. Telecom Australia Engineering Instruction, Lines, Cables, A 3902, "Coaxial Cable: Cable Design, Attenuation and Impedance Considerations."

2. Telecom Australia Engineering Instruction, Long Line Equipment, General, P 0402, "Commissioning Tests for Broadband Systems".

Appendix 1

REFLECTIONS, RETURN LOSS AND FREQUENCY RESPONSE

In any transmission line such as a coaxial tube, the characteristic impedance is the ratio of the voltage and current phasor amplitudes of a single travelling wave, propagating down the line. Changes in the characteristic impedance of the line produce reflections of the propagating signal. Some of the signal energy which was originally travelling from the signal source (such as a repeater) to the load (the next repeater) then travels in the reverse direction back towards the source. This signal energy returning to the source has been removed from the signal travelling to the load, and causes an apparent increase in the attenuation of the line.

However, the signal returning to the source may be partially reflected by other impedance discontinuities, and hence a second forward travelling signal is produced. This signal has suffered a delay, relative to the signal which has not been reflected (the direct signal), of twice the distance between reflection sites, divided by the propagation velocity. This leads to a phase relationship between the direct and doubly reflected signals which varies sinusoidally with frequency. As the total received signal is the sum of the direct and doubly reflected signals, the received signal varies in both amplitude and phase, about the values in the absence of reflections, in a sinusoidal manner with frequency.

For the analogue frequency division multiplex systems currently in use by Telecom Australia, the sources of reflection include the mismatches between the coaxial tubes and the repeaters and the mismatches across joints. As will be explained in Appendix 2, the cable/repeater reflections are quite large, due to the difficulty in matching the input and output impedances of the repeaters to those of the coaxial tubes. The combination of two repeater reflections produces a sinusoidal ripple in the response of the minor repeater section of the coaxial system, the period of which is related to that repeater section length, while the magnitude is dependent on the magnitude of the repeater mismatches and the attentuation of the repeater section and, hence, the frequency. For example, a 4.5 km repeater section gives a ripple period of around 31 kHz in the frequency domain and the magnitude of the ripple is greatest at the lowest frequency used, 312 kHz. A complete coaxial system comprises many minor repeater sections and the overall response (between the terminals of the system) is determined by the statistical relationship between the ripple periods of each repeater section and these periods are varied slightly by deliberate, random variations of the minor repeater section lengths.

Television transmission is affected directly by the echo which arises from the two-way propagation time of the doubly reflected signal. An amplitude or phase ripple in the frequency domain is equivalent to a time delay (echo) in the time domain. The deliberate introduction of anti-phase echoes can be used to compensate for both amplitude and phase ripples. This is the principle of the transversal equaliser.

Double reflections involving joints also produce sinusoidal ripples in the frequency response of each minor repeater section, the period of these ripples being related to the distances between the repeaters and joints and between joints in the section. The perturbations in the response of the overall system are determined by all possible combinations of joint and repeater reflections between the terminal stations. If a limit is placed on the allowable response perturbations in order to guarentee an acceptable transmission performance, and allowance is made for any deliberate variation in the length of cable and repeater sections, the impedance mismatch allowable at joints and repeaters can be calculated. The calculated limits have a statistical basis, but are significantly relaxed compared to the worst case, when the lengths of all cable and repeater sections are equal.

Appendix 2

MATCHING OF END IMPEDANCE AT REPEATERS

The purpose of this Appendix is to explain the philosophy behind the selection of end impedance limits for tubes which joint on to repeaters by fairly short lengths of semi-flexible coaxial cable ("semiflex") at underground repeaters and by considerably longer lengths of single tube coaxial cable, combined with the short lengths of semiflex, at above-ground repeaters such as main and terminal stations, situated within telephone exchanges. In Appendix 1, it was indicated that the reflection coefficient from a repeater termination is very significant both when the repeater under consideration is terminating the tube and, also when the repeater is driving the tube. If the repeater input or output impedance is denoted by Z_R, then the reflection coefficient at any frequency seen from the multi-tube cable for the general case of both single tube semi-air spaced and semiflex cable being used (see **Fig. 4**) is

$$\rho = \frac{Z_{A1} - Z_0}{Z_{A1} + Z_0} + \frac{Z_S - Z_{A2}}{Z_S + Z_{A2}} e^{-2\gamma_1 \ell_1} + \frac{Z_R - Z_S}{Z_R + Z_S} e^{-2(\gamma_1 \ell_1 + \gamma_2 \ell_2)} \qquad \text{......(A2-1)}$$

where $\gamma_1 = \alpha_1 + j\beta_1$ is the propagation coefficient in the single tube cable of length ℓ_1,

$\gamma_2 = \alpha_2 + j\beta_2$ is the propagation coefficient for the semiflex of length ℓ_2,

Z_0 is the impedance of the tube in the multi-tube coaxial cable,

Z_{A1} is the impedance of the single tube coaxial cable jointed to it and

Z_{A2} is the impedance at the semiflex end of this single tube cable, all at the frequency concerned.

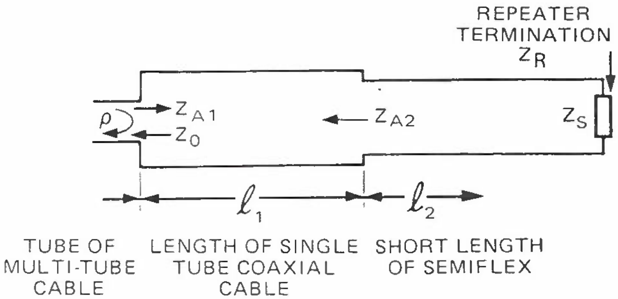

Fig. 4 — Termination at Above-Ground Repeater

The single tube cable is jointed to the semiflex which can be assumed to have a constant value of impedance Z_S (because of its short length). Reflections from within the cables are negligible.

Two cases will be considered, namely jointing to an underground minor repeater and jointing to an above-ground repeater.

Case 1 — Jointing to an Underground Repeater

When jointing to an underground repeater, the single tube coaxial cable is not present; hence, ℓ_1 becomes zero and $Z_{A1} = Z_{A2} = Z_0$ and Equation A2-1 simplifies to:

$$\rho = \frac{Z_S - Z_0}{Z_S + Z_0} + \frac{Z_R - Z_S}{Z_R + Z_S} e^{-2\gamma_2 \ell_2} \qquad \ldots\ldots (A2\text{-}2)$$

If ℓ_2 is small, then

$$2\gamma_2 \ell_2 \simeq 2j\beta_2 \ell_2 = 2j \frac{2\pi \ell_2}{\lambda_2} = j \frac{4\pi \ell_2}{\lambda_2}$$

where $\lambda 2$ is the wavelength in the semiflex at the frequency concerned, so that

$$e^{-2\gamma_2 \ell_2} \simeq e^{-2j\beta_2 \ell_2} \simeq 1 - 2j\beta_2 \ell_2 = 1 - j\frac{4\pi \ell_2}{\lambda_2}$$

This assumption of ℓ_2 being small is acceptably true for the lengths of semiflex currently being used for the upper frequencies currently in use and proposed.

The assumption of course becomes better at lower frequencies because $2j\beta_2\ell_2$ is almost directly proportional to frequency. For higher frequencies (such as 60 MHz and digital systems), a more complex analysis is required.

Thus Equation A2-2 becomes

$$\rho \simeq \frac{Z_S - Z_0}{2Z_0} + \frac{(Z_R - Z_S)(1 - 2j\beta_2 \ell_2)}{2Z_0}$$

as $(Z_S + Z_0) \simeq (Z_R + Z_S) \simeq 2Z_0$, and so

$$\rho \simeq \frac{Z_R - Z_0}{2Z_0} - \frac{j4\pi f \ell_2 (Z_R - Z_S)}{2Z_0 v_2} \qquad \ldots\ldots (A2\text{-}3)$$

where v_2 is the phase velocity in the semiflex.

The absence of exponential terms means that the two reflection sites have effectively been combined to form a single reflection site in the cable structure, and so cannot produce a frequency response ripple. However, for a longer length of semiflex, the two reflection sites cannot be combined and tend to produce a ripple in the frequency response of the system. However, such a ripple is not considered significant as long as the period of the ripple is more than twice the maximum frequency of the system. The ripple period T is given by:

$$T = \frac{v_2}{2\ell_2} \qquad \ldots\ldots (A2\text{-}4)$$

where v_2 and ℓ_2 are as previously defined.

Returning to Equation A2-3 and making the very reasonable assumption that Z_R, Z_0 and Z_S are real, then Equation A2-3 is composed of two components, one real and independent of frequency (to a first approximation), and an imaginary component which is directly proportional to frequency. Because $\frac{4\pi f \ell_2}{v_2}$ is small, the real component dominates the reflection coefficient.

Let $Z_R = Z_N \pm \Delta Z_R$ and $Z_0 = Z_N \pm \Delta Z_0$, where Z_N is the nominal impedance of 75.00 ohm (installed), then the maximum and minimum values of the reflection coefficient are

$$|\rho| \simeq \left| \frac{\pm\Delta Z_R \mp \Delta Z_0}{2Z_N} \right| \qquad \ldots\ldots (A2\text{-}5)$$

The conditions in the worst case must be considered. Typically ΔZ_R may be up to 10 ohm, so this value must be combined with the worst possible value for ΔZ_0, taking into consideration the sign (positive or negative). If ΔZ_0 is 0.1 ohm, as would be given by Spare Drum Quality cable, the worst value of $|\rho|$ is

$$|\rho|_{max} = \left|\frac{10.1}{150}\right| = 0.067 = 23.4 \text{ dB}$$

Consider next the case where the normal tolerance of $\pm$ 0.3 ohm is permitted, then

$$|\rho|_{max} = \left|\frac{10.3}{150}\right| = 0.069 = 22.3 \text{ dB.}$$

This level of improvement, obtained by insisting that all tubes (terminating at repeaters) meet the Spare Drum Quality Specification on the limits of the end impedance, does not justify the extra cost involved in manufacture. If the term containing $Z_R - Z_S$ is considered, the relative improvement is even less, further justifying the using of the normal tolerance.

Case 2 — Termination at Above-Ground Repeaters

The second case of termination at above ground repeaters will now be considered. Firstly, Equation (A2-1) must be rearranged

$$\rho = \frac{Z_{A1} - Z_0}{Z_{A1} + Z_0} + e^{-2\gamma_1 \ell_1} \left[\frac{Z_S - Z_{A2}}{Z_S + Z_{A2}} + \frac{Z_R - Z_S}{Z_R + Z_S} e^{-2\gamma_2 \ell_2} \right]$$

$$\simeq \frac{Z_{A1} - Z_0}{Z_{A1} + Z_0} + e^{-2\gamma_1 \ell_1} \left[\frac{Z_R - Z_{A2}}{2Z_0} - \frac{j4\pi f \ell_2}{2Z_0 v_2} (Z_R - Z_S) \right] \qquad . (A2\text{-}6)$$

using the results of Case 1, assuming ℓ_2 is small.

However, the assumption of ℓ_1 being small cannot be made, and the two terms in Equation A2-6 cannot be combined as in Case 1 to make a single equivalent reflection site.

Hence this combined reflection coefficient must be interpreted as two reflection sites, the first one between the multi-tube cable and the single tube and the second between the single tube and the equivalent reflection as from Case 1. The former site must satisfy the criteria of a maximum impedance difference of 0.2 ohm and because Z_{A1} has a tolerance of only ± 0.1 ohm (because all single tube coaxial cable is manufactured to Spare Drum Quality Specification), then Z_0 must have a tolerance of ± 0.1 ohm also. Ideally, the length restriction on ℓ_2, as discussed in Case 1, should be applied; however, practical considerations often prevent this, although fortunately the number of above-ground repeaters is normally much smaller than the number of underground repeaters, thus easing any potential ripple problem due to a large ℓ_2.

In Brief

New Standard for Graphical Symbols for Electro Technology, Part 14 — Telephony and Telegraph Transducers

The Standard Association has recently published a further part in the series of standards on graphical symbols for electrotechnology, in this instance on telephony, telegraphy and transducer symbols, AS 1102.14.

The purpose of this part of the standard is to specify symbols representing elements and devices for use in diagrams representing switched telecommunications networks. The symbols are intended for use with any type of eqipment, being intended to convey concepts only and thus being independent of the actual device performing the switching.

This part also includes symbols for transducers which are not limited to telecommunications equipment. Symbols are given for transducers for both recording and reproducing equipment.

This part 14 is based on Publications 117-9A, 9B and 9C issued by the International Electrotechnical Commission. The symbols are identical with those established by the IEC concept, where the established usage in Australia has made unqualified acceptance of the IEC recommended symbol difficult. A number of examples have been added, representing Australian practice.

Copies of AS 1102.14 ($6.00) may be obtained from the offices of the Association. (Postage and handling 80 cents extra).

Graphic Symbols for Electrotechnology, Part 13 — Microwave Technology

Another part in the series of standards for graphical symbols for electrotechnology covering microwave technology is AS 1102.13.

This part gives symbols for transmission paths, one-, two-, and multi-port devices and functions, couplings, probes, measuring devices and tubes for use in diagrams for microwave devices and equipment.

Examples of the use and combination of the symbols are also given. For a complete understanding of the methods involved in the use of the symbols reference is necessary to other Parts of AS 1102 and also AS 1103, Diagrams, charts and tables for electrotechnology, particularly part 3, Basic principles for the presentation of elements of electrical diagrams, and part 4, guiding principles for the preparation of circuit diagrams.

This new part of the standard is technically identical with the recommendations of Publications 117-11 and 117-11A issued by the International Electrotechnical Commission.

Copies of AS 1102.13 ($4.40) may be obtained from the offices of the Association in any capital city and Newcastle. (Postage and handling 60 cents extra).

New Standard for Enamelled Round Copper Winding Wires

A new standard for enamelled round copper winding wires replaces sections of AS C73-1969 and is in metric units.

The standard (AS 1194) covers dimensions and material requirements for the base wires and for the enamelled coating and tests to prove compliance with the specification.

The nominal diameters of conductors specified are unchanged from AS C73 and are identical with those specified in IEC Publication 182 'Basic Dimensions of Winding Wires'. The diameters specified are preferred sizes, but an Appendix provides guidance for the selection of non-preferred intermediate sizes.

Copies of AS 1194 ($21.00) may be obtained from the offices of the Association in State capitals and Newcastle. (Postage and handling $1.50 extra.)

ABSTRACTS: Vol. 30, No. 1

DEW, I. A. and MURPHETT, A.: 'LED's as Replacement Lamps in Existing Switchboards'; Telecom Journal of Aust., Vol. 30, No. 1, 1980, page 58.

Incandescent switchboard lamps have remained the preferred source of illumination despite their relatively short service life and high replacement costs. Light emitting diodes as presently produced while offering substantially greater life expectancies cannot compete with the incandescent lamp because of their much lower luminous intensity.

This article makes a critical comparison of the two types of light source and presents evidence to show how the deficiencies of the LED may be overcome. A prototype development of a multichip LED, designed for use as a switchboard lamp is described.

EDVI-ILLES, A., LEE, F. Y. and WION, F. W.: 'Packet Switching for Data Communications — An Overview'; Telecom Journal of Aust., Vol. 30, No. 1, 1980, page 26.

Packet switching is gaining increasing acceptance as a method of providing switched data transmission services. This paper presents a brief overview of the history and development of packet switching, the operation of packet network, the relevant international standards, a summary of the applications well served by packet switching and the expected developments that secure the future of packet switching as an enduring technology.

HALL, L. J., LYNCH, J. K. and LLOYD, R. R.: 'Coaxial Cable Impedance Considerations — Manufacture, Testing and Allocation of Tubes and Cables'; Telecom Journal of Aust., Vol. 30, No. 1, 1980, page 69.

In order to obtain satisfactory transmission performance on a coaxial line system, reflections on the coaxial tubes must be carefully controlled. The most significant reflections are those occurring between repeaters and the coaxial tubes and those at joints, where coaxial tubes of different end impedances meet. This paper firstly defines end impedance and its measurement, and then indicates the limits required in the impedance matching of end impedances of the coaxial tubes at both joints and repeaters. The measures taken by the manufacturer of coaxial cable to control the end impedances of coaxial tubes are also discussed.

JINMAN, M.: 'Route Planning Rules for Primary PCM'; Telecom Journal of Aust., Vol. 30, No. 1, 1980, page 34.

Like many planning problems, the design of PCM route planning rules is an exercise in engineering judgment. There is undoubtedly a "right" solution, but it cannot be identified with certainty until it is much too late to matter. However, the potential gains — or losses — are such that the continuing effort to get as near as possible to the correct solution is well worth while.

LEWIS, R. J.: 'The Development of Cellular Plastics Insulated Filled Cable'; Telecom Journal of Aust., Vol. 30, No. 1, 1980, page 46.

Following the successful development of filled cable overseas, Telecom Australia has developed and introduced a range of small size (up to 100 pairs) cellular plastics insulated filled cable, suitable for Australian environmental and manufacturing conditions. A very extensive developmental programme including contract work costing $473,000 by an Australian and a Japanese cable manufacturer, was undertaken by Telecom. The cable has been designed for direct burial in the rural section in the network, and uses copper conductors, cellular plastics insulation, a proprietary petroleum jelly filling compound, paper core wrap and a moisture barrier sheath. The more important design considerations for filled cable are described together with a summary of the electrical and transmission properties. The article also includes short sections on manufacturing, costs and installation practices; it concludes with a preview of likely future developments.

MASSIH, G.: 'VDU/TRESS System'; Telecom Journal of Aust., Vol. 30, No. 1, 1980, page 40.

This paper outlines briefly the developments of the Public Telegram Service in Australia and its evolution to the present system known as TRESS (Transmitter Reperforator Switching System).

A further development — VDU/TRESS — has recently been introduced following successful field trials. VDU/TRESS is a new phonogram input system aimed at cost reduction and increased efficiency through the use of new input equipment (VDU) and a more effective utilisation of staff.

MAY, T. S.: 'Test Console for Customer Fault Despatch Centres'; Telecom Journal of Aust., Vol. 30, No. 1, 1980, page 20.

Customer Service line testing facilities have always been and will continue to be essential to the process of attending to customer service faults. The APO Exchange Test Desk has until recently been the standard means of providing these facilities, but with the advent in metropolitan areas of centralised Fault Despatch Centres (FDCs) a number of specialised test desks have been developed for this application. This article briefly describes a test console which has been developed to meet the requirements of a modern FDC pending the introduction of a new generation remotely controlled test network.

ORTON, R. L. and EVERS, J.: 'Operations and Maintenance Facilities Provided by ARE 11'; Telecom Journal of Aust., Vol. 30, No. 1, 1980, page 12.

Following the installation and evaluation of the ARE 11 field trial exchanges an improved version of the ARE 11 was developed by L. M. Ericsson. The new version, ARE 11, stage 2, provides enhanced operating and maintenance facilities.

TREBILCO, W. J.: 'The Improved Multi Purpose Coin Telephone: CT3(I)'; Telecom Journal of Aust., Vol. 30, No. 1, 1980, page 3.

Multipurpose Coin Telephone No. 3 (CT3) was introduced in 1971 to provide the public with STD calling from coin telephones and to reduce operator assistance traffic. However, CT3 was developed prior to the high inflationary upturn in our economy and it became apparent that its limited tariff facilities would restrict future policies. Therefore, it was decided to redesign the CT3 to provide it with an expanded and more flexible tariff ability and, in addition, incorporate a number of other electrical and mechanical improvements.

This article describes the design changes which have led to the development of the improved multi-purpose coin telephones CT3(I).

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