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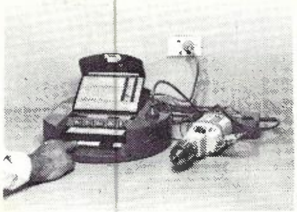

COVER
ELECTRICAL SAFETY
TEST SET

The Telecommunication Journal of Australia

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OVERSEAS APPLICATIONS

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Electrical Safety Test Set for Power Outlets and Appliances

R. NEAL, ASTC, Grad M.I.E. Aust and U. KAZENWADEL, B. Eng. (Elec)

Safe use of electricity is of growing importance with the increasing availability of portable electric power tools and appliances as labour saving devices. Their wide application within Telecom has emphasised the need for an operationally simple test set to verify the safety of the electric supply and any devices which may be plugged into this supply.

INTRODUCTION

Electricity, like fire, is a good slave but a bad master — electricity under many circumstances can kill. Strict control in the use of electricity has been recognised by governments and in Australia legislation has been framed to control electric wiring systems and the manufacture and sale of appliances.

The methods of carrying out safety checks have not always been clearly defined and there is no known commercially available single instrument that can test the safety aspects of both the power supply outlet and the appliance to be used.

Over the past 25 years the PMG Department — Australian Post Office — Telecom Australia has been active in the development of a test set which would test a standard power outlet and check extension cords and appliances to ensure that they are safe to use.

The first of these test sets went into field use in 1962 with a limited number of 50 units. Since that time two similar but improved versions of the same general design have been manufactured and placed in field use. All of these earlier units were for use by technically trained staff only and therefore had limited application.

In 1971 it was decided that a new approach was needed and that a test set to carry out all of the safety tests should be able to be used by non technical persons. This was considered to be achievable by making more use of the many sophisticated solid state devices becoming available.

ELECTRIC SUPPLY IN AUSTRALIA

Electricity generation and distribution in Australia commenced around 1890, initially in country towns and followed within a few years by the capital cities. It was not until the 1930's that legislation was introduced to control and supervise the development of electric supply for public purposes in New South Wales although in Victoria the State Electricity Commission was established by act in as early as 1918.

Since the 1930's a great deal of co-ordination of standards in the electric supply industry for the whole of Australia has been undertaken by the Standards Association of Australia (SAA) and the Electric Supply Association of Australia (ESAA).

In common with most early power generation systems direct current was initially distributed at 460V and 230V and it is only in the last 10 years that the last of these dc systems have been removed from the capital cities of Sydney and Melbourne where they were used to operate electric elevators in many of the older buildings.

Generation and distribution systems are generally operated by State Governments with little interconnection or interchange of power. The exception is New South Wales and Victoria who share with the Australian Capital Territory a large hydro electric generating system (Snowy Mountains).

Frequency is time controlled on all systems and therefore synchronous motors can be used to drive electric clocks and other items where constant speed is essential.

Although other power supply systems have been used in the past the well established and publicised standard throughout Australia for domestic and small commercial and industrial users is a 50 Hz 3 phase 4 wire system with a nominal voltage between phases of 415V and from any phase to neutral of 240V (nominal). Most distribution systems now use a multiple earthed neutral (MEN) arrangement to maintain the neutral close to earth potential. As well as earthing the neutral at each consumer it is common practice to also earth the neutral at intervals along the distribution route as shown in **Fig. 1**.

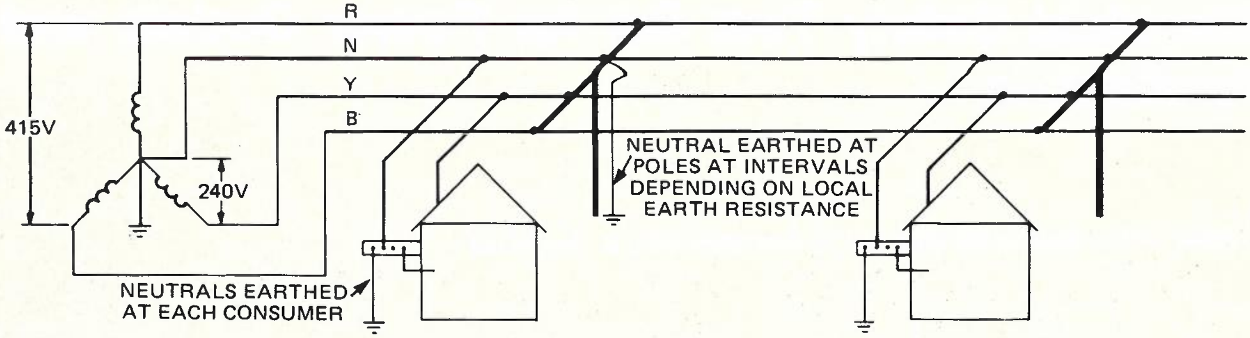
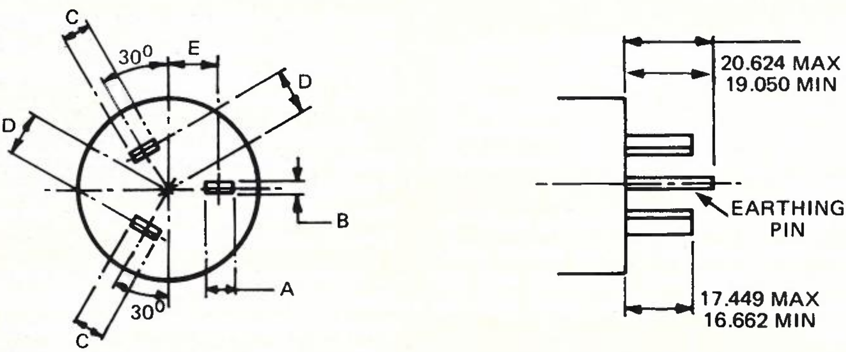


Fig. 1 — MEN Distribution System



DIMENSION	10 AMPERES AND BELOW	15 AMPERES	20 AMPERES
A	6.477 MAX 6.223 MIN	9.194 MAX 8.94 MIN	9.194 MAX 8.94 MIN
B (ALL PINS)	1.625 ±0.127		
C	6.477 MAX 6.223 MIN	6.477 MAX 6.223 MIN	9.194 MAX 8.94 MIN
D	7.924	7.924	7.137
E	10.312	10.312	11.887

Fig. 2 — Dimensions of Flat-Pin Plugs (mm)

STANDARD POWER OUTLETS AND CONNECTIONS

Australia is fortunate in having established at an early stage of electric supply history (1937) a standard plug and socket rated at 10 amps 240V which has not changed in dimensions since that date. Many improvements have been made to the general construction including terminations, cord anchorage and such like.

No circuit protection devices are included in either the outlet or the plug.

In more recent years this standard has been expanded to include a 15 amp and 20 amp outlet and plug. The only dimensional difference from the 10 amp unit is the width of the earth pin. **Fig. 2.**

The wider earth pin of these plugs prevents large power consuming appliances being plugged into an outlet rated at only 10 amp.

The earth pin of all plugs is longer than the current carrying pins to ensure that contact to the earth is always made first, and broken last.

The electrical connections for the plug are shown in **Fig. 3**. The connections to the current carrying pins have always been well defined. Since about 1958 a recommended order of connections of active and neutral conductors has been used and from this time all combination switch - outlets have had this order of connection to the socket.

Although this order of connection does assist in defining the active conductor through to the appliance it is mandatory for all portable appliances to be fitted with double pole switches. Irrespective of this standardisation the two current carrying conductors should be treated as live conductors at all times.

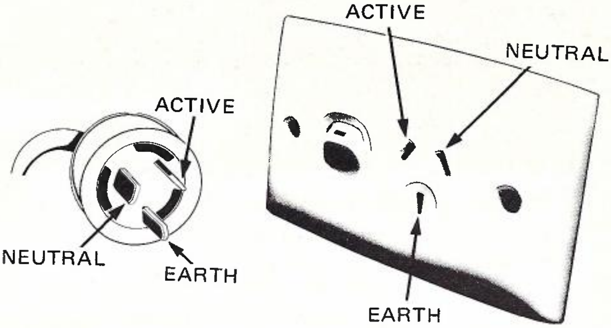
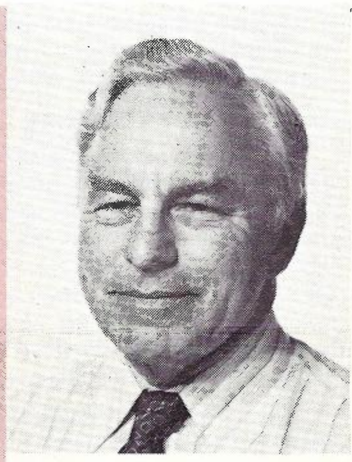


Fig. 3 — Electrical Connections of Plug and Outlet

BOB NEAL joined the PMG Department in 1948 as a Technician (Light and Power) and served as an electrical tradesman for 5 years in Victoria. A further 4 years was spent as an engineer in the Buildings Branch, Victoria.

In 1957 he was promoted to the Headquarters Buildings Branch and has occupied a number of engineering levels in that Branch. He is now Manager, Engineering Standards, Buildings Branch, Headquarters.

He graduated from Swinburne Technical College with a Diploma of Electrical Engineering in 1947.



ULF KAZENWADEL joined the Australian Post Office (now Telecom Australia) in 1971. He graduated with Bachelor of Technology degree in Electrical Engineering. After two years employed as an Engineer with McColl Electric Works Springvale, he joined Telecom as a Class 1 Engineer in the Longline and Telepower Equipment Branch, Headquarters. There he worked in the Telepower, Programme Development and Provisioning Sections. At present he is employed as a Class 3 (A/g) Engineer in the Engineering Standards Section of Buildings Branch, Headquarters involved in preparation of standards for building engineering services.

Year	Total fatalities	Damaged/faulty extension cords	Damaged/faulty household wiring	Damaged/faulty electrical appliances	Others
1971	81	15	7	7	52
1972	87	15	4	14	64
1973	110	24	6	21	59
1974	101	23	5	11	62
1975	113	20	3	14	57
1976	78	10	8	13	38
1977	73	13	12	5	43

Table 1 — Causes of Electrical Fatalities

STANDARDS OF WIRING AND APPLIANCES

Rules and regulations relating to methods of wiring and protection of systems have been developed, on an Australia wide basis, by the Standards Association of Australia in conjunction with electric supply authorities, manufacturers and government organisations.

In addition to SAA Wiring Rules Australian Standard 3000, Part 1, which apply to fixed wiring installations, the Standards Association of Australia has developed "Standards" and "Performance and Test" specifications for portable electrical appliances and their associated interconnecting systems — these are individual publications contained in SAA Wiring Rules Part 2.

ELECTRICAL FATALITIES

In spite of what is generally a well regulated, standardised and controlled electrical distribution system with regulations to control the standards of appliances and their connections which are common throughout the whole country there are numerous fatalities from electrical causes which often exceed 100 in any one year. Many of the fatalities are caused through carelessness, lack of knowledge and poor maintenance of extension cords and portable appliances.

Table 1 shows some of the causes of electrical fatalities over recent years.

Under the heading of "others" is included contact with overhead conductors, contact with live terminals and bare conductors, and employees of Electric Supply Authorities killed in the course of their duty.

The three causes listed in the table applying to damaged and faulty equipment could be minimised by having an easily usable test set which could be used by non-technical persons to give a clear indication of whether an appliance; extension cord or electric supply system is safe to use.

TEST SET CRITERIA

The following requirements were established as a basis for the design:

1. To test a standard 3 pin power outlet:
   a. to determine that the switch on the outlet controls the active conductor;
   b. to determine that the wiring is terminated on correct pins;
   c. to determine that the earth pin of the outlet is effectively earthed.
2. To test extension cords:
   a. to ensure that all conductors are connected to the correct pins of the plug and socket;
   b. to check that the earth pin of the plug and the earth terminal of the socket are connected together by a low impedance conductor.
3. To test appliances:
   a. to check that the insulation resistance between the windings and frame is adequate (double insulated, normal earth appliance or mineral insulated metal sheathed elements);
   b. to check that the earth pin of the appliance plug is connected to the exposed metal of the appliance (if it is not double insulated) and that this connection has a low impedance.

In addition to performing these tests the test set must not introduce a hazardous situation irrespective of the condition of the items to be tested.

TEST SET DESIGN

Test No. 1 (a) is achieved with a diode matrix and neon lamp such that a potential difference between any two of the three conductors will light the lamp. Operation of the outlet switch to off will extinguish the lamp if the outlet is wired correctly.

Test No. 1 (b) can only be verified by bringing a separate reference earth to the point to be tested. This is achieved by body earth. A very small current sufficient to trigger a cold cathode trigger tube is passed through the operator (similar to touch buttons on some elevators).

Test No. 1 (c), for an earth to be effective it must allow a low impedance path for any fault current from the active conductor. This is best tested by simulating a fault through this path. This test must not create a hazardous situation if the earth is open circuit or of high impedance.

Use was made of the findings published in reference 2. Effect of Current Passing Through the Human Body, and **Fig. 4** is reproduced from reference 2.

It will be noted that provided the current through a person — i.e. magnitude of current and/or duration of current — are kept within regions 1,2 or 3 there is little chance of any dangerous effects.

From this same document it is stated that the lowest probable values of body resistance for a 250V touch voltage can be regarded as 1000 ohms. This would represent an rms current of 250 mA. Examination of the curves shows that provided the duration of a 250 mA current is less than 50 ms the effects remain within zone 2 (usually no pathologically dangerous effects).

The test set has been designed to provide a fault test current of about 25 amps (if the circuit is in good condition) for a duration not exceeding 30 ms. This short duration has no effect on protection devices except for fast acting core balance circuit breakers which need to be removed or disconnected before testing takes place.

Test 2 (a). This test is carried out by placing the extension cord between a tested and good outlet and the test set and conducting tests again to prove the outlet satisfactory.

Test 2 (b) is carried out with a separate plug on the test set which tests the earthing conductor within the extension cord for a low impedance circuit.

Test 3 (a) uses a 500V dc voltage impressed between the windings of the appliance and the earthed frame or in the case of double insulated appliances an artificial conductor placed around the appliance (metal foil).

Test 3 (b) tests that the exposed metal of an earthed appliance is correctly connected to the earth pin of the plug by passing a short duration pulse of high current through that circuit and measuring the impedance.

SPECIFICATIONS

General

Mains supply voltage range: 216 — 280V.

This was selected on the basis of 240V ± 6% as applies in all States except Western Australia and 254V ± 6% as applies in Western Australia and applying a safety margin.

Temperature Range: 0 — 50° C.

Line Frequency: 50 Hz ± 10%.

Unit indication to be fail safe. Lamps to glow in event of satisfactory test only.

Power Outlet Tests

The power outlet tests shall provide a check on safety factors as described in **Fig. 5.**

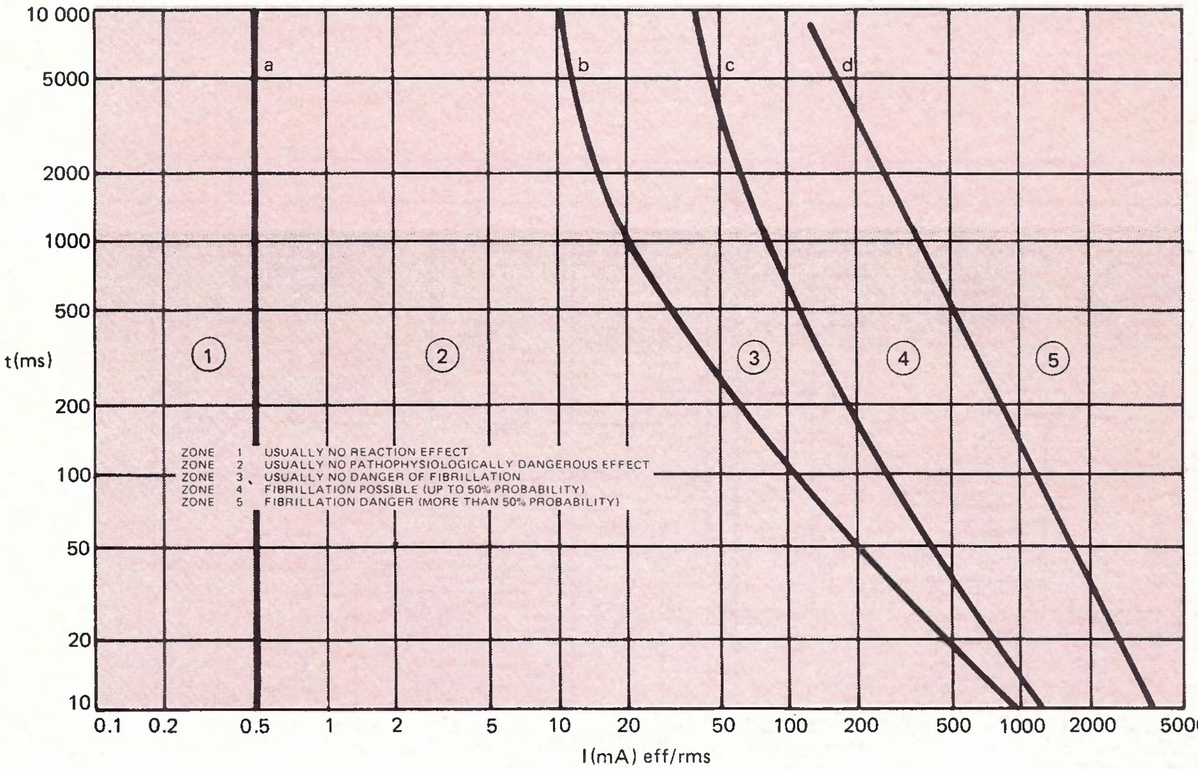


Fig. 4 — Zones of Effect of AC Currents (50/60 Hz) on Adult Persons.

Appliance Tests

These shall test appliances for the following conditions.

The resistance between the exposed metal of the appliance and the earth pin of the appliance plug is less than 0.5 ohm.

The insulation resistance, at a potential of 500V dc with respect to earth, in three ranges shall be:

- Not less than 10 Megohm — for double insulated appliances.
- Not less than 1 Megohm — for earthed appliances.
- Not less than 100 Kilohm — for metal sheathed elements.

Extension Cord Tests

These shall test extension cords for:

Continuity of wiring and correct connection of cord plug earth pin.

Impedance of earth conductor shall be less than 0.5 ohm.

NOTE: This latter test shall ensure that the earth conductor is connected to the earth terminals at both plug and socket of the extension cord.

Development of a Test Set to meet these specified requirements was achieved; its operation is outlined in the following test descriptions. A block diagram is contained in **Fig. 6. Fig. 7** shows the layout of components on the Test Set printed circuit board and a photograph of the Test Set appears on the front cover of this issue of the Journal.

OPERATION

Operation of the test set is based on a simple set of pass/fail operating instructions. These are detailed in Appendix A and clearly illustrate the ease of Test Set operation for which a technical background is not required by the operator.

NOTE: For a test to be successful, the appropriate neon must light which leaves no doubt that the operator has actually carried out the test correctly.

Power Outlet Wiring

Testing for Uncontrolled Active Conductors.

1. The circuitry for testing an uncontrolled active conductor is detailed in **Fig. 8.**

The "Mains On" neon indicator (L1) indicates the presence of an active conductor. The indicator should not light with the outlet switch at "OFF" position. If lamp L1 continues to glow, this indicates the presence of an uncontrolled active conductor.

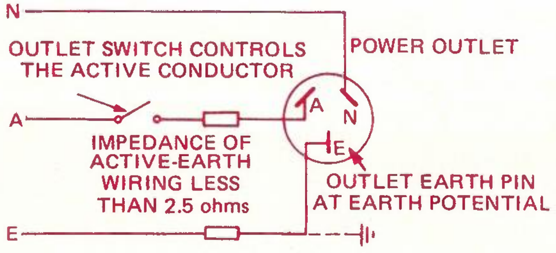


Fig. 5 — Power Outlet Tests.

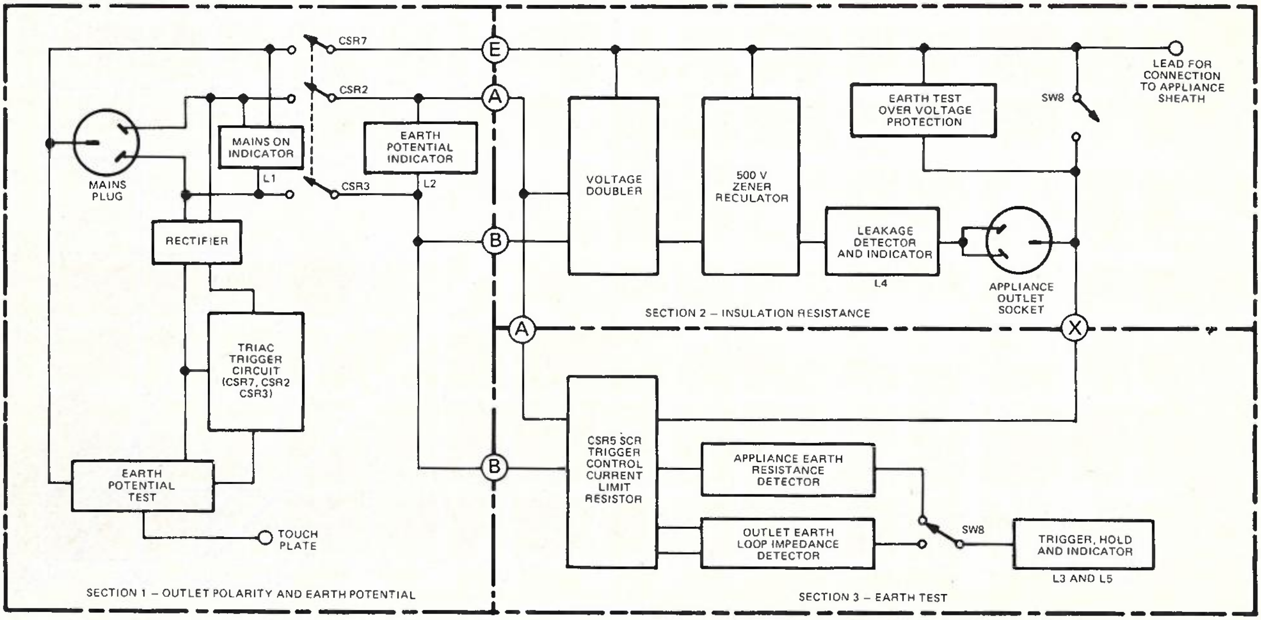


Fig. 6 — Block Diagram of Test Set.

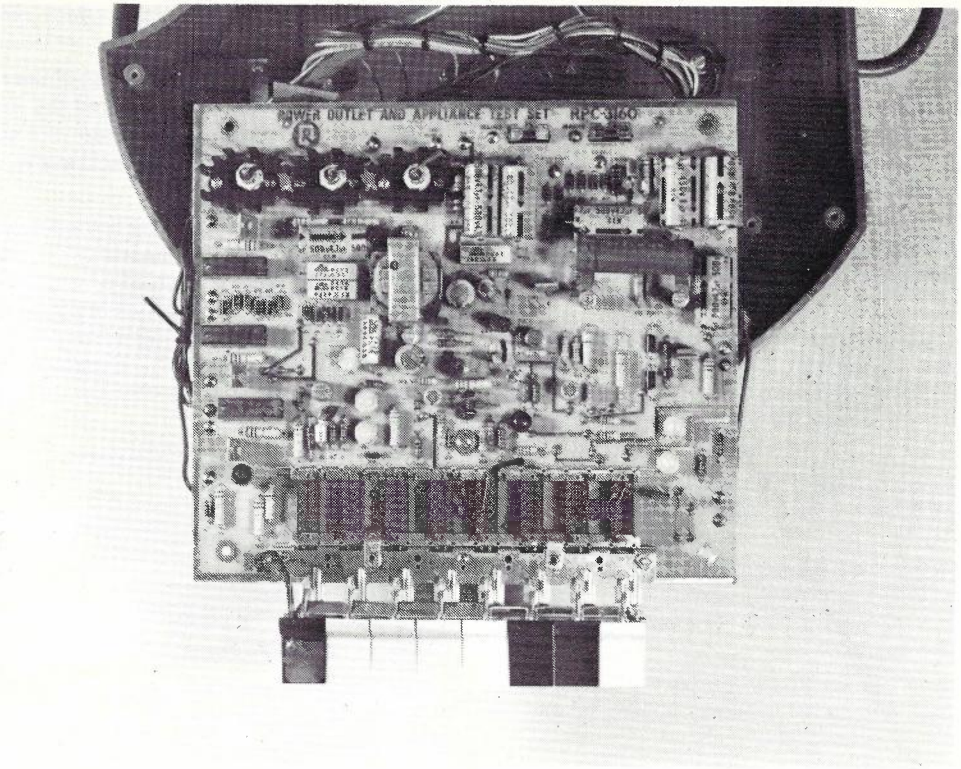


Fig. 7 — Printed Circuit Board of Test Set

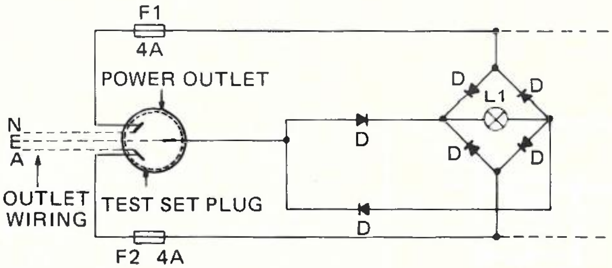


Fig. 8 — Uncontrolled Active Conductor Test

Earth Potential Test

Upon pressing the Earth Potential switch SW1 as shown in **Fig. 9**, a current of approximately 80 microampere flows through the connected grid of a trigger tube, via the metal "Touch-plate" on the switch to actual earth through the operator's body. If the earth-pin is at earth potential the tube fires and the triacs (used as switches) are operated causing the earth potential indicator L2 to glow. Operation of these triacs energises other test facilities in the unit.

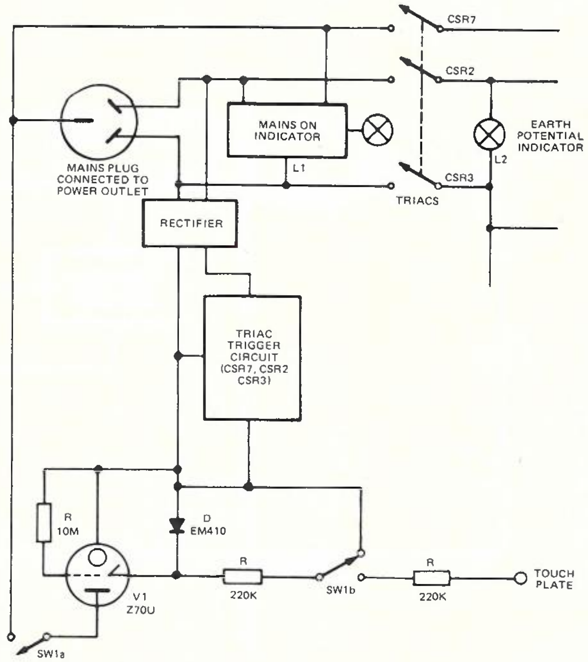


Fig. 9 — Earth Potential Test

Power Outlet Active Earth Loop Impedance

This test checks that the active-earth loop impedance does not exceed 2.5 ohms and is applied to ensure that in the event of a fault associated with the power outlet, sufficient current will flow to trip the protective circuitry (fuse) and that the frame of the appliance does not reach a dangerous potential above earth. The active conductor is switched through a resistor to earth for a very short period (30 milliseconds approximately), and the active-earth loop impedance is compared with an internal impedance.

If the loop impedance is less than 2.5 ohms, the output signal of the comparator triggers a circuit to indicate that the "outlet-earth loop" is good i.e. lamp L3 lights. The short duration of the earth-loop current has been selected to:

- minimise potential hazard of passing current through the earth conductor if it is open circuit or high impedance
- ensure that protective circuitry does not operate (except core balance circuit breakers)
- ensure that overheating and damage to the earth conductor is prevented.

A simplified circuit for measurement of Power Outlet active earth loop impedance is shown in **Fig. 10** and the following refers to its operation.

The mains from an outlet can be viewed as a voltage source of value Vs with a series source impedance of $Z_{A/E}$ (active-earth).

In the operation of the tester it is assumed that since most outlets are usually lightly loaded in comparison to the peak load of the tester, any load on the outlet circuit under test has only a minimal effect upon the measurement of $Z_{A/E}$.

Further it is assumed that most of the impedance $Z_{A/E}$ is between a particular outlet and the main switchboard and hence the current drawn from the supply by parallel outlets has only a minimal effect on the measurement of $Z_{A/E}$.

On operation of the earth impedance switch (trigger circuit) the silicon controlled rectifier CSR5 is triggered and a current flows from the source Vs through the source impedance $Z_{A/E}$ which has a voltage drop V_Z and through limiting resistor R39 which has a voltage drop of V_T. The test set effectively compares V_T with Vs which can be shown to be a comparison of R39 with $Z_{A/E}$ as follows:

Current $I = V_Z/Z_{A/E} = V_T/R39$

Voltage $Vs = V_Z + V_T$

and substituting to eliminate V_Z as this voltage cannot be measured results in

$Z_{A/E}/R39 = Vs/V_T - 1$.

Since R39 is fixed, by comparing ratio of Vs/V_T, the source impedance $Z_{A/E}$ can be determined.

Appliance Earth Resistance Test

As for the previous test a low impedance of the active-earth loop of the appliance conductors is essential. This test is carried out to ensure that earth conductor is connected to the frame of the appliance (not applicable to double insulated appliances) and that the impedance to the earth pin of the plug is less than 0.5 ohms.

A bridge arrangement as shown in **Fig. 11** is used where a 30 millisec pulse of current through CSR5 is

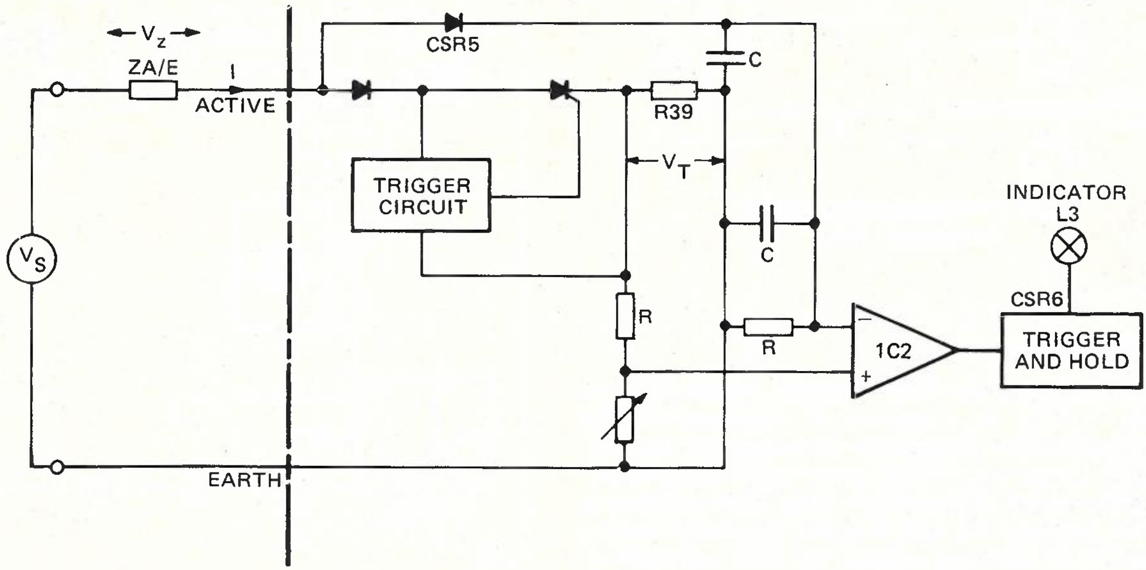


Fig. 10 — Test for Active Earth Loop Impedance of Power Outlet.

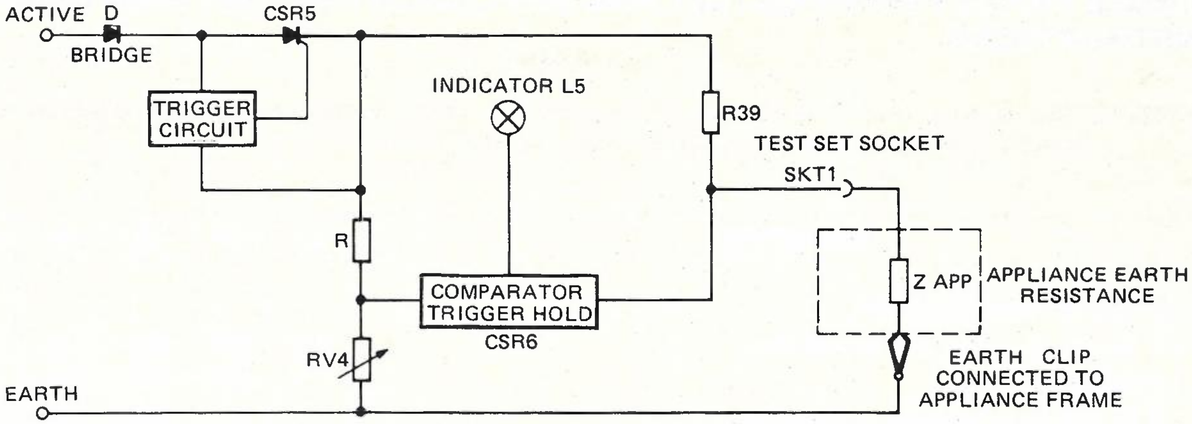


Fig. 11 — Appliance Earth Resistance Test

used as the current source and CSR6 is used as the detector. The voltage across RV4 is compared with the voltage across Z_{APP} (earth resistance between earth terminal in appliance plug and the appliance frame).

If the resistance Z_{APP} is less than 0.5 ohms the voltage across RV4 will be greater than the voltage across Z_{APP} and the comparator is triggered. This will cause the "Appliance Earth" lamp L5 to glow indicating a satisfactory result.

Appliance Insulation Test

Australian Standard ASC100 "Definitions and General Requirements for Electrical Materials and Equipment" requires that the insulation resistance between live parts of an appliance and its frame or case shall be measured at a voltage of 500V dc and shall be not less than:

10 Megohms for double insulated appliances
1 Megohms for earthed appliances
100 Kilohms for metal sheathed elements.

Consequently the insulation test with limits previously described in the Specification, has been incorporated to ensure that these minimum appliance insulation resistances are exceeded by the appliance being tested.

A voltage doubler circuit as indicated in Fig. 6 is used to raise the voltage to between 600V and 800V dc, depending upon input mains voltage. This voltage is then regulated to 500V. When any of the insulation test buttons is pressed, 500V dc is applied between both active and neutral pins of the test socket and the case of the appliance. If the voltage at the input of the comparator (leakage detector) is greater than that at the reference input the comparator then turns on the "appliance insulation" lamp (L4) indicating an adequate insulation resistance.

SELECTION OF ACTIVE-EARTH LOOP IMPEDANCE TEST CONDITIONS.

As with all new innovations, particularly where they affect staff safety there has been much comment on various aspects of the Test Set. Possibly the most contentious item relates to the active-earth loop impedance test. Supporters of the previously used 30 ampere continuous test feel that the Impedance Test conditions are inadequate to establish the satisfactory connection of the earth to a power outlet or appliance plug.

The previously provided 30 ampere continuous test was discarded and the Impedance Test incorporated because :

- Any attempt to destroy poorly connected wiring by application of the 30 ampere test was unlikely to be conclusive, and in fact a destructive test carried out on an item which was to remain in use after the test was completed was considered to be inappropriate.
- The Impedance Test does not suffer from the potential hazard of passing a large current (for a substantial time period) through the earth conductor; in the event of an open circuit in the building earth connection, people in contact with earthed appliances connected to other power outlets on the same circuit would be in danger.

MANUFACTURE AND USE

The Test Sets were manufactured by A&R Electronics, Box Hill, Victoria and were delivered during 1975/76. After an initial modification programme which was necessary to correct problems associated with variations in component characteristics (beyond those allowed for in the initial design) units were introduced in the field and have now been used successfully for periods up to two years.

The units perform within specifications determined as suitable for safety checking of power outlets, appliances and extension cords and apart from some failures, insignificant in relation to the total quantity purchased, have operated reliably and are meeting their intended purpose in the field.

REFERENCES

1. Research Laboratories Report No. 6860 Single Phase Power Outlet and Appliance Test Set by R. Proundlock.
2. Publication 479-1974. Effects of Current Passing Through the Human Body issued by the International Electrotechnical Commission.
3. Standards Association of Australia, Miscellaneous Publication MP 30, 1976. Report on Effects of Current Passing Through the Human Body.

SINGLE PHASE POWER OUTLET AND APPLIANCE TEST SET — OPERATING INSTRUCTIONS

WARNING: Test operation is to cease on failure of the appropriate lamp to indicate. Immediately label the outlet, appliance or extension cord as "UNSAFE". Follow up with report.

OPERATION	L1	L2	L3	L4	L5
1. TO TEST A POWER OUTLET					
1.1 Switch off outlet, plug in Test Set	OFF	OFF	OFF	OFF	OFF
1.2 Switch on outlet	ON	OFF	OFF	OFF	OFF
1.3 To test earth potential — Press SW1	ON	ON	OFF	OFF	OFF
1.4 To check lamps L3, L4 and L5 — Press SW5	ON	ON	ON	ON	ON
1.5 To test outlet earth loop impedance — Press SW8 to down position — Allow 10 seconds — Press SW7	ON	ON	ON	OFF	OFF
To reset L3 — Press SW6 (allow 10 seconds between tests)	ON	ON	OFF	OFF	OFF
2. TO TEST AN APPLIANCE (Use only a tested power outlet.)					
2.1 Plug appliance lead into Test Set socket and clip "Extension Earth" lead to metal of appliance. For double insulated appliance, wrap in aluminium foil and clip "Extension Earth" lead to foil. (Ensure good metal to metal contact.) Press SW8 to release to NORMAL Position. Carry out steps 1.1, 1.2 and 1.3.					
2.2 To test appliance insulation resistance — appliance switch must be on — press either:					
• SW2 for double insulated appliances	ON	ON	OFF	ON	OFF
• SW3 for earthed appliances	ON	ON	OFF	ON	OFF
• SW4 for metal sheathed elements	ON	ON	OFF	ON	OFF
2.3 To test appliance earth resistance (double insulated appliances excepted) Press SW7	ON	ON	OFF	OFF	ON
To reset L5 — Press SW6 (allow 10 seconds between tests).	ON	ON	OFF	OFF	OFF

3. TO TEST A THREE CORE EXTENSION CORD (Use only a tested power outlet.)

3.1 Switch off power outlet, insert extension cord plug into tested mains outlet and insert Test Set plug into extension cord socket and follow procedures 1.2 and 1.3

3.2 To test extension cord earth resistance — Disconnect extension cord plug from power outlet and insert into Test Set socket. Disconnect extension cord socket from Test Set plug and insert into green "Extension Earth" plug (rear compartment). Carry out steps 1.1, 1.2, 1.3 and 2.3.

From Cyclone "Tracy" to Radio Australia, Carnarvon

G. E. HATFIELD, B.E.E., M.S.E.E.

A high frequency broadcast transmitting station was established for Radio Australia at Carnarvon, WA, as an urgent measure following the loss of transmissions from the Darwin area as a result of cyclone "Tracy" on 25 December 1974.

The Carnarvon station utilised the former NASA tracking station, commenced transmission less than a year after "Tracy" devastated Darwin, and went into regular service in March 1976.

The new station comprises two transmitters of 250 kW and 100 kW, and four curtain antennas.

As Carnarvon is susceptible to cyclonic conditions special features were incorporated in the design of the antenna system to take this into account.

WHY A NEW STATION?

Cyclone "Tracy"

"Tracy" passed directly across the Radio Australia transmitting station on Cox Peninsula, some 30 km from Darwin, and then continued directly over the city and suburbs of Darwin causing a major disaster. Radio Australia suffered badly with all five logarithmic periodic transmitting antennas and two supporting masts being destroyed. Transmission lines were also damaged and the transport facilities destroyed — a bus, two launches for crossing the 10 km of Darwin Harbour, and the jetty on Cox Peninsula. There was also some damage to the buildings and mechanical equipment, and to the 11 kV mains power lines, the under water cable sections of which ruptured as a consequence.

The three transmitters and their control processor however suffered only relatively minor damage, when salt water entered the building through air vents.

The extent of the damage to the station facilities, and to the city of Darwin and its services, were such that restoration of transmissions would be impracticable for a considerable period — estimated to be of the order of two years.

The Government decided that more expeditious action was needed to restore part of the lost Radio Australia services, and action was taken to establish a temporary transmitting station elsewhere as a matter of urgency.

Less than 3 months after "Tracy" the Government approved the establishment of a temporary station somewhere in Western Australia at an estimated cost of $2.9m.

Action to Restore Radio Australia Services

Tenders were called on a world-wide basis for a completely operational system comprising one high powered transmitter, antennas to cover a 60° arc, and sufficient antennas, transmission lines and switching to enable two simultaneous transmissions. The successful tenderer for the major part of the project, Brown Boveri (Australia), was notified just over 3 months after cyclone Tracy. The contract was based on a hypothetical site near Perth, WA and was subject to negotiation on factors which depended on site location and site conditions.

A second transmitter (100 kW) originally ordered for Darwin for the HF inland service, was also diverted to the new station.

The use of the Carnarvon site was announced on 21 April 1975, and the following week a conference was held on site with all parties involved (including representatives from overseas principals of the contractor) to define site dependent factors, the programme of work, and a system of management and reporting which would avoid unnecessary delay to the project.

As the Carnarvon area is also subject to cyclonic conditions the antenna system was designed to take this into account, and includes an electrical winching system for each antenna so that antennas may be lowered in the event of high winds in the area.

Planning of the rehabilitation of the Darwin station has been proceeding and a decision taken by the Government to restore the station.

The three 250 kW transmitters have all been made workable and are now being operated (on diesel power) into a load to maintain their condition while restoration proceeds. From comparisons with other electronic equipment in the area the initial cost of tropic proof coating applied to appropriate parts of the transmitters and their control processor has been well justified in minimising consequent deterioration.

ENVIRONMENTAL ASPECTS OF STATION DESIGN

Station Location

The station is situated on a low ridge 20 to 25m above the surrounding countryside, approximately 6 km line of sight from Carnarvon, and near a major highway providing good road access. The station location, on a low undulating ridge, is not ideal for HF broadcasting and was expected to affect the radiation pattern of the antennas. Consequently flight tests were made after installation in conjunction with the Flying Unit of the Department of Transport. The data from these measurements is being analysed to estimate the actual radiation patterns. Some significant deviations from the nominal patterns over flat ground have been shown by the analysis of these data up to date.

The constraints and conditions imposed by the available site and buildings were established at the initial conference. This enabled the necessary design modifications to be made to the equipment prior to shipping. The major factors were those affecting transport and the antenna system, such as:

- other than the distance of 1000 km from Perth, there were some transport problems which would need particular attention to avoid time delays in the delivery of equipment,
- the site is not perfectly flat, requiring both some levelling and some alterations to tower heights and catenary design,
- Carnarvon is in a cyclone area, in contrast with a hypothetical site near Perth, so that both the antenna system and the support structures needed reconsideration from this aspect,
- the site is only some 5 km from the sea, and subject to moist sea breezes; severe corrosion of existing structures was obvious.

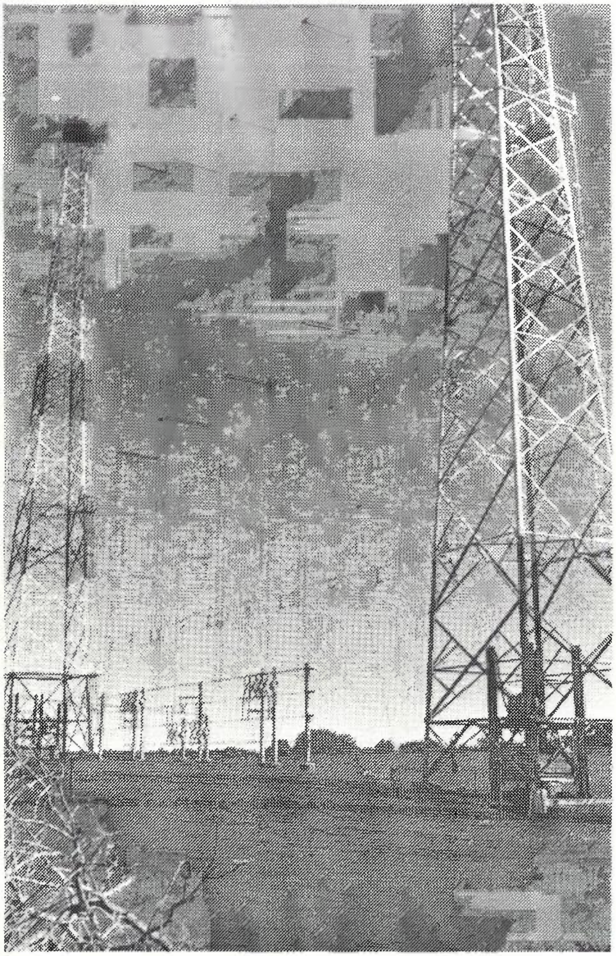
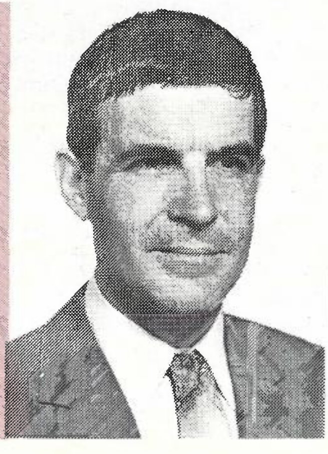


Fig. 1 — The 15, 17, 21 MHz Antenna and Slewing Switches.

GIFF. HATFIELD joined the Australian Post Office as a Cadet Engineer in 1954 He worked in Victorian Planning on the introduction of crossbar and extended switching projects before moving to Headquarters Radio. There he was involved in the extension of television services beyond Sydney and Melbourne to the other capitals, to country centres and to remote areas. Following two years overseas studying for a Masters Degree and examining color television, he was involved in the Adelaide-Perth microwave system and was a key figure in the introduction of color television to Australia. He was in charge of the Radio Australia, Carnarvon, project and is currently responsible for the limited rehabilitation of Radio Australia, Shepparton, while also studying for a Master of Business Administration.



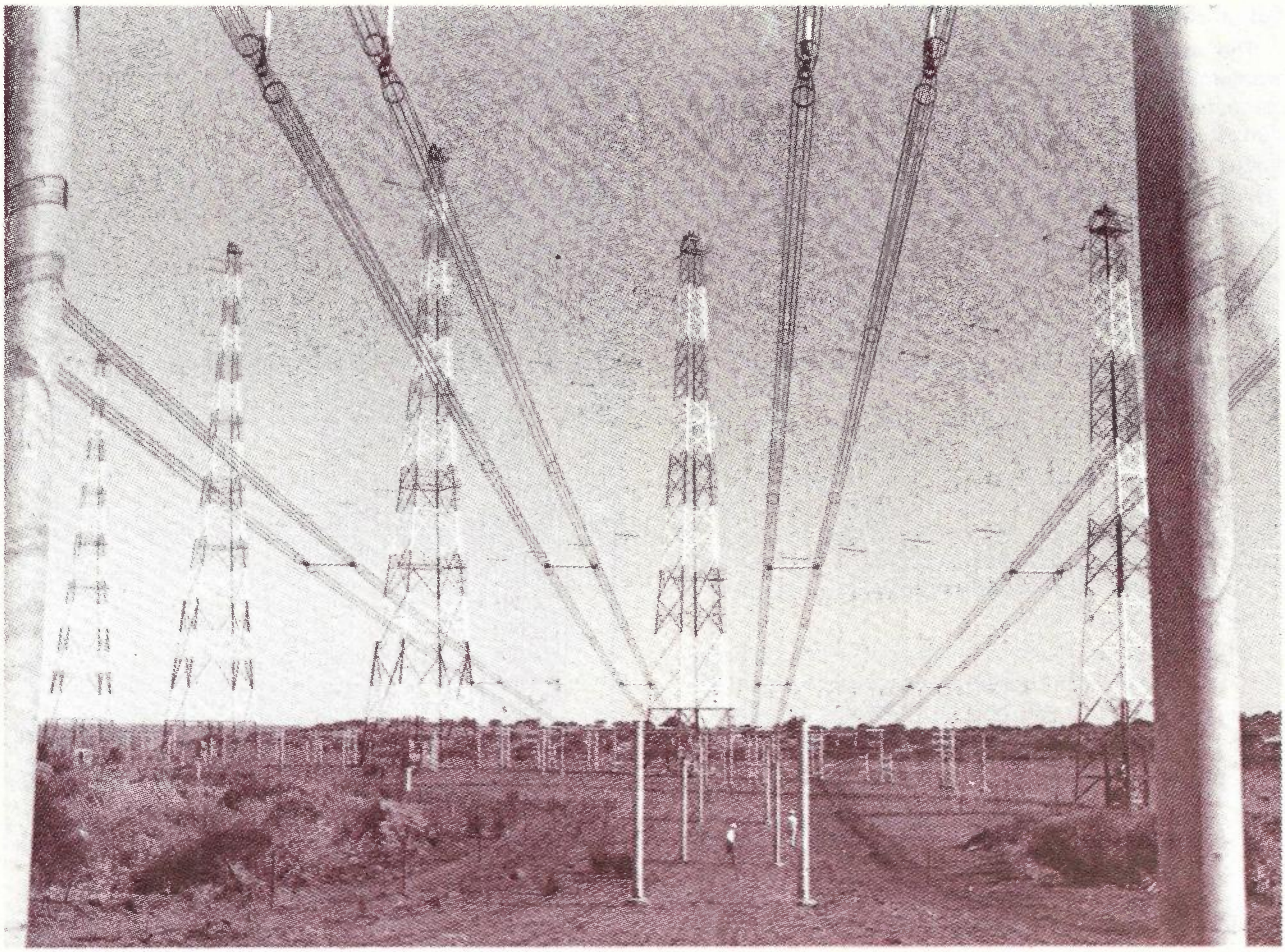


Fig. 2 — Transmission Lines to Four Antennas.

Cyclone Protection

In considering cyclone protection, the attitude was taken that the station design should give maximum protection to equipment at times when there is a possibility of high winds, even though this may mean closing the station for several days to protect equipment likely to be damaged.

Important factors which were adopted following the on-site conference at Carnarvon and consideration of the damage at Darwin were:

- that the existing NASA buildings incorporate adequate cyclone protective features,
- that maintaining a clean site is vital, particularly removal of any matter which could become flying debris and might cause physical damage — loose branches and other timber, pieces of metal, plastic or cables,
- the protection of towers from damage or destruction is particularly important in minimising any interruption to service due to cyclonic conditions,
- spare insulators would be the most critical items in rebuilding any antennas which suffered damage,
- electric winching systems would be used to lower the antennas to the ground for the duration of any cyclone,
- in the time scale involved possible design changes to the antenna system were limited; in particular the provision of stronger insulators was not practicable,
- self supporting towers would be used because of probable delays in the availability of suitable wire rope for the guys needed for guyed masts.

Corrosion

The environment of the Carnarvon site was known to be conducive to severe corrosion. Avoiding electrically dissimilar metals in contact is the best insurance against possible corrosion. This is the approach taken by all concerned, though it has not been possible to avoid all such junctions and physical protection has also been necessary.

The Carnarvon environment is so severe that even the life of galvanising is only a few years if unprotected. All ropes, etc., have therefore been coated with a protective grease, and all towers painted, to achieve the maximum lifetime, while stainless steel components have also been used where appropriate.

The major factor in the corrosive environment is a south westerly breeze heavily saturated with a strong salt solution. These conditions seem to persist over some months from late spring through to mid summer.

Salt Encrustation

The moist salt laden winds of the area raise more problems than corrosion. Salt is deposited on all external components particularly those of the antenna system, including insulators. This deposit is aggravated on lower insulators by salt laden moisture running down. Insulation resistances can be reduced, particularly during moist conditions. This can also result in impedance changes during operation, such as when an antenna heats, drying the insulators, soon after commencing to operate on that antenna, especially early in the morning. One effect of the salt is to cause irregular surface currents over the insulators, leading to spot heating and spalling of the glazed surface.

Control by regularly washing away any salt deposits on critical areas is being evaluated. The frequency with which washing is required seems to be seasonal and particularly dependent on wind conditions and natural washing by rain. Since the median rainfall is below 10 mm for 8 months of the year, with rain on 3 or less days of those months, natural washing is never expected to be of significant assistance.

Present indications are that it may generally be necessary to wash insulators approximately every four months, and more frequently between October and February, to keep impedance changes to a level such that the ability to match the transmitter output is not seriously affected. A detailed assessment can only be made after several seasons of experience has been gained, however present experience suggests that under severe conditions significant encrustation can occur in only a few days. Tests are also being made with silicone coating and protective moisture deflectors on lower insulators to minimise build-up.

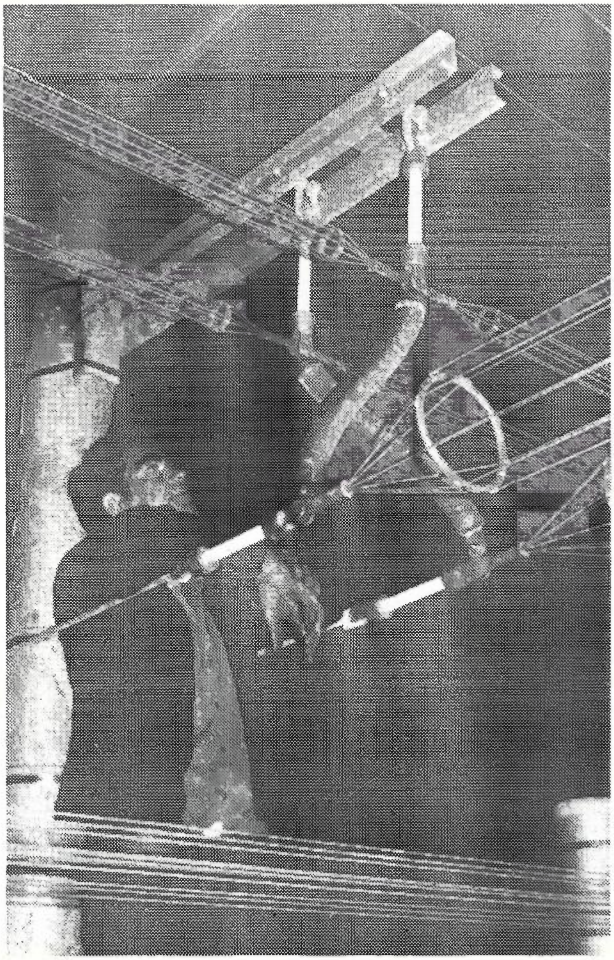


Fig. 3 — Impedance Matching.

ANTENNA SYSTEM

Antenna and Transmission Line Configuration

The four antennas are each of HR4/4/0.5 configuration using folded broadband half wave dipoles. The largest antenna covers the 6, 7 and 9 MHz international broadcasting bands and is suspended from 100m self-supporting towers. The highest frequency antenna (**Fig. 1**) covers the 15, 17, 21 MHz bands, while the other two cover the 7, 9, 11 and 11, 15, 17 MHz bands.

The antennas are connected to the transmitters by parallel two wire balanced transmission lines, each "wire" comprising a cage of 6 wires (**Fig. 2**). Precise impedance matching of the antenna systems is achieved by varying the diameter of the cage (**Fig. 3**).

The antennas all have their main beams directed on a bearing of 347° true to SE Asia, and can be electrically slewed to 325° towards India or to 009° towards China and the Philippines with switches located below the antenna (**Figs. 1&4**).

Only a few changes were able to be made to the design of the antennas and their transmission lines. Reducing the number of wires used to obtain electrically thick conductors reduced wind loading, thereby increasing the safety factor of insulators and reducing tower loadings. This however naturally reduced the strength of the conductors. These conductors, of multi strand copperwire are now the limiting factor in terms of simple tensile strength, however, under cyclonic conditions brittle failure of insulators under impact, twist, or bending is still expected to be a critical factor.

Antenna Electrical Design

Each antenna comprises an active curtain of 16 dipoles and a passive non-resonant reflecting screen with a separation between curtain and screen of a quarter of a wavelength at the geometric mean frequency.

The folded half wave dipoles are horizontally polarised and arranged in four bays and four stacks. The horizontal sections of the folded dipoles are constructed as multiple wire cages in a similar manner to the transmission lines (**Figs. 2&3**). This construction enables a broadband characteristic to be achieved allowing for compensation of reactive components, while minimising wind loading.

A branched feeding arrangement (**Fig. 4**) for each bay aids in maintaining both impedance matching and current distribution, hence radiation pattern. The feed lines also

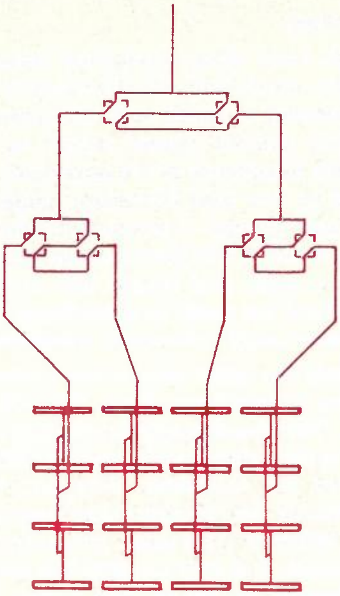


Fig. 4 — Antenna Schematic Configuration, Feeding and Slewing.

use the cage construction and diameters of the cages are varied to trim the impedance as with the transmission lines **(Fig. 3)**.

In tuning an antenna each section is tuned individually before they combine, so that each bay presents a closely similar impedance to the slew lines and switching, and avoids significant variations in the final impedance with slew switching.

The final trim of the overall impedance is carried out in the feeding transmission line **(Fig. 3)**. At Carnarvon a match giving a vswr of some 1.4 was achieved over a frequency ratio of 1.65 (from 5.9 to 9.8 MHz). To achieve this match all practicable degrees of freedom were utilised:

- diameter of line (including tapered change)
- length of line over which the diameter was changed
- distance of the changed diameter from a combining point

Wind Loading Factors

The antenna design wind speed is 45 m/s at ground level and increasing with height, as are all the design wind speeds. The design of the towers is based on a wind speed of 50 m/s with full antenna loading and of 63 m/s with the antennas lowered and anchored to the ground.

Lowering the antennas by winch is a major feature of the system design. However, there is always some possibility of not having time to lower some or all antennas in the event of the rapid change of course of a cyclone. Even though antennas might then be badly damaged by conditions as severe as occurred during cyclone "Tracy" in Darwin, they could also survive largely intact. Consequently an additional tower design criteria set was that towers should survive winds to 63 m/s without any permanent deformation, even with antennas remaining in place.

The antenna suspension is based on the counterweight and catenary system, which minimises increases in loading on the towers due to increased wind speeds. The active side of the antenna is suspended from one catenary and the screen from a separate catenary. The two catenaries are separated at the ends by heavy tubular spreader bars, which are connected to the main support ropes. These main ropes pass over a sheave at the top of each tower, down the centre, and onto the drum of the electrically driven pulley atop the counterweight **(Fig. 5)**.

Winch Lowering

All four antennas are supported by counterweighted catenary ropes which are wound onto electric winches forming part of the counterweights **(Fig. 5)**. These

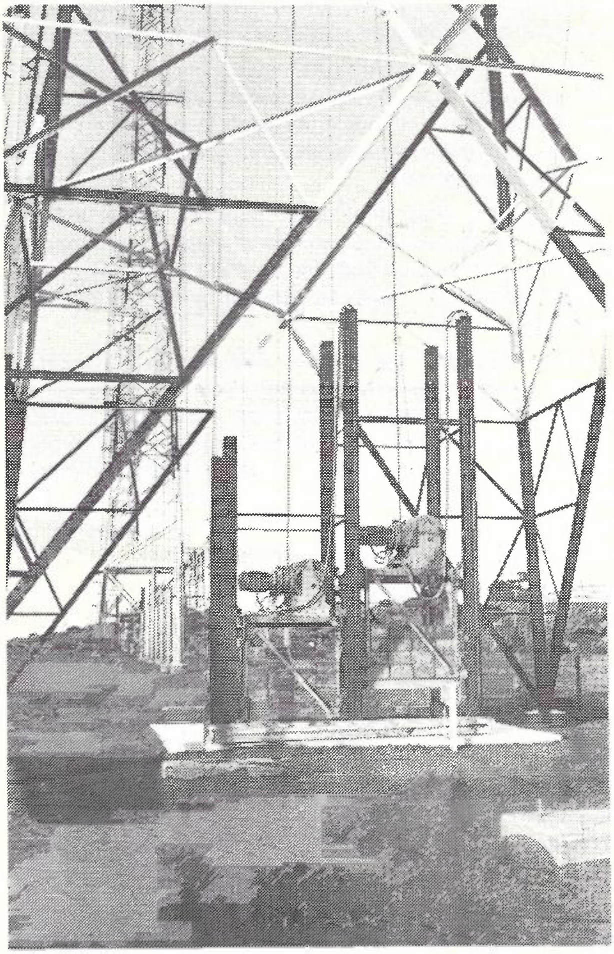


Fig. 5 — Winch/Counterweight Systems.

winches enable the antennas to be lowered to the ground to avoid damage from cyclonic winds and from flying debris.

Each antenna has a counterweight weighing up to 8 tonnes at each end of its supporting rope, one counterweight normally being on the ground. Part of each counterweight is the winch driven by an electric motor, with sufficient length of steel rope wound on the winch drum to permit the antenna to be lowered completely. Antenna and screen, supported from their catenaries, are lowered simultaneously. Large wooden blocks are fitted to the towers to prevent the steel rope rubbing against the tower when the antenna is close to the ground.

Each of the four antennas have individual controls for the two winches associated with that antenna. The controls are located some distance to the rear of the antennas and approximately mid way between the towers supporting that antenna. This gives the winch operator a good view of the whole antenna and its screen. To facilitate lowering operations at night, if necessary, provision was made for connecting flood lights to each tower.

When an antenna is lowered it is folded onto the ground, its location being guided by staff so as to avoid kinking elements or damaging insulators. A few connections are undone during lowering, where feeder lines form an extra plane to that of the main dipole plane.

When the antenna and its screen are on the ground they are held down by straps being passed over them, and attached to anchors embedded in concrete blocks. This is to prevent movement, and consequent damage while on the ground.

To ensure that the main support ropes will lie correctly on the winch drums as raising is commenced, where there is no load from the antenna, an initial tension of approximately 1 tonne is applied by means of 1½m long brake blocks.

Only days after the system was installed a cyclone passed close to the area and antennas were lowered in earnest. The winds on this occasion were of the order of half the design maximum and represented a real test of the system. A minor problem was revealed with slight kinking and tearing at some brazed joints, but this was rapidly rectified and does not now occur even in considerably stronger wind conditions.

BROADCAST TRANSMITTERS

Transmitter Types

The station has two transmitters, a 250 kW Brown Boveri transmitter from Switzerland with motor driven tuning, and an automatically tuned 100 kW Harris/Gates transmitter from the USA which uses a pulse duration system of modulation (pdm). Both transmitters are capable of accepting clipped signals to raise the average level of modulation. Their output can be switched to a calibrated test load or to any one of four broadband curtain antennas.

Both transmitters are recent designs, and both used closed circuit evaporative (steam) cooling of the anodes of the main tubes, with external fan cooled radiator type condensers.

100 kW Transmitter

In this high level plate modulated transmitter the modulation tube, driven with 70 kHz duration modulated pulses, is connected in series with the power amplifier tube. With this system power output is effectively controlled by the impedance of the modulator, which can be determined by low level (transistor stage) bias. This enables very rapid change — a turn OFF time of some 5 microseconds, which in turn permits both rapid frequency changing (10 s max) and simple but comprehensive protection, without the need to dump large amounts of energy as in more usual "crow-bar" protective systems.

There are only five tubes used in the transmitter, with a RF driver and a modulator driver. The fifth tube is a damper diode. This tube provides a discharge path for the energy stored in the inductors of a low pass filter which is placed between the modulator tube and the output amplifier to remove the 70 kHz pulse frequency which must not be radiated. This tube conducts alternately with the modulator, and aids towards the low distortion and high efficiency of the system (some 60% with average modulation).

The pdm system permits modulation beyond 100% (including through zero carrier). This factor, combined with the absence of transformers to cause tilt and/or ringing, make the 100 kW transmitter highly suited to the use of techniques (such as speech peak clipping by say 6 dB) to raise mean modulation levels. When clipping speech the frequencies between 2 and 5 kHz, which largely determine intelligibility, are boosted by up to 10 dB, while low and high frequencies (below 100 Hz and above 7 kHz approximately) are attenuated.

The transmitter tunes automatically to any of ten preset frequencies. Tuning is controlled by plug-in cards on which potentiometer settings determine servo motor positions, jumper straps determine the application of short circuit switching to the main tuning coils, and diodes determine the frequency setting of the associated synthesiser.

A member of the station staff designed modifications to the Harris transmitter to enable it to program a frequency synthesiser automatically during its tuning process.

The output tuning inductor comprises a number of discrete coils which are switched in and out of circuit in different combinations to cover the frequency range 3.2 to 22 MHz in 11 bands. Using this technique spurious responses are minimised and moving contacts avoided on the high current inductors.

250 kW Transmitter

The output is a single grounded cathode, plate modulated, tetrode, with additional modulation of the screen via a tertiary winding on the modulation transformer. The RF drive is by a single tube, while the final modulation amplifier uses a pair of push-pull operated tubes feeding a modulation transformer.

This transmitter is also designed to utilise a clipped audio signal to raise the mean modulation level, and the clipper includes tilt pre-compensation to correct for the effect of the transformer.

The final stage tuning has the main tank coil formed around the final tube, and three parallel variable vacuum capacitors arranged at 120° intervals which are motor driven in synchronism. This concentric arrangement gives uniform current distribution and minimises return current through cabinet panels.

Tuning takes place from a central control panel, with band switching of coarse tuning (including the tank coil) and motor positioning for fine tuning. A bank of 8 switches are used to set motor positions according to settings on a 3 figure LED readout, following which the transmitter can be brought immediately to full power.

The control panel includes a mimic diagram with associated analogue metering for major parameters, and a comprehensive digital logic monitoring and diagnostic system for indicating status and to enable rapid isolation of faults. The transmitter also includes an extensive personnel protective system, which incorporates specific provision for over-riding to permit maintenance work. The over-ride system activates warning mechanisms in the relevant section of the transmitter to keep personnel working on that section alert to the altered safety conditions.

CONCLUSION

Radio Australia Carnarvon commenced broadcasting programmes on 20 December 1975 less than a year after cyclone "Tracy" hit Darwin, and was placed into regular scheduled service early in March 1976.

A number of special features were incorporated into the design of the antenna system in order to avoid major damage by future cyclones. These were shown to be effective when a cyclone passed near the area late in February 1976, subjecting the station to high winds.

Experience gained in the installation, commissioning and subsequent operation has added to that gained from the earlier Radio Australia transmitting installations at Shepparton and Darwin, particularly in the operational aspects of modern high power, fast tuning transmitters, and towards the future development of antenna systems in cyclone prone areas, of importance to the rebuilding of the Darwin station in the near future.

Death of George Black

The first Life Member of the New South Wales Division of the Telecommunication Society of Australia Mr George A. Black died in Sydney on 26th September 1978 aged 72.

He joined the P.M.G.'s Department in Melbourne in 1922 as a Junior Mechanic in Training becoming Traffic Officer in the Telecommunications Division in 1941 and transferring to Sydney. He retired in 1966 as Assistant Superintendent, Service Standards.

In 1931/32 Mr Black was closely associated with the inauguration of the Telecommunication Society in Melbourne carrying over his involvement to Sydney where from 1941 he served as the Society's Representative in the Telecommunication Division. He continued this activity until his retirement in 1966. He was a very enthusiastic member of the Society with considerable ability to transmit this enthusiasm to those about him.

Mr Black was elected Society Life Member in 1966 and despite retirement kept his association with the Society, fre-known nationally for his participation in and contribution to National Television quiz shows.

Solar Power for Telecommunications

M. R. MACK, MIE Aust.

This article outlines the basic theory of solar photovoltaic power systems and the way in which Telecom is applying these systems to provide relatively small quantities of power for communication systems in areas where mains power is not available. It includes methods used to dimension the solar array and battery and describes how the power generated by the solar array is controlled. Future trends and use of solar cells are also briefly discussed.

INTRODUCTION

In a country such as Australia, where communication systems linking major centres have to span vast distances and reach out into rural areas, the provision of reliable, low maintenance primary power plant is particularly important. Many types of power sources have been used in the past, depending upon load and application, however no primary power source has had a greater impact than solar cells.

Telecom Australia is now using solar photovoltaic cells in increasing numbers to power telecommunication services in isolated areas of the country. In this decade solar cells have progressed from an exotic power source, limited primarily to space use, to become a viable and generally preferred power source for loads up to about 150 watts.

This amount of power is small when considered in terms of powering two 75 watt household incandescent lamps, however new designs of microwave radio equipment, with very low power consumption, has made it possible to completely power broadband radio relay repeaters by solar means. The first system of this kind is linking Alice Springs to the STD Network via 13 solar powered repeater stations between Alice Springs and Tennant Creek.

The solar cell industry is still in its infancy, although we have seen a tremendous growth in the last 3 or 4 years and the cost of solar modules has fallen, by an order of magnitude, to about $15-20 per peak watt, depending on volume. Large United States government solar cell procurements through the Energy Research and Development Administration (ERDA) (now Department of Energy) is largely responsible for recent growth of the industry in the US, however commercial sales are also growing rapidly. The worldwide production of solar cells in 1977 has been estimated to be as high as 1 MW (Ref. 1) and double this figure in 1978.

When the potential of solar power for telecommunication applications was realized, Telecom embarked on a "Solar Power System Development Programme" aimed at developing a solar power system package capable of supplying about 125 watts of continuous power. This programme is now completed and has culminated in the use of such a package on the Tennant Creek — Alice Springs microwave radio system. A number of similar systems are currently being planned.

Solar photovoltaic generators are also being used to power the following equipment in isolated areas:

- VHF subscriber radiotelephone systems;
- UHF small-capacity radio systems;
- high-capacity microwave telephone and television repeaters;
- open-wire telephone repeaters;

SOLAR CELL THEORY

Solar cells operate on the photovoltaic effect which was discovered over a hundred years ago. Photovoltaic conversion occurs in a thin stationary layer of solid material when light strikes the surface. Basically electric charges are freed and, if made to flow through an external circuit and load, they can perform work.

Silicon solar cells are by far the most widely used and were first developed in 1954. Their main use has been for providing power for satellites since the 1957 launching of Sputnik.

Most silicon cells used today are sliced from purified cylindrical monocrystalline silicon ingots "grown" under controlled conditions at high temperature. The ingots are sliced into wafers approximately 0.5 mm thick. These slices must be ground and finished. As much as 75% of the silicon is lost in cutting and grinding. The largest diameter wafers used are about 100 mm. The crystal is doped with an impurity such as phosphorus to make it N-

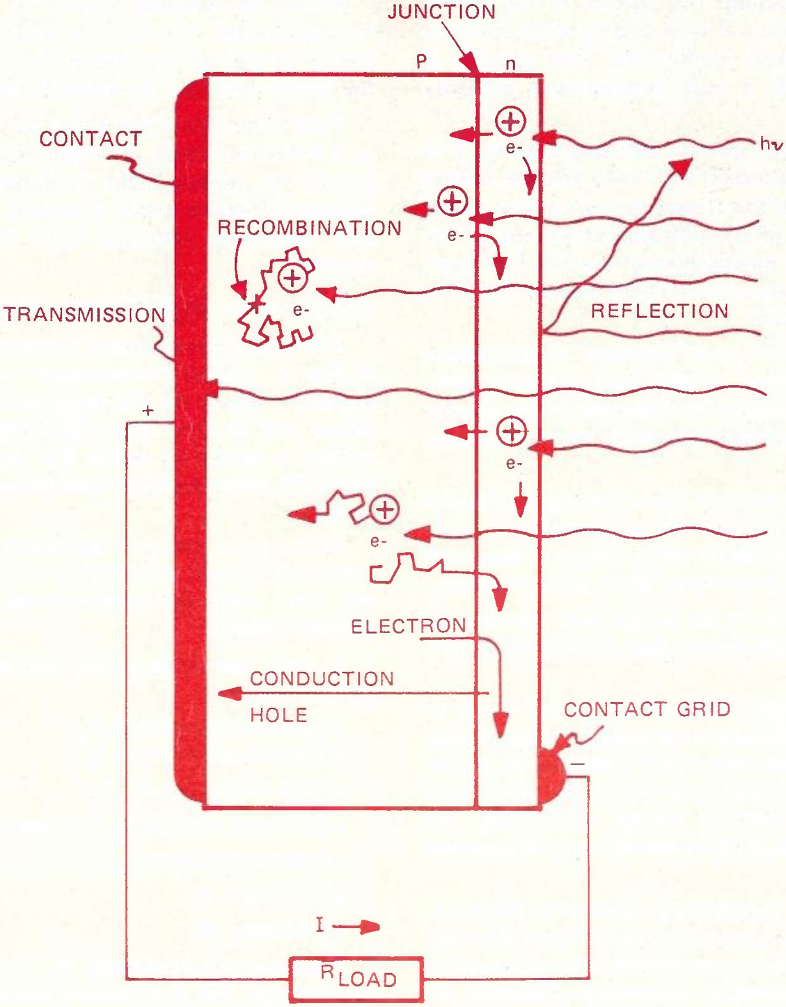
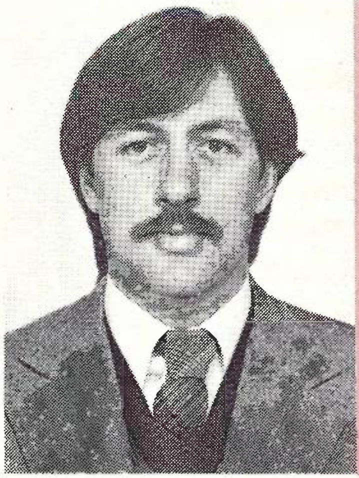


Fig. 1 — Photovoltaic Cell and Current Flow.



MICHAEL MACK graduated in 1971 with a Diploma of Electrical Engineering from Caulfield Institute of Technology. He is a member of the Institution of Engineers Australia.

Since joining the PMG Department in 1972, he has worked on various aspects of communications power plant; in particular, power supplies for isolated area applications.

He is currently a Senior Engineer in the Telecom Power Section, Headquarters Building Branch.

type or electron conducting. The surface of the cell or wafer is then doped with a P-type dopant such as boron making it P-type or hole conducting. This process is usually carried out by a high temperature diffusion process.

Electrons in the N-type portion diffuse across the P-N junction into the P-type region and holes likewise diffuse across the junction into the N-type region until a potential, equal to the sum of the diffusion potentials of the holes and electrons, is established across the P-N junction. Hence a permanent electric field is established in the region of the junction.

As seen in **Fig. 1**, photons or "packets" of light falling on the cell with sufficient energy, will generate hole-electron pairs. Those outside the influence of the electric potential of the junction recombine while those within are separated.

Silicon at room temperature has a band-gap of about 1.08 eV (i.e. the energy required to generate a hole-electron pair). Photons of light having energy in excess of 1.08 eV are capable of generating these pairs in silicon.

With no light incident on the active face, the cell exhibits the normal forward reverse bias characteristic of a P-N junction diode.

To generate electricity, contacts must be made to either side of the cell. Usually a continuous metallization is used on the underside and a grid provided on the illuminated surface. The grid must of course allow light through to the cell surface, whilst minimizing cell resistance. Resistance is partly governed by grid type and junction depth.

Not all of the light is converted to electricity, some being reflected and some generating heat within the cell. Commercial solar cells have conversion efficiencies of up to about 15%. The theoretical conversion efficiency for silicon is about 22% at room temperature.

When an external circuit is connected to an illuminated cell, the intrinsic junction potential gradient drives the photon generated electrons around the external circuit and can be made to do work.

Solar cells often have a blue surface tinge which is due to a titanium dioxide anti-reflective coating. Another approach to reduce light reflection is to introduce a pyramidal texture which is etched into the surface of the cell, deflecting reflected light from one pyramid to another.

SOLAR CELL ELECTRICAL CHARACTERISTICS

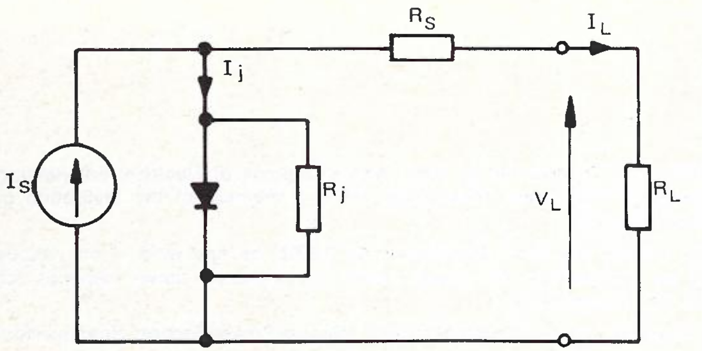
The equivalent electrical circuit of a solar cell is shown in **Fig. 2.** Typical characteristic curves for one cell are shown in **Fig. 3.** As the maximum voltage from a single silicon cell is only about 500-600 mV, cells are connected in series to obtain the desired voltage. Usually about 36 series cells are used for a nominal 12V charging system.

Under peak sunlight conditions (100 mW cm^{-2}) the maximum current delivered by a cell is approximately 30 mA cm^{-2}. Cells are therefore paralleled to obtain the desired current.

A solar cell is generally specified by the following parameters.

- Open circuit voltage, V_o
- Short circuit current, I_s
- Peak output power, P_p
- Optimum voltage, V_p (voltage at P_p)
- Optimum current, I_p (current at P_p)
- Efficiency, η
- Fill factor, FF

The open circuit voltage, V_o, is a function of the band gap voltage. The short circuit current, I_s, is a function of the total separated charge. The maximum power of an



I_S =	TOTAL SEPARATED CHARGE
I_j =	LEAKAGE CURRENT ACROSS P-N JUNCTION
I_L =	LOAD CURRENT
R_j =	JUNCTION RESISTANCE TO LEAKAGE
R_S =	SERIES RESISTANCE
R_L =	LOAD RESISTANCE
i_L =	LOAD CURRENT
V_L =	LOAD VOLTAGE

Fig. 2 — Solar Cell Equivalent Electrical Circuit.

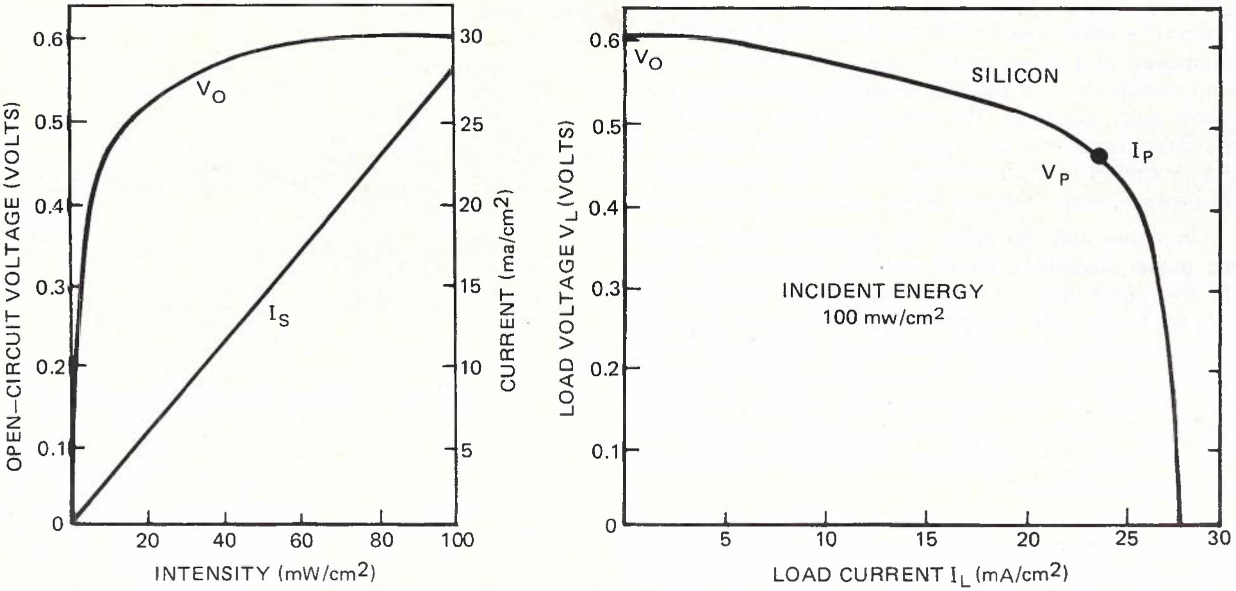


Fig. 3 — Output Characteristics of a Silicon Solar Cell.

ideal solar cell would therefore be $V_O.I_S$ (assuming a "square" characteristic), because of series resistance, R_S and shunt leakage resistance, R_j the maximum power is given by $P_p = V_p.I_p$.

As can be seen from Fig. 3a, the short circuit current, I_S, is proportional to radiation intensity. The open circuit voltage increases logarithmically with I_S and hence intensity, except at very low light intensities.

The practical I.V curve shown in Fig. 3b consists of a current region and voltage region. As the leakage across the cell increases with increasing temperature, the voltage reduces and so does the peak power obtainable from the cell.

In practice solar cells are operated to the left of the knee of the curve, in the current region.

A measure of the quality of the cell is called the fill factor, FF, which is defined as $FF = V_p.I_p/V_O.I_S$; the nearer FF is to unity, the higher the quality the cell.

TERRESTRIAL INSOLATION

The insident solar radiation flux is often referred to as insolation. The major energy output from the sun is in the form of electromagnetic radiation centred near the visible region of the electromagnetic spectrum. The solar radiation which reaches the earth's atmosphere varies slightly with the annual variation in sun-earth distance. At the mean sun-earth distance the solar energy outside the earth's atmosphere is approximately 1.35 kilowatts per square metre (kW m^{-2}) and is called the solar constant.

The solar spectrum is considerably altered by the earth's atmosphere. At sea level, with the sun directly overhead, on a clear day, at normal humidity, the total radiant flux is reduced by about 20 - 30%. The solar radiation is scattered back into space by air molecules or is absorbed in the atmosphere itself by various natural gases such as ozone and water vapour. **Fig. 4** shows the extraterrestrial and terrestrial sunlight spectrum.

Much of the harmful ultra-violet wavelengths have been removed after passing through the atmosphere and there are gaps (which are not shown in Fig. 4) in the infra-red region. The peak insolation received on the

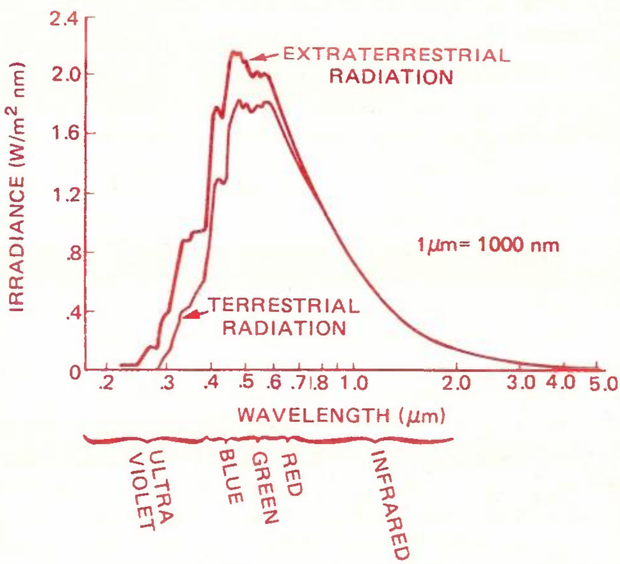


Fig. 4 — Spectrum of Sunlight Showing Atmospheric Attenuation.

earth's surface is approximately 1.0 kW m^{-2} normal to the beam. The solar energy arriving at the earth's surface is composed of a direct component and a diffuse component and the sum of the two is usually referred to as the global solar radiation. The direct radiation arrives from the direction of the sun "disk". The diffuse radiation is that scattered to the ground and is usually considered to be approximately isotropic when considering solar cells.

On a clear day the direct component is about 80% of the global insolation. Cloud naturally has marked effect on the percentage of direct and diffuse reaching the ground. Under light to moderately cloudy conditions the global radiation received is only about 10-50% of the incoming value. The direct component may be reduced to less than 1% of the incoming value under very cloudy conditions; however there is usually an appreciable diffuse component which arrives at the earth's surface under these conditions.

This paper is concerned only with the direct conversion of sunlight to electricity as practically applied to the powering of communication systems. However, it is interesting to see where the solar energy goes, to give an insight into the different ways in which solar energy can be utilized. The total incoming solar energy has been estimated at about 1.73 x 10^{17} watts. **Fig. 5** shows how this energy is divided. Approximately 30% is reflected, while 47% is converted to heat and re-radiated, keeping a natural balance. The rain cycle accounts for another 23%, while wind, waves and convection currents account for about 0.2%. Only a tiny percentage is stored by photosynthesis in plants and amounts to only about 0.025%.

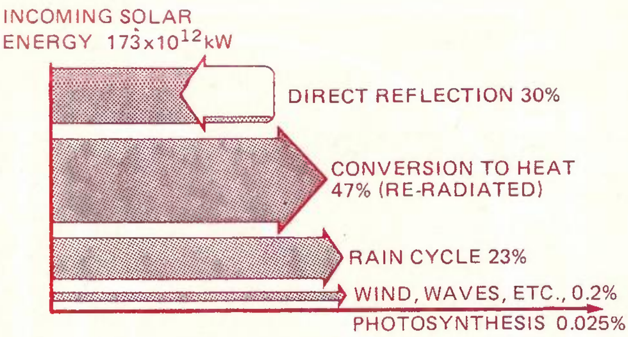


Fig. 5 — Where Solar Energy Goes.

BASIC SOLAR POWER SYSTEM

A basic solar photovoltaic power system of the type commonly used by Telecom, consists of four main components:

- Silicon solar array
- Voltage regulator (charge regulator)
- Blocking diode
- Storage battery

A simple schematic is shown in **Fig. 6.** The solar array consists of a number of series/parallel connected cells to obtain the desired voltage and current. A current is produced which is proportional to the insolation. This current is used to charge the storage battery and to feed the load.

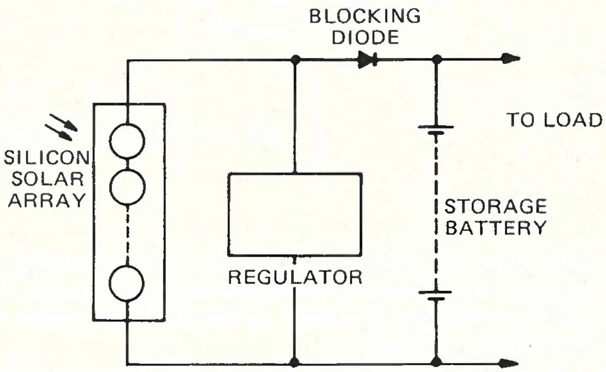


Fig. 6 — Simplified Solar Power System.

The blocking diode prevents the battery from discharging back into the solar array during the night. Lead-acid storage batteries are generally used for this application and store the energy generated during high radiation periods. Energy is then given out to the load at night and during low radiation periods.

The battery is a very important part of the system and biases the solar array, thus providing the basic voltage regulation. As there is no control over the radiation intensity a regulator is necessary to limit the battery voltage during high radiation periods, since, without regulation, the solar array can produce charging currents capable of causing excess battery voltage.

SOLAR ARRAY AND BATTERY CAPACITY

The capacity of a solar array is dependent upon a number of factors: the load, the storage capacity used and the solar radiation received at the particular location. The ratio of peak array size to average 24 hour load, varies between about 6:1 and 9:1 in Australia when battery reserves of between about 12-20 days are used.

To date Telecom Australia's experience has been limited to fixed orientation/inclination non-tracking silicon solar arrays. We are fortunate to have a storage battery which has been used for exchange float duty for over 20 years and appears well suited to the solar application. This battery is of the Faure -x or pure-lead positive pasted-plate type.

NEED FOR CHARGE REGULATION

A solar array is a solar radiation controlled current source. The curve in **Fig. 7** shows the charging current on a clear day and cloudy day. The curve is sinusoidal on a clear day for a fixed array. During summer the storage battery will be returned to a fully charged state and the peak charging current might reach the 50 hour rate.

If the constant current recharge curve for a Telecom battery is studied **(Fig.8)** the voltage is substantially flat, varying between about 2.0V/cell and 2.25V/cell. At about 90% capacity returned, there is a sharp rise in voltage which is termed the gassing point and occurs at about 2.35V/cell, depending upon the charging rate, temperature etc.

At the end of charge, a plateau is reached at the substantial voltage of about 2.7V/cell. That is, for a nominal 24V battery, the voltage might rise to in excess of 32V. Voltages of this magnitude may be unacceptable, damaging the equipment being powered, while excessive gassing will cause electrolyte loss and increased grid corrosion. The need for some form of charge regulator is clear.

Because a solar battery may be in a state of partial discharge for many months of the year, a certain amount of boost charging is desirable and a compromise voltage limit of about 2.35V/cell has been chosen. The voltage may be limited in a number of ways which may include linear dissipating shunt-type regulators or incremental open-circuit non-dissipating types.

The curves in **Fig. 9** are typical of a 12V charging system, consisting of a solar module or array with a peak power of 34 watts. Without a regulator the battery will normally operate between about 12V and 16V corresponding to 2.0V/cell and 2.67V/cell respectively.

Under peak insolation the solar array current varies from about 2.3A at 12V to about 2.1A at 16V. This curve would be typical of a good quality solar cell array and any additional series cells would not appreciably improve the solar array charging capability.

The charge regulator limits the voltage to just below the gassing point and the battery will continue to be "floated" at about 2.35V/cell.

POWER CONDITIONING AND REGULATION

This need for voltage regulation may be achieved in a number of different ways.

Regulation techniques generally fall into 2 categories: linear and incremental regulators. Linear regulators are usually shunt-type regulators which clamp the battery voltage at some preset level by dissipating excess array generated power, which would otherwise raise the voltage and gas the battery. Incremental regulators limit the voltage by disconnecting the solar array in steps or increments.

LINEAR SHUNT REGULATOR

A simple linear shunt regulator incorporating a Type 723 voltage regulator integrated circuit is shown in **Fig.10.** When the battery voltage is below about 2.35V/cell (level set by RV1) no current flows through the dissipating elements RL and TR1. During periods of high solar radiation, when the battery voltage reaches the set point, the differential amplifier within the 723 begins to turn TR1 on, which was previously cut-off. Current is shunted through the dissipating elements until the voltage stabilizes at the set point voltage. The battery is then floated at 2.35V/cell until the array output reduces or the load increases. This regulation system is commonly used on small solar power systems where the load may vary considerably, as will be the case when powering subscriber radio telephone equipment.

The major drawback with this system is that the excess power generated by the array must be dissipated by the regulator which, if mounted in a combined equipment shelter, may produce excessive temperatures. That is, high ambient temperature usually occurs under peak sunlight conditions often when the storage battery is near fully charged and the regulator is called upon to dissipate the excess energy generated.

Of course regulators may be mounted external to the equipment shelter, but this is not always practicable and separate protection from the weather is necessary.

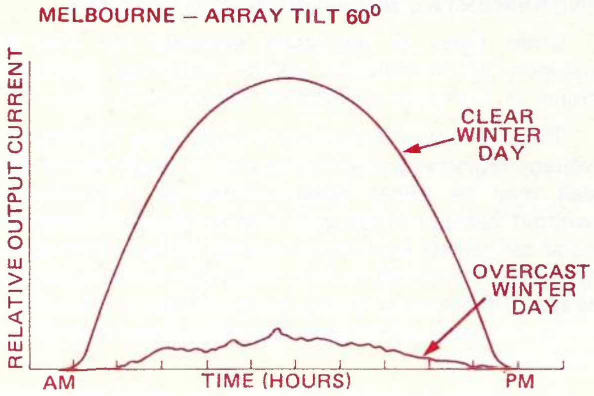


Fig. 7 — Comparison Between Charging Curves for Clear and Overcast Winter Days in Melbourne for an Array Inclined at 60°.

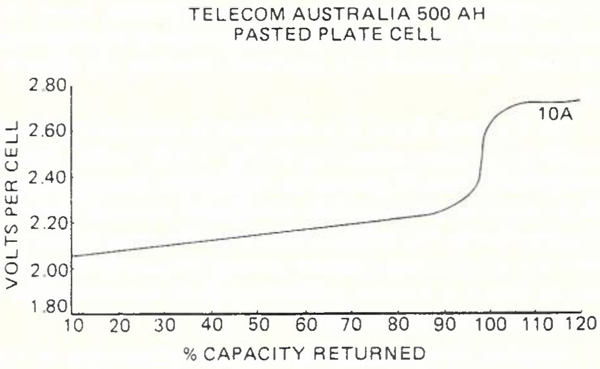


Fig. 8 — Constant Current Charge Characteristics - 25°C.

INCREMENTAL/SWITCHING REGULATORS

Other types of regulators generally fall into the category of incremental and/or switching regulators. Some of the types considered are shown in **Fig. 11**.

The characteristic curve of a solar array consists of a voltage region and a current region. A single silicon solar cell may be either open-circuited or short-circuited without damage to the cell. That is, on open circuit, the solar cell reverts to a voltage source, and a current source when short circuited. In both modes the power generated is zero. Theoretically, a solar array consists of a number of series cells having the same open-circuit and short-circuit characteristics.

It is a simple matter therefore, to sense the battery voltage and open-circuit or short-circuit the solar array when the voltage reaches the preset maximum. To prevent instability some hysteresis is incorporated in the voltage sensing so that the solar array is switched back into the circuit at a lower voltage. In practice, electromechanical switching devices are not used and it is more convenient to use a solid state switch. To short-circuit a solar array as in Fig. 11(a) it is convenient to use a power transistor for, under normal solar radiation conditions, the transistor is cut-off and power is not required to hold it in a saturated state. (It is important to keep power consumption of sensing and control circuitry to an absolute minimum). When the voltage reaches the high cut-off level, the transistor is saturated, shorting the solar array.

On the other hand, if a transistor is used as the series element to open circuit as in Fig. 11(b), under normal conditions it would have to be held in the saturated state, thus requiring drive current. Additional circuitry could be used to derive this drive current from the array output, so that the drive current passes through the series transistor to the load and battery. A blocking diode is not required if a transistor switch is used.

Another series switching element alternative is the thyristor, with additional circuitry necessary to provide turn-on and commutating — off pulses. This method will be discussed in more detail later in the article.

A single switch to disconnect the whole solar array simultaneously does not provide optimum charge to the battery nor does it provide system redundancy. A better approach, especially for larger systems, is to divide the solar array into groups, each diode isolated from the others and each with its own regulator as shown in Fig. 11(C). This system approaches more closely to linear regulator operation and switches out only the amount of array capacity necessary to maintain a particular voltage level.

Effect of Shorting Solar Arrays

It has been found that shorting of solar arrays is not recommended, since, under certain conditions a solar array or module may be damaged.

Although ideally all solar cells in a solar module should be matched in output, in practice there is some variation between cells. The output current is limited by the solar cell with the lowest output. If a solar module is shorted then some cells within will generate and some will dissipate power and under certain conditions hot spots may occur.

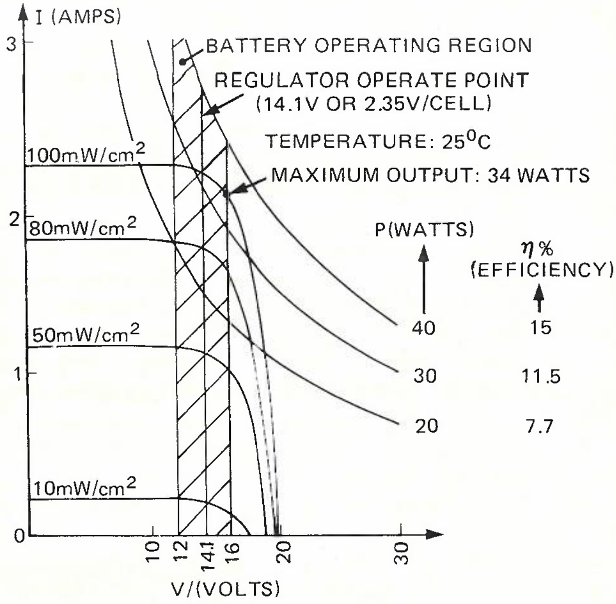


Fig. 9 — Typical Solar Module Characteristic Curves.

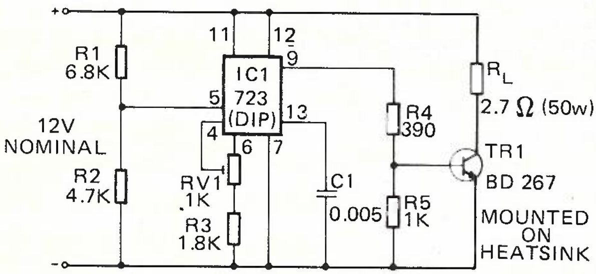
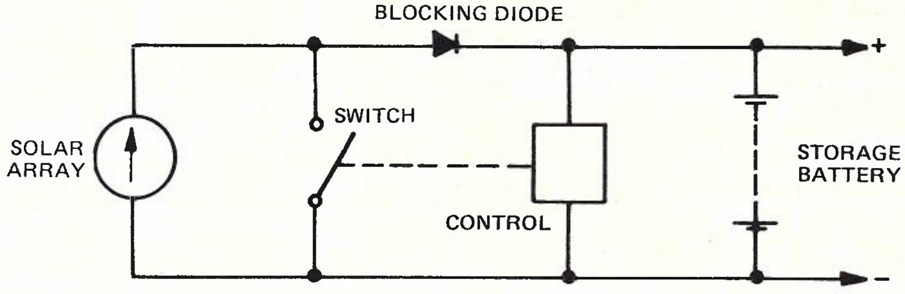


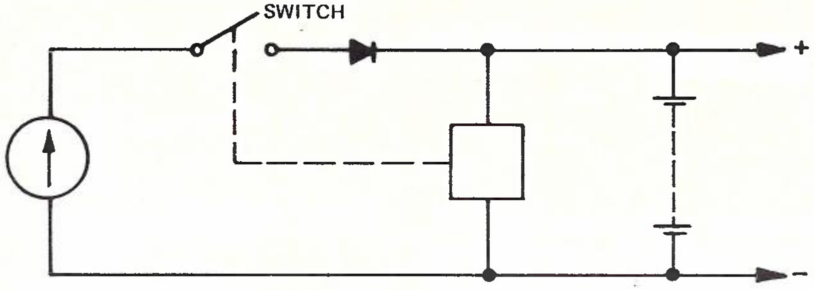
Fig. 10 — Linear Shunt Regulator for 12V — 60W Solar Array.

Fig. 12 shows the three quadrants of possible operation of a solar module. Normal operation is in the first quadrant. If the module is shorted then the net voltage must be zero, however the operating point of individual cells will be either in quadrant I or II. Quadrant IV is the normal forward bias direction of the photo-diode.

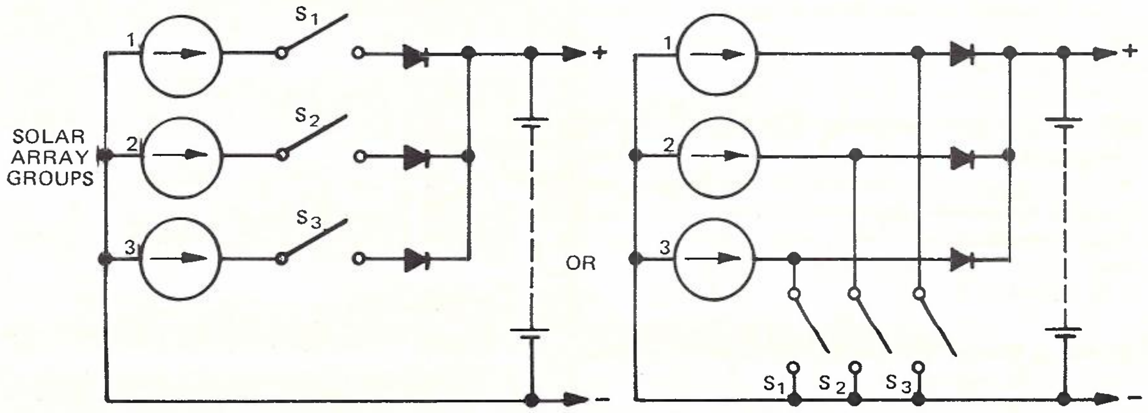
Consider the equivalent circuit of a 3 cell module shown in **Fig. 13**. Assuming high quality cells, R_s will be small so it may be neglected for the time being. R_j should ideally be large and a negligible leakage current will flow.



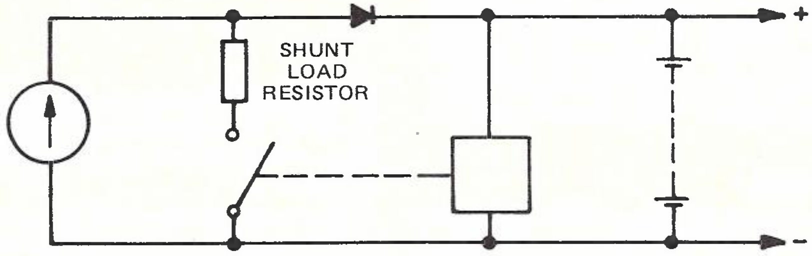
(a) SWITCHING-SHORT CIRCUIT



(b) SWITCHING-SERIES



(c) INCREMENTAL SERIES OR SHORT CIRCUIT



(d) SWITCHING SHUNT

Fig. 11 — Incremental/Switching Regulators.

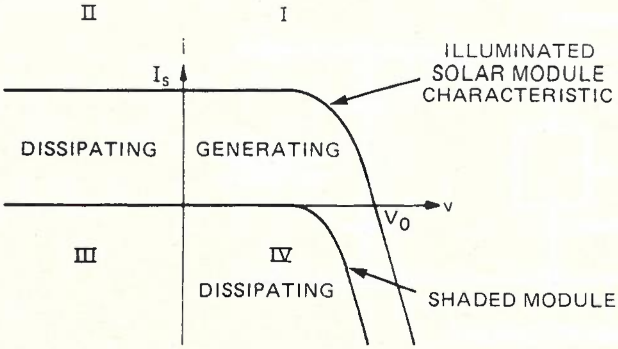


Fig. 12 — Characteristic Curves for Illuminated and Shaded Solar Module.

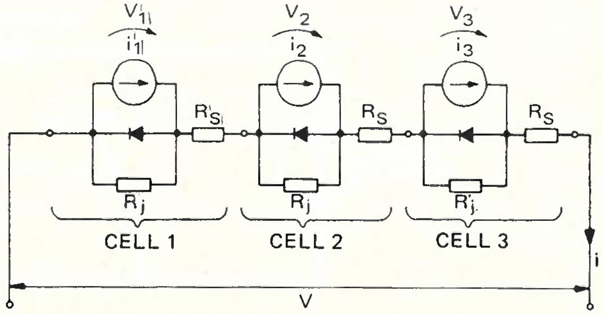


Fig. 13 — Equivalent Circuit of a 3 Cell Module.

If one cell is completely shaded, i_1 will be zero and no current will flow. The same applies if the terminals are shorted; in which case the voltage v_1, reverses and is the sum of the open-circuit voltages of v_2 and v_3.

As no current flows, no power is dissipated in the shaded cell. If the shadow is gradually removed, the photovoltaic current increases and the short-circuit current is limited by the current through this cell. The voltage across cell (1) is still in the reverse direction and therefore power will be dissipated in cell (1) and will be equal to that generated by cells (2) and (3).

The shaded cell tends to bias the other cells by establishing the current I_x as seen in **Fig. 14.** The power dissipated in the partly shaded cell will be $V_x.I_x$. As the shade is removed, the power dissipated will increase to a maximum which may be close to the peak output of cells (2) and (3). When the shade is almost completely removed, the voltage and power will reduce and will be zero when unshaded.

In practice a 12V nominal solar module will have 34-40 series cells and if one cell is partially shaded it is feasible that the peak power generated in the unshaded cells will be dissipated in the shaded cell when the module is shorted with resultant overheating of material in the vicinity of the cell. This can also occur, to a lesser degree, if the module is not shorted, but operated at a low voltage. For this reason, Philips have introduced a SOAR chart for their BPX47A panel, which is analogous to the method used for specifying the "safe operating area" of transistors.

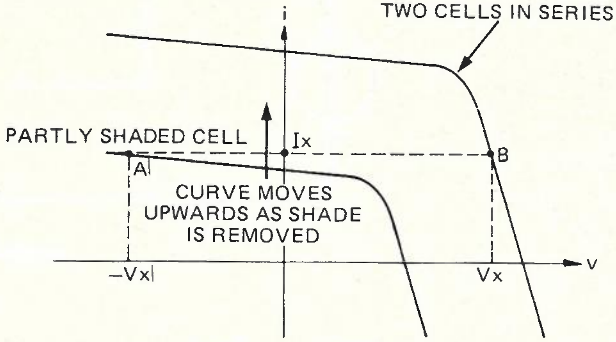


Fig. 14 — Effect of Partially Shading One Cell.

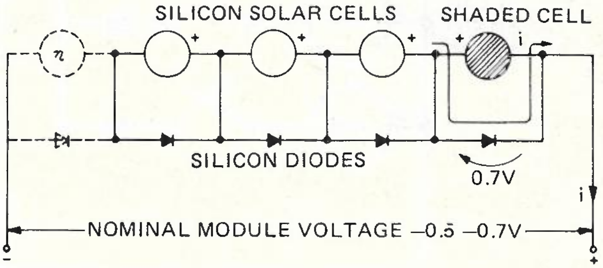


Fig. 15 — Effect of Bypass Diodes Across a Shaded Cell.

Shading of Solar Arrays

As shown above, shading of shorted solar arrays can cause overheating and damage module materials. In the normal charging mode, the charging current from a solar array will normally reduce proportionately with the amount a single cell is shaded. Shading may occur due to bird droppings, leaves etc.

The output from some solar modules does not fall to zero when a cell is shaded. This is usually due to a relatively low junction leakage resistance, shown in Fig. 13 as R_j. The characteristic curve of such a "leaky" cell has a marked slope in the current region and hence a low fill factor.

This leaky characteristic is useful however, especially for small systems where there may only be one solar module used. Another method of achieving this characteristic is to incorporate diodes across each cell in a string as shown in **Fig. 15**.

Under normal conditions, with no shading, each diode is reverse biased and each cell generates. When one cell is shaded it ceases to generate and becomes a high

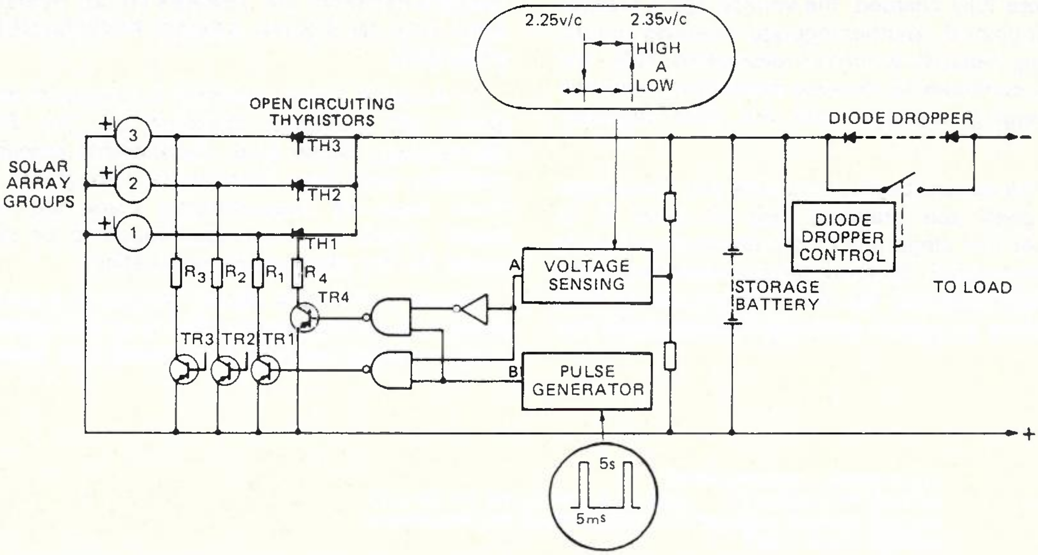


Fig. 16 — Thyristor Open Circuit Incremental Regulator.

resistance (shunt leakage resistance) and tends to be reverse biased by the other cells, causing the diode across the cell to conduct, bypassing the shaded or partially shaded cell.

If this cell was generating, say about 0.5V, then the overall voltage drop of the solar module will be about 0.7 + 0.5 = 1.2V. As there is usually more than 34 cells in a typical 12V module and because cells are operated in the current region of the I-V curve, the operating point will change slightly and the current will only reduce by about 2%. With two cells shaded the current will reduce by about 11%.

Not only do diodes across each cell limit the drop in output when a few cells are shaded, but they also protect each cell in the event of a short circuit being placed across the module. Short circuit regulation techniques could then be used effectively.

Thyristor Open-Circuit Incremental Regulation

A simplified schematic of a thyristor open-circuit control is shown in **Fig. 16.** The solar array is separated into a number of groups; each group having a thyristor as the open circuit element, which also obviates the need for a blocking diode.

A voltage sensing circuit with hysteresis senses the battery voltage. When the voltage reaches a level of about 2.35V/cell, the output A goes high. This enables pulses from the pulse generator to be applied to the base of TR1 which momentarily raises the cathode voltage TH1 above the anode voltage, thus switching TH1 off and disconnecting array group 1. While the battery voltage remains in the differential region, 2.25V/cell — 2.35V/cell, the base of TR1 is continually pulsed.

When the battery voltage falls below 2.25V/cell, output A is low and pulses are transferred to the base of TR4 which in turn pulses the gate of TH1, which switches on, reconnecting the array group.

Generally there is a separate regulator for each array group which operates independently. The voltage levels of each regulator are set to the same nominal value. All regulators do not operate simultaneously because of small variations in the set points.

Diode Voltage Dropper

Additional protection to the load may be simply achieved by using a diode voltage dropper (see Fig. 16) which can be switched between the battery and load, should the battery voltage exceed the equipment operating maximum.

Normally the contacts are closed, but when a high battery voltage is sensed by the diode dropper control, the relay coil is energized which open-circuits the contacts across the diodes and reduces the voltage to the load.

Incremental Regulator Operation

The curves in **Fig. 17** show the effect of incremental regulator operation on the battery voltage and array current of a typical solar power system incorporating 5 array groups and 4 regulators. During the summer, the secondary battery approaches a fully charged state. As the solar array output current increases, the battery voltage will increase. At point A the battery voltage reaches 2.35V/cell and one regulator operates and disconnects one solar array group, reducing the charging capacity by 20% and the voltage falls below 2.35V/cell. As the charging current continues to rise and the battery becomes more fully charged, the voltage again reaches 2.35V/cell at point B. Another regulator operates and the array charging capacity is further reduced by 20%. The voltage then continues to increase more slowly with the reduced charging capacity until the third regulator operates.

By noon the current begins to reduce and the voltage reaches a peak and gradually falls to point D at 2.25V/cell. At this stage one of the disconnected array groups is reconnected, the array current increase and the battery voltage increases. The array current continues to fall and the array groups are gradually switched back into circuit.

MEASUREMENT OF TERRESTRIAL INSOLATION AND USE IN SIZING SOLAR PHOTOVOLTAIC SYSTEMS

In Australia global radiation is measured routinely at about 20 locations operated by the Bureau of Meteorology. Some other departments operate various radiation recording instruments throughout Australia. Other types of measurements made are "sunshine-hours" which have not been found to be particularly useful for the photovoltaic application.

Global radiation is usually measured on a horizontal plane with an instrument called a pyranometer. At some stations diffuse radiation is measured also. Data from the

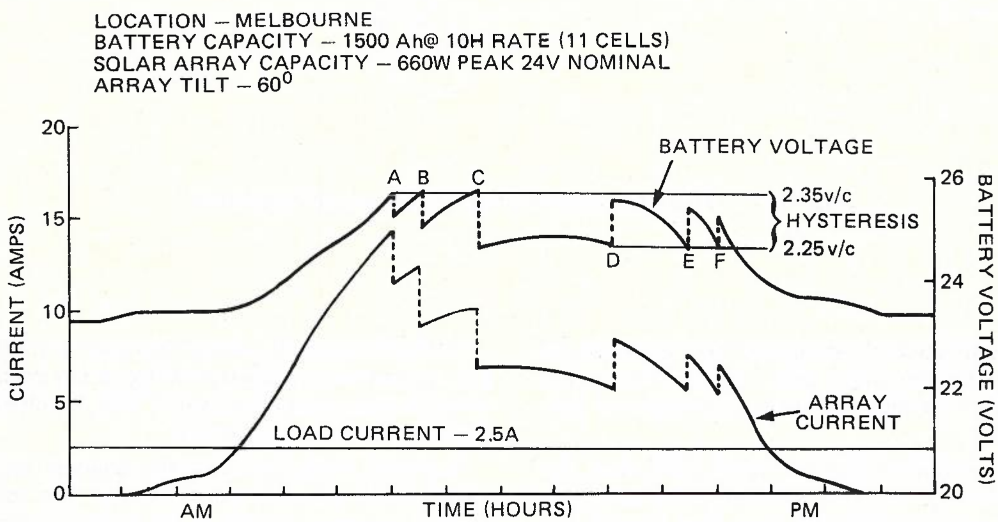


Fig. 17 — Effect of Incremental Regulator Operation on Battery Voltage and Array Current.

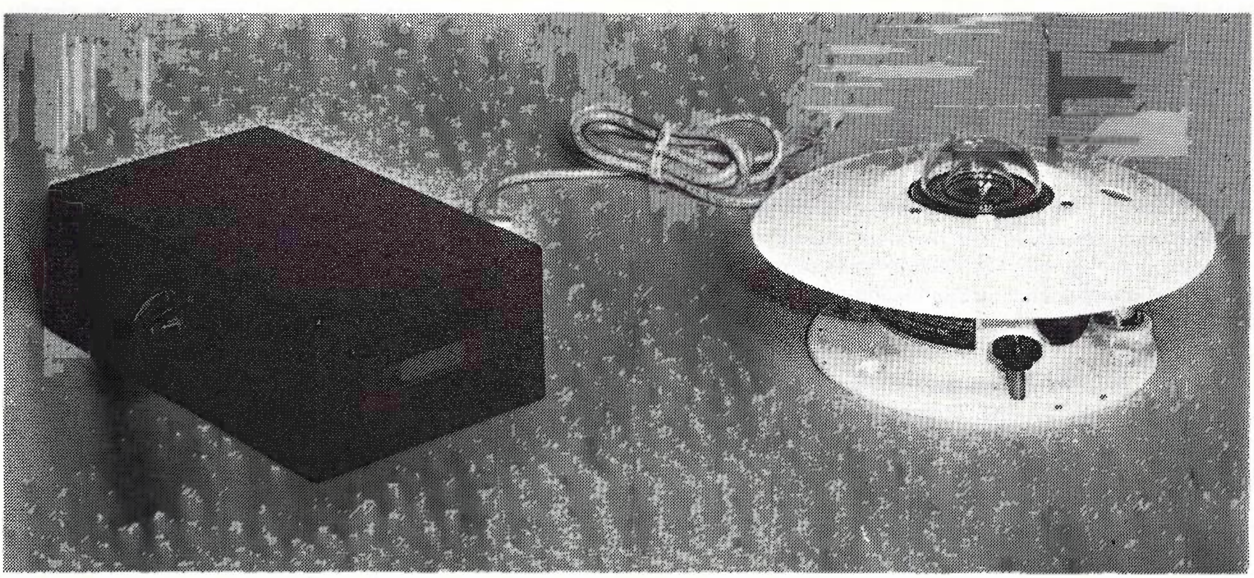


Fig. 18 — The Eppley Precision Spectral Pyranometer.

Bureau of Meteorology is usually available in mean hourly, daily or monthly total radiation in mW hr cm-²; accuracy of the data is about ± 5%.

A high quality pyranometer, the Epply Precision Spectral Pyranometer, is shown in **Fig. 18**. This pyranometer can measure global radiation either totally or in defined wavelength bands with the use of suitable filters. A wire wound thermopile is used in the instrument which generates a small potential which is related to the total amount of radiation received. Temperature compensation is incorporated to compensate for ambient temperature changes so that at zero light intensity the output voltage is zero.

The output of such a device must be integrated over the hour or day to yield the total radiation (energy) falling on a unit area, over the period. Integration can be achieved in a number of ways, although electronically is by far the simplest means.

Solar insolation data available in Australia is usually measured at major centres whereas the majority of Telecom installations utilizing solar cells are in isolated areas of Australia and to dimension a system, insolation data available as near to the installations as possible must be used. Installations may be many hundreds of kilometres from the nearest radiation measuring stations and some judgement in determining the final solar array capacity is necessary.

Solar radiation measurements could be made at an installation during the planning stages of a project, but this can usually only be justified for larger systems.

The radiation data available is usually measured with a non-selective pyranometer. Hence information on the spectral energy distribution of the radiation is not available and this may vary from day to day and between different locations. The response of a solar cell is wavelength-dependent and its performance is significantly affected by the spectral energy distribution. Also thermopile measuring devices have a much slower response than solar cells. It can be seen therefore that some care must be taken in applying available radiation data to the sizing of solar cell systems.

Probably a better way of measuring sunlight for solar power system work is to use a calibrated solar cell, since solar cells of different types vary in their spectral response, ideally, solar insolation should be measured with the same type of cell that will be used for the system to be installed. Devices of this type have been considered (Ref. 2) where the output of a solar cell is fed into a shunt resistance. The current through the shunt and thus the voltage across it, is proportional to the incident solar radiation intensity.

This measurement gives the instantaneous radiation, but this must be integrated to give total radiation. The simple system incorporated in Ref. 2 is shown in **Fig. 19**. An electromechanical integrator called an "E cell" is used with a multiplier resistor which provides a "charging" current proportional to the solar cell short-circuit current. The "E cell" integrates by depositing silver atoms on a gold electrode. This process is fully reversible and the "memory" can be read out in a few minutes with a constant current. The time to read out is therefore proportional to the total solar energy incident on the solar cell during the measuring period.

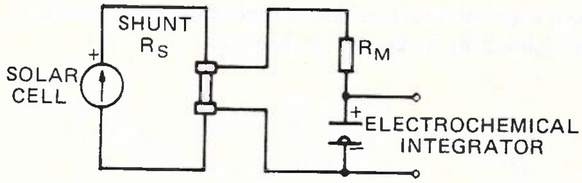


Fig. 19 — Simple Solar Cell Radiation Measuring Instrument.

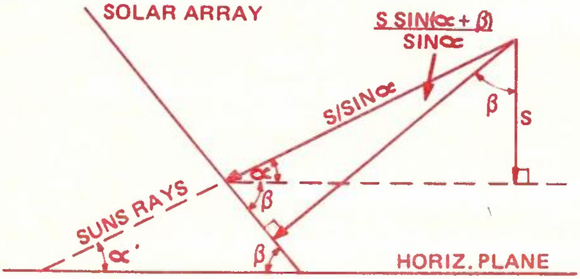


Fig. 20 — Solar Radiation on a Tilted North Facing Solar Array.

This device would be cheap, enabling many of them to be installed at proposed solar installations. Because the device used to measure the solar radiation is the same as the final energy producing device, factors such as effect of dust, shading and temperature variation would be automatically taken into account.

CORRECTING SOLAR RADIATION FOR AN INCLINED SOLAR ARRAY

Relationship Between Radiation on an Inclined Plane and Horizontal Plane

The mean daily global solar radiation, R is usually only available for a horizontal surface. If the mean daily diffuse radiation, D is also available, then the equivalent amount of solar radiation falling on a solar array inclined to the horizontal at an angle, β may be found. Horizontal solar arrays do not often optimise the collected solar radiation. At the equator this may be so, but for reasons of self cleaning, it is not recommended to mount solar arrays horizontally.

The mean direct daily solar radiation on a horizontal plane, S, is given by:

$$S = R - D \qquad (1)$$

From **Fig. 20**, assuming parallel solar rays, it can be shown that the direct component of radiation, S on a surface inclined at angle, β is given by:

$$S_\beta = S \sin \frac{(\alpha + \beta)}{\sin \alpha} \qquad (2)$$

where α is the noon time altitude of the sun and from **Fig. 21** is given by:

$$\alpha = 90° + \phi - \delta \qquad (3)$$

where ϕ is the latitude and δ is the declination of the sun given by:

$$\delta = 23.45° \sin \frac{360}{365} (d - 81) \qquad (4)$$

*North is positive for ϕ and δ

where d is the day number (Jan. 1st = 1)

The total radiation, R_β on the tilted solar array becomes from (1) and (2).

$$R_\beta = \frac{S . \sin (\alpha + \beta) + D}{\sin \alpha} \qquad (5)$$

which assumes that the diffuse radiation, D is independent of array inclination. Relationship (5) is only strictly true at midday, but as total daily solar radiation is generally only available, this relationship will be applied to obtain correction for array tilt.

When sizing a solar power system it is more convenient to use mean daily solar radiation data for each month and relationship (5) is applied, again introducting a small error.

OPTIMUM ARRAY TILT

The optimum solar array tilt will depend on the energy demand throughout the year and the ability of the storage battery to store the energy generated by the solar array.

Where all generated energy is utilized and the energy demand is constant throughout the year, an expression for the optimum tilt can be found from (5) (see Ref. 3). In practise, a storage battery of sufficient capacity to store all generated energy is not practical and a compromise between solar array size and battery capacity must be made. Cost and battery life play an important part in system dimensioning.

The optimum array tilt is usually the one which provides the most even effective radiation throughout the year.

Where a high summer radiation — low winter radiation cycle occurs, such as in Melbourne, the optimum solar array angle is usually the latitude plus some angle up to a maximum of 23.45°. At latitude plus 23.45° the solar array is perpendicular to the sun's rays in mid-

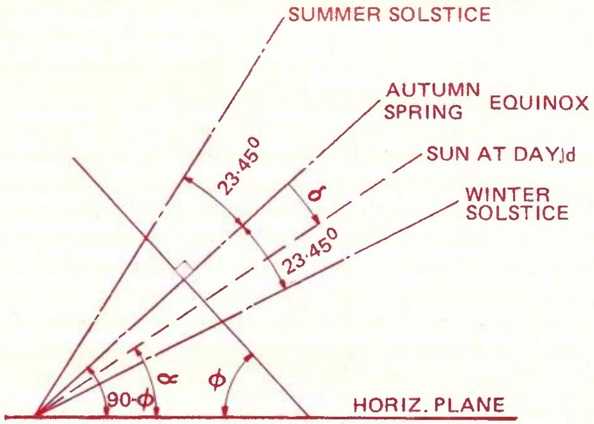


Fig. 21 — Relationship Between Sun Altitude, Declination and Latitude (Southern Hemisphere).

winter and the winter sun is optimized. The higher percentage diffuse radiation content during the winter will tend to reduce the effect of variation of solar array tilt.

SYSTEM DIMENSIONING

Obtaining Load Data

The first step in sizing a system is to obtain reliable load data. What is the nominal voltage of the system? In Telecom's case it is usually 12V, 24V or 48V. Over what limits is the voltage able to swing before equipment operation suffers? A variation in voltage is inherent in solar power systems.

What is the average load of the equipment? In many cases this is relatively easy to determine, such as in the case of microwave radio repeaters. Here the load is substantially constant and predictable, but this is not so with small VHF subscriber systems where, although the stand-by or receive current is constant throughout the day, the substantially higher transmit current provides an average drain which is dependent upon user call rate. This may vary throughout the year and from one subscriber to another, depending upon the users own special requirements.

It is important to specify load accurately, because an undersized solar array will mean eventual battery total discharge and system failure while an oversized array will be a waste of capital.

Array Sizing

To assist with the sizing of a solar power system, a computer programme Solar 2 has been written in BASIC language, which greatly accelerates solar power system design. A successive approximation approach is used with the central objective being that the battery should never fall below 50 per cent charge during poor weather.

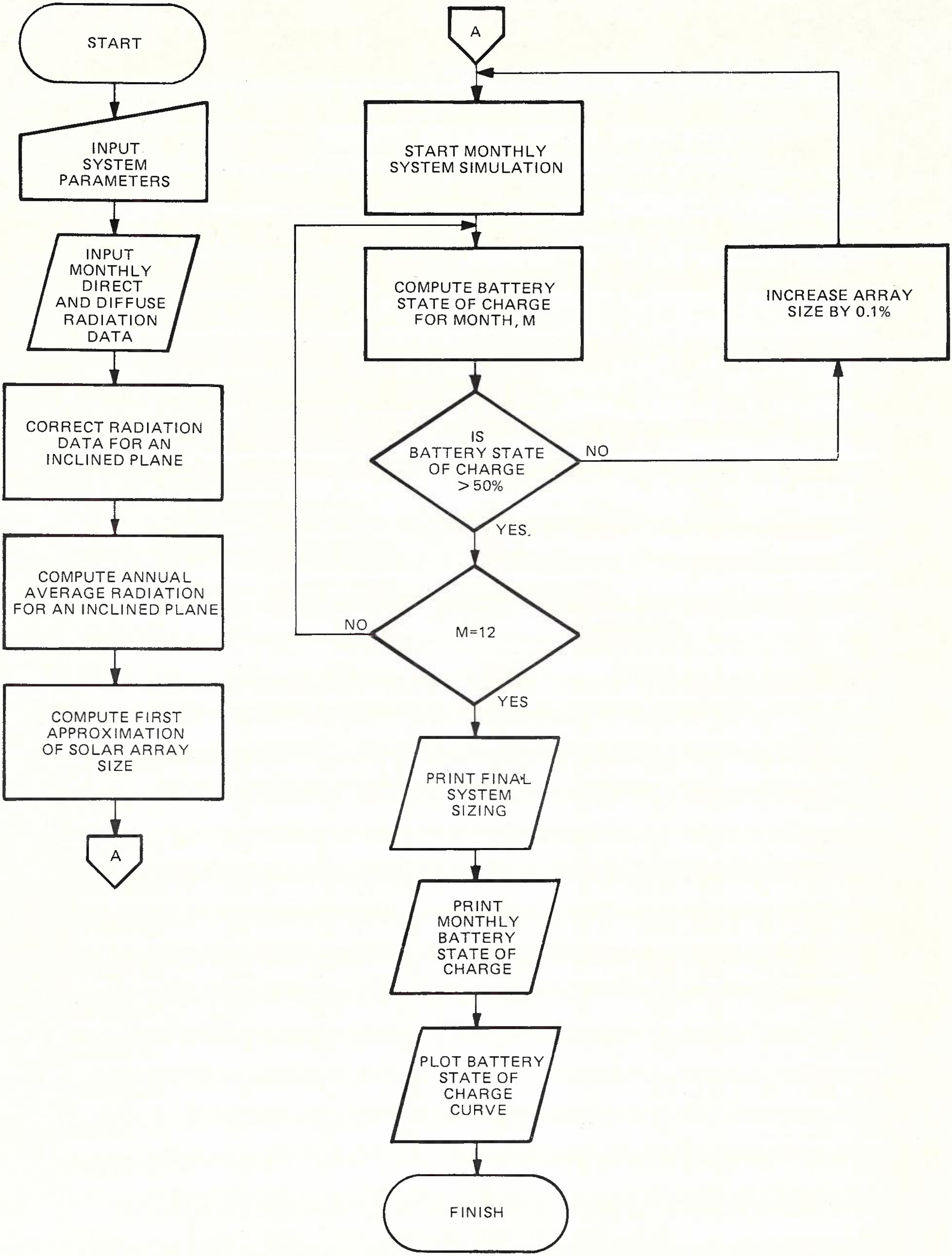


Fig. 22 — Flow-Chart of Telecom Solar 2 Computer Program.

NUMBER OF APPROXIMATIONS = 207

SOLAR POWER SYSTEM ANALYSIS PROGRAM

SITE NAME : MELBOURNE

LATITUDE = 37.8 DEGREES
ARRAY INCLINATION = 60 DEGREES

RADIATION MEASURING STATION - MELBOURNE
YEAR OF RADIATION - 1973

VOLTAGE = 24 VOLTS
LOAD = 100 WATTS AVERAGE
CURRENT = 4.16667 AMPS

BATTERY CAPACITY = 1500 AMPERE HOURS

ARRAY SIZE, FIRST APPROX. = 18.8995 AMPS PEAK
ARRAY SIZE , FINAL = 22.8117 AMPS PEAK

AVERAGE CORRECTED RADIATION = 582.554

PRINT OUT,YES/NO?YES

MTH	RADIATION			AMPERE HOURS				BATTERY STATE	
	HOR	COR	DIF	ARRAY D	ARRAY M	LOAD M	DIFF M	START	FINISH
1	629	478	210	142.6	4419.2	3146.5	1272.7	1500.0	1500.0
2	559	499	149	134.3	3761.6	2842.0	919.6	1500.0	1500.0
3	396	443	166	126.3	3913.8	3146.5	767.3	1500.0	1500.0
4	309	448	127	119.1	3573.2	3045.0	528.2	1500.0	1500.0
5	199	365	98	96.0	2975.0	3146.5	-171.5	1500.0	1328.5
6	167	347	79	88.3	2650.0	3045.0	-395.0	1328.5	933.5
7	195	380	82	95.8	2969.6	3146.5	-176.9	933.5	756.6
8	254	400	120	107.8	3340.6	3146.5	194.1	756.6	950.7
9	368	448	148	123.5	3703.6	3045.0	658.6	950.7	1500.0
10	500	476	197	139.5	4325.0	3146.5	1178.5	1500.0	1500.0
11	491	386	241	130.0	3899.6	3045.0	854.6	1500.0	1500.0
12	676	487	214	145.3	4505.3	3146.5	1358.8	1500.0	1500.0

PLOT,YES/NO?YES

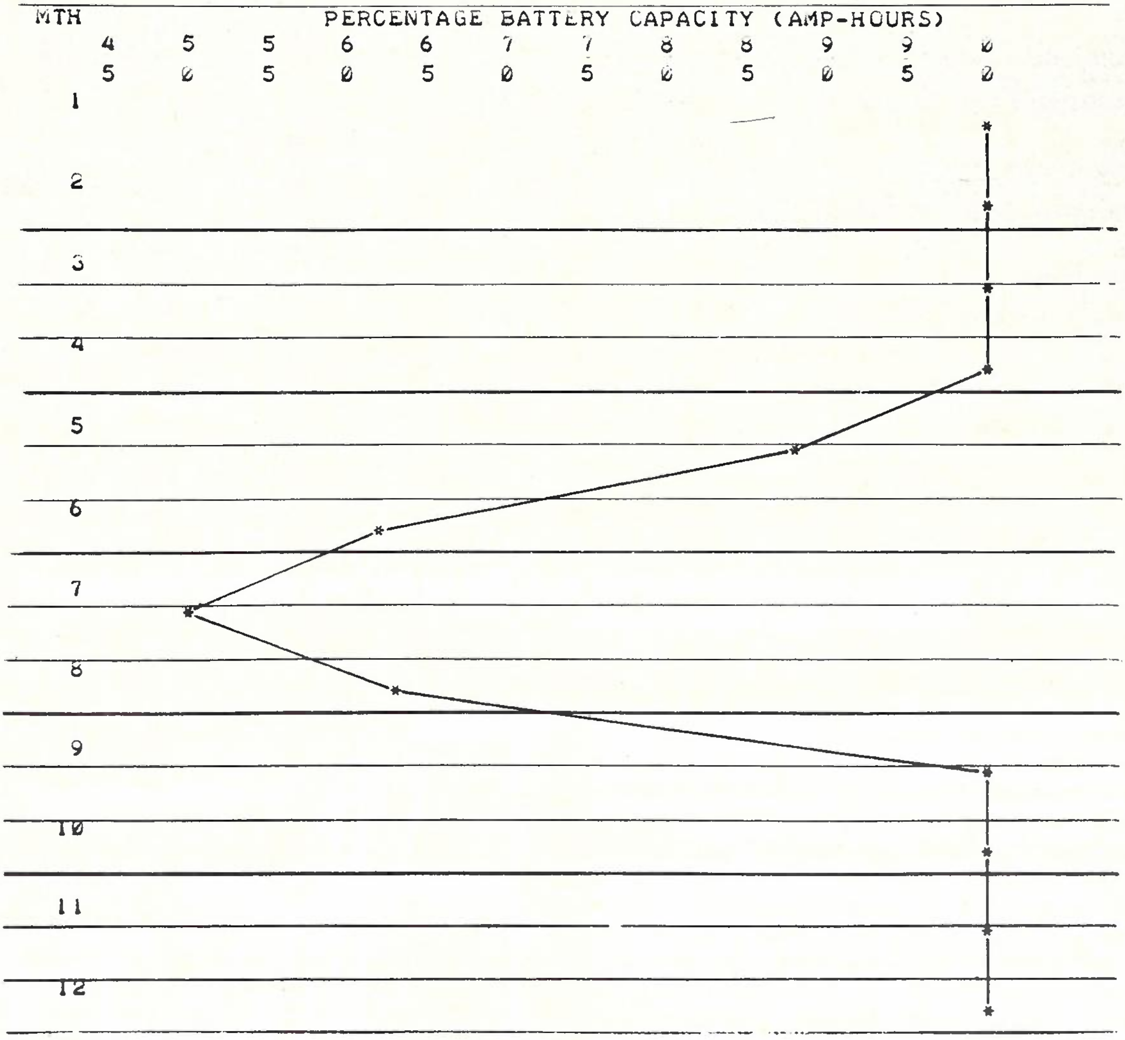


Fig. 23 — Typical Computer Printout and Plot for a 100 Watt — 24V Load in Melbourne.

This figure has been selected as a reasonable compromise between solar array cost and, more importantly, long battery life.

A simplified flowchart for the computer program is shown in **Fig. 22.** The basic steps in the computer programme are:

- System parameters such as average load, nominal system voltage, site latitude, battery capacity and estimated optimum array tilt, are entered.
- Monthly direct and diffuse solar radiation data measured on a horizontal surface are entered.
- The direct radiation data is then corrected for array tilt; the diffuse radiation needs no correction as it is assumed to be isotropic.
- The annual average daily radiation intercepting the inclined array is calculated. This is the sum of the diffuse and corrected direct radiation.
- The first approximation of array size, in terms of peak current, is computed from the relationship

$$I_p = A_d \cdot k/R_d$$

where:

I_p, peak array current (amps at 100 mW cm^{-2})

A_d, average daily load ampere-hours

R_d, annual average daily radiation (mWhr cm^{-2})

k, factor incorporating unit conversion, allowance for battery charging efficiency etc.

(Sizing is on the basis of current, because ampere-hours in and out of the battery are more relevant than watt-hours, since the voltage varies).

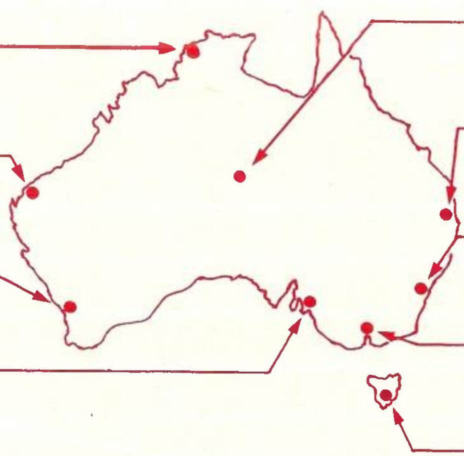


Fig. 24 — Optimum Array Angle and Peak Array Size for 24V 100 W Solar Power Systems for Various Sites Within Australia.

- The first approximation of array current is then used on this relationship, transposed to give daily array output in ampere-hours as a function of peak array current and monthly average daily radiation. The performance of the system throughout the year is then simulated.
- The simulated battery state of charge at the end of each month is checked. If it is greater than 50 per cent, then the system simulation continues to completion. If however, the battery falls below 50 per cent state of charge, the array size is increased by 0.1 per cent and the simulation repeated with the new array size.
- A brief printout of the sizing may be obtained or a complete printout and plot of battery state of charge, obtained.

Should a more detailed analysis be required a second program (Solar 4) is used, which operates on a daily basis. This program is also able to analyse a hybrid solar power system incorporating a standby generating source.

A typical computer printout and plot is shown in **Fig. 23** for a 100 watt 24 volt load in Melbourne.

No attempt has been made to provide in the program a facility to compute the optimum array inclination. The optimum tilt may be quickly found by running the program a number of times and finding the tilt for minimum array size.

The solar array capacity and optimum inclination for a load of 100 watts continuous (24V), is shown in **Fig. 24** for a number of locations in Australia. A battery capacity of 1500 ampere-hours has been used giving a reserve of about 15 days from a fully charged battery.

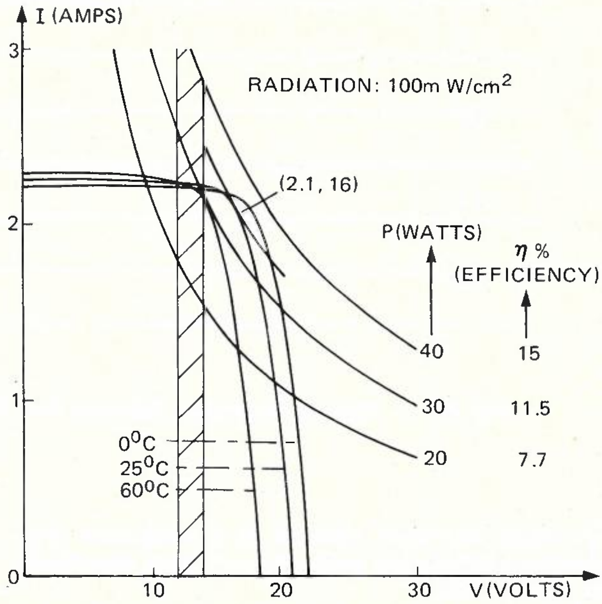


Fig. 25 — Variation in Solar Module Output with Temperature.

Need for Engineering Judgement

Although the computer program greatly reduces the calculation time, much engineering judgement is necessary in designing the system for a particular site. Some of the problems have been mentioned, such as obtaining reliable power-load figures and determining what radiation data should be used for a particular site.

Experience is necessary in relating the parameters of a particular solar module type to the peak current figure computed. That is, the characteristic I-V curve must be studied in the battery operating region taking into account voltage drops due to blocking diodes, regulator "switches", shunts etc. As the output of a solar array will reduce with increasing temperature, the likely temperature experienced at site must be taken into account. The temperature of a solar cell within a solar module may be 15-20°C above the ambient temperature under peak sunlight conditions. It is difficult to include a factor to account for higher cell temperatures especially as the temperature cannot be related easily to the instantaneous radiation throughout the day.

Consider the curves in **Fig. 25.** These show the typical variation in solar module output with temperature for a module with a nominal 12V output. The voltage in the voltage region reduces with temperature, while the short circuit current increases slightly. Although the net effect is a reduction in the peak output of the solar module, the effective charging current in the battery operating and regulating region varies only slightly. The lowest module current in this region is selected and is divided into the peak current found from the computer printout.

A knowledge of the storage battery is also necessary to ensure that the battery discharge depth is kept to an acceptable level, the charge efficiency is included and an allowance is made for the battery self discharge losses which will vary with the age of the battery.

SOLAR POWER SYSTEM DEVELOPMENT PROGRAMME

Low Drain Equipment

The introduction of low drain, highly reliable microwave radio equipment meant that solar power could be considered for use on major trunk systems. Solar power sources have the potential to match the high reliability and low maintenance of the radio equipment (claimed mean time between failure in excess of 100,000 hours).

Economic Study

An economic study was made about three years ago to establish the load up to which solar power could be economically justified. If the relative cost of a solar power system and equivalent duty and standby diesel system are compared, it can be shown from **Fig. 26** that solar power is economic for loads of up to about 200 watts dc.

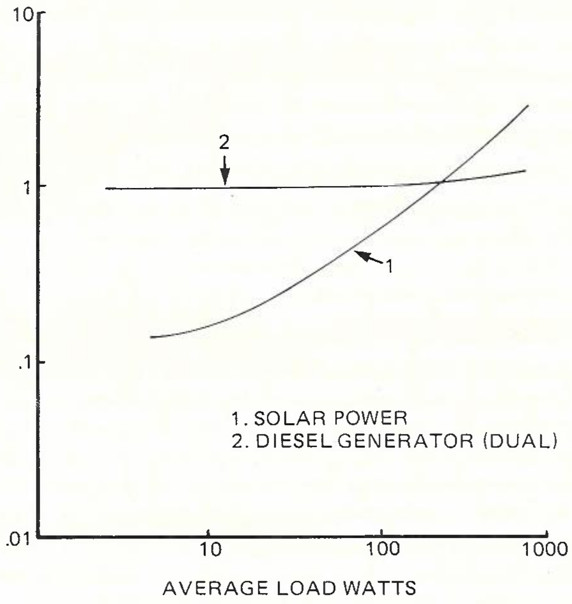


Fig. 26 — Relative Cost of Solar and Diesel Power System for a 15 Year Life.

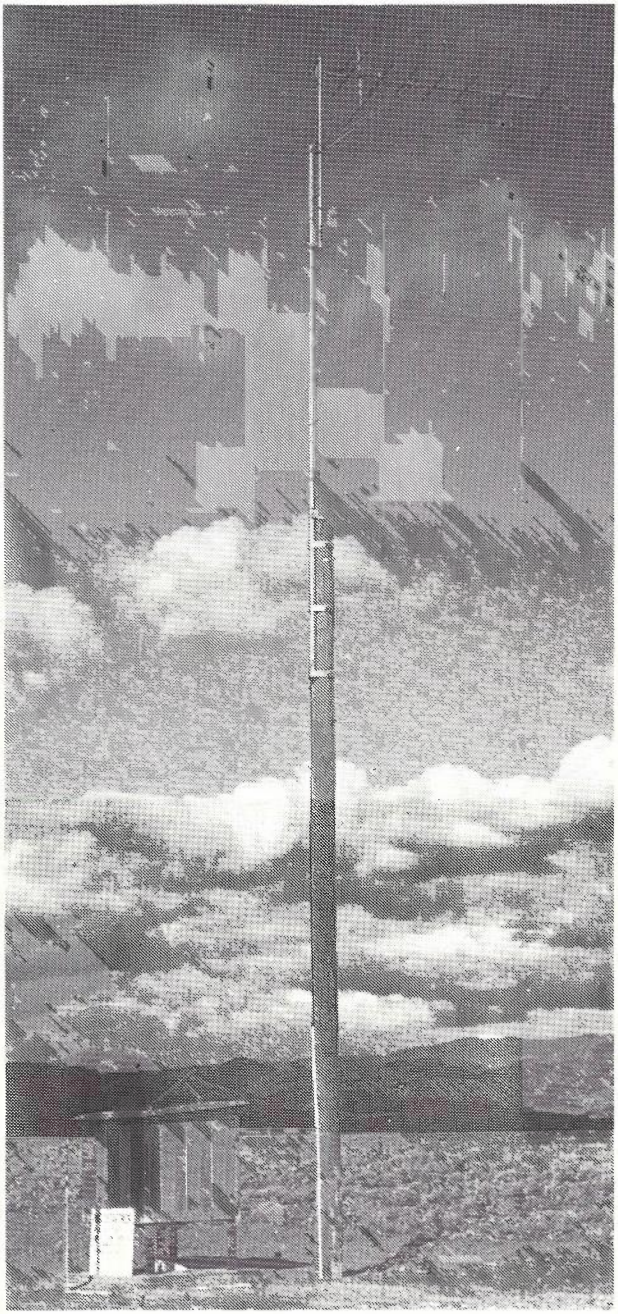


Fig. 27 — Solar Powered VHF Subscriber Radio-telephone at Wilkatana, South Australia; Array Output 21 Watts — 12V, 2.5 Watt Load.

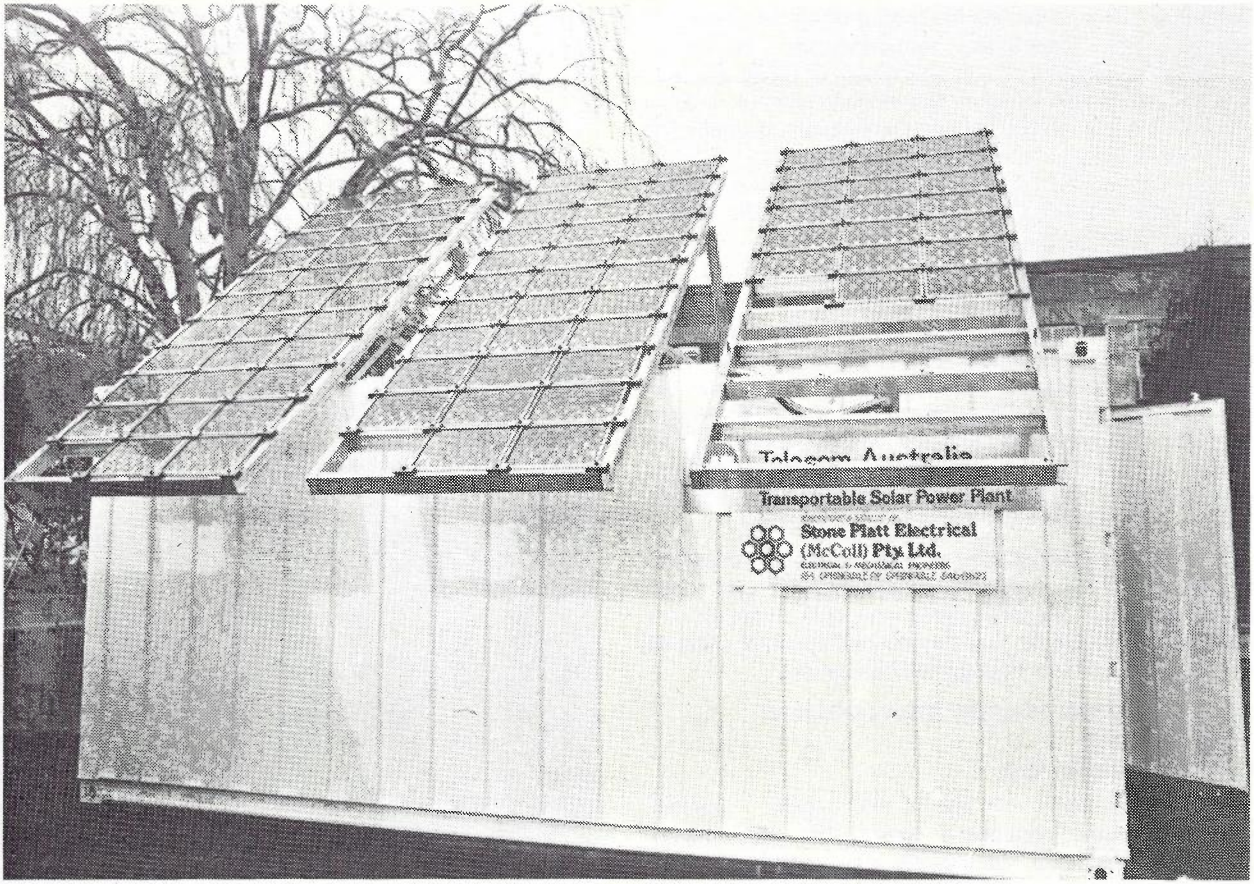


Fig. 28 — "First-Off" Production Solar Power Plant for Tennant Creek — Alice Springs System — External.

As modern microwave radio relay systems being considered for purchase would have loads of approximately 125 watts average, Telecom initiated a programme to develop a stand alone solar power package capable of supplying about 125 watts continuous power.

Main Phases of the Programme

The main phases of the programme to develop a practical solar power package for microwave radio relay systems, were:

- provide accelerated environmental life testing of solar modules;
- develop a prototype solar power plant package;
- evaluate an ISO Shipping Container shelter;
- evaluate an integrated power shelter/array mounting;
- develop regulating and control techniques for solar array, battery and load;
- produce a prototype power control cubicle;
- investigate the preferred type of lead-acid batteries for solar photovoltaic applications;
- investigate the effect of dust accumulation on the output of solar arrays;
- develop computer-aided techniques for optimising system size;
- investigate and analyse ways of protecting solar modules from damage by birds;
- investigate vandalism and security aspects;
- perform present-value and annual cost studies.

The power plant package was assembled by April 1977 and has satisfactorily completed engineering trials and much of the above development and investigation work has now been completed.

Applications in Telecom

Prior to the development programme, designs for small solar power systems had been completed and Telecom has currently more than 50 smaller installations in operation throughout Australia. Many of these power small VHF subscriber radio systems with loads generally less than about 4 watts.

The first of these systems was installed in 1974 and has operated satisfactorily since. The system is situated at Wilkatana, near Port Augusta and is shown in **Fig. 27.**

Some of the planned solar power installations for the next two years are:

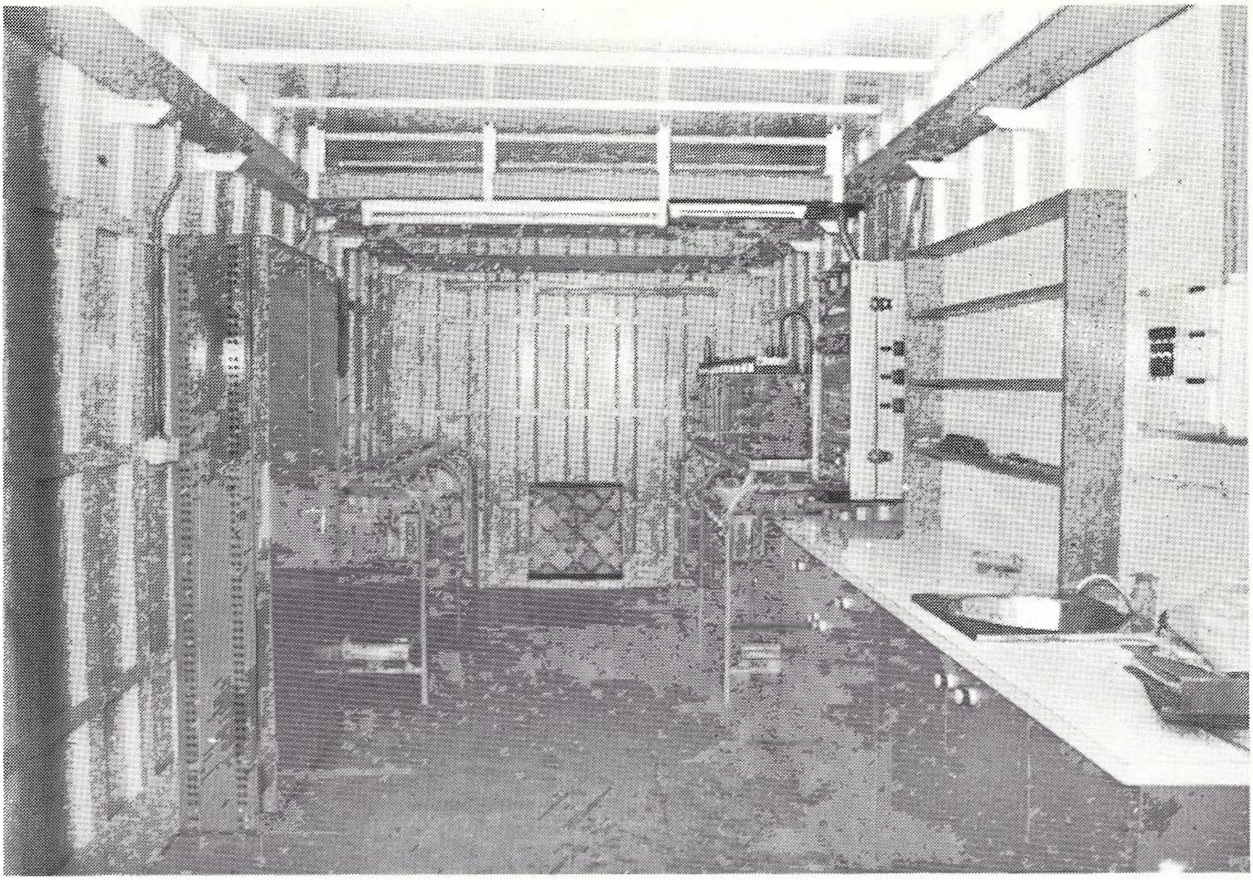


Fig. 29 — "First-Off" Production Solar Power Plant — Internal View Showing 1500 Ah Battery, Control Cubicle and Staff Amenities.

- Subscriber radio telephone services to 13 islands in the Torres Strait, 9 terminals of which will be solar powered.
- A microwave radio 960 channel system from Kalgoorlie to Leonora in Western Australia with 3 repeaters using peak array outputs of about 900 watts.
- A similar 960 channel microwave system between Coen and Mossman with 6 repeaters using about 900 watt solar arrays.

The first large scale use of solar power is on the Tennant Creek — Alice Springs microwave radio system in Central Australia. The first-off production unit based on the Telecom package approach developed as a result of its solar energy programme, is shown in **Figs. 28 and 29.**

There are 13 non-mains powered repeaters over the 580 km route. At 11 stations 814 peak watt arrays will charge 1500 Ah batteries and provide 132 watts for microwave radio, supervisory and waveguide dehydrator equipment. At 2 stations with diversity the load will be 143 watts and the solar arrays 858 watts peak. These figures represent a ratio of about 4.6:1 between peak array current and load current and reflects the relatively high incidence of solar radiation in this area.

New low consumption microwave radio equipment is being used to provide a "1+1½" system (that is 960 telephone channels plus 960 standby telephone channels plus a one-way television bearer into Alice Springs). Air conditioning is not required as radio equipment is being housed in underground shelters which keep the diurnal and seasonal temperature variations to a minimum.

STORAGE BATTERIES FOR SOLAR POWER SYSTEMS

Basic Requirements

The storage battery is a very important part of the photovoltaic power system; in fact storage is most important in any solar power system. The correct choice of battery is not easy considering the rather unpredictable mode of operation. The basic requirements are:

- low self discharge
- long life in the unusual solar charging mode
- low maintenance
- transportability
- high charge efficiency
- low cost

The self-discharge within a battery and inefficiencies in the charge cycle must be met with an increase in solar array capacity. This increases the cost of the solar array. Telecom use lead-acid batteries for exchange stationary-battery applications which have self-discharge rates of less than 3% of their capacity per month if left open-circuit.

The figure is low compared with typical lead-antimony automotive batteries, which are not satisfactory for solar duty.

The solar battery should be low maintenance as it will normally be installed at an unmanned isolated station. Preferably, boost charging should not be required and only biannual top-up of electrolyte should be necessary.

As the batteries may have to be transported long distances, over rough roads, they should be of sufficient strength or packaged adequately to prevent damage. Unfortunately, lead-acid batteries designed for long life on float duty often have soft pure-lead positive grids. The Telecom batteries are of this type and require special packaging techniques to prevent damage during transport.

Telecom purchase a large quantity of lead-acid batteries, which are locally manufactured, and therefore benefit from low, volume, prices. Nickel-cadmium batteries are not considered to offer any significant advantages over the Telecom battery for solar applications, and can be up to four times as costly.

Mode of Operation

The mode of operation of a solar battery is quite unusual and often unpredictable — dependent on site weather conditions. Batteries are normally operated in either the constant potential (float mode) or cycling mode, where the battery undergoes regular deep discharge and re-charge.

A very shallow daily cycling of the battery will be superimposed on relatively deep annual discharge, shown in **Fig. 30** for a system in Melbourne. This curve shows the average monthly solar radiation both on a horizontal and inclined plane. The solar radiation exhibits a large variation in the summer/low winter radiation cycle which is typical of southern and non-tropical areas of Australia. This cycle produces an annual "notch" in the battery charge curve. A larger solar array than is necessary is required to keep the battery in a nominal fully charged state throughout the year, however the battery is kept above about 50% capacity by design, during the winter and appears to be a reasonable compromise between system cost and battery life.

A minimum battery reserve is achieved if the radiation is consistent throughout the year and this can be achieved to a certain degree by inclining the array to face the sun during the poor weather. In Fig. 30 it can be seen how the high summer radiation on a horizontal plane is reduced on a plane inclined at 60°. The winter sun is likewise fully utilized.

The battery remains in a discharged state for up to 5 months of the year and it is the performance of the battery during this period that is of interest in terms of life and performance.

A large battery giving 12-20 days reserve at the 10 hour rate, is considered necessary for most Telecom systems. The charging source is small when compared with other forms of charging systems used to charge such a large battery. Under peak sunlight conditions the charging rate may only be as high as the 50-to-100 hour rate, compared with the 10 hour rates normally employed.

Likewise the discharge rates are very low, typically about the 300-hour rate. As can be seen from **Fig. 31** considerably more capacity is available at the low discharge rate, down to a limiting voltage of 1.85V per cell.

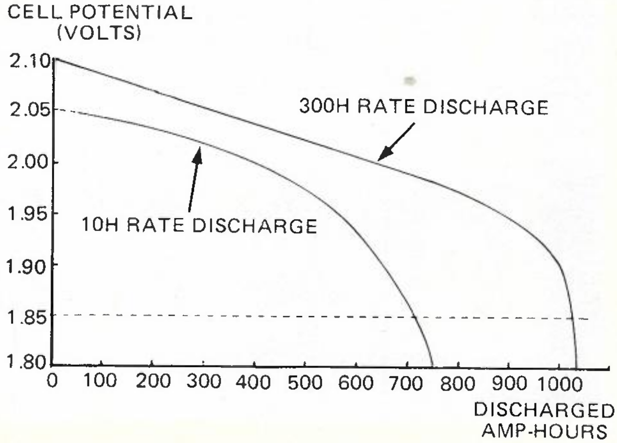


Fig. 31 — Constant Current Discharge Curves for a Nominal 550 Ah Pasted-Plate Battery at Different Rates Assuming a Limiting Voltage of 1.85V per Cell.

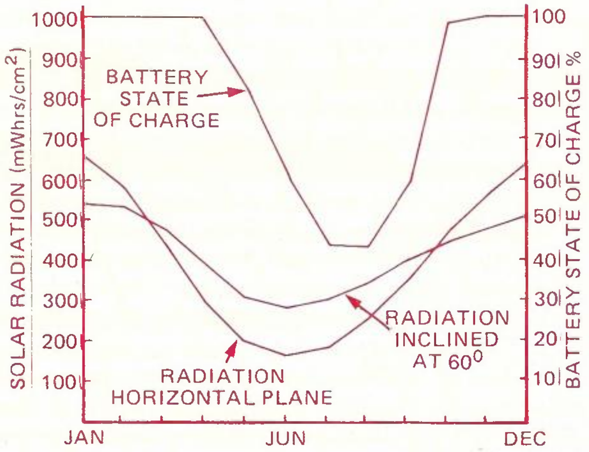


Fig. 30 — Average Global Radiation for Melbourne and Battery State of Charge.

It can be seen from the 300-hour rate discharge curve, that at 1.85V per cell the battery is operating at the knee of the curve and the useable capacity beyond this point is minimal. Telecom size solar power systems using 10-hour rate battery capacity ratings rather than the 100-hour or 300-hour rate as it is not thought advisable to discharge the battery so deeply on a regular basis, although in an emergency, this reserve can be used.

Low-Loss Alloys

The composition of the positive-plate grid material plays an important role in the performance of lead-acid batteries. The use of a lead-antimony alloy grid structure in automotive cycling and some stationary batteries, greatly improves the cycling performance and life of the battery and also strengthens the grid structure for vehicle applications where vibration will destroy softer pure-lead grid structures. The life of lead-antimony grid batteries, on float duty however, is usually short.

Telecom has used pure lead positive-grid cells in exchanges for over 20 years. They have a long life generally in excess of 15 years. Electrolyte usage is low, about 1/5 that of antimonial types, and as mentioned before, they have a low self-discharge at a relatively low cost. They appear well suited to the solar application which is considered to approach float operation more than true charge/discharge operation.

A pure-lead 12V-25 Ah battery has been operating with a small trial solar power system in Melbourne for about 5 years. Recently one cell was removed and analysed, and two other cells tested for capacity. The battery positive plates were in good condition, with no corrosion on the positive grid; a common cause of battery failure. Positive grid corrosion is accelerated by high temperatures, continued overcharging and the presence of antimony in the positive grid. Little loss of positive active material was evident and the battery capacity had not deteriorated.

Pure-lead positive grid batteries are recommended for

Fig. 32 — Telecom Pasted-Plate Lead-Acid Batteries from L to R: 6V — 90 Ah, 2V — 200 Ah, 2V — 500 Ah, 6V — 45 Ah, 12V — 25 Ah.

solar applications, although lead-calcium low-alloy grids have been used extensively in the USA for stationary applications and have similar characteristics to the Telecom battery. These batteries are also being used by companies in the USA for solar applications.

Australian manufacturers make pure-lead positive pasted-plate batteries in a range of capacities from 25 to 3000 Ah. Some typical batteries are shown in **Fig. 32.** Note the explosion proof vents on top of the cells. These batteries have fairly large electrolyte reserves above the plates and a yearly or twice-yearly top up with distilled water is all the maintenance that is necessary.

An annual winter boost charge would probably extend the battery life, with the long term performance under solar duty yet to be fully investigated. The Telecom Research Department has been investigating some of these aspects. Although a life of 15 years can be expected on float duty, only about 6-8 years is expected on solar duty.

SOLAR-CELL MODULE PERFORMANCE

Along with solar cell electrical performance, the performance of the package in which the cells are encased is equally important. For many years solar photovoltaic module manufacturers have striven to offer a solar cell package capable of long life (in excess of 15 years) and endurance in the severe terrestrial environment.

Most solar module manufacturers have had packaging problems and many failure mechanisms have been reported. The haste with which manufacturers have tried to reduce costs and subsequent use of new, and in many cases, unproven, materials has contributed to the incidence of failures. Plastics are being used extensively in the manufacture of solar modules and some of the failures can be attributed to their use.

Some of the more common failure mechanisms encountered are:

- delamination of silicone-rubber encapsulants from cells, surface materials and substrates;
- penetration of moisture into the cells, causing corrosion and deterioration of cell grid and underside metallization materials;
- breakdown of interconnection between cells;
- discolouration of clear 'potting' encapsulants;
- deterioration of materials, especially plastics, used in the packaging;
- cracking of the silicon-cell wafers;
- damaged interconnects and output terminals.

Telecom has not recommended the use of soft silicone-rubber-surfaced solar modules, mainly because of cleanability and the problem of attack by parrots. Apparently the destructive habits of parrots in Australia are not encountered elsewhere in the world. Parrots in Australia have caused severe damage to exposed plastic surfaces on waveguides, aerial fittings and PVC cables used in our communication systems.

Glass surfaced modules have been preferred for Telecom applications. These modules are easily cleaned and their output restored to its original value. Tests carried out with typical Australian fine red "bull" dust show that a considerable layer of dust can accumulate without significantly reducing the output of the module. The cells can be covered to the stage where they are barely distinguishable and the output falls only by about 25-50%. Much of the sunlight is probably scattered by the fine dust particles and is finally reflected onto the surface of the cells.

A number of different types of solar modules are shown in **Fig. 33.** These range from the smallest — a 0.36 peak watt module manufactured by Sharp with an acrylic case; to the largest — a 30 watt peak Solar Power Corporation module with a polyester "structural" package with soft silicone-rubber surface. Other modules include glass covered types which have a clear silicone-rubber potting material.

Testing Programme

A testing programme carried out by our Research Department in 1976 highlighted a number of these failure problems. The test panels were subjected to 20 temperature cycles with temperature changing from -40C to 25C to +80C, followed by 2000 hours in a "weather-o-meter" illuminated by a xenon arc and at a temperature of 40C, 52% relative humidity and sprayed with water for 3 minutes every 20 minutes.

Encapsulation testing for the Jet Propulsion Laboratories in the USA (Ref. 4) has shown that from limited real-time exposure tests, some materials are not suitable for solar cell encapsulation. These are polyurethene, polyester, kapton, Mylar and UV-stabilized Lexan. Acrylic and glass both appear to be suitable for module covers. Clear silicone-rubber appears to pick up and hold dirt when used as module covers.

Telecom is currently conducting environmental testing of a number of new solar modules so that suitability of module can be assessed in time for collective purchase of solar power plant in 1979.

FUTURE TRENDS

Silicon Technology

Silicon has been attractive for photovoltaic conversion because of the relatively high conversion efficiencies, the abundance of the material, and silicon semi-conductor technology is highly developed. Most silicon solar cells are produced from monocrystals grown from highly pure semi-conductor grade silicon. This is an expensive process with only about 5% of the starting silicon appearing in the final slice.

The use of lower grade silicon and polycrystalline solar cells has the potential to greatly reduce the cost of silicon solar cells.

One technique being used by Mobil-Tyco in the US, and the Japanese Solar Energy Company, to produce solar cells is the growth of silicon ribbon crystals by the vertical edge-defined film-fed method. A continuous ribbon crystal is obtained. The crystal is drawn through a die, from a crucible of molten silicon. The temperature, growth rate, die material, etc., are very critical. This method of producing solar cells is considerably faster than for the conventional method. Rectangular cells are produced and packaging density therefore improved. Efficiencies of up to 10% have been achieved using this method.

Polycrystalline silicon solar cells are also being investigated and AEG-Telefunken market solar modules using these cells. In contrast to mono-crystalline silicon, polycrystalline silicon consists of many individual crystals or grains, separated by grain boundaries. These boundaries tend to degradate the performance of the cell. Low cost solar-grade polycrystalline silicon slices may be produced by casting of vapour deposition on a substrate. This subject is far more involved than the brief description given above, but a more detailed description is beyond the scope of this article.

Considerable work is being carried out in the US on concentrator systems using special silicon cells and appears to have some merit, while the cost of conventional "flat plate" modules is high.

Other Technology

There are two main types of semi-conductors, single chemical element and inorganic compound types. Silicon is of course a single element, but there are a number of binary compounds such as gallium — arsenide (Ga As), cadmium-telluride (Cd Te), cadmium-sulphide (Cd S) and copper-sulphide (Cu_2S) and higher-order inorganic compounds which meet the basic conditions for solar energy conversion.

Single-crystal solar cells of silicon and Ga As have yielded efficiencies up to about 16%, while Cd S and Cd Te polycrystalline cells have yielded efficiencies up to 7 or 8%.

CONCLUSION

The future use of solar power in Telecom is no doubt assured, even though a tremendous growth in solar power systems is not envisaged. The rate of increase will depend upon future solar cell development and reduction in cost.

Efforts to reduce communication equipment power consumption and the use of thermally efficient equipment shelters, not using electrically powered air conditioning, has no doubt been a large contributing factor in the use of solar power on major broadband trunk systems.

Solar power can be easily justified for communication

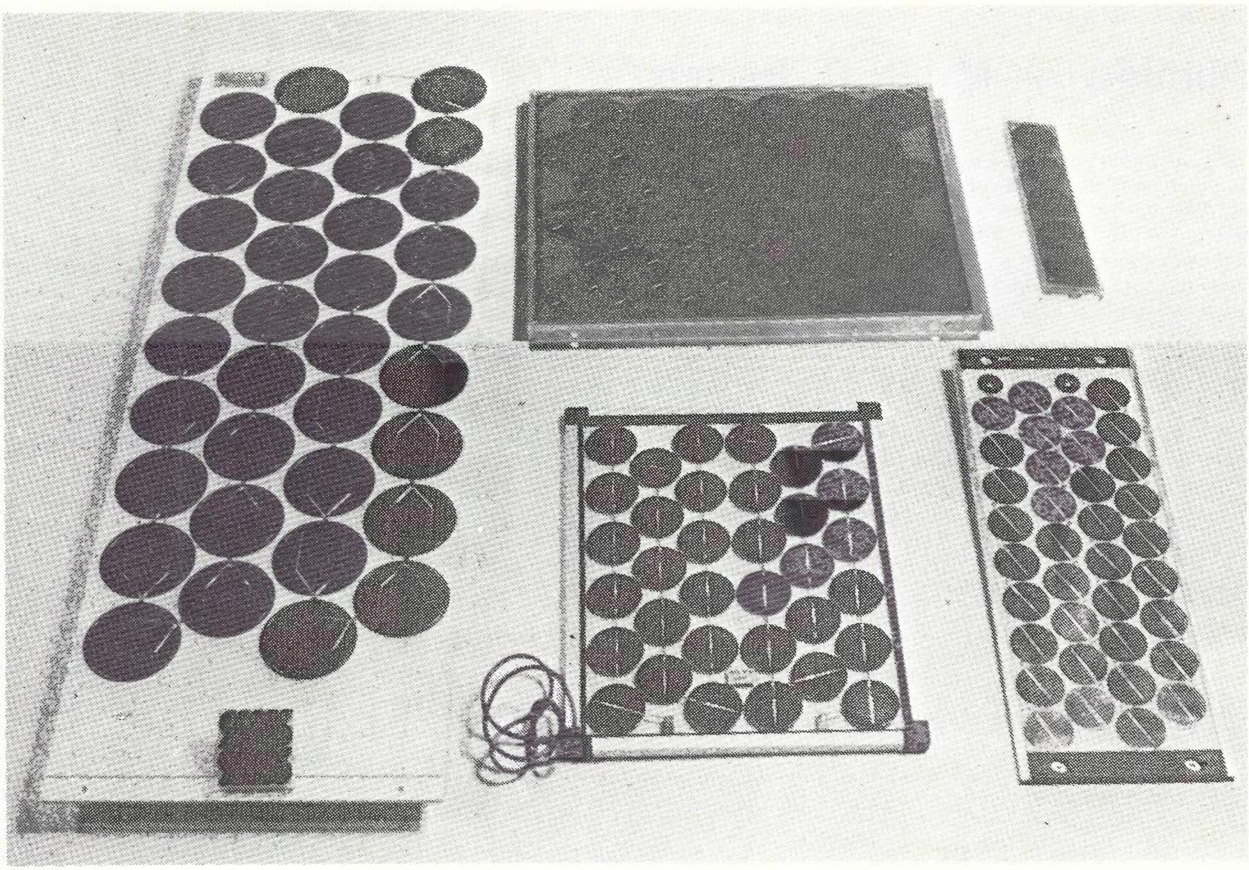


Fig. 33 — Various Types of Solar Modules.

loads of less than about 150 watts in isolated areas. A solar power installation can be justified for larger installations depending on:

- Local solar radiation conditions
- Maintenance and capital cost of alternative power systems
- Fuel cost of alternative systems and site accessibility
- Expected or guaranteed life of solar modules
- Efforts made by equipment manufacturers to reduce equipment drain.

The cost of solar cells is steadily reducing. However solar cells represent less than 40% of the total system cost, so that the cost of other items of plant must be reduced also. If the predicted cost reductions are achieved then it may be feasible to use smaller batteries with larger arrays.

On the other hand, the cost of conventional diesel powered plant has doubled in the last 3 or 4 years and this trend will ensure the continued use of solar power.

Future articles will detail the development and application of the solar power package used in the Tennant Creek — Alice Springs microwave radio relay system.

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Obituary — Mr R. C. Barton

It is with sadness that we record the tragic death of Mr R. C. Barton, former member of our Board of Editors. Mr Barton was involved in a car accident which occurred close to Damascus, Syria, on 28 November, 1978.

Mr Barton graduated as an Engineer in 1951 and his whole career was associated with radiocommunications and sound and vision broadcasting, firstly in the P.M.G.'s Department and later with Telecom Australia, both in the Victorian State and Headquarters Administrations.

Between 1962 and 1967 he undertook an assignment with the International Telecommunication Union (ITU) and worked in Africa and Geneva on the planning and installation of long distance communication networks for developing countries. On returning to Australia he worked at Headquarters in the Radiocommunications Construction Branch on system provisioning and in the Planning Division on long distance network planning.

During 1971-72 Mr Barton undertook a further ITU assignment in Saudi Arabia and after returning to Australia worked on the planning of such projects as the Canberra Black Mountain Communications Tower and the National Satellite System. He was Superintending Engineer, Radiocommunications Construction Branch before vacating this position in late August 1978 to proceed on a third ITU mission which was to take him to Geneva and Saudi Arabia and, tragically, to his death.

Mr Barton was very well respected among all staff associated with him throughout his career.

EC Grade Fully Annealed Aluminium Conductors in Paper Insulated Telephone Cable

R. J. LEWIS and N. W. PETERS

An earlier paper in Volume 21, No. 3, of this Journal reported on the manufacture, installation and economic application of large size helical paper insulated EC grade aluminium cable in Telecom Australia's network. The paper was based on experience gained from laboratory work and early field trials.

The purpose of the present paper is to report on the developmental work and field installations that have taken place since 1970, and the extent of savings that are being made by the use of paper insulated aluminium cable.

INTRODUCTION

The earlier paper detailed Telecom Australia's interest in aluminium cable for use as a substitute for copper during periods of copper shortage, and as a means of saving money where aluminium cable is cheaper. Cable manufacturing installation and maintenance experiences were described, together with details of the Series 1 field trials with 0.63mm Fully Annealed (FA) and ¾H conductors, and the Series 2 trials with 0.52mm FA conductors. The paper reported on the unacceptably high level of open circuit faults which had occurred at the wire jointing connectors of one 0.52mm installation. The cause of these failures is detailed in the present paper. Further field trials during 1970-72 with 0.52mm and 1.15mm cables were foreshadowed and the possibility of routine use of aluminium cable, where it is economically attractive, from January 1972 was reported.

The present paper is concerned with the development and use of 0.52mm, 0.81mm and 1.15mm aluminium cable by Telecom Australia from 1970.

FIELD TRIALS SINCE 1970

The basic cable design had been established by 1970 as, EC grade FA aluminium conductors, helical paper insulation, unit twin core construction and a moisture barrier sheath; although at that time only 0.63mm and 0.52mm cable had been used. The field trials since 1970 have been primarily to provide experience with aluminium cables to the Australian cable industry and to confirm the performance of wire jointing connectors applied to them. Each connector system was subjected to an extensive laboratory evaluation before field trial and details of the development and evaluation of connectors, for each conductor gauge, are provided in other Sections of this paper.

The Series 3 field trials of 0.52mm and 1.15mm cable foreshadowed in the 1970 paper, were installed during 1971-74. A connector designed and manufactured in Australia was used for 0.52mm cable and the 1.15mm cables were jointed by a twist and weld technique using a specially developed welding tool. The 0.52mm gauge was seen as attractive because a large quantity could be used in the subscriber network without the larger diameter of the aluminium cable incurring a significant duct penalty. The duct penalty costs with 0.52mm cable are very small because cable larger than 1800 pairs is seldom required, and 1800/0.52mm cable can be installed in Telecom Australia's 100mm diameter ducts. The 1.15mm trials were conducted because this gauge offered the greatest percentage savings, compared with copper, and a significant quantity was required for installation in the junction network at that time. At the 1970 prices of aluminium, $A586/tonne and copper, $1,480/-tonne, the saving on maximum size 0.52mm cable was 30%, but was 48% for 1.15mm cable.

An economic study conducted in 1974 showed that with the large quantity of 0.64mm copper cable being installed in metropolitan junction networks there was a large potential saving in the substitution of 0.81mm aluminium cable for 0.64mm copper; even though the maximum size aluminium cable for installation in 100mm ducts contained only 800 pairs compared with 1200 for the copper cable. Consequently, a fourth series of field trials comprising 10 projects and 32,000 Pkm of 0.81 cable were installed in 1974-1976. Three types of connectors were used including one of Australian design and manufacture. In this application the connectors had to provide for jointing the 0.81mm aluminium to 0.64mm copper (at exchange terminations) and to 0.50mm copper (at loading coils). Sufficient of these cables had been satisfactorily completed by March 1976, for the decision to be taken to start routine use of 0.81mm cable in the junction cable network under the general surveillance of six State Co-ordinators; one for each of the six States of Australia. These co-ordinators had been appointed to generally co-ordinate planning and installation, and to provide feedback to Headquarters during the initial stages of routine use. Although paper insulated junction and subscribers cables used in Australia are identical, 0.81mm cables were not, at that stage, introduced into the subscriber main cable network. The range of conductors that would have had to be jointed to the 0.81mm aluminium included 0.40mm and 0.90mm copper. By March 1977 suitable connectors became available and 0.81mm aluminium began being used for subscribers cables.

The Series 3 field trials, with 0.52mm and 1.15mm cable, were completed by 1974 and although the results of the two 0.52mm projects were satisfactory, it was considered that this was not sufficient to justify starting routine use. In addition, some doubts were held regarding the ability of connector jointed 0.52mm EC grade FA conductors to withstand the stresses imposed during cable joint re-arrangements, that would be required during the life of some cables. A fifth series of field trials comprising 9 projects, and 15,300 Pkm of 0.52mm cable was, therefore, organised. In addition, a 300 pair cable installation was set up at Telecom Australia's Maidstone (Victoria) Test Site to obtain data on the incidence of faults, particularly open circuits, in 0.52mm cable joints following re-arrangement work. Fortuitously at about this time it also became necessary to re-arrange a 600 pair joint in one of the early 0.52mm cables, due to development in the area served by the cable. Both re-arrangements were judged to be successful with the level of faults not significantly different to that expected for copper. By March 1977, sufficient of the 0.52mm cables installed in the Series 5 field trials had been satisfactorily completed for the decision to be taken for routine use of 0.52mm cable to start; again under the general surveillance of the State Co-Ordinators.

A larger size connector of Australian design and manufacture has been developed and laboratory tested for the 1.15mm gauge. The laboratory tests were satisfactory and even though the connectors have not been used in field trials there is sufficient confidence in this robust, large gauge conductor for routine use to start as soon as bulk supplies of the connector become available.

We have thus reached the stage where satisfactory jointing methods are available for all three gauges and two are already in routine use.

During the period 1973-1976, a separate development project for longitudinally applied sealed paper insulation (SPI) was proceeding for both copper and aluminium conductor cable. Technically satisfactory cable has been produced in each gauge with a mutual capacitance of 45 nF/km, the standard mutual capacitance for voice frequency cable in Telecom Australia. However, for the larger gauges, higher manufacturing costs will probably restrict the use of SPI with aluminium to 0.52mm.

Conductor Joining

Aluminium cable is used by Telecom Australia in conjunction with existing copper cables for network extension purposes. It is jointed to copper tail cables to permit termination at field cabinets and exchange main frames. Thus the associated jointing system must be capable of handling copper to aluminium connections.

The corrosion potential of the combination of metals is controlled by making the application of a dry air pressure protection system mandatory for paper insulated aluminium conductor cables. This has not presented a problem since gas pressurisation of main subscriber and junction cables is already standard practice in Australia.

The difficulties with jointing aluminium lie in:-

- The rapidly forming insulating coating of oxide Al_2O_3 which must be removed to effect electrical connection.
- The relative fragility of small gauge aluminium (0.52mm) conductors compared with their copper counterparts.
- The notch sensitivity of aluminium.
- A wider variability of the tensile and elongation characteristics of cable conductors manufactured from aluminium in comparison with copper.

JOINTING METHODS

The simple unsoldered crank twist joint which has a population in the hundreds of millions in existing copper networks is not directly applicable to aluminium because of the oxide film. However, with the addition of specialised soldering techniques including zinc enriched solder and non corrosive oxide removing fluxes, twist joints may be made to provide satisfactory electrical connections. This method is not considered an adequate solution to jointing aluminium cables today because of the escalation of labour costs.

Jointing methods which have been examined and field trialled during the aluminium cable development project include:-

- Soldering
- Cold Pressure Welding
- Electric resistance welding
- Machine applied in-line connectors
  - — Wire in slot type
  - — Tang type

The preference for mechanical connectors which has emerged from the work is based on:

- The uniformity of the electrical connection which they produce.
- The inherent productivity of the jointing machines with which they are applied.

In-line connectors however produce a variable mechanical performance between individual joints. This characteristic can become a serious disadvantage particularly where the conductor material is EC grade aluminium which is very sensitive to notching.

A breakdown of the jointing methods used in the trials is shown in Table 1.

Trial Group	Conductor	Jointing Method
Series 1 65/66	0.63mm FA EC Al 0.63mm ¾ H Al	Twist and weld or sleeve and crimp
Series 2 69/70	0.52mm FA EC Al	A-MP (Green)*
Series 3 71/74	1.15mm FA EC Al 0.52mm FA EC Al	Al/Al twist and weld Al/Cu twist and solder Utilux H2562-1**
Series 4 74/75	0.81mm FA EC Al	A-MP (Red)* A-MP (Mini Brown)* Utilux H2562**
Series 5 75/	0.52mm FA EC Al	A-MP (Mini Pink)* Utilux H25-62-1** Egerton No. 6**

*Wire in slot Connector — **Tang type connector

Table 1 — Summary of Jointing Methods

SUMMARY OF JOINTING EXPERIENCE

The jointing experience gained from the Series 1 and 2 trials has been reported previously. Series 2 had confirmed that the smaller diameter 0.52mm fully annealed conductor could be made into cable on the existing cable making plant and that by using connectors the jointing productivity could be lifted significantly; to higher levels in fact than pertained with manual jointing of copper. They also showed that handling this conductor after jointing with A-MP standard green connectors carried the risk of an unacceptably high percentage of open circuits in a completed cable installation. Investigation showed that this was the result of the variability and notch sensitivity of the material in combination with the wire entry geometry and absence of a stress relieving mechanism in the connector. Work was commenced to establish an improved connector and to investigate alloy materials for this small gauge conductor.

It is of interest to note that the Series 2 trials involved the first usage of any magnitude of machine applied connectors in the Australian main cable network; and indeed expedited mechanisation of large size copper cable jointing. There are sufficient machines available today to handle collectively the 2 and 3 wire jointing of all gauge combinations and there is little residual need for hand jointing in copper main subscriber or junction cables.

Series 3 trials conducted during 1971/4 were initially mounted in order to give design and manufacturing experience with 1.15mm EC aluminium conductors. At that time none of the existing connector systems were capable of accommodating this large diameter conductor and recourse was made to an improved welding technique. Tooling was developed specifically for the purpose.

Fig. 1 refers.

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 Section Manager, Installation Engineering (Civil and Mechanical).

NOEL PETERS joined Telecom in 1946 after war service with the Royal Australian Air Force on radio system maintenance. He was progressively Technician, Senior Technician and Technical Instructor in Telephone Switching and Long Line Equipment areas. Following completion of a Diploma of Communication Engineering at the Royal Melbourne Institute of Technology in 1964 he worked as a Field Engineer installing major conduit routes in the city of Melbourne. Since 1968 he has been engaged in the design and development of external plant installation practices at Telecom Headquarters as Senior Engineer Installation Engineering.

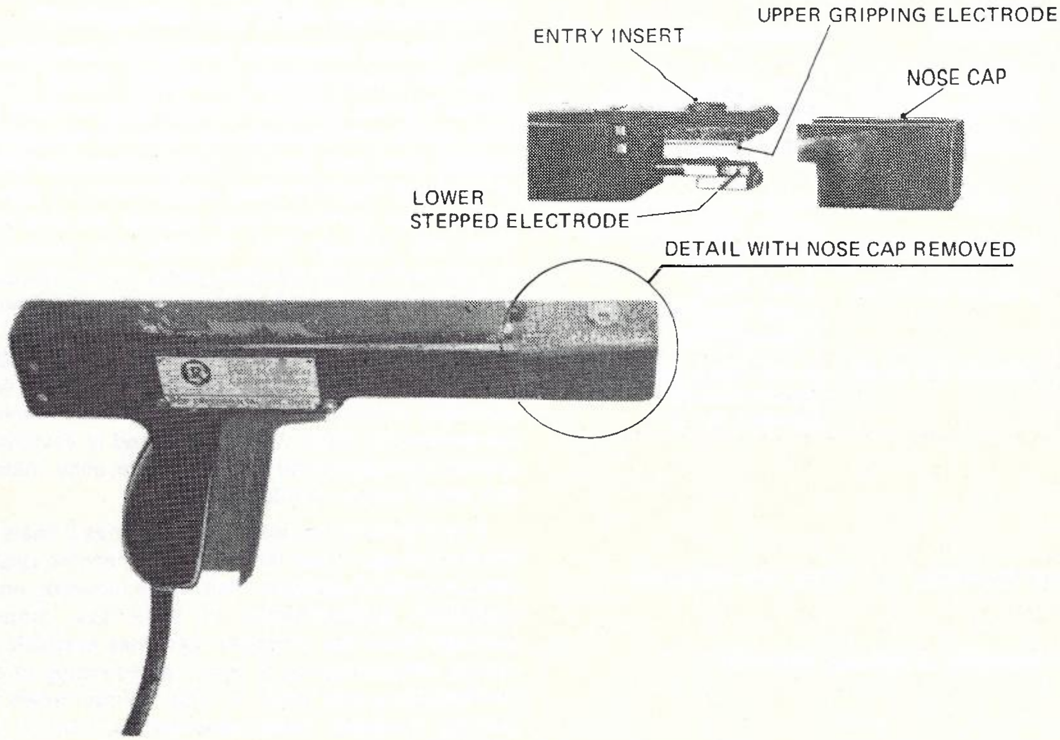

Fig 1 — Conductor Welding Tool

Type of Conductors	Ratio of Joint Mean B/S to Conductor Mean B/S	% of Batch Which Failed Within The Joint	Joint Mean B/S (N)				Ratio of Standard Deviation to Mean (/$\bar{x}$)	Mean Conductor Breaking Strength (N)
			Min.	Mean	Max.	S.D.		
0.32 SPI - 0.40 Pe	100	70	20.0	20.35	21.0	0.36	0.018	20.08
0.32SPI - 0.40 Pe	100	30	20.0	20.53	21.0	0.19	0.009	20.08
0.64 SPI - 0.64 Pe	100	0	77.5	79.35	81.0	1.07	0.013	79.00
0.40 SPI - 0.40 SPI	99.8	65	29.0	31.18	31.5	0.66	0.021	31.25
0.64 Pe - 0.64 Pe	100	0	78.0	80.30	82.0	1.16	0.014	79.00
0.40 Pe - 0.40 Pe	100	55	30.0	31.65	33.0	0.63	0.020	31.25
0.32 SPI - 0.32 SPI	96.0	60	13.0	19.28	20.5	1.68	0.087	20.08
0.64 SPI - 0.64 SPI	100	15	80.0	80.13	80.5	0.22	0.003	79.00
0.81 SPI - 0.64 Pe	95.4	0	34.5	37.10	43.5	2.34	0.063	38.89
0.52 SPI - 0.40 Pe	91.8	25	12.0	17.68	20.5	2.48	0.140	19.25
0.52 SPI - 0.81 SPI	89.5	45	13.5	17.23	20.0	2.53	0.146	19.25
0.81 SPI - 0.81 SPI	90.3	0	34.5	35.10	37.0	0.58	0.017	38.89
0.52 H - 0.52 H	100	10	12.0	14.73	16.5	1.19	0.081	14.68
0.40 SPI - 0.32 H	99.1	5	9.2	9.38	9.8	0.16	0.017	9.47
0.40 SPI - 0.40 SPI	93.2	0	8.5	8.83	9.0	0.24	0.027	9.47
0.40 SPI - 0.40 Pe	93.4	0	8.5	8.90	9.0	0.25	0.028	9.47
0.52 SPI - 0.40 Pe	100	0	15.5	16.47	21.0	1.10	0.067	15.95
0.52 SPI - 0.81 SPI	100	0	15.9	16.78	22.0	1.40	0.083	15.95
0.81 H - 0.81 H	98.6	55	47.5	48.75	50.0	0.64	0.013	49.42
0.52 SPI - 0.52 SPI	100	55	15.3	16.03	16.8	0.34	0.021	15.95

NOTES: In each case, 20 samples were tested. Aluminium conductors are **in bold type.**

SPI = Sealed Paper Insulation
Pe = Polyethylene Insulation
H = Helical Paper Insulation

Table 2 — Breaking Strength Test Results for Utilux H2562-1 Connectors

Al to Al joints were twisted and welded by this method and for the Al to Cu joints at loading coil and terminating cable tails, twisting and aluminium-soldering was used. It was recognised that the jointing productivity would not be great but this was accepted to gain the required design, manufacturing and installation experience with this cable type.

The trial results showed that the welding equipment plus its power supplies and charging facilities, were relatively expensive to provide in quantity. The welding handtool required frequent cleaning of the electrodes during usage and was prone to malfunction. Its inability to handle Cu/Al joints was an obvious disadvantage. The electrical performance of the Al joints produced was very good however, and their mechanical behaviour presented no problems as could perhaps be expected with this wire diameter.

The results of laboratory evaluation work in a Utilux (Australian) connector applied to the two wire jointing of 0.52mm FA aluminium conductors became available during the course of the Series 3 trials. Two additional projects with this conductor were included. Results showed that under field conditions the mechanical performance of this connector was marginally better than the A-MP standard connector with the same conductor. With some modifications it was expected this performance improvement could be optimised. **Fig. 2** refers.

Series 4 trials in 1974/5 covered the mid range 0.81mm diameter aluminium conductor which is the electrical equivalent of 0.64mm copper, the most commonly used conductor in our junction cables. The additional cross section of conductor over an 0.52mm wire offered a higher confidence level with respect to the notching problem and some installations were jointed out with A-MP (Standard Red) connectors. A series of smaller A-MP Mini connectors with different wire entry geometry to the standard was then becoming available in addition to an improved Utilux connector and projects covering 0.81mm wire and both of those connectors were included. The results led to a decision to release the cable for general use in junction applications. Subscribers main cable applications were excluded as it was not then possible to reliably joint 0.81mm aluminium to 0.40mm PEIUT pillar and cabinet tails to specified levels of performance.

Series 5 Trials. By mid 1975 the optimisation of a Utilux Connector biassed toward 0.52mm aluminium had produced the type H2562-1 which under bench testing exhibited better mechanical performance than had been achieved with any previous connector on this small diameter EC grade conductor Ref. 2. (Refer Table 2). This type and also the A-MP Mini Pink and the BPO No. 6 connectors were used on a series of projects to establish whether the notching problem could be controlled in the field to a level where routine use of the conductor could be established. All of the results are not in for these trials but the early indications were such that controlled usage under surveillance was undertaken.

CONNECTOR DESIGN

The functions of a connector are:

- To penetrate the in situ conductor insulation.

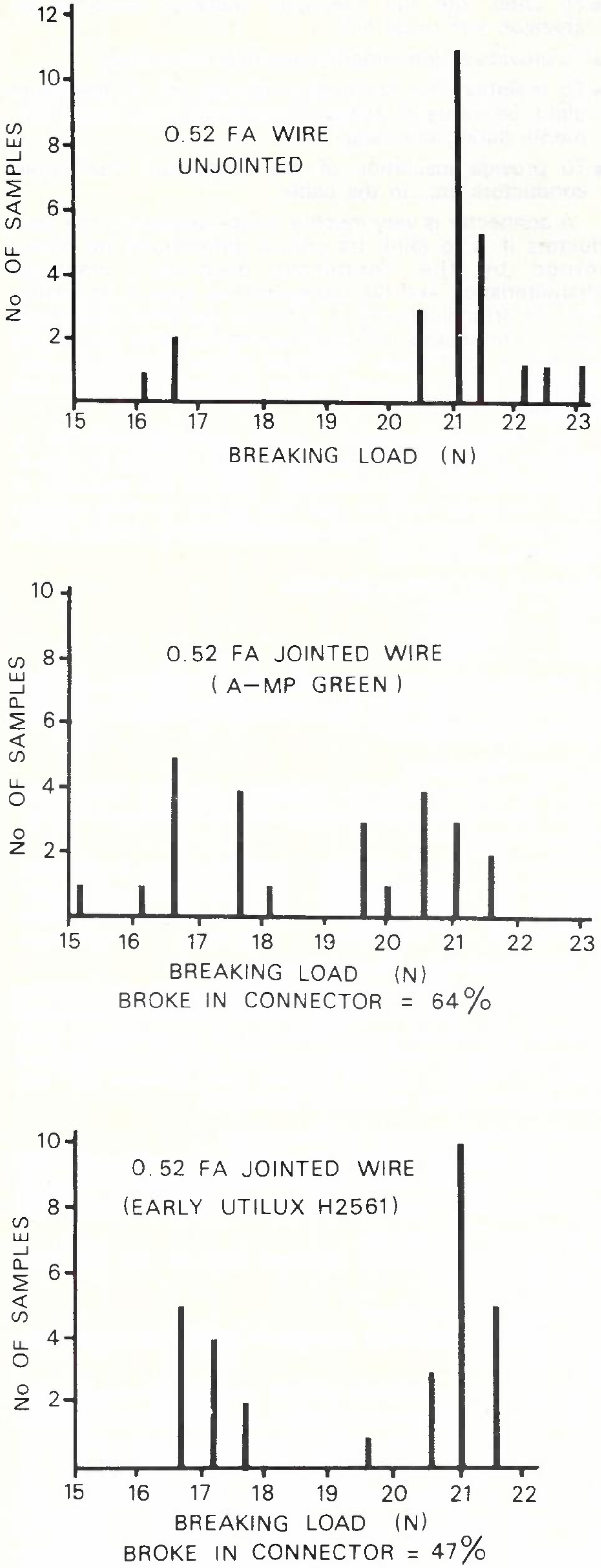

Fig. 2 — Breaking Strength 0.52 mm FA Aluminium Conductor

- To enter into the conductor material removing by abrasion any oxide film.
- To provide a high integrity electrical connection.
- To maintain the connection for the life of the cable plant, by virtue of stresses produced in the metal elements during crimping.
- To provide insulation of the connection from other conductors etc., in the cable.

A connector is very much a device tailored to the conductors it is to joint. Its critical dimensions are determined by the conductor diameter, material characteristics, and the thickness and type of its insulation. As an indication it is generally accepted that three sizes of connectors with overlapping diameter ranges are needed to joint paper insulated copper telephone conductors in the diameter range between 0.32mm and 0.90mm.

To accept aluminium wires manufactured on a resistance equivalence to copper basis requires an extension upwards of approximately 30% in the capacity of each connector size or else the ability to joint certain commonly required gauge combinations in mixed Al/Cu networks will be lost.

Preferred sub ranges are thus:
0.32 — 0.52mm
0.40 — 0.81mm
0.51 — 1.15mm

The Australian Specification (No. 1133) for connectors to joint large size gas protected cables has the following requirements:

1. Initial Resistance
The connection resistance measured between two points 50mm apart on the jointed conductors shall not exceed the following values:

0.32mm Cu — 14 milliohms	0.64mm Cu — 5 milliohms
0.40mm Cu — 10 milliohms	0.81mm Al — 5 millohms
0.52mm Al — 10 milliohms	0.90mm Cu — 4 milliohms
0.51mm Cu — 7 milliohms	1.15mm Al — 4 milliohms

2. Resistance After Thermal Cycling
The connection resistance measured similarly shall not exceed the initial value plus 2 milliohms for any conductor combination after the joints have been submitted to 25 thermal cycles. Each cycle shall consist of 45 minutes at 65°C followed by the same period at −35°C with a transfer time between the two temperatures of not more than 3 minutes.

3. Mechanical Strength of Connection
The mean breaking strength of a sample of twenty joints shall not be less than 80% of the mean breaking strength of a sample of ten unjointed wires. The minimum not being less than 70%.

4. Insulation Resistance
The insulation resistance of joints shall be not less than 100,000 Megohms.

5. Dielectric Breakdown
The dielectric breakdown strength of joints shall not be less than 1000V dc.

The jointing experience gained during the trials with locally manufactured connectors on aluminium has been progressively incorporated in connector designs to establish a range of 3 Utilux connectors designated for simplicity as Yellow, Red and Blue. These are small "in-line" type connectors some 15mm long. The material is brass post plated with tin after the punching and forming operations are complete. A connector joint is shown in **Fig. 3** and their wire jointing capability with respect to copper and aluminium conductors of Australian origin are shown in Table 3.

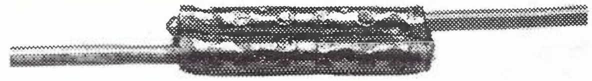

Fig. 3 — Crimped Connector (H2562-1 RED)

Yellow Connectors H2564-1 (S114/144)		Red Connectors H2562-1 (S114/143)		Blue Connectors H2563-1 (S114/145)	
Wire Diameter (mm)					
Wire 1	Wire 2	Wire 1	Wire 2	Wire 1	Wire 2
0.32 Cu	0.32 Cu	0.40 Cu	0.40 Cu	0.51 Cu	0.51 Cu
0.32 Cu	0.40 Cu	0.40 Cu	0.51 Cu	0.51 Cu	0.64 Cu
0.32 Cu	0.51 Cu	0.40 Cu	0.52 Al	0.52 Cu	0.81 Al
0.40 Cu	0.40 Cu	0.40 Cu	0.64 Cu	0.51 Cu	0.90 Cu**
0.40 Cu	0.51 Cu'	0.40 Cu	0.81 Al	0.51 Cu	1.15 Al
0.40 Cu	0.52 Cu*	0.51 Cu	0.51 Cu	0.64 Cu	0.64 Cu
0.52 Al*	0.52 Al*	0.51 Cu	0.52 Al*	0.54 Cu	0.81 Al
		0.51 Cu	0.64 Cu	0.64 Cu	0.90 Cu**
		0.51 Cu	0.81 Al	0.64 Cu	1.15 Al
		0.52 A1*	0.52 Al	0.81 Al	0.81 Al
		0.52 A1*	0.64 Cu	0.81 Al	0.90 Cu**
		0.52 A1*	0.81 Al	0.81 Al	1.15 A1
		0.64 Cu	0.64 Cu	0.90 Cu**	0.90 Cu**
		0.64 Cu	0.81 Al	0.90 Cu**	1.15 Al
		0.81 A1	0.81 Al	1.15 Al	1.15 Al

NOTES
* Use limited to installation of cable under surveillance of State Aluminium Co-ordinators.
** The H2563-1 connector cannot be used to joint 0.90mm copper conductor with polythene insulation thicker than 0.35mm.

Table 3 — Jointing Capability of Utilux Connectors

The mid range Red connector which accepts 0.40mm to 0.81mm wires is shown in **Fig. 4** and again with its side walls lowered to show the contact arrangement in **Fig. 5.** Tangs of reducing height and flattened profile at the outer edges of the connector provide stress relief for the parts of the conductors significantly notched to form the electrical connection. The hardness of different areas of the connector is controlled during manufacture to achieve the desired performance of the tangs during crimping.

The crimp is of a full roll configuration to prevent relaxation of the contacts with time and temperature variation.

A choice of manually operated or electro-hydraulically operated machines is available to crimp the connectors which are supplied in reels of 1000 in strip form. A manual machine is illustrated in **Fig. 6.**

Fig. 4 — Utilux H2562-1 Red Connector

QUALITY CONTROL OF FIELD JOINTING

A simple field instrument which measures the resistance of joint samples made prior to commencing a large size cable joint provides "field" quality assurance by checking that the machine type in use is in correct adjustment and is producing joints of satisfactory electrical performance within resistance limits specified for the type of cable conductors concerned. Ref. 3.

SERVICE HISTORY

A total of 38 individual field trial cables including both subscriber and junction cables have been installed since the first 0.63mm lead sheathed cables in 1965. All have been maintained under gas pressure and all are still in service. Their fault history has not been different from similar copper cables.

During 1976 one of the original 1965 lead sheathed cables developed a gas leak in the lead sheath due to corrosion and it was necessary to replace a length of cable. Conductors from a section of the recovered cable were metallurgically examined and no corrosion or other deterioration was detected in any of the conductors examined.

SAVINGS

The extent of savings offered by alumium cable depends primarily on the cost differential between copper and aluminium. The price of copper has fluctuated for most of the period since 1964 and an average Australian price of $A1,300/tonne has been forecast for 1977-78. The average price of aluminium has risen each year since 1973 and an average price of $A955/tonne is expected for 1977-78. (The rate for the Australian $ for August 1977 is approximately $A1.00 equals $US1.1025). At these prices attractive savings in the purchase price of aluminium cable compared with copper as shown in Table 4, are available.

Cable Size	Saving (%)
400/1.15mm	12
150/1.15mm	7.5
800/.81mm	11.5
150/0.81mm	6.5
1800/0.52mm	7.5
800/0.52mm	6.5
150/0.52	-1

TABLE 4 — Savings Related to Cable Size

The savings on maximum size cables i.e. 400/1.15mm, 800/0.81mm and 1800/0.52mm, can be obtained from **Fig. 7, 8 and 9** respectively for metal prices in the ranges, copper $A700-2,000/tonne and aluminium $A800-1,200.

It is considered that the savings derived from the figures are conservative and will increase when a greater proportion of cable used is aluminium.

It is worth noting that at 1973 average prices of copper $A1,240/tonne and aluminium $A580/tonne the savings on a 1,800/0.52mm cable was 23% on an 800/0.81mm cable 33%, and on a 400/1.15mm cable 36%.

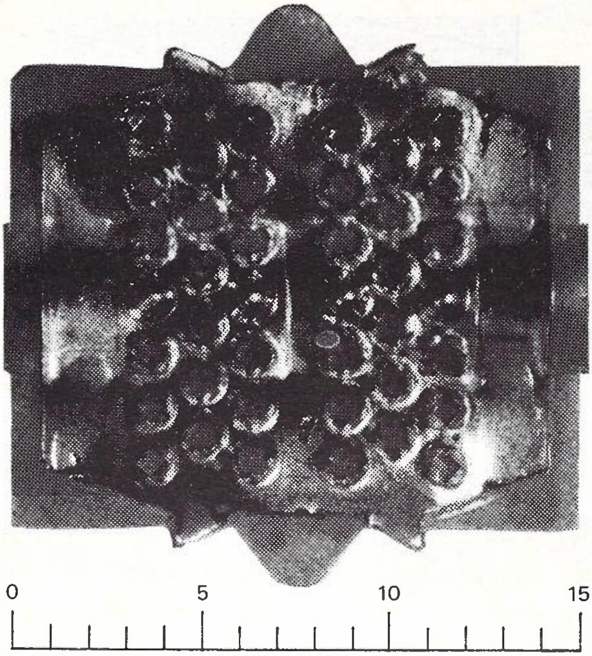

Fig. 5 — H2562-1 Connector with Side Walls Lowered

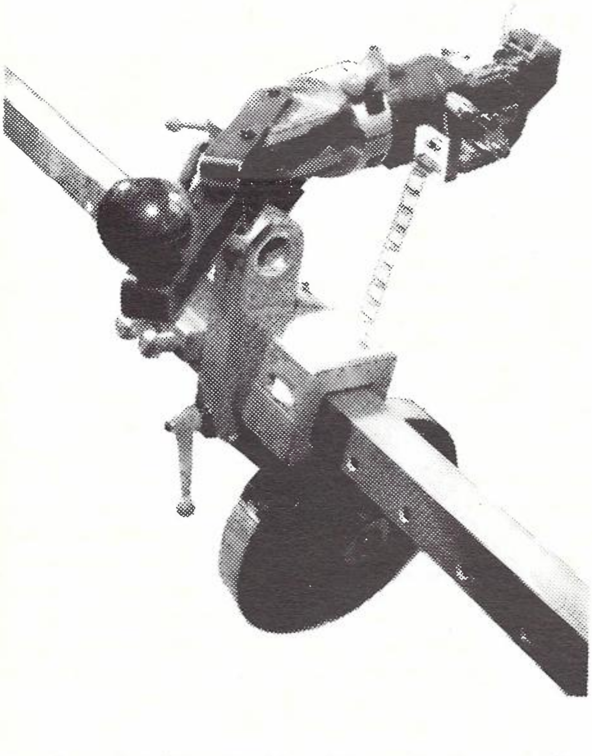

Fig. 6 — Jointing Machine (Manually Operated)

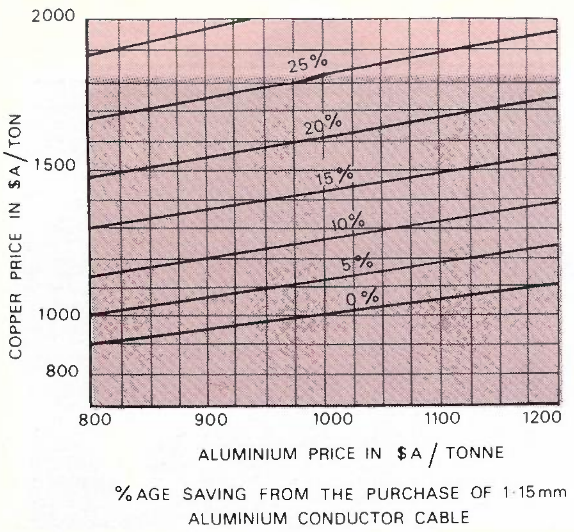

Fig. 7. % Saving from the purchase of 1.15mm Aluminium Conductor Cable

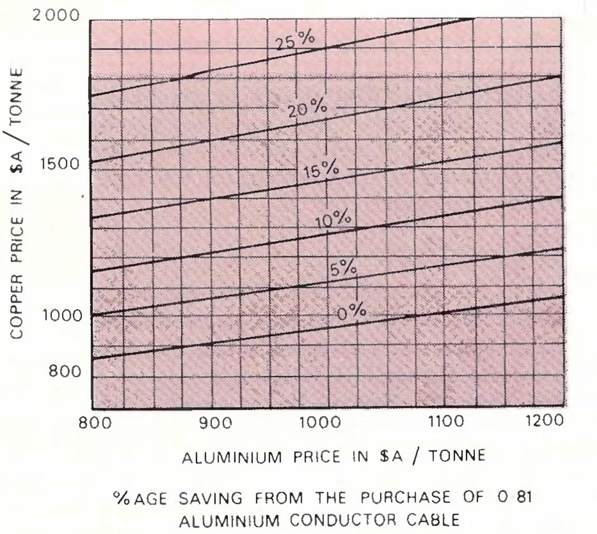

Fig. 8. % Saving from the purchase of 0.81mm Aluminium Conductor Cable

Since routine use has started 110,000 Pkm of 0.81mm and 20,000 Pkm of 0.52mm aluminium cable has been supplied at a saving of approximately $A265,000. Currently Telecom Australia's monthly large size paper cable order contains on an average over 20% aluminium cable. This will increase as the field user gains experience and confidence in aluminium cable. The introduction of 1.15mm cable will further increase the proportion of aluminium cable used.

DUCT COSTS

Aluminium cables occupy more duct space than the same pair size copper cables. This extra space is of little consequence except where a project would have used copper cable containing more pairs than the largest useable aluminium cable. Here the cable savings would often be more than offset by a need to carry out subsequent cable installations more frequently, thereby using more duct space and advancing the date at which additional ducts would have to be provided. PV of AC methods, as discussed in Ref. 1, provide tools for studying such situations, but are tedious to apply to individual projects and provide results that are heavily dependent on predicted interest and inflation rates and on predicted duct installation costs. The latter have risen rapidly from an average of $5,600/duct km in 1970 to $9,900/duct km in 1976. To overcome these problems the principle being adopted in Telecom Australia is to use aluminium whenever the installed cost of the cable per pair is less for aluminium than for copper provided the use of aluminium does not result in the duct route requiring augmentation in less than 15 years. This principle is expected to adequately allow for the value of the additional duct space used by aluminium and will result in a continuing use of large pair size copper cables.

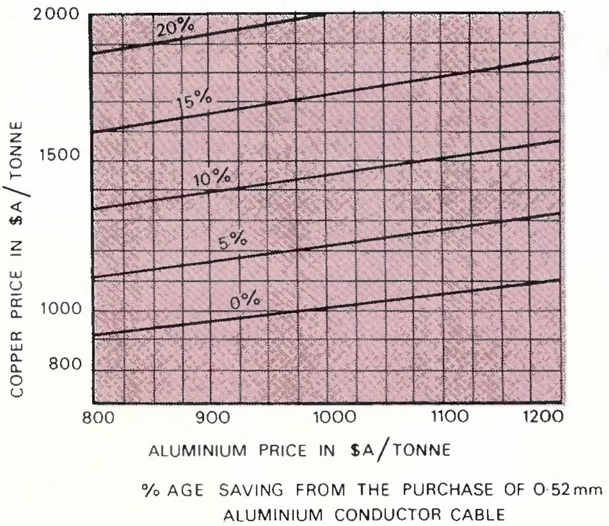

Fig. 9. % Saving from the purchase of 0.52mm Aluminium Conductor Cable

FUTURE

We have thus reached the stage in Telecom Australia where we have a range of large size aluminium cables, and their accompanying installation practices, that will continue to be used while metal prices and other cable manufacturing costs are such that the use of these cables is economically attractive. The processes for paper insulated copper and aluminium cables are so similar that it is possible to change the proportion of aluminium used quite quickly should the price differential change significantly, or should a shortage of either metal occur.

It is anticipated that the use of EC grade FA aluminium conductors with paper insulation will prolong the use of both helical and longitudinal paper insulation in Australia. The decision to use this material for the smaller 0.52mm conductor cables in lieu of a more robust alloy wire, Ref. 4, has been based on cost coupled with the experience which has demonstrated an ability to joint the conductor in the field. However, as labour costs increase, the slower paper insulating processes become less competitive, compared with high speed cellular plastics extrusion. As the tensile properties of EC grade aluminium are not suitable for high speed extrusion processes, cellular plastics insulation will require the use of alloy which would be more expensive than EC grade. Cellular plastics will therefore only become economically attractive when the cost of aluminium alloy or copper insulated with this material is comparable to EC grade FA aluminium insulated with paper.

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In Brief

NEW HANDBOOK TO ASSIST PLANNING OF TELECOMMUNICATION SERVICES IN RURAL AREAS

An international editorial group, meeting in Geneva, has just completed its work on a new handbook on **Rural Telecommunications.** This group is designated **GAS 3** in the nomenclature of the CCITT (International Telegraph and Telephone Consultative Committee) of the ITU*. The handbook covers planning of telephone and telegraph, as well as sound broadcasting and television services for rural areas. Detailed chapters on selection of wire and radio systems are included, ranging from single-channel radio and domestic, mult-terminal, satellite systems. There is also a chapter on financial planning and management.

An important part of the population of a developing country lives in rural areas. The size of the villages ranges from less than one hundred to around 5000 in population. Most of these villages throughout the world are not yet connected to any telephone network. Thus the economic and social life of these large rural populations remains essentially cut off from activities in the nation's cities.

How can this situation be improved? A critical part of the reply to this question is to be found in adequate technical and economic studies that must precede practical attempts to bring telephone and other communication services to rural areas. Great flexibility of choice among diverse technical means is possible. Selection of specific systems and equipments is likely to be different in each national case to be studied.

This book is intended to assist developing countries with these studies and is expected to be published and offered for sale by ITU during the first half of 1979. It will fill a need of telecommunication planners and engineers.

* The International Telecommunication Union is the specialized agency of the United Nations for telecommunications. It was founded in 1865 and has 154 Members countries. Its headquarters in Geneva comprise four permanent organs: the General Secretariat, the International Frequency Registration Board (IFRB), the International Radio Consultative Committee (CCIR) and the International Telegraph and Telephone Consultative Committee (CCITT).

2400, 4800 and 9600 Bit/s Data Transmission on the Switched Telephone Network.

C. T. BEARE Ph. D., B.E. (Hons), B.Sc., M.I.E.E.E.

The Telecom Australia Datel Service currently offers customers dial up data transmission facilities at speeds of 300 and 600/1200 bit/s on the switched telephone network. Data Transmission at the higher speeds of 2400, 4800 and 9600 bit/s is offered only on leased lines. This article discusses the results of trials of 2400, 4800 and 9600 bit/s modems undertaken on the switched network by the Datel section of Customer Networks Branch in Telecom Headquarters. As a result of these trials, Datel customers in the near future will be offered facilities for data transmission at 2400 and 4800 bit/s in the switched telephone network.

INTRODUCTION

A switched network voice channel has a nominal bandwidth from 300 to 3400 Hz and due to the nature of the network is subject to many impairments apart from basic noise and end to end attenuation. Modems designed to work at speeds of up to 1200 bit/s use frequency shift keying (FSK) modulation and are reasonably insensitive to poor channel conditions. However, at higher speeds modems need to use more sophisticated modulation techniques such as phase modulation and quaternary amplitude modulation (QAM), and the performance of these modems is highly dependent on the particular channel characteristic. For this reason, speeds of 2400, 4800 and 9600 bit/s are currently offered only on leased private lines where each circuit can be conditioned to meet specified attenuation and group delay characteristics.

Most higher speed modems now available commercially are equipped with adaptive equalizers which automatically equalise the switched line within a fraction of a second after connection to the line. Such modems can also adaptively retain equalisation during subsequent data transmission even in the presence of changing line characteristics. CCITT, the international body responsible for recommendation in the field of telecommunication, has produced recommendations for 2400 and 4800 bit/s adaptively equalised switched network modems (recommendations V26 bis and V27 ter respectively). Other countries are (or will be) also offering such services. These services can be used to provide more economical data transmission over the switched network and are useful as a back up facility in case of failure of a leased line service.

To identify any problems that may occur with higher speed modems in the switched telephone network a comprehensive trial was mounted. This trial, run between February and July 1978 covered over 200 sets of measurements on about 150 connections established within the Australian switched telephone network. The modems tested included 2400, 4800 and 9600 bit/s modems with types from different manufacturers, some conforming to CCITT recommendations and some not.

TEST ORGANISATION

The majority of these tests were carried out from locations in Melbourne and Sydney, the two major data traffic centres in Australia. About half of the tests were made from a fixed location (the instation) in Melbourne to a mobile station (the outstation) operating from various subscriber premises in urban and country areas. The other tests were carried out between two outstations.

To avoid complexity in the outstations, and for ease of operation it was decided to leave all equipment permanently set up at the instation. Tape recorders were used to transmit and receive analogue line signals and modem line signals at the outstations. To avoid degradation to the signals, the tape recording equipment was extensively modified.

By using a two track tape recorder and simultaneously recording the line signal (in FM form) and a crystal derived sinusiodal signal, it is possible by using suitable output circuitry to substantially remove the effects of wow, flutter, recorder and speed accuracy and tape dropout on the replayed signal. The apparatus was kept within the following specifications:

Frequency response

— 300-2800 Hz ($\pm$ 0.1 dB)

— 30-3400 Hz ($\pm$ 0.5 dB)

Harmonic Distortion

— All distortion products are less than 42 dB below the fundamental.

Signal/Noise Ratio

— Better than 50 dB (unweighted)

Timing Jitter

— Less than 4 μs peak-peak at or below 15 Hz

Frequency Asynchronous

— Less than 0.01 Hz at 1000 Hz

Amplitude Jitter

— Less than 0.02 dB

The mobile outstations then consisted only of a tape recorder with blank and master tapes together with a level-meter to measure noise and received levels on the line. The equipment at the instation **(Fig 1)** was used at a later date to analyse the recorded tapes.

Of the calls made, 67% were local calls and 33% were trunk (Subscriber Trunk Dialled) calls. 52% of the trunk calls were between Melbourne and Sydney the remainder being between adjacent trunk call areas and a small percentage between Melbourne and other major cities (including calls across the continent to Perth, a distance of 3300 km).

The permanent instation in Melbourne had access to various 2 wire lines some connected to step by step and some to crossbar exchanges. Of all test measurements, 24% were between 2 subscribers each connected to step by step exchanges,
30% between 2 subscribers each connected to crossbar exchanges and
46% between a crossbar subscriber and a step by step subscriber.

Normal subscriber lines used for measurement varied from the maximum length available at a particular exchange to, on occasions, no length at all when calls were made from within exchanges.

All measurements were made during normal working hours. Two calls were made between each pair of locations. On each connection the following parameters were measured in each direction:

- attenuation of 1000 Hz tone
- attenuation distortion
- group delay distortion
- harmonic distortion (700 Hz tone)
- peak to peak phase jitter averaged over 15 minutes

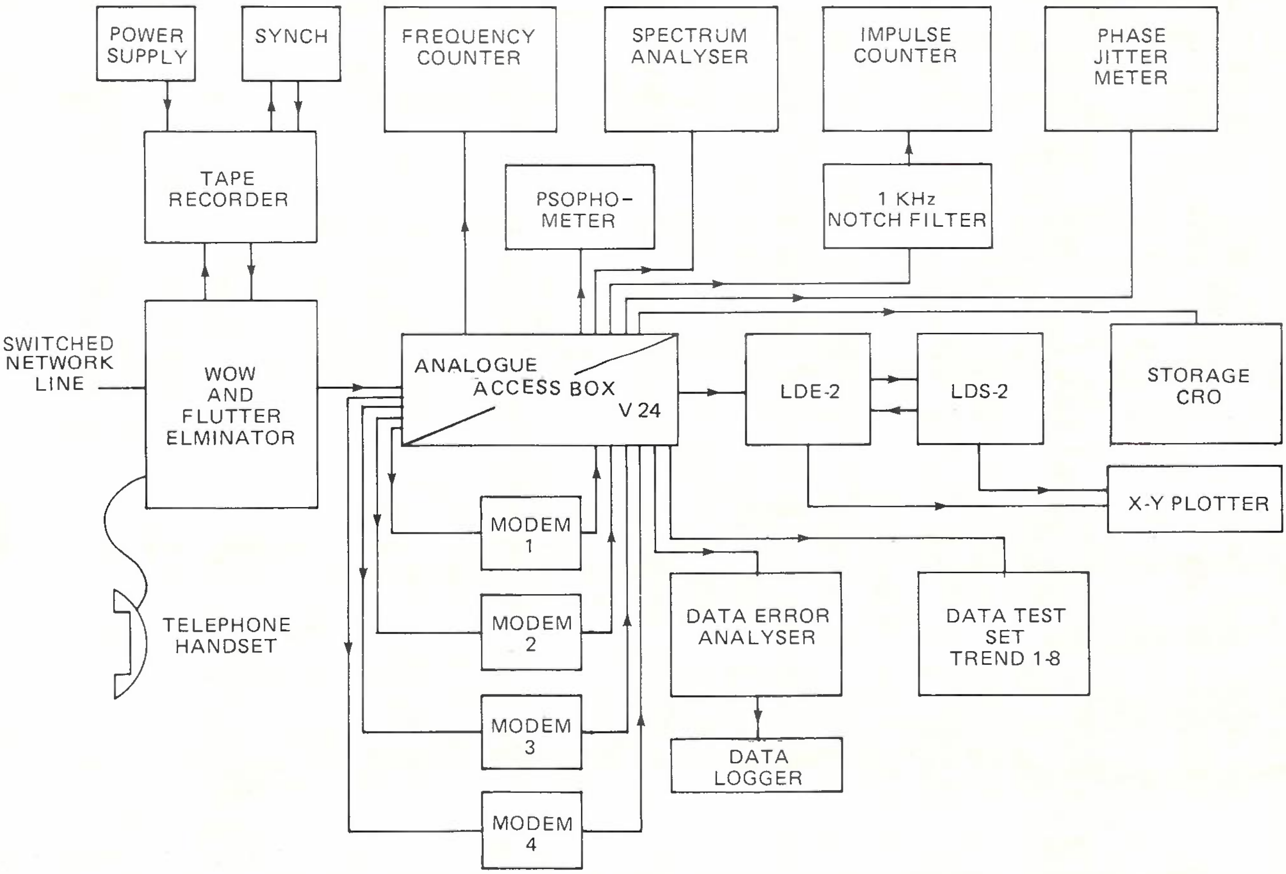


Fig. 1 — Instation Connection Diagram

- noise power (unweighted) in the band 300 Hz — 3400 Hz
- number of impulsive noises over a 15 minute period in the band 300-3400 Hz at thresholds of 0, -4, -8, -12dB in relation to level of data reception
- number of phase hits greater than 15° over a 15 minute period
- frequency offset (1000 Hz tone)
- peak voltage of multimetering pulses

Once the above parameters had been measured, and before the call was dropped, the following modem tests were made in each direction:

- bit error rate of a 15 minute period using the standard 511 bit repetitive test pattern
- block error rate on blocks of 1000 bits over the same period
- a polling test consisting of about 50 polls of a 511 bit block

These tests were carried out using 2400, 4800 and 9600 bit/s leased line modems. The modem signals were transmitted at either -6dBm or -10dBm (depending on the subscribers line length) and for analysing the results the received signal was replayed at -10dBm. **Fig 2** shows an example of a filled in test sheet for one direction of operation.

Due to various problems, not all modems were tested on each connection in the early stages of the trial. Also, as the trials progressed it was decided to restrict the modem tests to one direction per call and thus be able to include a larger number of connections in the limited time available. Analogue parameters were however still measured in both directions on each call.

DESCRIPTION OF MODEMS

One type of 2400 bit/s modem, three types of 4800 bit/s modems each using a different modulation method, and one type of 9600 bit/s modem were used in the trials. The characteristics of these modems are summarised in Table 1. A decision feedback equalised (DFE) 4800 bit/s modem which conformed to CCITT recommendation V27 ter was introduced at a late stage in the trials.

The 2400 bit/s modem was equipped with a manually strapped attenuation and group delay equalizer that was left strapped to a flat attenuation and group delay characteristic for the duration of the trial.

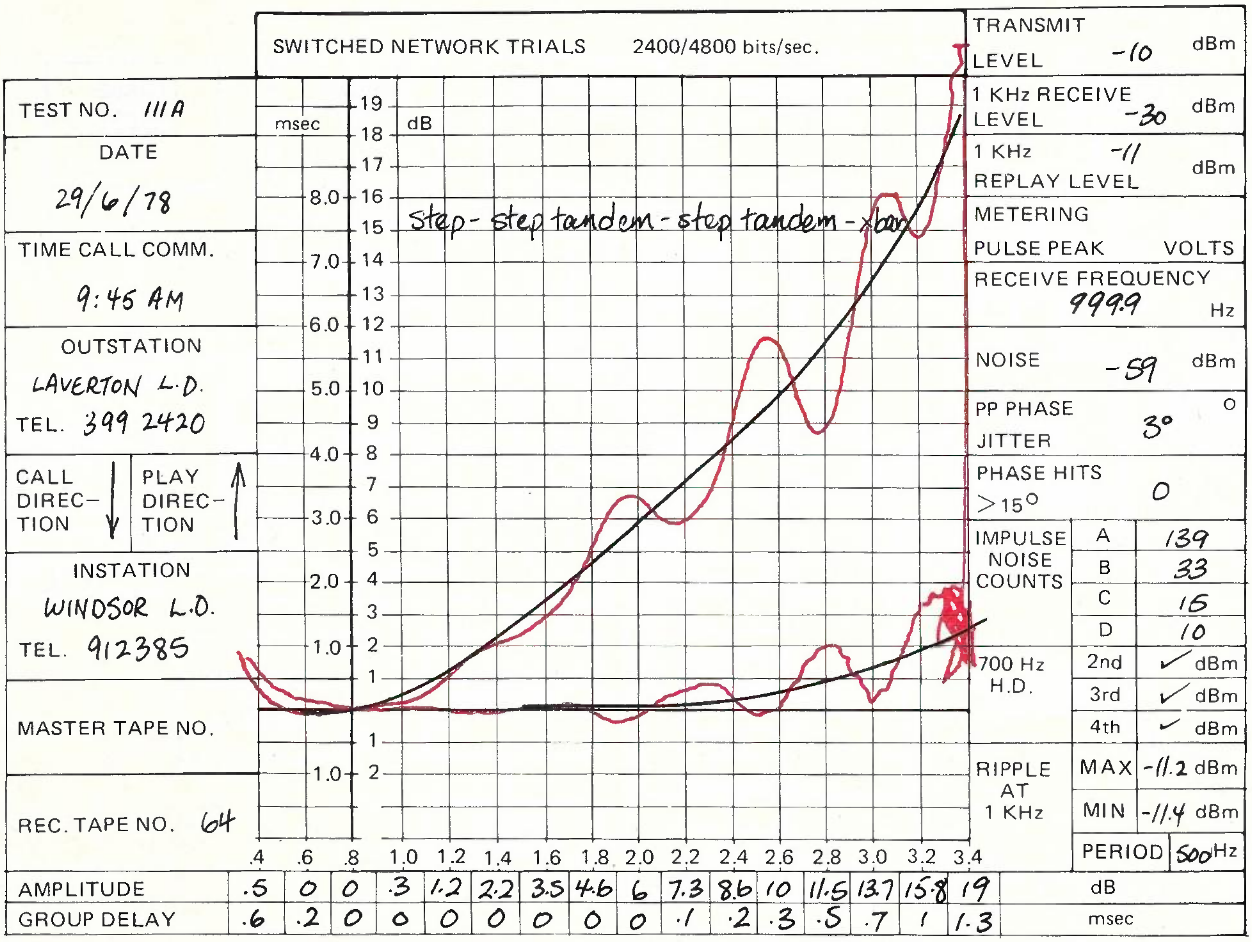
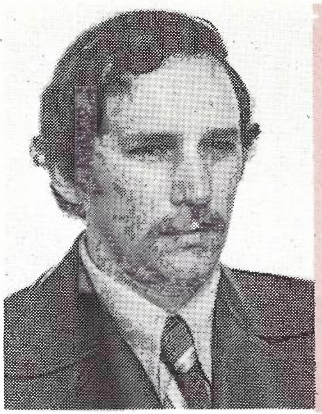


Fig. 2A — Example of Filled in Test Sheet

The 4800 bit/s and 9600 bit/s modems were all equipped with adaptive equalizers. When such modems are initially connected to the line a special data sequence called a training sequence is transmitted and this sequence allows the equalizer in the receiving modem to train (i.e. automatically equalise the line prior to actual data transmission). These modems usually include a strappable option to change the length of the training sequence — the longer the training sequence, the better the initial equalisation. The longest training sequence was used on all modems for training prior to the error rate measurements, and as throughput is important for polled operation, the shortest training sequence was used for the polling test.

MODEM	2400	4800 8 PHASE	4800 8 PHASE WITH DFE	4800 QAM	9600	
BITS RECEIVED	2M	4M	4M	4M	8M	PERMANENT CARRIER (LONG TRAINING SEQUENCE)
BIT ERRORS	23	0	146	0	47	
BLOCK ERRORS	1	0	2	0	6	
SUCCESSFUL POLLS	X	59/60	55/55	53/53	FAIL	POLLED HALF DUPLEX (SHORT TRAINING SEQUENCE)
MASTER TAPE NO.						
REC. TAPE NO.	33	96	93	77	20	

Fig. 2B — Example of Filled in Test Sheet



CHRIS BEARE obtained his honours Engineering degree at the University of Adelaide in 1973 after graduating in science the previous year. That same year he began work as an Experimental Officer at the Defence Research Centre, Salisbury. In 1977 after taking study leave from the Department of Defence, he completed a Ph. D. at the University of Adelaide in the field of high speed data transmission. He joined Telecom Headquarters as a Class 2 Engineer in 1978 and is currently a senior engineer in the Datel Section of Customer Networks Branch, Telecom Headquarters.

ANALOGUE TEST RESULTS

This section summarises the results of the analogue line measurements.

End to End Attenuation

The attenuation or line loss measured from end to end on each switched network call is shown in histogram form in **Fig 3.**

Noise

The noise power measured in the band 300-3400 Hz is summarised by the histogram in **Fig 4.**

Attenuation and Group Delay Distortion

Figs 5 and 6 give some indication of the group delay and attenuation characteristics likely to be encountered on a switched network call. Note that these results do not include the ripple introduced in the measurements (see **Fig 2**) by the effect of listener echo on the line.

Phase Jitter

The average peak-to-peak phase jitter over a 15 minute measurement period was estimated. In 90% of measurements the average phase jitter did not exceed 4 degrees peak-to-peak.

Data Rate bit/s	CCITT Recommendation	Modulation type	Equalizer type	No. of equalizer taps
2400	V26 (type B modulation)	4 phase	Fixed compromise	—
4800	V27 bis	8 phase	Linear adaptive	(15 complex)
	V27	8 phase	Decision feedback adaptive	4 forward 8 backward (complex)
	V29 (fall back)	QAM	Linear adaptive	31 (complex)
	—	VSB	Linear adaptive	43
9600	V29	QAM	Linear adaptive	31 (complex)

Table 1 — Modems Used in Trials

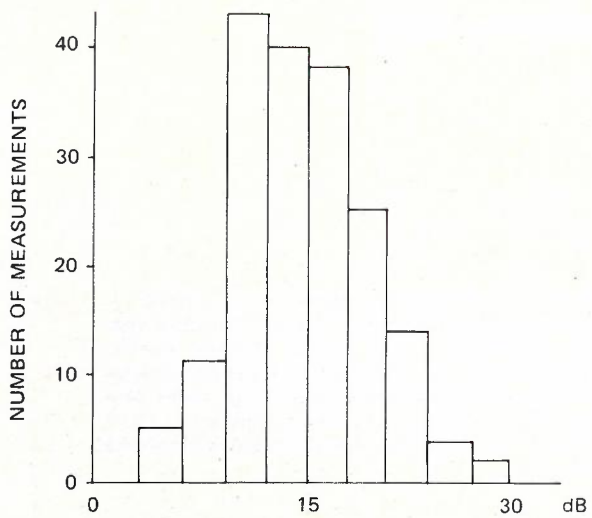


Fig. 3 — Histogram of End to End Attenuation at 1000 Hz

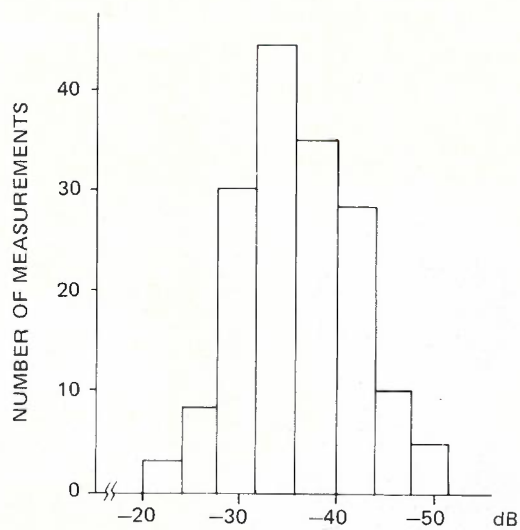


Fig. 4 — Histogram of Noise Power in Band 300-3400 Hz Relative to Received Data Level.

Impulsive Noise

Table 2 shows the results of impulsive noise measurements. The impulse counter was set to have a dead time of 1/2400th of a second. The number of counts recorded is expected to be higher than usually observed in typical data traffic due to the high incidence of step by step exchanges used in the tests. On some calls the impulse count was substantially higher than normal because of the influence of multimetering pulses.

Phase Hits

Less than 5 phase hits in a fifteen minute period were experienced in more than 75% of all measurements. Some phase hits are probably due to bearer or diversity switching in radio bearer systems. Again some counts are due to multi-metering pulse interference.

Frequency Offset

The transmitted 1000 Hz tone is derived from a crystal oscillator and the frequency of the received tone measured by an accurate frequency counter. In this way the offset introduced by carrier systems in the connection path was estimated. The offset was found to be 2 Hz or less in 94% of cases.

Listener Echo

The signal to echo ratio was deduced from the amplitude of the ripple on the attenuation curve, and the echo delay was deduced from the period of the ripple. In the majority of connections ripple on the attenuation curve increases with frequency indicating that echo is more severe at the higher frequencies. The signal to echo ratio was evaluated at a frequency of 1000 Hz and is shown in Table 3.

The distribution of echo delay in the results is influenced by the pattern of trunk calls set up, the majority of these being on the Sydney-Melbourne link. About 20 per cent of connections had no measurable echo.

Harmonic Distortion

Second, third and fourth harmonic distortion was measured with reference to a 700 Hz fundamental tone. The particular measuring equipment was limited to a resolution of −40dB harmonic to fundamental ratio. The numbers of cases this limit was exceeded was 7%, 4% and 2% for the second, third and fourth harmonics respectively.

% cumulative	Impulse counts
95	896
90	385
80	71
70	27
60	14
50	6
40	3
30	2
20	1
10	0
5	0

Table 2 — Cumulative Distribution of Impulsive Counts exceeding a threshold equal to the received data level. Measurement time: 15 minutes

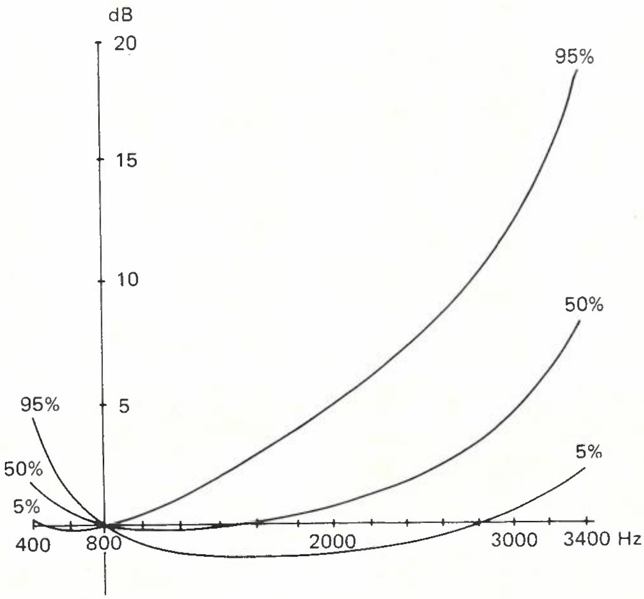


Fig. 5 — Distribution of Attenuation Distortion

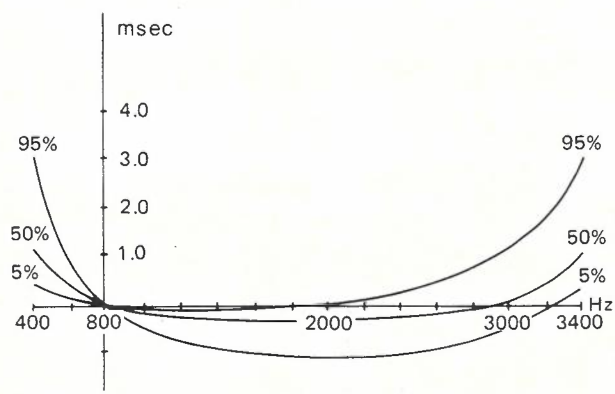


Fig. 6 — Distribution of Group Delay Distortion

Multimetering Pulses

In the Australian network, on Subscriber Trunk Dialled (STD) calls, the customer's meter is triggered by polarity reversals transmitted from the trunk exchange via the junction to the terminal exchange which houses the metering equipment. At this exchange the line reversals are detected and prevented from passing to the customer's line by filtering in the relay set. However, in all cases a low frequency pulse can still be detected on the customer's 2 wire line.

During these trials, the multimetering pulses were recorded on the tape recording equipment and the peak level was later measured on a storage oscilloscope. However, on less than 1% of calls, received data errors could be directly attributed to multimetering pulses.

DIGITAL TEST RESULTS

Test measurement results of bit error rates and block error rates (1000 bit blocks) are summarised in **Fig 7.** Note that the decision feedback equalised 4800 bit/s modem was used only on about the last 15% of connections. Comparing the percentage of calls with bit error rates better than 10^{-4} and block error rates better than 10^{-2} yields the following:

% cumulative	signal-to-echo ratio (dB)	echo delay (milliseconds)
100	8.8	33.3
95	20	19
90	23	12.5
80	29	10
70	31	4.2
60	33	3.3
50	35	1.8
40	39	1.4
30	45	1.0
20	∞	0
10	∞	0
5	∞	0
0	∞	0

Table 3 — Cumulative Distributions of Signal-to-Echo Ratio and Echo Delay

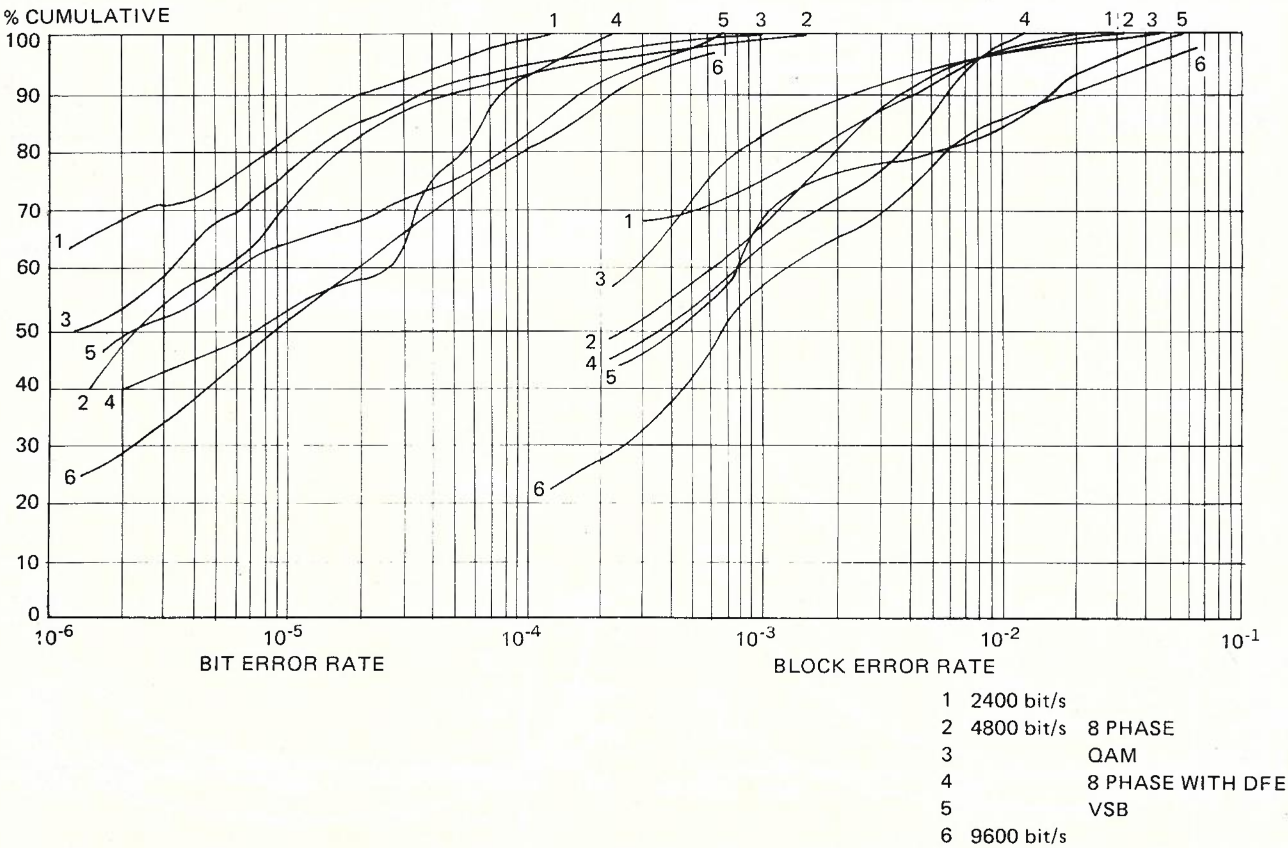


Fig. 7 — Cumulative Distribution of Bit and Block Error Rates

Modem	Percentage of measurements * having:		
	100% error free blocks	90% error free blocks	50% error free blocks
4800 bit/s VSB	67.5	80.5	84.9
QAM	80.0	90.8	94.8
8 phase	38.3	70.0	85.0
8 phase with DFE	89.6	90.6	94.6
9600 bit/s	55.0	80.3	82.7

* Approximately 50 polls per measurement

Table 4 — Polling Test Results

Modem	Bit error rate 10^{-4}	Block error rate 10^{-2}
2400 bit/s	98.7%	95.7 %
4800 bit/s VSB	82.6	84.8
QAM	94.4	95.2
8 Phase	93.4	95.4
8 Phase with DFE	92.9	96.3
9600 bit/s	78.5	84.7

However, on four connections 9600 bit/s operation was not possible as the modem would not successfully train due to poor line quality (steep sloping attenuation characteristics in three cases and severe echo in the fourth). The 8 phase modulation modem also failed to train on one connection (due to severe echo).

From **Fig 7**, and considering that each modem uses a different adaptive equalizer, it is not possible to demonstrate the superiority of any one modulation method. However, the polling results as summarised in Table 4 give some indication of the abilities of the adaptive equalizers in the short polling mode.

CONCLUSIONS

These tests were arranged to investigate the feasibility of 2400, 4800 and 9600 bit/s operation on the switched telephone network. The tests were organised to encompass as large a variety of connection paths as possible. In this manner, although the gross measurement results may not be statistically representative, the parameters that are likely to affect higher speed data transmission were likely to be identified.

Customers are generally interested in high throughput of error free data blocks. From the test results, even at 9600 bit/s when the modem equalizer can train successfully, the block error rate is less than 10^{-2} on about 85% of connections. Substantially better performance is achievable at 2400 and 4800 bit/s.

Impulsive noise, sloping attenuation characteristics and listener echo were the three major impairements to data transmission identified by these trials. Multimetering pulse interference is also significant especially for 9600 bit/s transmission. Further investigations are proceeding into the effect of multimetering pulses and listener echo on the data modems used in the trials.

As a result of these trials, Telecom will presently be offering Datel customers the facility for switched network data transmission at speeds of 2400 and 4800 bit/s.

A Perspective on Literacy

I. M. DARVENIZA

Society tends to look to the past whenever anxiety arises over a present day situation. This backward look compares 'then' with 'now' and has the conviction, often illusory, that times were better. Employers and tertiary institutions allege that young people cannot write grammatically, are poor spellers and cannot express themselves clearly. Have standards fallen and do they meet present day professional demands? What is literacy? If students do not meet the necessary standards of literacy for their college, what can the college do about it? This paper attempts to answer these questions and to give some guidelines for tertiary institutions to help students meet the demands of literacy in an engineering course.

EDITOR'S NOTE: The president of the Telecommunication Society's New South Wales Division, Mr R. Langevad, was the Chairman of the Conference on Engineering Education, held by the Institution of Engineers, Australia, in Sydney during July, 1978.
This paper, presented at the Conference, is one which is expected to have particular interest for our readers. It is reproduced here by kind permission of the Author and the Institution.

WHAT IS LITERACY?

What is literacy and why do we need a perspective on it? The term has been the subject of much debate in recent years but rarely is a definition attempted. First literacy does not just mean reading. The Concise Oxford Dictionary defines literacy as 'the ability to read and write'! If we add to this the ability to speak our native language concisely and fluently and to listen effectively to others speaking it, we come nearer to the broader meaning of literacy: the mastery of our native language in all its aspects, as a means of communication. The mastery of these four interrelated skills, reading, writing, speaking and listening, is a long term process and an extensive program of training at all ages is necessary.

HAVE STANDARDS DECLINED?

Society tends to look to the past whenever anxiety arises over a present day situation. This backward look often compares 'then' with 'now' and has the conviction, often illusory, that times were better. 'Letters to the Editor', frequently from older teachers, decry modern teaching methods and practices as producing poor readers and other problems. Employers allege that young people in their employ cannot write grammatically, are poor spellers and cannot express themselves clearly. If only schools returned to past methods, all would be well. But, would it and were these times past really conducive to better learning?

It is interesting to find in the Newbolt Report of 1921 in England, comments of the same kind. Boots Pure Drug Co. remarked that 'teaching of English in the present day schools produces a very limited command of the English language — our candidates do not appreciate the value of shades of meaning, and while able to do imaginative composition, show weakness in work which requires accurate description or careful arrangement of detail'.

Perspective is necessary but does not mean complacency, as the issue is a complicated one. In Queensland, with whom are todays young people being compared? They are being compared with a very different population. In Scholarship days only 60% of pupils finished Grade 8, and of these perhaps only 40% had passed Scholarship. Approximately one third of these 8th Graders entered secondary school, an academic elite population. Today more young people are staying on at school or going on to tertiary education; many of whom in the past would have gone into commerce or industry. Moreover there have been changes in the structure of employment in recent years. Agriculture and mining are employing fewer people, manufacturing industries about the same number, but the services industries now absorb about half the work force. This changing pattern of employment is making more demands on reading and writing skills, and thus exposing deficiencies that may have escaped attention in the past.

Table 1 shows the number of degrees awarded in Australia from 1955-1977. This can be compared with the population rise for the same period shown in Table 2.

There has been a 7 fold increase of bachelors degrees and an 8 fold increase in all degrees awarded in the period 1955-1975. The total mean population of Australia in this period only rose by 50%.

Factors such as these should be taken into account when observations are made about the standard of school leavers. But this does not alter the fact that these

Table 1
University Degrees Conferred in Australia, 1955-1975

Year	No. of Bachelors	% Of Total	No. of Masters	% of Total	No. of Doctorate	% of Total	TOTAL
1975	21 860	90.3	1 560	6.4	796	3.3	24 216
1974	21 115	91.0	1 310	5.6	771	3.3	23 196
1973	18 525	89.3	1 353	6.5	870	4.2	20 748
1972	16 877	89.5	1 186	6.3	784	4.2	18 847
1971	14 994	89.4	1067	6.4	717	4.2	16 778
1970	13 484	89.7	888	5.9	663	4.4	15 035
1965	7 937	90.9	479	5.5	315	3.6	8 731
1960	4 183	91.4	254	5.5	139	3.0	4 576
1955	3 167	92.2	175	5.1	93	2.7	3 435

standards are not satisfying present day requirements. It is not only employers who are dissatisfied, tertiary education institutions are also concerned about the inability of their students to write correct and coherent English. These remarks by experienced educationalists should be taken seriously. They are not comparing students with the past but measuring them against the demands of a professional function. It may be true that comparisons with the past are misleading, but the clear implication is that standards need to be raised to fulfil the demands being made on them.

UNIVERSAL SECONDARY EDUCATION

Universal secondary education has emphasised the need for schools to provide for the inter and intra differences in their pupils. The wide range of skills and abilities in high school pupils in the 70's seems to have been overlooked by many teacher training institutions. As a result present day teachers are often confused as to how to teach such a wide range of skills and abilities in their classrooms. These are classroom problems and the classroom teacher must be given help in learning to cope with them.

It is also recognised that reading has a place in secondary schools. Reading is a developmental process involving the mastery of increasingly complex, interrelated skills from pre-school to university levels. There are specific reading techniques to improve learning in the subject areas and these techniques are the prerogative of the subject area classroom teacher. Reading is a process and the teacher who uses that process must be, in part, responsible for the teaching of that process. But how can they if their training has not prepared them?

Table 2
Australian Population (mean) 1955 and 1975

1955	9 164 000
1975	13 773 700

Basic or functional literacy is another area of concern in secondary schools. In the past, functional illiterates could and did find a useful niche in society; in today's technological world, despite the impact of audio-visual media, the opportunities for these people are almost non-existent. Their educational handicap becomes a societal problem. The secondary school is the last opportunity for positive steps to be taken to ameliorate their handicap before they go out into society. Secondary schools can and should help these pupils to attain a sufficient standard of literacy to cope with their role in society, and to

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Table 3
Queensland TE Scores Engineering Students 1977

Source: Queensland Tertiary Admission Centre

Institution	Award	Maximum TE	+ No. of Students	Minimum TE	Total Students
University of Queensland	B.E.	990	53	880	220
Queensland Institute of Technology	B.E.	990	6	810	175
	A.Dip.	980	3	740	168
James Cook University	B.E.	990	2	830	42
Darling Downs Institute of Technology	B.E.	990	4	790	60
	A. Dip.	940	1	690	52
Capricornia Institute of Technology	B.E.	990	7	830	36
	A. Dip.	900	2	690	16

give them the tools for creative and critical reading to enhance their personal lives. Therefore secondary schools need expertise in remedial education.

Arithmetic skills are another problem area in present day secondary schools. The slow learners may need help with basic arithmetic skills and may never be able to move into the realm of mathematical concepts and abstraction. They need the real life situation to grasp the meaning of problem solving. But how does a busy classroom teacher cope with these pupils in a large class situation?

In 1974 it was recommended to the Director General of Education in Queensland and to the Director of Secondary Education that Resource Teachers would be a valuable addition to high school staffs. This recommendation was the result of a twelve month study tour, observing secondary schools and teacher training, particularly in reading, in North America, Britain and continental Europe. These Resource Teachers would be trained to give help and advice to pupils and teachers in secondary schools, on educational diagnosis; method and strategy to individualise instruction; reading and use of alternative materials.

In 1975 in Queensland, the first secondary Resource Teachers started work in secondary schools. The Resource Teacher is a member of staff who can support and advise colleagues in many ways. Their role is of necessity a flexible one. Each secondary school is comprised of a unique combination of individuals — pupils and teachers, and the needs of these individuals vary from school to school. Also each Resource Teacher brings to the role a unique set of abilities and skills. Such teachers are involved in withdrawing small groups of pupils for remedial lessons to give basic reading and arithmetic skills. They teach classes, team teach, prepare materials, organise Resource Rooms and give expertise in this challenging situation of universal secondary education.

Thus secondary schools are cognizant of their accountability to society, and of their need to cater for individual differences.

Table 4
TE Scores for Admission to Courses in 7 Large Universities from 4 States

	1975 Minimum TE Score Req. for Offer				
Engineering	760:	840:	840: 880:	840: 880.	880

CALIBRE OF ENGINEERING STUDENTS — (see Table 3)

But what of the calibre of students entering Engineering Schools? Queensland Tertiary Entrance scores are calculated from a state wide rank order of merit list. The top 360 students score 990 TE and the next 180 students score 985 TE, and so on down in bands of 180 students and 5 TE points. Thus students scoring 880TE would rank about 4000th and 690TE approximately 10 000th.

The Institution of Engineers, Australia in its submission to the Committee of Inquiry into Education and Training, September 1977 states the following — 'Regarding the standard of education of entrants to courses leading to graduation in engineering, it is the formally expressed opinion of many of our academics that the minimum standard of admission to many establishments is substantially lower than desirable to maintain an adequate standard of technical and professional education . . . It is furthermore, not only necessary that the student have the ability to attain an acceptable admission standard in basic subjects, but that he shall have attained this standard prior to admission so ***that staff time is not wasted in retracing secondary school work'.***

Appendix F.p. 2 of the submission states — 'Secondary level education should provide a sound introduction to oral and written communication which should be ***developed and practised throughout tertiary education'.*** It would appear then that academics are aware of, and take responsibility, in theory, for developing and practising tertiary communication skills.

HARVARD EXPERIMENT

In 1938 Harvard University undertook a longitudinal experiment to see if students could be taught to read better. The Bureau of Study Counsel at that University directed this project. Its findings are interesting — the project started with a rather mechanical emphasis on reading skills but found that the students opting for the course read well on standardised reading tests. They did not lack mechanical skills but rather flexibility and purpose in the use of them — they lacked the capacity to adjust themselves to the variety of reading materials and purposes that exist on a tertiary level. The program now concerns itself with not the correction of the disabilities of a few students, but the direction of the abilities of a large proportion of the freshman class. That such a prestigous University as Harvard whose students are among the academic elite of the U.S.A. feels the need and benefits from such a program, should point the way to Australian Universities and Colleges.

WHO IS LITERATE?

The following two paragraphs are from tertiary texts, one in education and the other philosophy.

'The previously-made distinction between derivative and correlative subsumption is also important in accounting for the relative susceptibility to obliterative subsumption of different kinds of potentially meaningful factual material. Derivative facts undergo obliterative subsumption more rapidly because, unlike correlative matter, their meaning can be adequately represented by the ideational systems that subsume them, thereby making possible a degree of factual reconstruction that is satisfactory enough for most purposes of communication'.

'The Transcendental Analytic has brought us to this important conclusion, that understanding can never do more than supply by anticipation the form for a possible experience; and, as nothing but a phenomenon can be an object of experience, it has taught us that understanding cannot possibly transcend the limits of sensibility, beyond which no objects are presented to us. The principles of pure understanding are merely exponents of phenomena, and for the proud name of Ontology, as a science that claims to supply in a systematic doctrine a priori synthetic knowledge of things as such, must be substituted the more modest claims of an Analytic of Pure Understanding'.

Are these paragraphs easily understood by engineers? It is doubtful. Each of these paragraphs uses a language that is not every day English. Each subject has its own language and it is unrealistic to expect students fresh from high school to have knowledge and erudition in engineering, philosophy or educational language. So who is literate? Just as reading a Grade 1 basal reader does not mean a child is literate for the community, reading at secondary school with all its implications of oral language and experiences does not necessarily make a student literate for engineering. The language of engineering has to be taught. The input skills of language are listening and reading and the output skills are speaking and writing.

Input	Output
Listening	Speaking
Reading	Writing

A hierarchical sequence of language skills for engineering would be

listening
reading
speaking
writing

with writing the most difficult of the four. Students who can listen to a lecture on engineering, who can read in that subject may still have difficulty writing an assignment on it. The literate person is one who has sufficient skills of language to meet the demands of his life style and/or training or vocation.

SEQUENTIAL DEVELOPMENT OF READING SKILLS

A sequential development of reading ability is shown in Table 5. Reading is seen as a pyramid of growth. Tertiary students should have the foundations from "Readiness" through to "Wide Reading" and some may have reached the tip of the pyramid. This reading ability has then to be developed and channelled into reading technical engineering materials. The technical vocabulary or jargon of each subject should be mastered. Mastering technical terms and their definitions is a basic prerequisite for understanding tertiary courses. One method is to keep a glossary of key terms on the inside cover of a text book. Write the word and the author's definition.

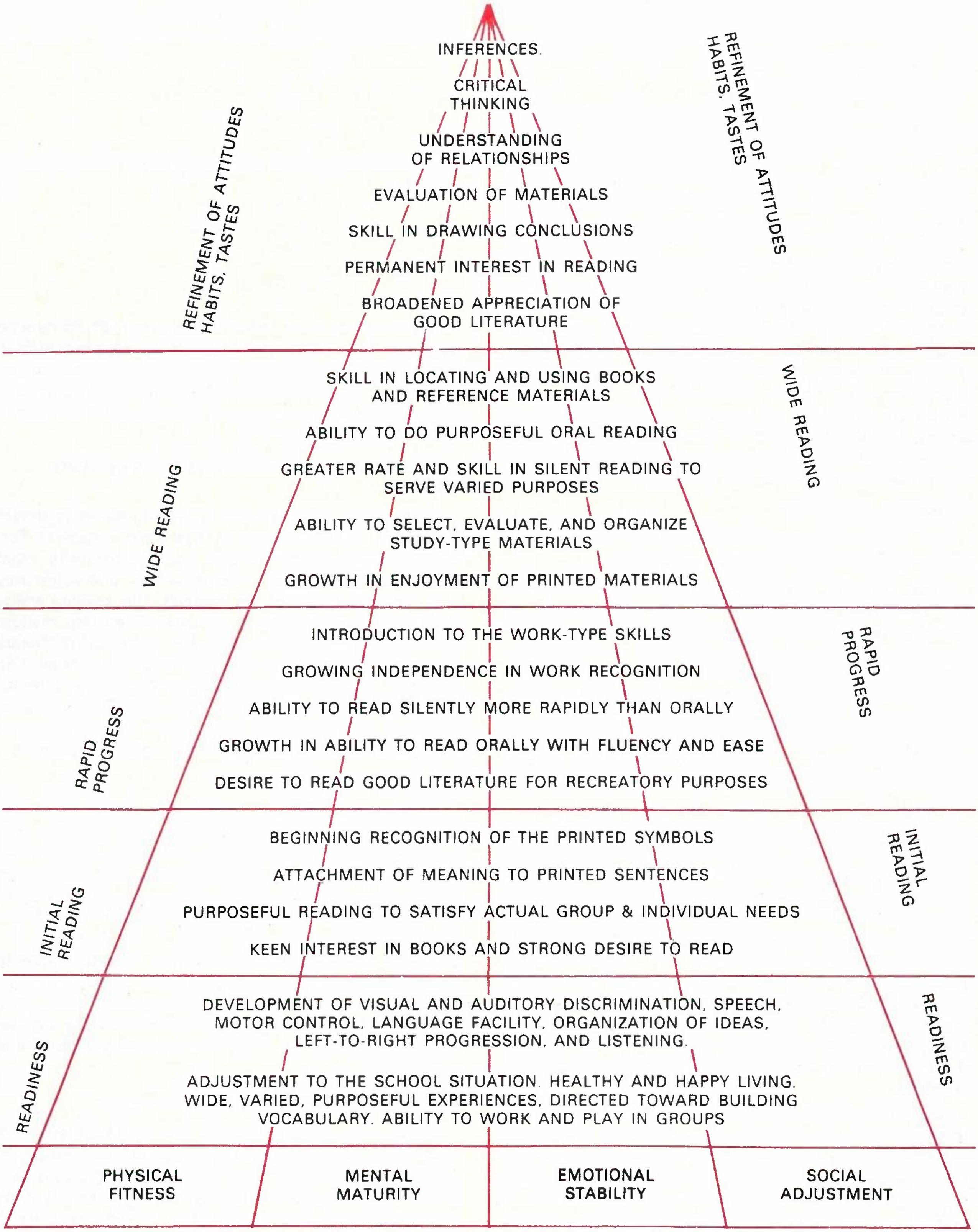
READING A TEXT BOOK

Reading a text chapter once is ***not*** enough. Most students retain less than 25% of a chapter's contents after one reading. A better method is to spend a few minutes ***skimming*** through the chapter, noting topic headings, charts and italics and ***reading*** the summary. This will give an overview of the contents and prepare for a more thorough reading. Next, turn the topic headings into questions and read for the answers. Test by trying to recall the answers. Selectively review by re-reading these sections which are not clear. If underlining is to be done, it should be done at this stage and not during the first reading of the chapter. The final step is the brief outline of the chapter.

READING PROFESSIONAL JOURNALS

Engineering students should have the foundations of continuing education fostered through the reading of professional journals. But professional journals are voluminous and many, and a word by word reading of the relevant seeming articles is tedious and time wasting. A suggested plan to attack for keeping abreast with current papers follows.

Table 5 — SEQUENTIAL DEVELOPMENT OF READING ABILITY



Pyramid of Growth (Source: Curriculum Bulletin No. 12, State Dept. of Educ. Augusta, Maine)

Suggestions for Reading Professional Journals

GENERAL

Editorials

1. ***Preview:*** title, introduction (paragraph 1), summary (last paragraph)
   — quickly.
2. ***Read:*** if further interested, read first sentence of the second paragraph for topic, then skip-phrase through paragraph, if it appears worth-while. Handle remaining paragraphs the same way.
3. ***Review:*** Look away from the material, verbalize the points of ***concern to you.*** Check back if necessary.

Announcements

1. ***Skim:*** for topic, if interesting to you
2. ***Check:*** for date, place, personnel

Special Articles (historical, etc.)

1. ***Skim:*** titles. For each of possible interest
2. ***Check:*** introduction and summary. If worth it to you
3. **. . .** handle balance of selections as with editorials

Reviews

1. ***Check:*** bibliographic note at beginning; ***If*** of possible interest
2. ***Skim:*** concluding paragraphs or sentences for reviewer's summary. If you wish to know more —
3. ***Read:*** rest of review by skip-phrasing

"SPECIFIC" (reports of studies and investigations)

General Approach

1. ***Evaluate*** titles; ***decide*** which you wish to know more about; for each
2. ***Skim*** introduction, illustrations, summary
3. ***If*** and to the extent ***necessary*** for you, read and review article.

Evaluating a study in detail

1. What is the problem? What actually was studied may be somewhat different than the title indicates . . . restate the problem in your own words, if possible.
2. What type of study is it?
   a. Exploratory
   b. Survey
   c. Descriptive
   d. Experimental

LECTURE NOTES

Taking good lecture notes is an essential component of learning a subject. However so often this important skill is thought to be learnt by osmosis and not by teaching. A suggested plan for lecture note taking follows.

Taking Lecture Notes

There are many reasons for taking lecture notes.

- Making yourself take notes forces you to listen carefully and tests your understanding of the material.
- When you are reviewing, notes provide a gauge to what is important in the text.
- Personal notes are usually easier to remember than the text.
- The writing down of important points helps you to remember them even before you have studied the material formally.

Instructors usually give clues to what is important to take down. Some of the more common clues are:

- Material written on the blackboard.
- Repetition.
- Emphasis.

  1. Emphasis can be judged by tone of voice and gesture.

  2. Emphasis can be judged by amount of time instructor spends on points and number of examples he uses.

- Work signals (e.g., "There are ***two points of view*** on . . ., "The ***third*** reason is . . .," "In ***conclusion*** . . .").
- Summaries given at end of class.
- Reviews given at beginning of class.

Each student should develop his own method of taking notes, but most students find the following suggestions helpful:

- Make your notes brief.

  1. Never use a sentence where you can use a phrase. Never use a phrase where you can use a word.

  2. Use abbreviations and symbols.

- Put most notes in your own words. However, the following should be noted exactly:

  1. Formulas.
  2. Definitions.
  3. Specific facts.

- Use outline form and/or a numbering system. Indentation helps you distinguish major from minor points.
- If you miss a statement, write key words, skip a few spaces, and get the information later.
- Don't try to use every space on the page. Leave room for co-ordinating your notes with the text after the lecture. (You may want to list key terms in the margin or to make a summary of the contents of the page.)
- Date your notes. Perhaps number the pages.

LISTENING SKILLS

Listening is the first input skill of language. In this age of media and muzak in every public place, the adolescent is a very poor listener. He is used to being bombarded with noise, colour and fast movement and has developed the ability to isolate himself from peripheral sounds. Many of these young people have developed bad listening habits, and can tune out whatever does not 'grab' them. They have to be taught good listening habits. A suggestion follows.

LISTENING

Ten bad listening habits:

Bad (how to tune out)

1. calling subject uninteresting and tuning out
2. criticising delivery (poor organization etc.)
3. getting overstimulated and tuning out
4. listening only for ***facts*** (utterly inefficient) ***worst*** listeners do this and think it's good
5. outlining everything (rigid)
6. faking attention
7. tolerating or creating distractions. (can't hear speaker, etc.)
8. avoiding difficult material.
9. letting "emotion words" throw you off.
10. wasting "the differential between speech and thought speed" Lecturer 100 wpm; average thinker 400 wpm. Mind wanders while speaker catches up. You're tuned "out for 50, in for 10".

Good (how to overcome)

1. can I USE it? sift, screen, bear down on subject.
2. dig out what's needed. Responsibility on YOU, not lecturer
3. "withhold evaluation until comprehension is complete" i.e. hear him out before judging
4. listen for ideas and concepts. Facts then arrange themselves. Helps retention.
5. mostly you can't. Use flexible techniques. (List of ideas and facts a good technique) —precis, abstract, etc.
6. concentrate (Who are you kidding?)
7. eliminate them. Be aggressive about it.
8. TRY it.
9. be aware some words throw you. Don't be thrown. Tolerate.
10. USE the time-gap to ***concentrate.***

Three ingredients of good concentration

- Anticipate what he's going to say and then compare what he said with what you thought was coming.
- identify his ***evidence***. How he back self up? (This where facts come in)
- recap, about every 5 minutes.

DEVELOPING COMPETENCE IN WRITING

Discussion is as basic to good writing as it is to good oral language activities. Speaking is one of the outputs of language, the other is writing. Through talk students can develop the easy use of technical words and the fluency of expression that supports fluent writing:

Talk gets ideas flowing

Talk familiarises vocabulary

Talk provides opportunity to set out sentence patterns or constructions

Talk promotes organisation for clarity

Talk establishes cause-effect relationship

Talk organises sequence of events.

Quality of expression is tied to quality of input. Just as children pattern their oral language on what they hear during oral exchanges so students will absorb from their listening and reading the pattern of technical language. Academics should draw students attention to clear well written technical language.

The conventions of writing develop as students write and are interested in others reading their product. The conventions of handwriting, spelling and punctuation help to facilitate communication with the reader. Proofreading is an essential component of good writing. Spelling of technical jargon words has to be learned, always remembering that spelling is a visual skill not an oral one (unless to confound small children).

The look of a word and the practice of writing it is important. Reading and spelling are often confused and there is concern for the 'good' reader who is a 'bad' speller. Reading is recognition while spelling is selection eg. pain; to spell the sound could be ai, ae, a . . . e, ei or ay.

Some of the points to ***avoid*** in technical writing can be itemised as follows

1. ***Ambiguity.*** Make sure writing has one meaning only.
2. ***Monotony of sentences.*** Vary the length and construction of sentences.
3. ***Pretentious writing.*** Do not use exaggerated expressions when simpler words will do.
4. ***Cliches, colloquialism, slang.*** Look for fresher turns of phrase.
5. ***Unfamiliar words.*** Do not use words if you do not know their meaning.
6. ***Circumlocution.*** Be concise and to the point
7. ***Unnecessary repetition.*** Do not repeat the same word or phrase too soon. Read each paragraph as it is finished and any repetition will be noticed immediately.

CLOZE TEST OF READABILITY

An informal measure of a student's success with textual material can be easily constructed. Select a 100 word passage from the text that stands on its own in meaning. Delete every tenth word and have the student fill in or Cloze the gaps. This Cloze test can be given as a group test to a class. The scoring for Cloze is the subject of much debate in educational circles. However if the student can successfully Cloze 6 or more out of the 10 gaps, he can read and study independently from that text. Less than 4 out of 10 shows inappropriateness of the text, for that student.

The term standard is applied to a piece of ______ having a known measure of some physical quantity, which ______ be used, normally by a comparison method, for the ______ of obtaining the values of the physical properties of ______ equipment . . . and so on.

PROOFREADING

Proofreading is not an innate ability; it is an acquired skill. The following exercises will help you master it, or at any rate will impress you with how difficult it is.

Hints for successful proofreading:

- Cultivate a healthy sense of doubt. If there are **types** of error you know you tend to make, double-check for those.
- Read very slowly. If possible, read **out loud.** Read one word at a time.
- Read what is actually on the page, not what you think is there. (This is the most difficult sub-skill to acquire, particularly if you wrote what you are reading).
- Proofread more than once. If possible, work with someone else.

Most errors in written work are made unconsciously. There are two sources of unconscious error:

- Faulty information from the kinaesthetic memory: if you have always misspelled a word like "accommodate" you will unthinkingly misspell it again.
- A split second in inattention. The mind works far faster than the pen or typewriter.

It is the unconscious nature of the worst mistakes that makes proofreading so difficult. The student who turned in a paper saying "I like girdle cakes for breakfast" did not have a perverted digestion. He thought he had written "griddle cakes" and because that's what he was sure he had written, that's what he "saw" when he proofread. If he had slowed down and read word by word, out loud, he might have caught the error. You have to doubt every word in order to catch every mistake.

Another reason for deliberately slowing down is that when you read normally, you often see only the shells of words — the first and last few letters, perhaps. You "fix your eyes" on the print only three or four times per line, or less. You take in the words between your fixation points with your peripheral vision, which gets less accurate the farther it is from the point. The average reader can only take in six letters accurately with one fixation. This means you have to fix your eyes on almost every word you have written, and do it twice in longer words, in order to proofread accurately. You have to look at the word, not slide over it.

In proofreading, you can take nothing for granted, because unconscious mistakes are so easy to make. It helps to read out loud, because 1) you are forced to slow down and 2) you hear what you are reading as well as seeing it, so you are using two senses. It is often possible to hear a mistake, such as an omitted or repeated word, that you have not seen.

Professional editors proofread as many as ten times. Publishing houses hire teams of readers to work in pairs, out loud. And still errors occur.

CONCLUSION

Tertiary institutions should recognise that the development and practice of literary skills have a place in engineering courses. This would be of most significance in first year courses where the students are exposed to technical language for the first time. The wide range of skills and abilities of engineering students in the 1970's has placed an even greater emphasis on the need for academic involvement in communication programs. The Harvard experiment has shown that even the top students feel the benefit of such programs. The suggestions given in the text of the paper could assist academics to develop listening, reading, and writing skills for their students.

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Telecommunications Traffic Measurement and Processing Methods used by Telecom Australia

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Telecom Australia expends significant resources on telecommunications traffic measurement. The motives and the techniques of making these measurements are the subjects of this paper.

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INTRODUCTION

Telecom Australia, in common with other telecommunications administrations, expends significant measurement resources in order to obtain reliable traffic data. This is done for several reasons:

- Firstly, to check if the current traffic needs are satisfied (i.e. the design grade of service is not being exceeded), and to provide traffic data which will be helpful to staff responsible for the maintenance of the network.
- Secondly, to supply traffic information of a type which will assist the efficient planning and design of telecommunications facilities to carry future loads in the most economic manner.
- In addition, special traffic measurements are undertaken when necessary — e.g. to evaluate new types of switching equipment, or to assist with tariff studies.

The traffic data which is gathered to satisfy the network supervision objective is also helpful for planning purposes. However, much more detailed traffic measurements are needed for the planning and design requirement than are necessary for network supervision. This is especially so in the case of networks utilising common control switching equipment and alternative routing.

I have shown in a companion paper (Ref. 1) that traffic measurements are only one of several types of measurements used by Telecom Australia to monitor the grade of service and switching loss performance of telecommunications system. However, this paper will be confined to traffic measurements only.

The items of traffic data which need to be measured at a telephone or telex exchange depend on the type of switching equipment. Originally, step by step equipment was mainly used in the automatic exchanges in Australia, and a very limited alternative routing capability was possible. For circuit group dimensioning it was only necessary to measure the traffic carried by each switching stage and each traffic route. On the other hand, close attention had to be paid to the efficiency of gradings, and individual circuit occupancy measurements were used to obtain the necessary traffic data. In the early 1960s, we started to use LM Ericsson (common-control) crossbar switching equipment, so measurements on short holding time common-control equipment became essential. The crossbar equipment permitted elaborate alternative routing to be used, and this method of trunking was henceforth widely implemented in Australia. Thus, it became important, for design purposes, to measure the dispersion of the traffic.

Traffic overload can cause serious and widely-spread congestion in networks which use common-control switching equipment, and/or alternative routing. Therefore, with the increasing use of crossbar equipment, we found it desirable to follow a policy of routine monitoring of the performance of the common equipment, and to regularly measure traffic intensity on the final choice routes.

Recently, we have commissioned several stored program controlled (SPC) trunk exchanges, and the traffic measurements have been adapted to suit the dimensioning and monitoring needs of these exchanges. In the near future, many of our ARF crossbar exchanges will be converted to partial SPC working (as ARE-11). The Operations and Maintenance Processor of this type of exchange is capable of gathering some traffic data on-line. Full SPC local exchanges will soon be introduced into our network and they will be equipped with extensive facilities for gathering and forwarding the traffic data required for planning and performance monitoring purposes.

Simultaneous with the changes in switching technology great advances have been made with the equipment used for measuring traffic, and in computer processing of the collected data. Considerable progress has also been achieved in the associated tasks of traffic forecasting, and exchange and route dimensioning, but these subjects lie outside the scope of this paper.

SPECIAL TERMINOLOGY

ARE-11, ARF, ARM, METACONTA 10C

Types of common control (crossbar or SPC) exchanges mentioned in this paper.

CALL CONGESTION LOSS (or CALL BLOCKING)

The ratio of the number of first call attempts which were unsuccessful (owing to the unavailability of suitable connecting paths) to the total number of first call attempts during the same period of time.

DISPERSION

The proportion of an exchange's originating traffic offered to the different destinations.

GRADE OF SERVICE

Busy signal systems:

- The route GOS is the probability of not being able to set up a connection to a chosen route or destination because of insufficient circuits.
- The network GOS is the average of the nominal exchange-to-terminal exchange grades of service over the whole network, weighted in proportion to the traffic flowing between the various pairs of terminals.
- The overall GOS is the total probability of call loss (from origin to destination) due to congestion at any switching stage involved in the connection.

Delay Systems:

- GOS is expressed as the probability of a call being delayed by more than some specified time. Sometimes average delay on all calls is used as a measure of delay GOS.

NOTE — Strictly speaking, Call Congestion Loss is a measurable quantity, whilst GOS is a design concept dependent upon specified assumptions about the traffic and switching system. The two terms are often used interchangeably.

OCCUPANCY

The mean traffic intensity over a period of time, carried by a circuit or group of circuits.

SPC

Stored Program Control.

SWITCHING LOSS

The proportion of calls, in a network, or a part of it, which are unsuccessful due to faulty performance of the switching equipment.

TDE

Traffic Data (measuring) Equipment.

TRAFFIC MEASUREMENT OBJECTIVES

Before discussing the measurement and processing techniques used by Telecom Australia let us consider the end uses of measurements, firstly for the planning and design requirement, and secondly for the congestion monitoring application.

Measurements to Satisfy Planning Requirements

As the number, location and calling habits of telephone and telex users change with time in response to demographic, social and economic factors, the traffics wanting to flow on the various links in a telecommunications network are never static. It follows that if the network is to continue to meet prescribed standards of congestion loss the quantities of traffic-carrying devices must change fairly frequently. Final routes, for example, should be augmented no later than when the traffic has reached a nominal value corresponding to the GOS objective previously fixed for each route. Over a period of a year the number of changes made to a network is usually considerable.

Considering the cost involved in making each individual change it behoves administrations to do all that is reasonable to ensure that there is a high probability that the planned changes will satisfy the actual traffic requirements until the time of the next review. The planned circuit quantities are based on estimates of future traffics but due to inevitable errors in forecasting there will be cases in which the planned quantity does not prove to be correct in the light of later information. However, this is not catastrophic since further changes can be made to correct the situation, although at a cost penalty. One design strategy which has been introduced to minimise the percentage of junction and trunk routes which need size changes to cope with changing traffics is 'modular engineering' (Ref. 2). With this method, circuit groups are only permitted to take on preferred sizes (e.g. 6, 12, 18, 24, etc.) and tend to stay at that size for a much longer time than if design increments of one circuit are used.

It is well recognised by planners in all fields that the greatest aid to accuracy in forecasting is reliable base data information. In the Australian national network regular and systematic traffic measurements are made in order to build up an accurate data base for use by planning engineers. Ideally, the time interval between collecting new sets of traffic data for a circuit group should be adaptively determined by such factors as:

- The revenue earning potential or strategic importance of the facility;
- The optimum economic interval between changes or additions to working equipment;
- The rate of change of the traffic parameters.

By extending this line of reasoning, one can determine how accurate the base traffic data needs to be, and the correct measuring technique to use. These aspects have been treated by authors such as Parviala (Ref. 3) and Chin (Ref. 4).

Typical planning and design tasks which require traffic data are:

- Selection of the best type of switching equipment to suit the traffic
- Dimensioning of switching equipment
- Dimensioning of junction and trunk circuit groups.

(Note — dimensioning is the process whereby equipment quantities are determined from traffic data).

To do these tasks in a sound engineering manner the designer may need the following types of traffic data:

- Average traffic usage rates (originating and terminating), expressed as erlangs per subscriber.
- Traffic offered to each group of switching equipment.
- Mean and variance of traffic offered to final choice of traffic routes.
- Call, or preferably, traffic dispersion information.
- If dispersion data are not available, occupancy measurements on all traffic routes will be needed, preferably supplemented by a count of calls offered and calls carried.
- Average holding times of calls and of common switching equipment.

For queueing systems, in addition to estimates of offered traffic loads, measurements are necessary to determine the distribution of holding times of the offered calls, and the distribution of service times.

Measurements to Satisfy the Monitoring and Maintenance Requirements

Telecom Australia makes routine measurements on telephone and telex systems to compare GOS and switching loss with standards. Several measurement techniques are used for this purpose, including:

- Traffic measurements
- Service assessment of subscribers' live traffic by manual operators
- Artificial test call generators
- Automatic monitoring of subscribers' traffic
- Automatic marker disturbance recording
- The analysis of technical assistance (trouble) reports from subscribers.

I have shown in another paper (Ref. 1) that on its own, no one of these methods is sufficient to assess the GOS, or to pin-point equipment items which, due to underprovision or misoperation, are the cause of unsatisfactory performance.

Since final choice routes are dimensioned to carry the estimated busy season traffic at a specified loss, traffic measurements have a special place in monitoring the route, network and overall GOS. For example, after measuring and averaging the busy hour traffic over a number of days, the appropriate traffic tables can be used to estimate the (theoretical) GOS being experienced by traffic offered to the final choice routes. In order to monitor networks which employ alternative routing, it is desirable to have facilities which are suitable to measure traffic on the high usage as well as the final choice routes.

Ideally, for congestion supervision, the traffic measuring equipment should either be permanently in place or be able to be set up at short notice, and the maintenance staff should be trained in the correct method of checking and using the equipment.

In order to access the GOS on delay systems it is necessary to have equipment capable of measuring the arrival rate and holding time parameters of calls offered to the queues, and the service time parameters of calls handled by the servers.

Turning now to exchange maintenance, the need exists for an additional type of measurement to check that each individual circuit in the group is carrying its fair share of the offered traffic.

Example: A route occupancy traffic reading indicates that there are sufficient primary switches to carry the measured traffic yet complaints from users of no dial tone point to a shortage of primary switches. The true cause may not be insufficient switches but one of the following:

i. Subscribers' originating traffic is not evenly distributed across the grading.
ii. An unsatisfactory interconnection scheme exists — e.g. too many individuals, and not enough commons.
iii. Some individual devices are not able to be selected by the previous stage — e.g. because of a sticking relay or wiring error.
iv. Faults on one or more switches causing no-progress on calls, resulting in callers repeating their attempts until they obtain a satisfactory connection.

Route occupancy data will be inadequate in these cases to ascertain the underlying cause of the trouble. The position can be clarified by measuring and comparing the traffic carried during the busy period of the day by each switch in the group. This type of measurement is called 'circuit occupancy' or 'individual circuit monitoring'. To detect faulty equipment (e.g. (iv) above), a holding time measurement on each device may be needed; faulty items will have holding times significantly different to the average for the group.

TRAFFIC MEASURING AND PROCESSING TECHNIQUES

Introduction

CCITT Recommendation E500 deals with the Measurement and Recording of Traffic on International circuit groups. The Recommendation suggests that "the recording equipment should make a record of the traffic flow carried during the mean busy hour for at least the 30 days of the year in which the mean busy hour traffic flow is the highest." Processing methods may then be employed to calculate values for the average traffic flow for the 30 and for the 5 busiest days during the year. This is the preferred method. The second preference in the Recommendation suggests "a measuring period of 10 consecutive normal working days during the busiest season of the year." Such comprehensive measurements, warranted in the case of international circuit groups because of the exceptionally high cost of each circuit and fast rate of growth in offered traffic, are not generally justified in national networks, except perhaps in the case of high cost trunk routes.

In networks which utilise alternative routing, plant congestion can only be encountered by traffic offered to the final choice circuit groups. It is therefore our practice to monitor the final choice routes more carefully than high usage routes. Fortunately, the final choice routes comprise only a small proportion (e.g. 20%) of the total number of routes in a network, thus minimising to some extent the resources required for this aspect of network management. On the other hand, interpretation of the measurements is complicated by the fact that if all routes have been provided as planned and congestion is indicated on a final choice route this condition could actually be due to some high usage route circuits being inoperative, or traffic greater than predicted being first offered to:

- one or more of the direct high usage routes, or
- one or more of the high usage alternative routes, or
- the final choice route itself.

Measurement Standards

In the Australian urban networks, in order to satisfy the planning requirements, extensive traffic measurements are taken at terminal exchanges at approximately two-yearly intervals. At tandem and transit exchanges these full-scale readings may be done more frequently if warranted, but not usually more often than once per year. By a full-scale reading I mean a route occupancy reading over a period of five or possibly ten days, with sampling scans generally at three minute intervals covering the busier periods of each day. At ARF crossbar and SPC exchanges, a traffic dispersion measurement is generally taken at the same time as the route occupancy reading. Call holding time information is obtained as a by-product of the dispersion measurements. Individual circuit measurements (i.e. circuit occupancy) are done on an as-required basis and may be simultaneous with the route occupancy and dispersion measurements. In step exchanges, traffic dispersion and call holding time readings are carried out separately from occupancy measurements.

At rural exchanges, traffic readings are done at intervals which vary from two to five years depending on the size and importance of the exchange. The rural networks in Australia utilise transit centres called Minor Switching Centres. This is fortunate from the point of view of network monitoring since, as the rural terminal exchanges tend mainly to have all their routes via the parent minor switching centre, it is possible at a minor switching centre to measure the traffics on most of the junction routes in and out of the subsidiary terminal exchanges. Both-way circuits are used extensively in rural networks. To satisfy the planning requirement, it is the practice to measure the traffic intensity separately in each direction.

Comprehensive on-site measurements are done at private automatic branch exchanges (PABXs) at intervals of about five years, or as dictated by traffic considerations, or subscriber requirements. For large PABXs it is usual to read the traffic on their exchange lines during the regular readings at the parent exchange. If congestion on the exchange lines exceeds the design limit the customer can be required to increase the number of lines.

Traffic Data Equipment (TDE)

The standard measuring equipment used in most of our crossbar and step exchanges and in the telex exchanges is called Traffic Data Equipment (TDE). The equipment comprises:

a. A permanent rack which is wired to every traffic carrying group in the exchange. The rack is equipped with the necessary relay sets to allow a route occupancy measurement to be done manually on selected circuit groups at any time; the reading is done using a meter located in the maintenance control area of the exchange.

b. Plug-in relay sets to permit route and circuit occupancy readings to be done automatically.

c. Plug-in relay sets to permit traffic dispersion and holding time measurements to be done automatically.

d. A magnetic tape data recorder (used in conjunction with the equipment mentioned in (b) and (c).

Important features of the TDE are that the various types of measurement may be performed simultaneously; the measuring process is automatic; and the output data is recorded onto reels of computer compatible magnetic tape. These aspects assist considerably in controlling the costs of gathering (and processing) the large amounts of data involved.

The following sections give a brief description of the Traffic Data Equipment, its method of operation and the associated data processing system. More detailed information about the TDE is given in Ref. 5.

TDE Automatic Route Occupancy Measurements

In Telecom Australia step and crossbar exchanges, the measurement of route occupancy is essentially a measurement of resistance. Each device, while it is occupied, applies earth via a 100,000 ohm resistor to a commoning point. The resistance between the common point and earth thus varies with the number of occupied circuits. The common point of each circuit group is wired to the measuring equipment — e.g. the TDE rack.

The data collection equipment for TDE route occupancy measurements enables the number of occupied devices in each circuit group to be recorded. A fully-equipped TDE rack has the capacity to measure a total of 800 groups, each containing up to 200 devices.

Before a reading commences, the time clock is set to the desired number of weeks, days of the week, and time periods each day the traffic data is to be measured. Once set, the time clock automatically initiates at regular intervals, the operation of the various relay sets which gather and record the traffic data.

At the commencement of a scan, the time clock forwards a start signal to the Priority Module, which initiates the recording of a Time Block onto the output tape. The time block consists of header characters, exchange identification code and the week, day and time in hours and minutes. (The function of the priority module is to control the recording priority of data presented at its input; data available for short periods is given a higher recording priority than data available for longer periods). The time clock next forwards a start signal to the access switch, which selects the first group of ten traffic reading leads to be measured, and switches them through to the route occupancy control relay set where each is tested for fault conditions prior to being extended one at a time to the digital ohmmeter. The ohmmeter proceeds, by a process of comparison to balance the resistance of the reading lead against a combination of eight set resistors, each equivalent to a fixed value of traffic (viz. 128 Erlang, 64E, 32E, 16E, 8E, 4E, 2E and 1E) and then requests the priority module to transfer this result, in binary form, onto the output tape as a route occupancy block. When all ten reading leads in the first group have been measured and the information transferred to magnetic tape, the route occupancy control relay set commands the access switch to select the next group of reading leads. At the completion of the last measurement cycle a signal is sent to the time clock which switches all relay sets to normal in readiness for the next scan. Scan intervals may be selected in the range 15 seconds to 4 minutes, but generally a 3 minute interval is used.

TDE Manual Route Occupancy Measurements

When performing manual route occupancy measurements, control of the switching and measuring functions of the equipment is transferred to keys on the manual control panel which is located in the maintenance control area of the exchange. Traffic is read visually on a large-face meter as each circuit group reading lead is switched manually to it. (The meter is calibrated in erlangs and is therefore refered to as an Erlangmeter). The values may be recorded onto standard forms for later analysis. The scanning interval depends on the number of groups being read. An upper limit on speed is about 40 reading groups per 3 minutes, but by lengthening the scan interval (e.g. to 10 minutes) more groups can be read.

TDE Automatic Circuit Occupancy Measurements

The data collection equipment for circuit occupancy measurements identifies each device within a group and records its condition as idle or busy. The equipment can record the condition of up to 800 devices. The process of measurement is similar to that described for route occupancy, with the exception that the digital ohmmeter is not required. The occupancy information recorded specifies which of the items in the particular group of ten under test, are in use. The priority module, under control of the circuit occupancy relay set, transfers this data for ten items at a time onto the output tape.

TDE Automatic Dispersion Measurements

The TDE can be used to measure dispersion at ARF terminal exchanges, and at ARF transit exchanges equipped with registers. The dispersion equipment is designed to monitor a maximum of 320 group selector (GV) inlets, and the related GV markers and code receivers (KM), in association with a maximum of 100 registers. Data can be recorded at a rate of about 3000 calls per hour. Dispersion data are gathered continuously as calls originate, are switched and released. Three data blocks are recorded on magnetic tape for each call, as follows:

Register Data Block — for a new call, the following data are recorded after the register calls forward to the GV code receiver —

GV marker and KM identification
Dialled digits from register
Register identification
The time at that instant.

GV Marker Data Block — the following data are recorded after the GV outlet is selected:

GV marker and KM identification
GV inlet number
Whether or not congestion is encountered.

Call Release Data Block — the following data are recorded when a call on a GV inlet being observed is released:

The state (busy or idle) of a sub-group of 20 inlets, which includes the released inlet. (Note — there are 16 sub-groups).
The time of the call release.

As the various blocks of information become available the particular relay sets concerned request the priority module to transfer the data onto the output tape.

TDE Measurement Processing

The processing of TDE measurement data is done off-line on a large scale computer. An Exchange Reference Data file of information about the traffic carrying circuits at each exchange is maintained at the computer site. When a traffic reading is in progress at an exchange a record is maintained on file of any circuit changes which affect that exchange. (This is necessary because although it is desirable to minimise the number of changes to circuits which occur during a traffic reading, some changes are inevitable). We find it essential to check readings for compatibility against the known exchange data. For example, in processing a route occupancy reading we compare the number of devices in use at the time of each scan with the number of devices supposed to exist on that route. This is called the validation process. All data rejected on the compatibility tests are collated onto an error report. Investigations are then commenced to try to ascertain whether the exchange master file data were incorrect or whether the problem is in the recorded data being inaccurate, and corrections are then inserted into the data processing system. A simplified flow chart for the data processing system is shown in **Figure 1.**

Output Reports from TDE Measurements

The output reports from processing provide the following information:

Route Occupancy Measurements

- Traffic averages for each half hour for every device group.
- The maximum and minimum number of devices simultaneously occupied for each reading session.
- For each circuit group, the time consistent busy hour and its average traffic over a five day measurement period.
- Similar data for combinations of device groups.
- The variance-to-mean ratio of the traffic on specified circuit groups.
- A summary of the time consistent busy hour, and the busy hour traffic, as measured and seasonally corrected.

Circuit Occupancy Measurements

- Traffic averages for each half hour for every device, or for the group as a whole.
- A summary of the average occupancy of the individual devices at the time consistent busy hour of the group.

Dispersion Measurements

- Percentages of calls and traffic, and average call holding times, for all identified destinations, and for certain groups of destinations.

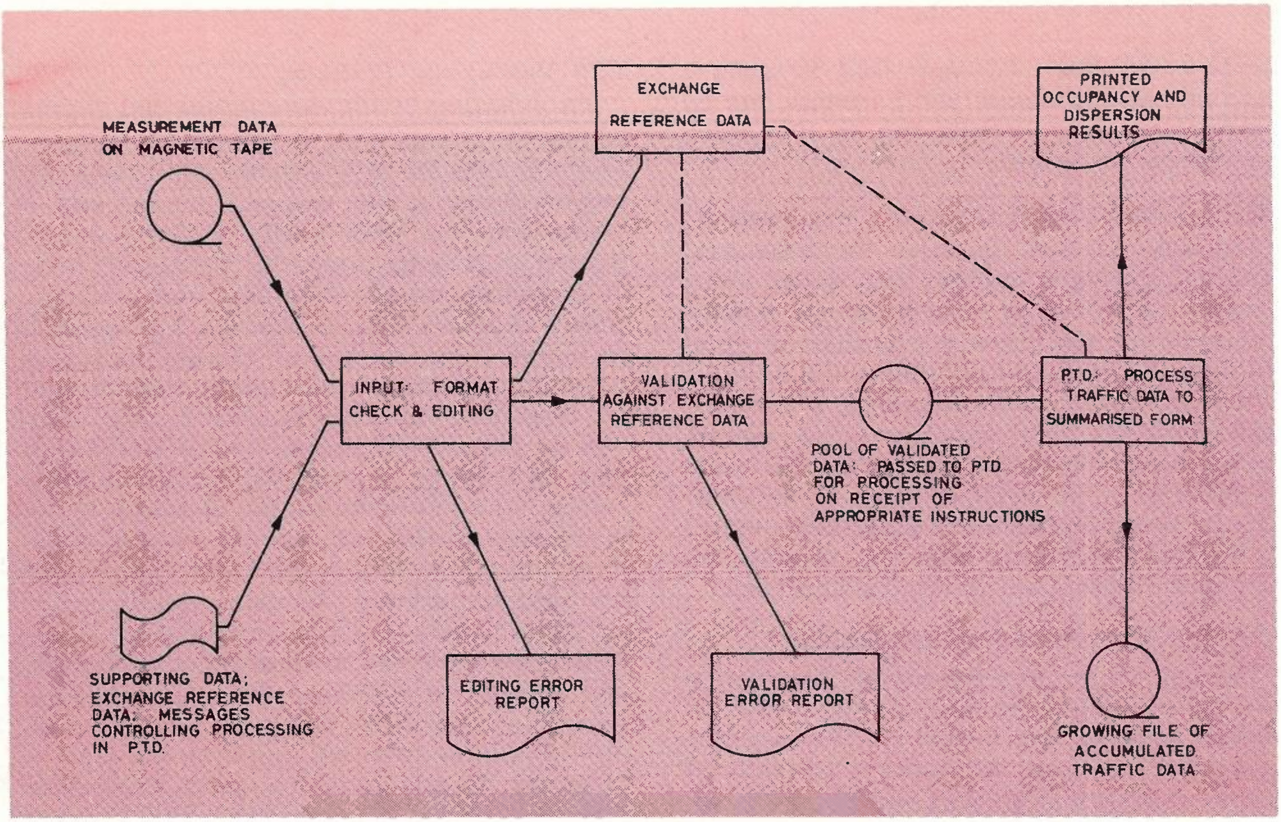

Fig. 1 — Traffic Data Processing System.

This information is presented separately, as averages over the measurement period for morning sessions, afternoon sessions, and evening sessions. If desired, the dispersion information can be obtained for a specified time period — e.g. for the time consistent busy hour of all outgoing traffic.

Sample output reports are included in Appendix 2.

Traffic Measurements at SPC Trunk Exchanges

The TDE is not used to obtain traffic measurements from Metaconta 10C SPC trunk exchanges. Instead, when occupancy, dispersion or call holding time measurements are required, the appropriate computer programs are loaded into the central processor, and following an input command, the measurement process proceeds concurrently with the normal switching functions of the exchange. The data obtained are transferred from a buffer area to magnetic tapes. These tapes also contain call billing and other data; pre-processing is therefore necessary to extract the traffic data, which is then processed in the same manner as TDE data, i.e. as shown in **Fig. 1.**

Interpretation and Utilisation of Measurement Data

Using the processed output from route occupancy measurements we can compute from the carried traffic on high usage routes an estimate of what the offered traffic was at the time of measurement. (A seasonal correction factor may then be applied to provide an estimate of what the offered traffic would be in the busy season of the year). Knowing the offered traffic, one can use the standard traffic tables to compute the number of circuits required on high usage routes, and to estimate the overflow to the final choice routes. A comparison may then be made between the actual number of circuits on the high usage routes and the required number of circuits. For final choice routes the congestion loss can be estimated from the measured traffics by referring to the appropriate traffic tables. Then, if congestion exists on a final choice route, it will be apparent whether this is due to under-provision of circuits on high usage routes causing excess overflow to alternative and final choice routes, or whether it is due to greater traffic than forecast being first-offered to the final choice route itself. Corrective action can then be initiated to alleviate the situation.

The estimation of offered traffics from traffic intensity measurements on high usage routes is time consuming and prone to error. For planning purposes, the re-dimensioning of outgoing routes can be done more efficiently and with greater accuracy if traffic dispersion measurements are available; this is because the processed output gives an estimate of the percentage of traffic offered to each destination code. Re-dimensioning using call dispersion data is not as accurate as when traffic dispersion data is used, due to the variation in average holding times of calls to different destinations, and at different times of the day.

The complete re-dimensioning of switching equipment and all incoming and outgoing junction and trunk routes is a lengthy process, and the results will generally not be available until some time after the measurements are completed. In fact, the traffic study does not generally initiate an immediate redesign, and the measurement data may be stored for some time until required by the planning engineers. However, an approximate check on the adequacy of switching equipment and circuit quantities on final choice routes is quickly performed by referring to the appropriate traffic table, using the carried traffic and the required GOS. Attention may then be promptly directed to routes experiencing congestion.

Sampling Accuracy

The accuracy of the sampling method of performing traffic intensity measurements is a function of the scanning interval (t), the number of busy hours over which the observations are averaged (T), the average holding time of calls (d), and the actual traffic (A) being carried on the route (Refs. 6,7). For routes with negligible loss, we can predict with 90% confidence that the mean of the measured observations will lie in the range —

$$A \pm 1.645(A.t/T)\,[(1+e^{-t/d})/(1-e^{-t/d})]^{1/2} \qquad (1)$$

(For high usage routes the range may usually be smaller because the variance of the measured traffic is generally less than its mean). The relative error is the width of the confidence interval divided by A.

When the mean traffic carried on a group of devices is small, or the average holding time is short, the three minute scan interval may mean that only a low degree of confidence can be placed in the results based on three minute, five day, sampling. If the circuit group has special importance despite its small size — e.g. a group of common control devices — then the method may be modified to yield a more accurate result. There are several ways of doing this. For example, we can decrease the sampling interval from three minutes to a smaller value; this may be accomplished by giving the particular circuit groups involved several spaced-appearances on the access switch to the traffic recorder. In the limit, if we go to continuous sampling — e.g. by the use of a chart recorder, or an equivalent instrument — the best possible accuracy is obtainable, but at a higher processing cost than if conventional sampling is used. (Note — such readings are still subject to statistical error due to source traffic variations with time).

The accuracy of estimating dispersion is a function of the sample size (n) and the actual proportion of calls to each particular destination. For example, if the actual proportion of calls to a particular destination is P, we can be 90% confident that the observed call dispersion will lie in the range —

$$P \pm 1.645\,[P(1-P)/n]^{1/2} \qquad (2)$$

We can improve the precision by taking a larger sample. However, the smaller the percentage of traffic to a destination the greater is the relative error for a sample of given size.

Supplementary Route Occupancy Measurements

A full-scale traffic measurement using TDE is an efficient method of measuring the mean and the variance of the traffics carried on a large number of circuit groups at an exchange, and for supplying dispersion information. As stated earlier, it is used (at exchanges greater than 1000 lines) to give a comprehensive traffic reading at intervals of approximately two years.

We use supplementary measurements to monitor the traffic carried on some of the final choice trunk and junction routes. One of these methods is to do a manual reading at the exchange using the Erlangmeter which is part of the permanently installed TDE equipment. Traffic intensity is sampled on the desired routes at intervals of (say) three or five minutes during the busy hour for five successive days. Sample values are recorded manually and the average is computed, thus yielding an estimate of the mean busy hour traffic.

The TDE is used in this manner by maintenance staff from time-to-time to get traffic data for routes thought to be in congestion. It is also usual at the larger exchanges to use manual readings to measure traffic on key circuit groups during the busiest period of the year. This enables key indicators, such as traffic usage rates per subscriber, to be measured throughout the network in the busy season.

A further refinement in use is to transmit daily route occupancy data for the route busy hour to a central location where it is automatically stored on magnetic tape ready for off-line computer processing. Ref. 8 describes one such system in detail. It is possible that on-line processing of this data by minicomputer will be used in due course.

Another method giving regular surveillance of final routes involves the use of Erlanghour meters. The Erlanghour meter is an integrating current meter which is calibrated to give a numerical indication of the traffic in erlang-hours which a circuit group has carried over the period of the measurement. The Erlanghour meters are switched on by a clock for the period of the pre-determined busy hour only. (Note that only the mean traffic and not the variance may be obtained from the Erlanghour meter reading, but this does not represent a significant weakness since an estimate of the variance-to-mean ratio will be known from a previous TDE measurement for each final choice route). One may compute from the appropriate traffic capacity tables the traffic that the route is designed to carry, knowing the number of circuits on the route, the design GOS and an estimate of the variance-to-mean ratio. At weekly or monthly intervals the measured traffic can be plotted on a graph and compared with the traffic capacity of the route. (In addition, the theoretical GOS on the final route may be computed from standard traffic tables). When the carried traffic is nearing the design figure, corrective action may be initiated in time to prevent the route going into congestion. One reason for Telecom Australia using Erlanghour meters for final route supervision is that the measurement data may be telemetered to a central location over junction cables and thus a considerable number of final choice circuit groups may be monitored from one location (Ref. 8). On the other hand, Erlanghour meters which depend on a variable speed direct-current motor for current integration, are not very accurate. However, the accuracy of the more modern electronic types is quite satisfactory.

When ad hoc rather than regular surveillance of traffic intensity on a final route is required we often use a chart recorder. The traffic recording lead for the circuit group (which is connected to the 100,000 ohm resistor on each circuit in the group), is wired to an input of the chart recorder. Thus, the recorder can be set up fairly easily and may be left unattended. A drawback is that the time taken to process the data is rather extensive. One processing method is to take sample values of the chart recording at intervals of three minutes, and by averaging over the busy hour, to compute the busy hour traffic. Another method is to use a planimeter to integrate the area under the curve for the period of the busy hour. If processing of chart recordings is being done on a large scale, digitising machines may be used to sample the chart recording at regular intervals; the output is recorded onto punched paper tape or magnetic tape and is suitable for computer processing.

At ARM trunk exchanges, a metered record is obtained for each route showing the total period of time during which all circuits are occupied. This information may give the first indication of imminent congestion on a final choice route, and will also show the effect on the grade of service of temporary outages of junction circuits.

Holding Time Measurements

The processing system produces reports which show the average holding time of calls to all destinations.

At crossbar exchanges special equipment is used to measure the holding time of common control devices — e.g. registers and code senders. In its simplest form, the equipment may comprise a pulse generator (with a pulse repetition frequency of (say) 1 pulse per second) which actuates a numerical meter at this rate for the period that the device being measured is in use. Another meter registers once per call and the ratio of the first meter reading to the second gives the average holding time. A refinement of this method is to have the successive pulses corresponding to a call in progress recorded onto punched paper tape. Using an 8-channel punch, data may be simultaneously recorded for 8 devices. By computer analysis, the mean and the distribution of holding times may be obtained — see Appendix 2(c).

For planning engineers to be able to dimension manual operator queues it is necessary to have data on the arrival rate of calls, and the average service time for each call offered to the operators. With SPC exchanges, including the Metaconta 10C, such data may be obtained from the routine statistics which are collected for supervision purposes. In older switching systems, event recorders can be used to measure the rate of call arrivals to the queues. The operator's service time for each call can be recorded (e.g. by the punched paper tape method), but a further component of the service time, not so easily measured, is the time taken by the operator to perform ancillary functions, such as writing of dockets and record keeping. From the gathered data, the percentage of calls experiencing a delay greater than the design figure may be computed, and also the average delay on all calls.

Holding time measurements are sometimes made to record 'delay before answer' on terminal equipment used at business premises — e.g. automatic call distributor equipment and the queues which offer calls to operators at private automatic branch exchanges.

Error Detection and Prevention

It can never be taken for granted that accurate results will be obtained from a traffic reading unless systematic precautions are taken to remove sources of error. Apart from sampling errors, invalid results can result from such factors as:

- errors in wiring between the traffic carrying circuits and the recorder
- malfunction of the recording equipment
- errors in the processing system.

Acknowledging this, we take special precautions to detect and prevent errors, and details are given in Appendix 1 of this paper.

FORTHCOMING DEVELOPMENTS IN TRAFFIC RECORDING

Before concluding this paper, it is appropriate to mention some forthcoming changes in our approach to traffic measurements — in particular:

- a system for daily recording of traffic,
- systems for individual circuit monitoring, and
- measurement facilities proposed for SPC exchanges.

Daily Traffic Recording

It is proposed to implement at crossbar and step exchanges an add-on monitoring system called Daily Traffic Recording (DTR) by which the call count and traffic intensity on selected circuit groups in metropolitan and rural exchanges will be recorded daily. The data will be telemetered to central locations for logging. This system will permit us to apply the standards of CCITT Recommendation E500 (which relates to international circuits) to a much greater extent in the national network than is done at present.

The system will comprise (a) traffic monitors in exchanges, (b) a centrally-located controller and data logger, and (c) a data transfer network. The monitors can read traffic data in analogue form from the traffic recorder leads associated with exchange equipment, or in pulse form from Erlanghour meters and call count meters. When directed by the controller, the monitors read the traffic and calls offered/calls lost data, temporarily store the information in a data holding register, and subsequently transmit the register contents to the central data logger. The telemetry network is operated at a transmission speed sufficient to ensure that all remote monitors can be interrogated within the desired scanning time (e.g. 3 minutes). The controller/data logger generates all control signals, accepts the data transmitted by the traffic monitors, and records it on a magnetic or paper tape for later computer processing. A description of one version of this system in use in Adelaide is given in Ref. 8.

For exchanges equipped with traffic monitors the system will be used to measure the following items:

a. Total originated, total terminated, and total local traffic. After weekly busy hour averaging these data will enable the average traffic per subscriber's line to be computed for every week of the year, including the busy season. It will also provide accurate means for seasonal correction of full scale traffic measurements taken outside the busy season.

b. Traffic intensity on selected circuit groups — e.g. final choice routes and common control equipment.

c. Call congestion loss and traffic congestion on final routes.

For final routes, the offered traffic may be accurately estimated from (b) and (c); this will permit traffic forecasts and network designs to be checked.

The system is seen as a significant step forward in our ability to accurately and economically monitor traffics at remote locations. This approach has also been specified for use at SPC local exchanges.

Individual Circuit Monitoring (ICM)

Commercially produced minicomputer and microprocessor based measuring equipment for large-scale monitoring of individual circuits is currently under evaluation by Telecom Australia. The equipment scans the state (idle or busy) of each circuit at frequent intervals (e.g. once per second). By this means, an accurate record of call seizures, occupancy and average holding time of each circuit is collected. From time-to-time, the calculated average holding time is compared with pre-specified upper and lower tolerance limits applicable to that circuit type, and exceptions are printed out. The rationale for this maintenance technique is that faulty items tend to have a holding time which is much shorter, or much longer than the range of values exhibited by devices which are functioning properly.

As a bonus, the individual circuits can be assembled in software data tables into groups. At desired intervals (e.g. every 15, 30 or 60 minutes), a printout can be obtained (remotely if desired) of the number of seizures and the traffic intensity for each group. This information can then be used for congestion supervision or for planning purposes.

The ability to measure, analyse, and report on live traffic in an on-line mode gives this new type of measuring equipment great potential as a maintenance aid and as a traffic gathering tool. An attractive aspect is that the ICM equipment can either be permanently installed at an exchange, or moved from exchange-to-exchange thus ensuring a satisfactory economic return. At existing crossbar and step exchanges ICM would have to be provided as an add-on facility (at relatively high cost) but will be built-in to SPC local exchanges.

Traffic Measurements at SPC Type Exchanges

Telecom Australia has several Metaconta 10C SPC trunk exchanges and is about to convert a very large number of ARF crossbar exchanges into partial SPC working (i.e. ARE-11). By the early 1980s, we expect to be installing full SPC local exchanges. The fact that SPC exchanges have in-built computing power gives traffic engineers hitherto unequalled opportunities for collection of traffic statistics.

With SPC local exchanges we have specified a requirement for the following data to be gathered on-line, and transmitted at 30 minute intervals to a central location:

- total originating traffic;
- total terminating traffic;
- total incoming traffic;
- traffic load statistics on selected groups;
- total call count on traffic offered to outgoing routes (calls offered, and calls failed due to congestion) — plus similar call count data for local traffic and for selected traffic groups.

This data will be used for daily traffic load, and congestion loss monitoring.

More extensive data are required for planning and design purposes, and will include:

- traffic occupancy for all circuit groups;
- traffic dispersion.

It will be possible to initiate the gathering of data by remote command. The specification is such that the data obtained should have a high degree of accuracy, and the automatic nature of the data gathering and transmission process should result in a low collection cost.

CONCLUSION

The statistical qualities of telecommunications traffic are very complex and special techniques, of the type described in this paper, have been developed to obtain accurate data at a reasonable cost. As mentioned, there are some differences in the types of data gathered for exchange maintenance and network monitoring compared with the more detailed data collected to meet the needs of planning engineers. Since much of the measuring equipment is used for both purposes it has been convenient to treat the overall subject of traffic measurement and processing practices for planning and maintenance in this one paper.

From the earliest days of traffic engineering, theory has generally been well in advance of our measurement capabilities. Possibly this will always be so. However, in recent years the considerable progress achieved in electronic technology has enabled a great step forward to be made in measurement and recording equipment. In addition, the advent of computers has, since the early 1960s removed constraints that previously existed in the processing area. Minicomputers and microprocessors are now being incorporated into measuring equipment and can be programmed to do on-line analysis and reporting. SPC exchange central processors have the capacity to provide traffic engineers with the information they need. Thus, modern technology has made possible a very considerable improvement in our capabilities for measuring and processing traffic data. The challenge to traffic and operations engineers is to make the best use of modern measuring equipment to help provide and maintain, a satisfactory telecommunications service in the face of ever-increasing traffic.

J.P. FARR is Senior Engineer, (Switching Standards), Regional Operations Branch, Western Australia. (See Vol. 28, No. 1, page 9.)

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ERROR DETECTION AND PREVENTION

It is necessary to employ special procedures such as the following, to eliminate and detect sources of error in traffic measurements.

Pre-measurement Checks

A typical 10,000 line ARF 102 exchange has about 3,000 common devices which carry traffic. With the day-to-day changes which take place to wiring in a working telephone exchange it is inevitable that over a period of time some errors will be introduced in the wiring between equipment items and the traffic recorder, and these should be detected and corrected prior to a traffic reading. Although it is certainly time consuming, we can do this by an electrical continuity test on each wire connecting an equipment item to the recorder. We generally recommend this procedure be followed since a significant number of cases of faulty wiring are generally detected and corrected at this stage, with corresponding enhanced confidence in the measurement results. After this testing is completed satisfactorily it is desirable to ensure that no changes are made during the period of the actual traffic recording.

Checks to be made during the Measurement Phase

The TDE equipment is provided with facilities in both manual and automatic reading modes for checking for unstandard battery conditions (as evidenced by a current flow which exceeds the known maximum), or unstandard earth conditions (as indicated by a resistance lower than the known minimum). Calibration loads of known values (e.g. 5, 10, 20 erlang) are permanently wired to known positions on the access switch. Variations from the standard value are easily detected and will indicate a fault in the recorder.

Data Editing

At the edit phase of the processing **(see Fig. 1)** the magnetic tape recording is checked for correct format and for parity errors, etc. Diagnostic messages are printed out by the computer when errors are detected.

Data Validation

At the data validation stage of processing **(See Fig. 1)** further checks are done—e.g. the maximum number of devices in use in each circuit group is compared with the number of devices supposed to exist on that route. If, on any occasion, the number of devices in use exceeds the size of the route, a diagnostic message is printed out by the computer. Similarly, for dispersion readings, each recorded call start is checked to see that there is an associated call finish, and vice versa.

Traffic Balances

For a route occupancy reading, when the first stage of processing has been done (i.e. the calculation of traffics for each half-hourly period), the computer program sums for each half hour the input traffic to each switching stage, and compares this total with the sum of the outgoing traffics. Errors of more than a small percentage indicate that there is inconsistency in the data—(e.g. if the output traffic exceeds the input traffic, some input devices may not be connected to the recorder).

Post-Processing Checks

When the processed results are available further checks are possible. For example, if route occupancy readings have been taken at both ends of the route in the same time period, the two results may be compared. Due to sampling errors the two results will not of course be identical but the application of Hayward's formula (Equation 1) enables us to determine the probability of a measurement error existing.

Finally, comparison of readings with previous measurements can be of help in indicating possible measurement errors, but we are limited by the degree of confidence in the individual measurements.

Conclusion

The above methods, which do not comprise an exhaustive list, show how a technical understanding of the measurement process, and switching system, enables logic to be applied to assist in minimising errors. The effort expended in reducing errors to a minimum will generally be recouped by the greater confidence which can be placed in the measurement results.

APPENDIX 2 — SAMPLE MEASUREMENT REPORTS

Sample output reports from traffic measurements using Traffic Data Equipment:

a. Detailed route occupancy information for one circuit group.

b. Portion of the summary of route occupancy information for all groups.

c. Portion of a call and traffic dispersion report.

Refer to the Section of the paper headed 'Traffic Data Equipment' for a description of these reports:

(a) TRAFFIC RECORDING ANALYSIS – DETAILS OF ROUTE OCCUPANCY

EXCHANGE: ATTADALE ARF

CIRCUIT GROUP: FIR I/C ROUTE FROM HILTON TANDEM

MORNING SESSION:

DAY	DATE	MAX. READ.	MIN. READ.	UNAVAIL AT MAX.	BUSY HOUR TRAFFIC	SEASONALLY CORRECTED BH TRAFFIC	HALF-HOUR-READING AVERAGES 09.00–09.30	09.30–10.00	10.00–10.30	10.30–11.00	11.00–11.30
TUE	7/06/77	50	12	0	37.85	41.63	33.20	42.40	33.30	31.00	27.60
WED	8/06/77	47	18	2	33.10	36.41	31.10	35.00	31.00	35.20	23.10
THUR	9/06/77	46	19	0	37.05	40.75	35.50	38.30	35.80	32.80	28.50
FRI	10/06/77	42	16	0	34.65	38.11	32.50	36.80	31.40	29.20	24.70
MON	13/06/77	43	16	3	35.50	39.05	30.40	36.80	34.20	24.80	22.00
AVERAGE FOR PERIOD					35.63	39.19	32.54	37.86	33.14	30.60	25.18

S.C.F. 1.10 NR.SUBS: 4910 NR.CCTS: 60 TCBH: 09.30-10.30 TCBH TRAFFIC: 35.50 (UNCORR)

AFTERNOON SESSION:

DAY	DATE	MAX. READ.	MIN. READ.	UNAVAIL AT MAX.	BUSY HOUR TRAFFIC	SEASONALLY CORRECTED BH TRAFFIC	HALF-HOUR-READING AVERAGES 14.00–14.30	14.30–15.00	15.00–15.30	15.30–16.00	16.00–16.30
TUE	7/06/77	36	15	2	25.80	28.38	22.70	20.50	20.80	22.10	29.50
WED	8/06/77	30	12	1	22.25	24.47	17.10	20.90	23.60	19.40	23.20
THU	9/06/77	40	11	0	26.10	28.71	19.30	21.50	22.20	23.10	29.10
FRI	10/06/77	35	10	0	22.65	24.91	16.20	15.90	18.90	18.70	26.60
MON	13/06/77	43	13	0	33.60	36.96	20.30	19.70	23.50	31.20	36.00
AVERAGE FOR PERIOD					26.08	28.68	19.12	19.70	21.80	22.90	28.88

S.C.F. 1.10 NR.SUBS: 4910 NR.CCTS: 60 TCBH: 15.30-16.30 TCBH TRAFFIC: 25.89 (UNCORR)

(b) TRAFFIC RECORDING ANALYSIS – SUMMARY OF ROUTE OCCUPANCY

INDIVIDUAL EXCHANGES READ	SUBS.
ATTADALE ARF	4910

MORNING SESSION: 9.00–11.30 7/06/77–13/06/77
AFTERNOON SESSION: 14.00–16.30 7/06/77–13/06/77
EVENING SESSION: 18.00–20.30 7/06/77–13/06/77

CIRCUIT GROUP NAME	AVAIL-ABIL-ITY	NR. CCTS	TCBH BEGIN TIME	TCBH TFC (UNCORR)	TCBH TFC (SEAS) (CORR)	BUSIEST HR TFC (UNCORR)	BUSIEST HR TFC (SEAS) (CORR)	AVE CCT OCCY	TFC AT TCBH O/GRP	V/M RATIO	BHOR JUR BHTR	TRAFFIC TABLE	CCTS REQD.
FIR I/C FROM SOUTH PERTH IGV		05	9.30	3.25		3.55		0.65				HU	
FIR I/C FROM SUBIACO IGV		07	10.00	3.57		3.88		0.51				HU	
FIR I/C FROM TUART HILL IGV		05	10.00	2.48		2.81		0.50				HU	
FIR I/C FROM VIC PARK IGV 1		05	10.00	3.68		3.98		0.74				HU	
FIR I/C FROM PIER OM 'X' TANDEM		05	9.00	2.80		3.08		0.56				HU	
FIR I/C FROM COTTESLOE STEP	20	20	10.30	8.62	9.48	9.78	10.76	0.43.		1.21		BC 20 .005	18
FIR I/C FROM HILTON TANDEM	60	60	9.30	35.50	39.05	35.63	39.19	0.59		0.78		J 1300 .005	55
TOTAL I/C JUNCTION TRAFFIC		279	9.00	130.61				0.47					
TOTAL I/C GIV TRAFFIC		315	9.00	132.57				0.42					
TOTAL O/G GIV TRAFFIC		430	9.00	130.13				0.30					
TOTAL TERM TRAFFIC		480	9.00	151.15	166.27			0.31			0.034		
TEST VALUE 2 E		02	.00	2.00		2.00		1.00					
TEST VALUE 10 E		10	.00	10.00		10.00		1.00					
TEST VALUE 25 E		25	.00	25.00		25.00		1.00					

(c) TRAFFIC RECORDING ANALYSIS – TRAFFIC AND CALL DISPERSION

ORIGIN: MULLALOO 1GV

MORNING 8.30–11.30 25/06/76–1/07/76
AFTERNOON 14.00–16.30 25/06/76–1/07/76
EVENING 18.00–21.00 25/06/76–1/07/76

DESTINATION		TOTAL CALLS			AVERAGE CALL HOLDING TIME (SECONDS)			PERCENTAGE OF CALLS			PERCENTAGE OF TRAFFIC		
CODE	DESTINATION	MORN.	AFTN.	EVEN.	MORN.	AFTN.	EVEN.	MORN.	AFTN.	EVEN.	MORN.	AFTN.	EVEN.
21	CENTRAL	1300	530	177	104	143	67	8.3	5.2	2.0	5.25	4.43	0.54
23	PIER	199	139	10	219	155	167	1.3	1.4	0.1	1.69	1.26	0.08
24	MT HAWTHORN	128	96	52	114	187	439	0.8	1.0	0.6	0.57	1.05	1.05
25	PIER	181	108	19	172	243	130	1.2	1.1	0.2	1.21	1.53	0.11
26	GOVERNMENT INDIAL	179	82	9	81	131	26	1.2	0.8	0.1	0.56	0.63	0.01
27	SPARE	3	1	2	13	4	20	0.0	0.0	0.0	0.00	0.00	0.00
28	BULWER	628	294	113	113	143	205	4.0	2.9	1.3	2.75	2.46	1.06
20	CENTRAL INDIAL	102	63	4	191	260	232	0.7	0.6	0.1	0.75	0.96	0.04
31	COTTESLOE	273	171	212	200	155	286	1.8	1.7	2.4	2.11	1.55	2.78
35	FREMANTLE	149	127	57	154	190	168	1.0	1.3	0.6	0.89	1.41	0.44
37	HILTON	70	51	93	409	322	305	0.5	0.5	1.1	1.11	0.96	1.30
39	PALMYRA	64	35	50	261	148	311	0.4	0.4	0.6	0.65	0.30	0.71
30	ATTADALE	80	37	81	175	196	463	0.5	0.4	0.9	0.54	0.42	1.72
41	SCARBOROUGH	327	180	305	290	260	286	2.1	1.8	3.4	3.67	2.74	4.00

"Potentiometric" 100 Pair Cable Identifier

A. J. WILSON, M.I.E. Aust.

A 100 pair cable identifier which provides a digital readout of pair number and leg of wires at the point of enquiry, by using potentials which are directly proportional to the pair number and are of the same sign as the leg, has been developed. Its principles of operation and its physical realizations are discussed in this article.

INTRODUCTION

In past eras cables were made up in concentric layers of 2 pair (star quad) units. In each layer one quad carried a characteristic whipping which identified it as the reference pair. Jointing was carried out so that quads were jointed pair to pair in strict rotation enabling a jointer to find any pair by counting layers and then quads from the reference quad in the layer. Not always was such an ideal arrangement achieved in practice and it was therefore necessary to confirm the rotation by sending a tone on the pair from an exchange MDF or pillar terminal to prove the pair and then the individual wires of the pair.

More recent cables are made up of units of concentric layers of pairs. The units, which contain 25, 50 or 100 pairs depending on the size of the cable, are then made up in concentric layers to form a cable of circular cross-section. Within each unit there is a reference pair per layer but only the reference pair in the outer layer is jointed to the corresponding reference pair in the next cable length. The remaining pairs within a unit are jointed randomly to pairs in the corresponding unit in the next cable length. This has two beneficial effects:

- it speeds up jointing,
- it reduces crosstalk.

The major disadvantage is that without a ready means of identifying pairs and wires of the pairs it presents a tedious job when the cable is being terminated on pillar terminals, or cabinets, where the sequence and polarity must be identical with that existing on the MDF; or in the case of junction cables where the MDF sequences and polarities must correspond; or in the case of cable damage repair where a section of cable is replaced by the random jointing of one end and the identification and jointing of the other end.

Traditional methods consist of using a man at each end of the cable — one sending a tone and the other searching for it — to ascertain the identities of all wires.

A development which overcame the searching effort but still required a man at both ends of the cable was the Devey 100 pair identifier. This system uses an identifier that gives a digital readout on Decatron tubes at the exchange end of a cable when a probe is placed on a wire at the remote cable end. The identification is then relayed over a speak circuit to the remote end jointer.

The disadvantages of this system are:

- The jointer must wear a headphone for prolonged periods and concentrate on his mate relaying the wire numbers,
- It requires two people full time to operate,
- The physical arrangement necessary at the exchange precludes more than one jointer identifying at a time within one cable or adjacently terminated cables.
- The physical design of the connector which connects to the link mounting provides for small piston type contacts to press on the ends of the tags to which the cable is terminated. These ends can have solder dags or resin blobs which militate against good contact. The contact pressure is determined by the position of the tag end with respect to the edge of a metal surround which forms part of a mounting plate on large MDFs. As this is not a critical dimension, it is not controlled to the extent that is necessary for this application.
- In transportable exchanges, this mounting plate is not used and hence the Devey identifier cannot be connected.

The poor contact aspect is a real problem with this device and the author has witnessed instances where up to 50 per cent of the wires in a cable could not be identified because of it.

DESIGN OF AN IMPROVED IDENTIFIER

Two main requirements for a new design were apparent:

- An effective connector for the link mounting,
- A system which carried the identification of each wire on the wire itself so that the jointer could read it off directly with a digital readout.

The essential design criteria of an effective connector were established as:

- The device must make a wiping contact with the link — not the cable terminating tag — of sufficient force to ensure good contact despite thin films of resin of corrosion products,
- It must be capable of easy alignment on all types of link mounting and not dependent on top and bottom mounting plates for attachment and positioning,
- The device must be easy to fit without projecting levers that would foul travelling ladders and add to the weight, and increase the risk of, and danger from, dropping from the top of an MDF.

A design was evolved which consisted of 23 single knives and one double knife which are pivoted at one end on a vertical shaft. This is located by a mounting plate that slips into position over the front of the link mounting block. The knives each carry 8 nickel silver contact springs which are elastically deformed as they are slid into contact with the link mountings and so ensure a reliable contact. As the knives can be rotated into position singly there is no need for elaborate lever systems and isolation of wires can be easily effected. **Fig 1** shows a connector to suit 100 pair link mountings.

Various methods of providing the identification on the wires were examined. These included tones, coded pulses, time referenced pulses, and DC potentials.

The use of DC potentials was pursued because of the simplicity of providing voltage division by elements mounted directly on the knives and because it required only two wires to connect from the ganged knives to a power supply.

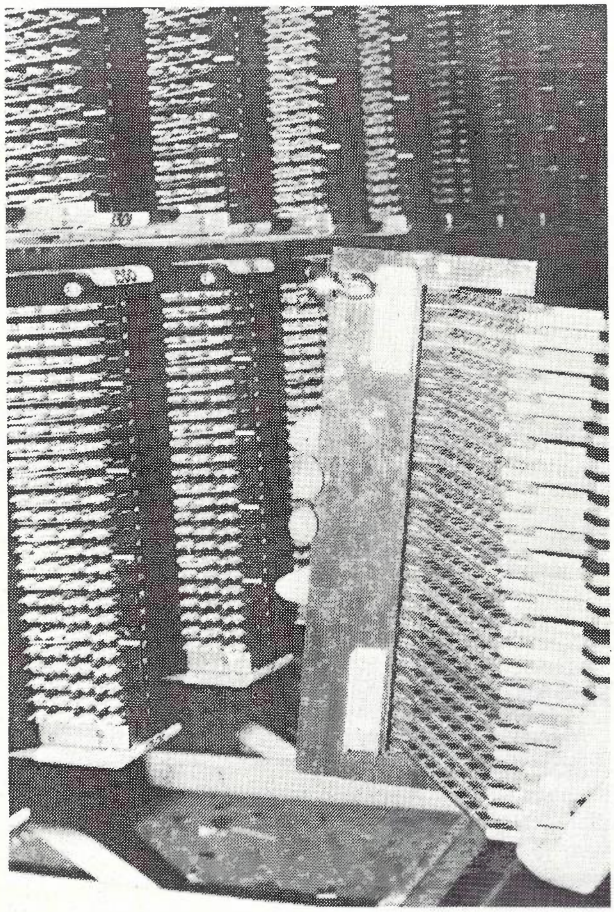
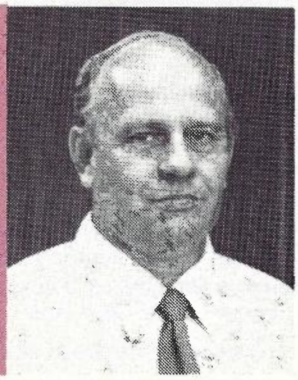


Fig 1 Connector for 100 Pair Link Mountings

Other systems would have required far more elaborate electronic circuitry which would most likely have had to be mounted separately from the connector and interconnected with it via a 200 wire cable.

AUSTIN WILSON joined the PMG Dept in 1946 as a Technician-in-Training. In 1956, he was appointed a Trainee Engineer after serving as a Senior Technician on Long Line Installation, Country Maintenance in North West Queensland, and Metro Installation in Brisbane, followed by a year as a Technical Instructor.

In 1960, he was appointed Engineer Grade 1 and has since served in Rockhampton, Central Office Lines Section, Trunk Service, Country Exchange Installation, Metro Installation and, for the last six years, has been Senior Engineer, Internal Plant for Metro North Brisbane.



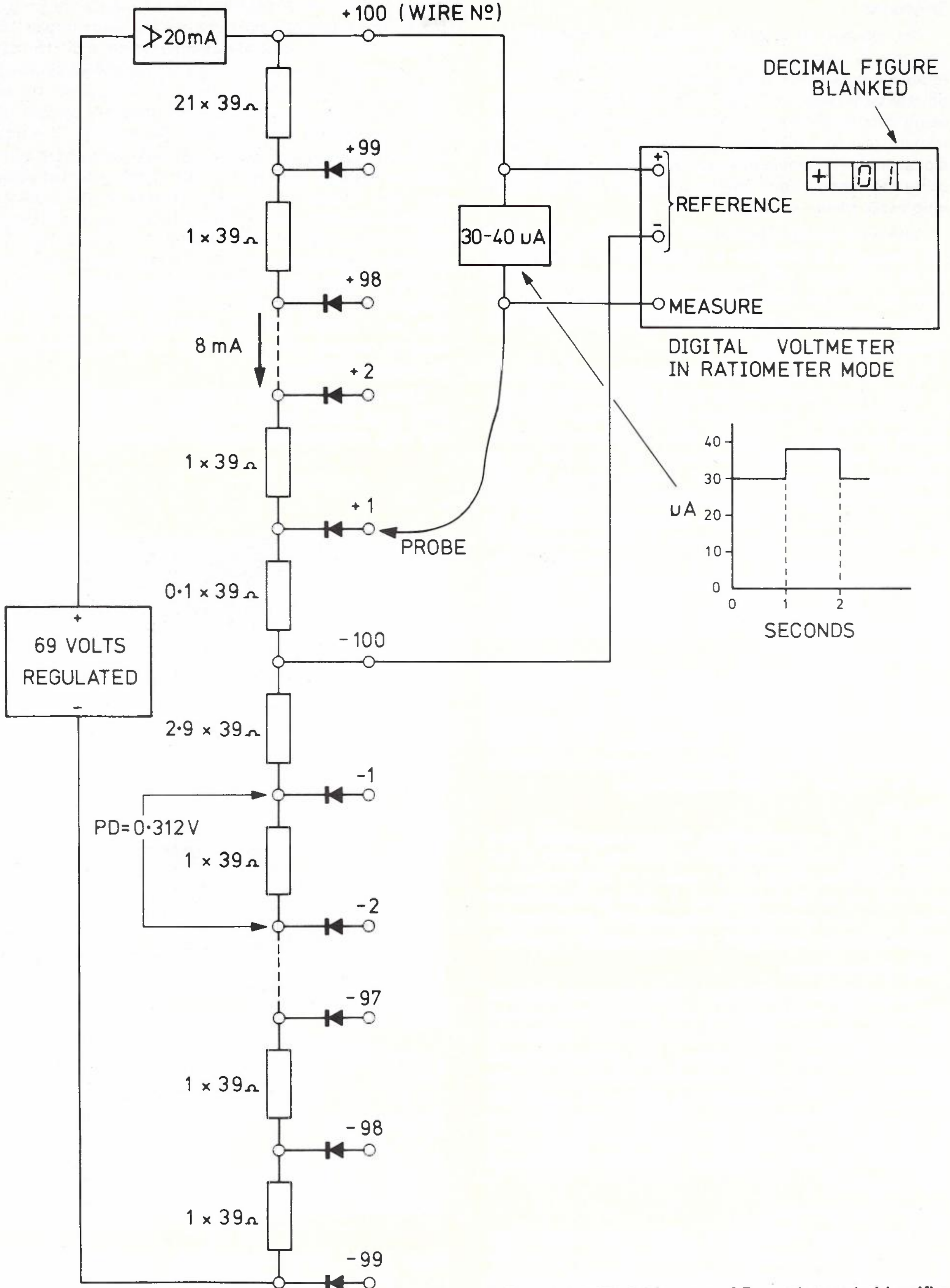


Fig 2 Schematic Diagram of Potentiometric Identifier

Principles

The identity of a wire is derived by measuring its potential in both magnitude and sign with respect to a reference wire which is pair 100 -ve. The units of potential are very close to 0.312 volts with the precise value being determined by the potential of pair 100 +ve with respect to pair 100 -ve. This potential is applied to a digital voltmeter where it is used as a reference instead of using the meter's own internal reference. This is called ratiometer mode working.

Reference to **Fig 2** will show how all the +ve wires are connected to points on a voltage divider so that they are all +ve to pair 100 -ve and their potential is related to their pair number. In like manner all -ve wires from 1 to 99 are connected to points which are -ve to pair 100 -ve.

Immunity to Cable Faults

If a simple voltage divider network is used then any faults on pairs 1 to 99 would affect the network and give erroneous results. Hence each wire is isolated from the divider by a diode. To ensure that the diodes provide a constant voltage drop irrespective of the wire being measured, a stepped constant current source is connected to the search probe and is driven by the potential on pair 100 +ve. The current which steps between 30 and 40 microamps every second provides a potential drop of 1.4 times 0.312 volts or 1.4 units as read by the digital voltmeter. When the probe is placed on a wire the reading is 1.4 units more positive than the potential of the point of the divider network to which it is attached.

Margin for Variations

The points on the voltage divider network are arranged so that the reading on the digital voltmeter reads 0.5 units higher than the wire number. This allows a variation of +0.4 or -0.5 before an error occurs in the unit digit. The decimal figure is not displayed in the search mode so that no operator confusion is generated.

Example

If pair 1 +ve is considered, it has a connection via a diode with a voltage drop of 1.4 units to a point in the divider network which is 0.1 units +ve with respect to pair 100 -ve. In like manner pair 1 -ve is connected via a diode to a point which is 2.9 units -ve with respect to pair 100 -ve to give a reading of -1.5 on the digital voltmeter.

Faulty Cable Indicator

Leakage resistance between wires will cause incorrect readings to be displayed if the wire has leakage to one or more other wires which are more -ve than it. To alert the operator that such is occurring, the constant current generator is stepped at a 1 second rate between 30 and 40 microamps. This causes the reading to constantly change and indicate to the operator that a fault exists and to disregard the reading. To successfully identify every one of a 100 pairs the leakage resistance must exceed 2.5 megohms.

Receive Unit Calibration

Because pair 100 +ve is used to drive the probe constant current generator it has to be +ve to pair 99 +ve by much more than one unit of 0.312 volts. In fact it is 19.6 units, i.e. 6.1 volts more +ve. This is readily achieved with a preferred value of resistance of 820 ohms. The total potential between the wires of pair 100 is equal to 119.1 units of potential which is 37.16 volts. This potential is used to calibrate the digital voltmeter by adjusting it by means of a screw potentiometer to read 119.1 when the search probe is connected to pair 100 +ve. This facility is provided in one position of a three position lever key. The digital voltmeter when used in this manner reads in units of 1/119.1 of the potential across pair 100. Hence the voltage applied to the potential dividing network which is 69 volts can vary + or - 5 volts before the margin of safety which is -0.5 or +0.4 of a units digit is deteriorated by 0.1. The deterioration is caused by the isolating diodes which have a constant absolute potential drop irrespective of dividing network potential. But as a simple voltage regulator can maintain the dividing network potential within ± 0.5 volts this is only of academic interest.

This system will work without introducing error on lines up to 3000 ohms loop resistance. It is not usual for the loop resistance of subscriber cable to exceed 1200

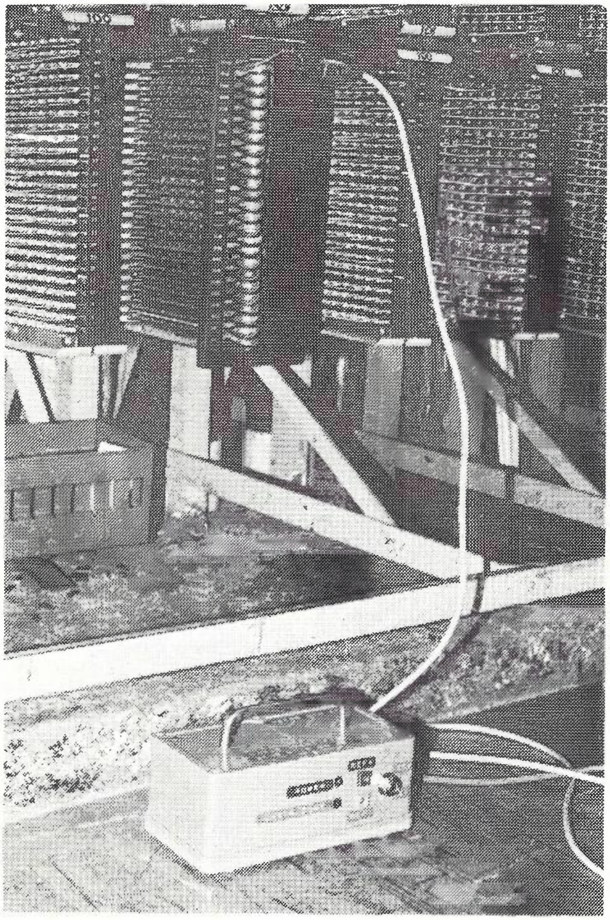


Fig 3 Send Unit Connected to 100 Pair Link Mounting Connector in Position on the Link Mounting Block

Fig 4 Receive Unit in Operation

ohms and as 3000 ohms represents 27 kilometres of 0.65 mm junction cable there is virtually a zero probability that it would be required to work outside its capability.

Identification of Individual Wires of a Contacting Group

Where two or more wires in a 100 pair unit are in contact there can only be one reading obtained for them all, and this is the reading of the wire within such a group which is connected to the most negative part of the potential chain. If this wire is isolated by withdrawing the knife and placing an insulating strip over the contact and then re-inserting, then the next most negative wire in the contacting group will be displayed. Hence all wires of the group can be progressively identified.

Design Realisation

The final design consists of a **Send Unit** which is 240 volt ac operated and connected via a three way plug-in cord to a 25 knife connect unit which attaches to a 100 pair or 50 pair link mounting, and a **Receive Unit** which is powered either by an internal 9 volt battery or an external 12 volt battery.

Send Unit

The Send Unit shown in **Fig 3** consists essentially of a regulated 69 volt dc power supply which is current limited to 20 milliamps. These values are sufficiently low to avoid danger or discomfort to the jointer but adequately high to achieve resolution to the first decimal point on a small commercial digital panel voltmeter. A supervisory light is provided to indicate that the potential dividing chain is electrically intact, and there is provision to connect to pair 100 (reference pair) either via a standard MDF shoe plug or 4 mm banana plug. This feature allows the use of a pair, other than one within the 100 pair group being identified, as a reference pair if difficulty is experienced in finding pair 100.

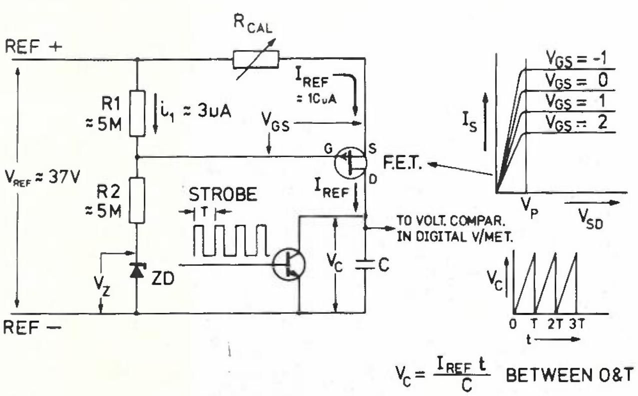
Receive Unit

The Receive Unit shown in **Fig 4** is constructed around a Digital Panel Voltmeter which is nominally 6 volt operated, but still operates down to 4½ volts. The Digital Panel Meter (DPM) is connected in the ratiometer mode in which its readings are in units which are some constant times an externally connected reference current. In this case the externally connected reference current is supplied by pair 100 and the constant is set by calibrating the meter to read 119.1 units when pair 100 is also connected to the measure terminals. As the circuit into which the reference current flows is a capacitor which is periodically discharged by the strobing clock, it was necessary to evolve a circuit, shown in **Fig 5** which would not only provide a constant charging current as required, but ensure that this current be a linear function of the voltage on pair 100. This is achieved with a FET which is biased by a voltage which is a fraction of the voltage of pair 100 minus a fixed offset (achieved with a zener diode).

The stepped constant current supply for the search probe is similarly obtained with a FET whose bias is stepped at a 1 sec. rate by a multivibrator.

Idle Blanking of Display

In the search mode the display is blanked by a logic circuit unless a reading of 00 to 99 is to be displayed — this conserves the battery by reducing the drain from approx 160 mA to about 70 mA when actual identification is not being carried out.



SUMMING VOLTAGES AROUND F.E.T. BIASSING LOOP

$i_1 R_1 + V_{GS} = I_{REF} R_{CAL}$

V_{GS} IS VIRTUALLY CONSTANT FOR LARGE RELATIVE VARIATIONS OF I_{REF} BECAUSE $I_{REF} = 10uA$

$i_1 R_1 = (V_{REF} - V_Z)\frac{R_1}{R_1 + R_2}$

IF ZENER DIODE IS CHOSEN SO THAT $\frac{R_1}{R_1 + R_2} V_Z = V_{GS}$

THEN $\frac{V_{REF} R_1}{R_1 + R_2} = I_{REF} R_{CAL}$

$\therefore\ I_{REF} = \frac{V_{REF}}{R_{CAL}} \times \frac{R_1}{R_1 + R_2}$

i.e. I_{REF} IS DIRECTLY PROPORTIONAL TO V_{REF}

Fig 5 Circuit to Provide Reference Current to the Digital Voltmeter — Current Must Be Constant and Directly Proportional to Reference Pair Voltage

Receive Unit Power Supply

The battery consists of six D size cells giving 9 volts. This is regulated to provide a 6 volt supply to the panel meter until the battery falls below about 6.8 volts. The battery can fall to approx. 5 volts before the Panel Meter gives erroneous readouts, but at about 5 volts the LED (readout) brilliance has waned sufficiently to make reading difficult and warns of low battery voltage before errors are incurred. With these voltage ranges (9 volts down to 5 volts) it is possible to use the battery to approximately 90% of its stored capacity.

Receive Unit Function Switch

A three position lever key provides a calibrate position, a search position and a voltmeter position where the Receive Unit can be used as a conventional 0-100 DC voltmeter. Also in this position the voltage of the internal battery can be checked by pressing a non-locking button switch.

Housing of Send and Receive Units

The Receive Unit is mounted in a low cost, easily obtainable Rigid PVC adaptable box of dimensions 20 cm x 10 cm x 7 cm (approx.). This provides a very serviceable housing with good impact strength, easy operation, and very good electrical and thermal insulation. The latter two attributes are particularly necessary as the input impedance is about 10 megohms and stray leakage could be troublesome; further, if the unit is left in the sun, as easily could happen in the field, a high thermal insulation is required to prevent rapid temperature rises causing differentials which would affect the meter's accuracy. The 100 pair Send Unit is mounted in the same type of box.

Connectors

Connectors have now been developed and field tested to provide connection to new type 100 pair and 50 pair link mountings, old 50 pair link mountings, 900 pair and 1800 pair pillar terminals.

Pillar Terminal Send Unit

A battery operated Send Unit is available for pillar terminal use.

A 600 PAIR IDENTIFIER

A more recent development which at present has not been fully field tested is a 600 pair identifier.

This system shown in **Fig 6** consists of a Send Unit which is 6 x 100 pair send units which are electrically isolated from one another but mounted in the one box and using the one power transformer. The reference pair of each 100 pair unit is modulated with a pip tone. The number of pips corresponds to the hundreds group to which it belongs. The jointer can find his reference pair very easily with his "F" set and he positively identifies it as belonging to a specific hundreds group.

The normal 100 pair Receive Unit is used for identifying and it will give readouts only on wires in the hundreds group to which the reference pair which is being used belongs.

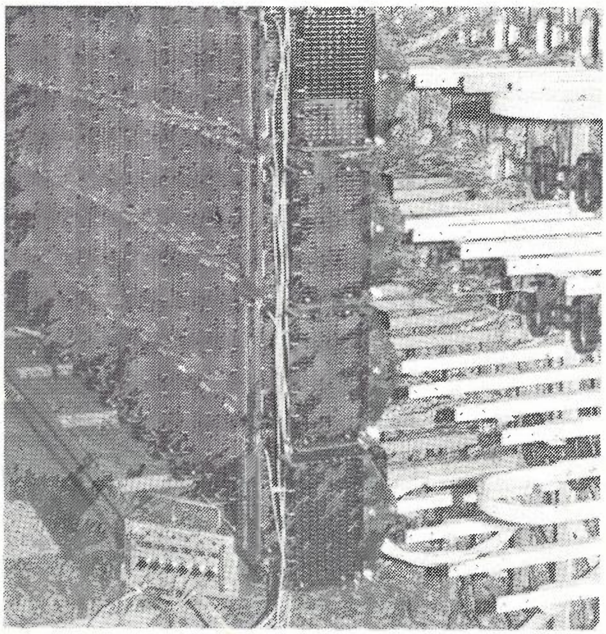


Fig 6 600 Pair Send Unit in Operation

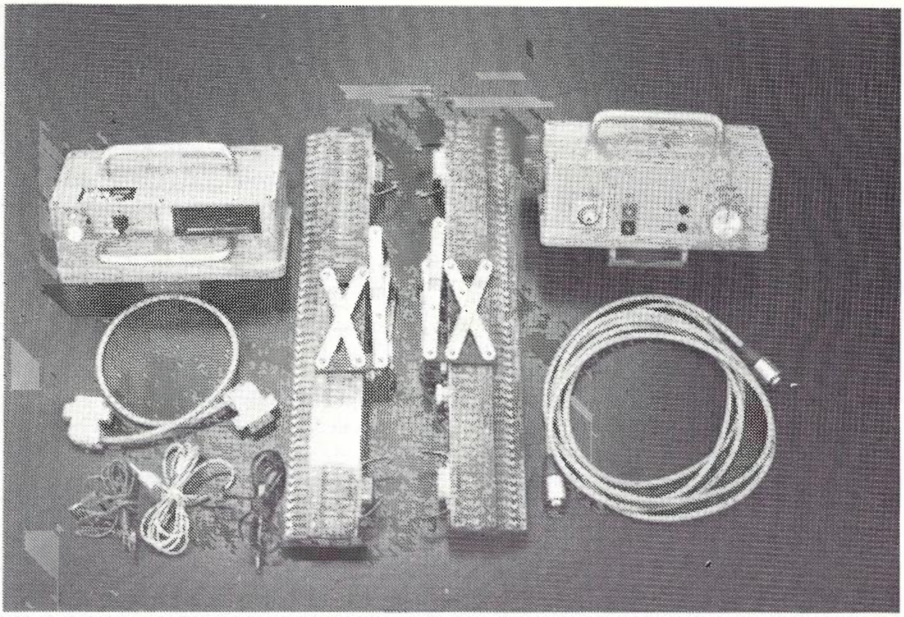


Fig 7 Pillar Identification Kit

A jointer can thus operate independently of the telephone exchange and having set up a 600 pair Send Unit at the start of the day could identify and joint all pairs within a normal working day using a jointing machine. Alternatively a Send Unit can be set up for any multiple of 100 pairs from 1 to 6. The 100 pair units do not necessarily have to be in sequence within the cable. Another application is to the situation wherein a number of jointers are identifying different units within the same cable at separate locations simultaneously, or, in the case of a major fault, at the same location.

If voice communication is required between the sending end and the jointer it can be provided on the reference pair with any form of speak sets on condition that they are capacitively coupled to it.

SENDING FROM A PILLAR OR CABINET

The pillar terminal connector — which is a pair of 50 pair connectors — (shown in **Figs 7** and **8**) can be connected to a 100 pair tail terminal strip or to 100 pairs of a 200 pair tail terminal strip (as fitted to 1800 pair pillars) with or without jumpers connected. If the connectors and a 600 pair Send Unit are available then up to 600 pairs can be set up for identification.

In general, identification will be performed on non working cables. If there are telephones connected to pairs but the exchange links are removed, positive identification can be carried out provided pair 100 is not looped by a subscriber. Precautions such as the removal of the jumper from pair 100 if identifying back in the main cable from a pillar, or opening pair 100 at the joint if identifying a distribution cable, would be desirable. If a pair is looped by the subscriber then both legs will be identified as -ve legs of the correct pair. If correct polarity is required then it would be necessary to open one leg to determine it.

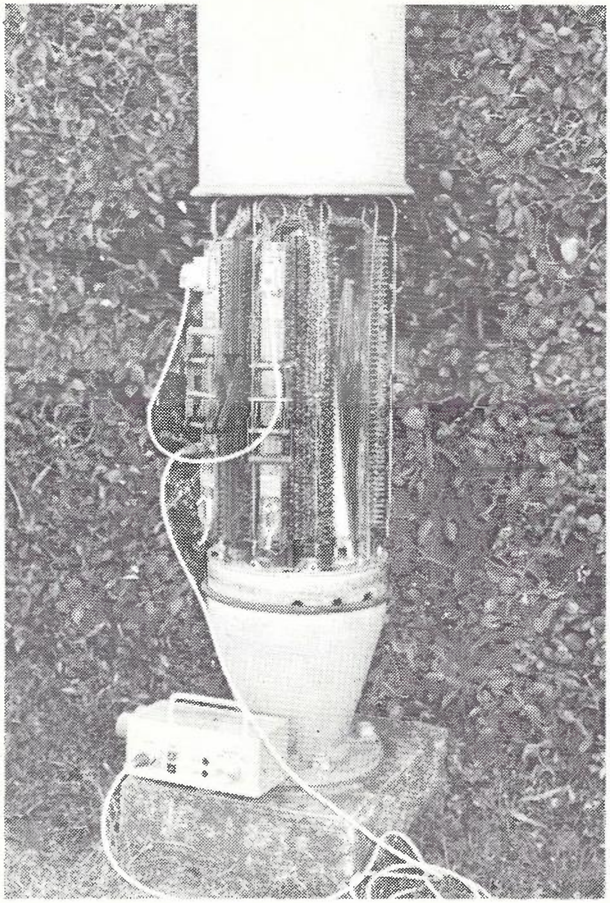


Fig 8 Pillar Terminal with Send Unit Connected via Pillar Connect Units Ready for Identification

IDENTIFICATION IN WORKING CABLES

The identifier can be used to a limited degree in working cables without interference to working services.

The constraints are as follows:

- Only spare pairs can be correctly identified.
- The pillar terminal connector is the only means yet developed to connect to a working cable without disconnecting services.
- If pair 100 is not spare, or not available at the point of identification, then it must be insulated from the connector by placing plastic tubing over the terminals. Another pair which is spare and available at the point of identification must be used for a reference pair.

When working pairs are probed completely different and erroneous readings will be obtained on each leg of the pair making identification quite positive. Confirmation is easily effected by switching the identifier to the voltmeter mode and checking for exchange battery potential on the pair.

CONCLUSION

A more effective and efficient system of cable identification has been developed with the resources of the Technical Evaluation Centre attached to District Engineer Metro North Brisbane.

The identifier lends itself to further development as a control unit for a cable pair tag dispenser, which could print the tag as required or select a pre-printed one from a carousel or similar device.

ACKNOWLEDGEMENT

Special acknowledgement is due to Mr J. Gulley, Technical Officer, whose skills and ingenuity were mainly responsible for the physical realisation of the connectors.

In Brief

"How to Use an Oscilloscope," a new colour videotape program designed to provide a basic education in the theory and operation of waveform measurement with oscilloscopes is now available from Hewlett-Packard Company.

The three videotape program has a total running time of 76 minutes. The first two tapes are dedicated to front panel controls, the last to measurements. Hewlett-Packard models 1740A general purpose and 1741A storage scopes are used in the demonstration, however, the programs offer general instruction in the use of all oscilloscopes.

Topics discussed include:

Tape 1

- Measurement of peak-to-peak ac voltage, time period, frequency and dc component of a waveform
- Measurement of low-level signals such as power supply ripple
- Triggering or synchronising the scope to obtain a stable display on the CRT
- Avoiding errors in control settings that could lead to measurement inaccuracies.

Tape 2

Completes the coverage of the front panel controls of general-purpose oscilloscopes, including the dual-channel operations of dual trace, A+B, A−B, and A versus B modes. Also covered are selectable and composite triggering, trigger-view mode, bandwidth limit and delayed sweep operation.

Tape 3

- How to check scope and probe
- Three types of probes
- How to make typical oscilloscope and voltage measurements
- Solving the problem of viewing low rep-rate signals and one-shot events with a storage oscilloscope.

Each video cassette in the program costs $300, though large orders are eligible for discounts of as much as 35%. All cassettes are in a 3/4-inch format. A descriptive brochure is available without charge from HP offices.

For further information contact HEWLETT-PACKARD AUSTRALIA PTY LTD 31-41 Joseph St., BLACKBURN, VICTORIA 3130. Telephone 89 6351. Branches in Adelaide (272 5911), Brisbane (229 1544), Canberra (80 4244), Perth (386 5455), and Sydney (449 6566). Also in Auckland and Wellington, New Zealand.

Meet the logical solution to those illogical computer network problems . . . HP's new Serial Data Analyzer. It's easy to use, flexible and low cost, ($5800).

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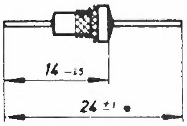
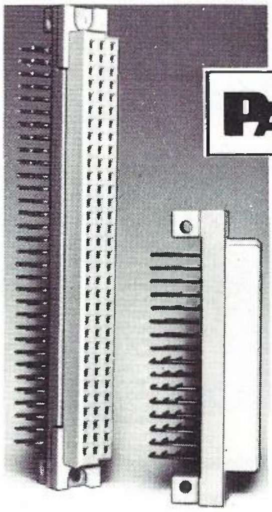
This is a STETTNER Ceramic Feed-through Capacitor



It fits a 3.6mm dia. hole. Capacitance range is 2 to 220pF. Larger sizes up to 1200pF. The Stettner range includes pearl capacitors as small as 3.3mm dia x 4mm, as well as disc, tubular, multilayer and other special forms for modern circuitry. They are used world wide by manufacturers of electronic and communications equipment, appliances, instruments etc., wherever reliability is important.



PANDUIT GmbH PRINTED CIRCUIT CONNECTORS

This Munich-based specialist developed a competitively priced range of printed circuit connectors, and they have already proved themselves on the European market. Expected to be equally popular in Australia, these connectors feature reliable, longlife contact design as well as excellent legibility of the contact numbers.

WATKINS-JOHNSON

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These exceptionally lightweight, thin-film, Voltage Controlled Oscillators are specifically designed for use in portable and even hand-held equipment. Economical and high-performance, they are ideally suitable for direct printed circuit board integration, particularly for high volume applications.

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- Militarized
- Octave Bandwidth
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Encapsulated Power Supply produced by BULGIN

Renowned for their reliable and high quality, small electronic components, Bulgin developed this power unit to supply a power line for a vast array of direct current loads, including small signal lamps, relays, transistor or integrated circuits, transducers, etc., etc. These supplies are encapsulated in chemical-resistant plastic and epoxy resin for long service. On overload, supply closes to a trickle current, and recovers without attention on removal of the overload.

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For more information about the 832 Data Comm Tester, call your nearest Tektronix office.

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Meet the Latest Addition to the HP9800 Family

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It's easy to use, even for a beginner. System 35 is ready to begin solving your problems as soon as you turn it on. There's no complicated start-up procedure to follow, no operating system to load, no compiling to do. It lets you interact with every step of the problem solving process – on the spot, with no waiting.

The System 35 offers Enhanced BASIC Language – the same as used with System 45 containing powerful FORTRAN and APL features. Also available is Assembly Language capability – which provides a valuable option for skilled assembly programmers who need more speed and power. Hewlett-Packard offer a range of desktop calculators, from the small 9815, to the powerful 9825, and the full graphics capability of the 9845. Now with the addition of System 35 HP have a desktop calculator that suits your individual applications.

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ABSTRACTS: Vol: 29, No. 1.

BEARE, C.T.: '2400, 4800 and 9600 Bits/s Transmission on the Switched Telephone Network;' Telecom Journal of Aust., Vol. 29, No. 1, 1979; page 54.

The Telecom Australia Datel Service currently offers customers dial up data transmission facilities at speeds of 300 and 600/1200 bit/s on the switched telephone network. Data Transmission at the higher speeds of 2400, 4800 and 9600 bit/s is offered only on leased lines. This article discusses the results of trials of 2400, 4800 and 9600 bit/s modems undertaken on the switched network by the Datel section of Customer Networks Branch in Telecom Headquarters. As a result of these trials. Datel customers in the near future will be offered facilities for data transmission at 2400 and 4800 bit/s in the switched telephone network.

DARVENIZA, M.: 'A Perspective on Literacy'; Telecom. Journal of Aust., Vol. 29, No. 1, 1979, page 62.

Society tends to look to the past whenever anxiety arises over a present day situation. This backward look compares 'then' with 'now' and has the conviction, often illusory, that times were better. Employers and tertiary institutions allege that young people cannot write grammatically, are poor spellers and cannot express themselves clearly. Have standards fallen and do they meet present day professional demands? What is literacy? If students do not meet the necessary standards of literacy for their college, what can the college do about it? This paper attempts to answer these questions and to give some guidelines for tertiary institutions to help students meet the demands of literacy in an engineering course.

FARR, J.P.: 'Telecommunications Traffic Measurement and Processing in Telecom Australia; Telecom. Journal of Aust., Vol. 29, No. 1, 1979, page 70.

Telecom Australia expends significant resources on telecommunications traffic measurement. The motives and the techniques of making these measurements are the subjects of this paper.

HATFIELD, G.E.: 'From CYCLONE "Tracy" to Radio Australia, Carnarvon; Telecom. Journal of Aust., Vol. 29, No. 1, 1979, page 13.

A high frequency broadcast transmitting station was established for Radio Australia at Carnarvon, W.A. as an urgent measure following the loss of transmissions from the Darwin area as a result of cyclone "Tracy" on 25 December, 1974.

The Carnarvon station utilised the former NASA tracking station, commenced transmission less than a year after "Tracy" devastated Darwin, and went into regular service in March, 1976.

The new station comprises two transmitters of 250 kW and 100 kW, and four curtain antennas.

As Carnarvon is susceptible to cyclonic conditions special features were incorporated in the design of the antenna system to take this into account.

LEWIS, R.J. and PETERS, N.W.: "EC Grade Fully Annealed Aluminium Conductors in Paper Insulated Telephone Cable;" Telecom Journal of Aust., Vol. 29, No. 1, 1979, page 45.

An earlier paper in Volume 21, No. 3, of this Journal reported on the manufacture, installation and economic application of large size helical paper insulated EC grade aluminium cable in Telecom Australia's network. The paper was based on experience gained from laboratory work and early field trials.

The purpose of the present paper is to report on the development work and field installations that have taken place since 1970, and the extent of savings that are being made by the use of paper insulated aluminium cable.

MACK, M.R.: "Solar Power for Telecommunications;" Telecom. Journal of Aust., Vol. 29, No. 1, 1979, page 20.

This article outlines the basic theory of solar photovoltaic power systems and the way in which Telecom is applying these systems to provide relatively small quantities of power for communication systems in areas where mains power is not available. It includes methods used to dimension the solar array and battery and describes how the power generated by the solar array is controlled. Future trends and use of solar cells are also briefly discussed.

WILSON, A.J.: 'Potentiometric 100 Pair Cable Indentifier;' Telecom. Journal of Aust., Vol. 29, No. 1, 1979, page 83.

A 100 pair cable identifier which provides a digital readout of pair number and leg of wires at the point of enquiry, by using potentials which are directly proportional to the pair number and are of the same sign as the leg, has been developed. Its principles of operation and its physical realizations are discussed in this article.

NEAL, R. and KAZENWADEL, U.: 'Electrical Safety Test Set for Power Outlets and Appliances;' Telecom. Journal of Aust. Vol. 29, No. 1, 1979, page 3.

Safe use of electricity is of growing importance with the increasing availability of portable electric power tools and appliances as labour saving devices. Their wide application within Telecom has emphasised the need for an operationally simple test set to verify the safety of the electrical supply and any devices which may be plugged into this supply.

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Volume 29, No. 1, 1979

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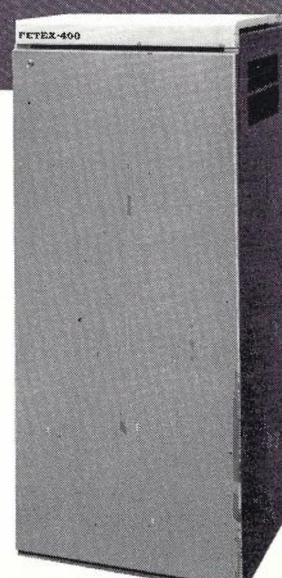

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