Volume 30, No. 2, 1980

the telecommunication journal of Australia

IN THIS ISSUE

30/2

THE TELECOMMUNICATION JOURNAL
OF AUSTRALIA
Volume 30, No. 2 1980
ISN 0040-2486

CONTENTS

COVER
INSTALLED PLATE
HEAT EXCHANGER

The Telecommunication Journal of Australia

The Journal is issued three times a year (February, June and October) by the Telecommunication Society of Australia. The object of the Society is to promote the diffusion of knowledge of the telecommunications, broadcasting and television services of Australia by means of lectures, discussions, publication of the Telecommunication Journal of Australia and Australian Telecommunication Research, and by any other means.

The Journal is not an official journal of the Australian Telecommunications Commission. The Commission and the Board of Editors are not responsible for statements made or opinions expressed by authors.

Residents of Australia may order the journal from the State Secretary of their State of residence; others should apply to the General Secretary. The current subscription rates for both Telecommunication Journal of Australia and Australian Telecommunications Research are shown on the inside back cover of this issue. All rates are post free (by surface mail). Remittances should be in Australian currency and made payable to the Telecommunication Society of Australia.

Editors of other publications are welcome to use not more than one-third of any article, provided credit is given at the beginning or end, thus, "The Telecommunication Journal of Australia". Permission to reprint larger extracts or complete articles will normally be granted on application to the General Secretary.

Information on how to prepare and submit manuscripts and contributions for the Journal is available from members of the Board of Editors and their outposted representatives.

Membership fees and subscription orders should be addresed to:

WITHIN AUSTRALIA

The State Secretary, Telecommunication Society of Australia,

Box 6026, G.P.O., Sydney, N.S.W. 2001.
Box 1802Q, G.P.O, Melbourne, Vic. 3001.
Box 1489, G.P.O., Brisbane, Qld. 4001.
Box 1183, G.P.O., Adelaide, S.A. 5001.
Box T1804, G.P.O., Perth, W.A. 6001.
Box 10,000T, G.P.O., Hobart, Tas., 7001.

OVERSEAS APPLICATIONS

The General Secretary, Telecommunication Society of Australia,
Box 4050, G.P.O., Melbourne, Victoria, Australia, 3001.

ADVERTISING

All inquiries from prospective advertisers should be directed to:
ADVERTISING MANAGER,
Box 4050, G.P.O., Melbourne, Australia, 3001
Telephone (03) 630 6259

Application of CSIRO Plate Heat Exchangers for Low Energy Cooling of Telecom Buildings

D. PESCOD, Dip.Mech.Eng., Dip.Elec.Eng., M.I.E.Aust., and
R. K. PRUDHOE, Dip.Elec.Eng., Post Dip. H.V.A.C., M.I.E.Aust.

Modern telecommunications equipment must be cooled to remove waste heat and maintain an acceptable temperature and humidity. Plate heat exchangers developed by CSIRO Division of Mechanical Engineering for use as coolers can provide the necessary cooling for both equipment and personnel with low energy usage and low capital outlay.

Existing air conditioning systems have relatively high operating costs, because of high energy usage and maintenance requirements. The new system, known as the PHE system, is now in commercial production. It uses water as a refrigerant and saves substantial amounts of energy by utilising the latent heat of vaporisation of water, and exhausting the vapour to the outside atmosphere, whereas other systems must recycle the refrigerant vapour by compression or absorption. Such systems may use up to thirteen times the energy requirements of the PHE system. With the PHE system, all circulated air is fresh and the moisture content of the air is not changed during the cooling process. In cooler weather, the heat exchanger recovers much of the heat from the exhaust air when combined with a building heating system.

Laboratory tests at CSIRO on a prototype have confirmed the performance as predicted from earlier experimental units. The first commercial installations are operating in the Caulfield and Balranald Telephone Exchanges. Large scale application of plate heat exchangers for low energy cooling of buildings could become a major contribution to national energy conservation.

Reprinted from the Annual Conference Adelaide 1980, published by the Institution of Engineers, Australia, publication 80/2.

The current cost of electrical energy for air conditioning in Australian Telecommunications buildings is approximately $8m per annum. The types of air conditioning systems used are of conventional design, which satisfy functional needs but tend to waste a lot of energy. These systems have evolved from a period when fuel was plentiful and energy costs were cheaper. Today the times have changed. National energy resources are becoming progressively depleted and fuel costs are forever rising. It is now the age to conserve energy. The majority of air conditioning systems are now outdated as regards energy conservation. This is because of inherent inefficiencies of individual interacting components, the types of systems used, and the inability of these systems to use the minimum amount of energy to satisfy actual seasonal cooling and heating loads.

The majority of systems throughout the nation are substantial energy wasters. These systems have evolved from the application of design philosophies in a period when energy conservation was not so important. Examples of energy wastage in conventional plant are: inefficient motors, fans, drives, and pumps; poor selection of design criteria; use of constant air volume systems, which do not adjust the fan energy to satisfy actual cooling and heating requirements; the use of large central plant with long duct runs; badly designed ductwork which results in high resistance to air flow; poor plant selection; plant overdesigned; terminal re-heat systems; poor insulation; non-use of heat recovery systems.

The importance of energy conservation is now being recognised on a world-wide scale. Individuals and organisations are joining together in the drive to save energy. It is important that we learn from what has happened in the past. Elms (1979, Ref. 1) has stated that between 40 and 50% of all energy consumed in buildings is used for control of the environment and lighting.

There is a strong need to stop using air conditioning systems with a large energy appetite. In fact we believe that Government legislation should be introduced to ensure that air conditioning systems used in all future buildings are highly efficient. Additionally, strict legislation should be employed to ensure that all of the individual components in plant, such as fans, motors and pumps, etc. meet specified minimum standards. We are hopeful that the time will come when the Government will provide incentives for industry to install plants using minimum energy, consistent with the desired result.

Telecom is currently engaged in a national energy management programme which has been activated by a growing awareness of rising fuel costs, the progressive depletion of energy resources, and the need to implement new types of energy conserving systems. This programme encompasses the optimisation of air conditioning plant in existing buildings, and the development of low energy air conditioning plant for future buildings.

Telecom first became interested in the CSIRO plate heat exchanger (PHE) back in 1976. Although the PHE at that time was in an early stage of development it showed great potential as an energy saver. Following the assignment of manufacturing rights by CSIRO to Hydro Thermal Engineering Pty Ltd, Adelaide, Telecom negotiated with this company to supply PHE units for two prototype cooling installations. These plants were installed in 1979.

In development of the PHE system it has been very important to define a set of energy conserving oriented objectives to ensure success of the overall project. These objectives are as follows:

- Satisfactory control of the environment.
- Promotion of good health by using abundant fresh air, without increase in operating cost.
- Minimum energy usage. (Minimum operating cost.)
- Minimum capital cost.
- High reliability.
- High efficiency of individual components.
- Use of variable volume air flow.
- Simplicity and ease of maintenance.
- Long life.
- High resistance to corrosion.
- Modular design.
- Minimal air duct resistance.
- Minimal plant room area.
- Heat regenerative system.
- Availability of satisfactory servicing.

DESCRIPTION OF EQUIPMENT

Principle of Operation

The essential parts of a PHE cooling and heat recovery unit are shown diagrammatically in **Fig. 1**. Outside air is drawn through filters by a fan, and is blown horizontally through a plate heat exchanger, where it is heated or cooled as required, before entering the space to be conditioned. Return air from the conditioned space is drawn upwards through the heat exchanger by a second fan before being discharged outside. In cold weather, much of the heat in the exhaust air is transferred to the incoming air as the air streams pass through the heat exchanger. Projections moulded onto the plastic heat exchanger plates create turbulence in the air streams and greatly increase the heat transfer coefficient.

When the conditioned space is to be cooled, water is sprayed over the heat exchanger to wet the surfaces of the plates on the exhaust side. The plates are cooled by evaporation, and the water vapour is carried away by the exhaust air. Thus the heat exchanger becomes an evaporator in which the cheap, non-polluting refrigerant vapour is discarded and the energy cost of recycling by compression or absorption is avoided.

In **Fig. 2**, this cooling cycle is shown on a psychrometric chart and compared with a direct evaporative cooler. It may be seen that the PHE cooler does not raise the moisture content of the air entering the conditioned space, and that this supply air is significantly cooler than the air from a direct evaporative cooler. The theoretical minimum supply air temperature to the conditioned space with a direct evaporative cooler is the wet bulb temperature of the ambient air (23° in this case). The theoretical minimum supply air temperature with the PHE

DON PESCOD is a Senior Research Scientist with the CSIRO Division of Mechanical Engineering, Highett, Victoria. He has worked on research and development of special forms of air-conditioning for the last 20 years. Don is the inventor of the CSIRO plate heat exchanger (PHE) and first conceived the concept of the PHE as a low energy cooling and heat recovery system back in 1968. Since then he has been deeply involved in all aspects of the PHE system which is now in commercial production.

BOB PRUDHOE is a Senior Engineer with Systems Design Section of the Headquarters Buildings Sub-Division, Telecom Australia, and has worked on air-conditioning systems for the last 15 years. He believes that conventional types of air-conditioning systems have a large energy appetite and that there is a strong need to develop simple low energy systems which will provide a healthy refreshing work environment. Bob first became interested in the CSIRO plate heat exchanger system back in 1976 and considered it had great potential as a substantial energy saver for the heating and cooling of Telecom buildings. Since then he has been actively involved in development of the PHE system and has arranged prototype PHE cooling installations.

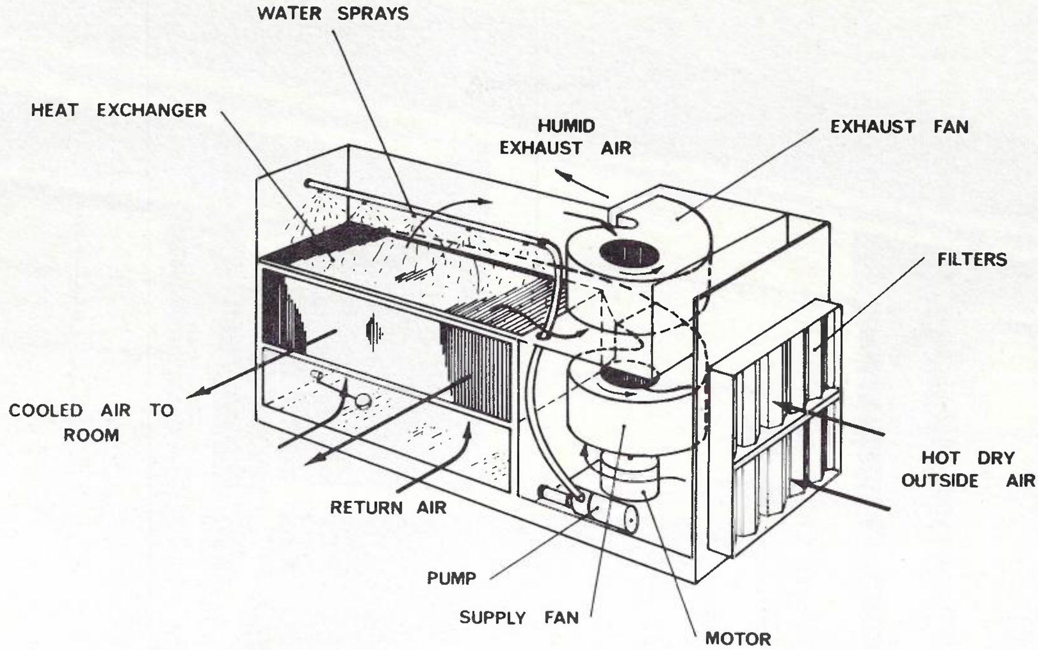


Fig. 1 — PHE Cooling and Heat Recovery Unit.

cooler is the dew point of the ambient air (17° in this case). To obtain reasonably comfortable conditions with direct evaporative coolers, the ambient wet bulb temperature should be below about 21°. The PHE, on the other hand, may be used with ambient wet bulb temperatures up to 25°.

Excess water sprayed into the heat exchanger drains into a sump and is recirculated by a small pump. The energy requirements amount to little more than that needed to move the air; Pescod (Ref. 3) has estimated that for normal installations, these would be between one-fifth and one-ninth of conventional refrigerated air conditioning plant, depending upon the geographical location and the building design. A special feature of this system is the use of outside air for cooling without recirculation, thus very effectively removing odours and contamination within the conditioned space. The system has been described in more detail by Pescod (Ref 2), and by Wooldridge, Chapman and Pescod (Ref 6).

Commercial Units

A prototype of the units now being made under licence by Hydro Thermal Engineering Pty. Ltd. in South Australia was tested in the laboratories of the CSIRO Division of Mechanical Engineering in Victoria in 1979. The design differed in several respects from earlier experimental units developed by CSIRO, so it was important to check all aspects of the performance of this new design before production of commercial units commenced. An agreement for the co-operative development of PHE coolers had been made between CSIRO and Hydro Thermal Engineering Pty. Ltd. prior to commencement of this work.

The prototype PHE unit was constructed mostly of glass fibre reinforced plastics; the approximate overall dimensions were 3 m wide, 2 m high and 1 m deep. The

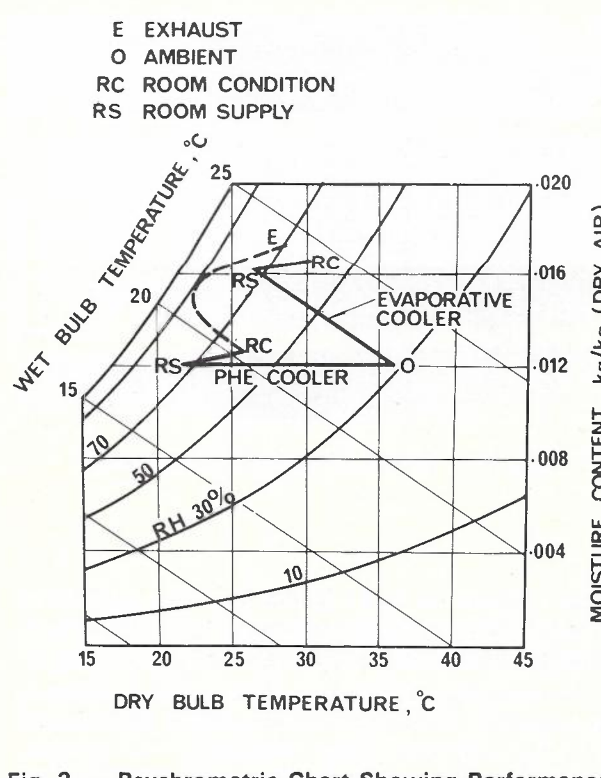


Fig. 2 — Psychrometric Chart Showing Performance of PHE Unit and Direct Evaporative Cooler.

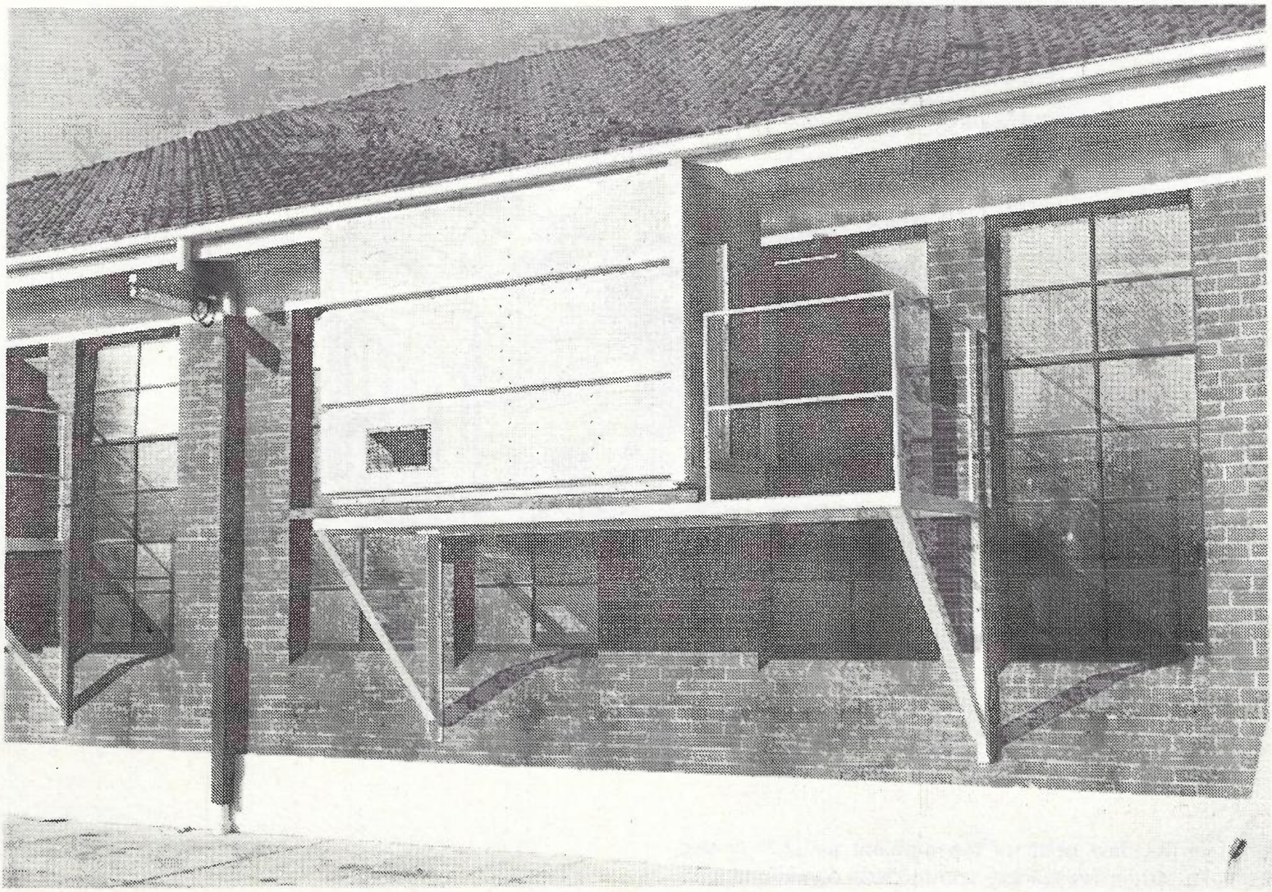


Fig. 3 — Outer Appearance of PHE Unit.

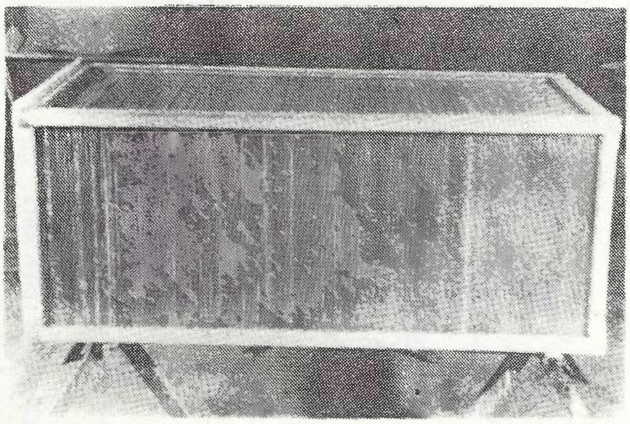


Fig. 4 — Plastic Plate Heat Exchanger.

design air flow-rate was 1.4 m³/s. The outer appearance is shown in **Fig. 3**, the heat exchanger is shown in **Fig. 4**, the spray chamber in **Fig. 5** and the fan section in **Fig. 6**.

The most important departure from earlier designs was the change in direction of the exhaust air flow through the heat exchanger from downwards to upwards. Previous research had shown that the counter-flow of air and water significantly increased the air resistance, but

Fig. 5 — Spray Chamber.

possible effects on the thermal performance had not been investigated. However, tests with parallel flow of air and water had indicated that the wetting of the plates had not been complete, as the water tended to form "rivulets" down the plates. It was hoped that the counterflow arrangement would make a significant improvement in the wetting of the plates by tending to spread the water more evenly, and hence improve the effectiveness of the cooler. The arrangement would also be more convenient for duct connections in most installations.

Development work by the licensee is continuing, and a range of models incorporating various improvements are expected to be in commercial production in the future.

DEVELOPMENT IN LABORATORY

The PHE unit was set up in the laboratory at the CSIRO Division of Mechanical Engineering, as shown diagramatically in **Fig. 7**. The two air streams could be independently controlled and measured. Temperatures and duct pressures were measured at all important points, and the temperature of the intake air could be controlled by means of a large electric heater in the supply duct. A smaller heater in the return duct could simulate room load. The water system and the electric power supply were also monitored.

Preliminary tests showed an uneven velocity profile through the supply side of the heat exchanger. A uniform flow is necessary for best performance, so a baffle was fitted into the supply duct at the heat exchanger to improve the velocity profile through the heat exchanger. In production units, the shape of the duct was modified.

During early performance tests it was noted that the air resistance in the wet passages was higher than had been expected from earlier research, and there was a tendency for water droplets to be lifted out of the passages and to be carried along in the airstream, especially with the higher air flows. Clearly, more investigations were necessary, and a series of tests with different means of wetting the plates and with different plate spacings and air velocities was conducted until sufficient information had been obtained to relate these parameters, and to select an optimum design for high cooling capacity and low fan power demand, without water carry-over.

There was also a tendency for a vortex to form at the entry to the exhaust fan, reducing its performance and tending to lift water into the fan from the floor of the fan chamber. This was corrected by enlarging the fan chamber, fitting straightening vanes to the fan inlets and by providing a drain from the floor of the chamber.

A reduction in the power consumption was considered desirable, and this was achieved by fitting a more efficient electric motor. Further reductions were planned by using motors capable of continuous operation at reduced speeds so that lower fan speeds could be used when outside conditions were not extreme. Substantial energy savings are then possible because the air power requirements vary approximately as the cube of the speed. A backward curved centrifugal fan was specially designed as an alternative to the less efficient forward curved fans originally used, and a prototype has been prepared for performance tests.

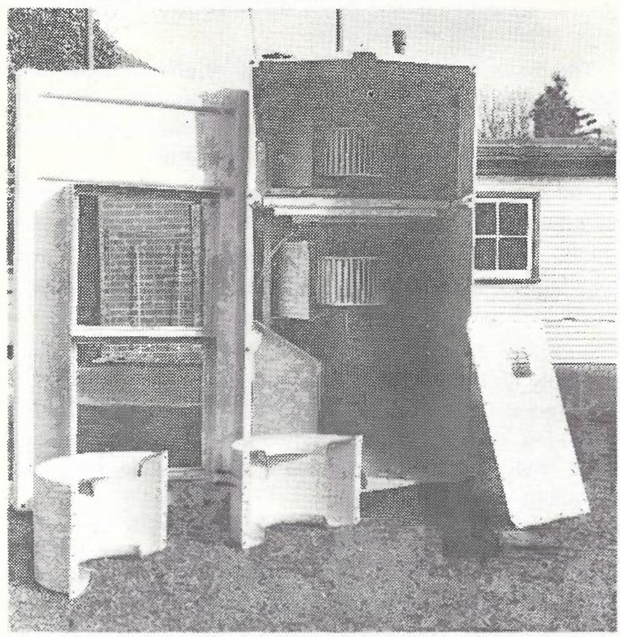


Fig. 6 — Fan Section.

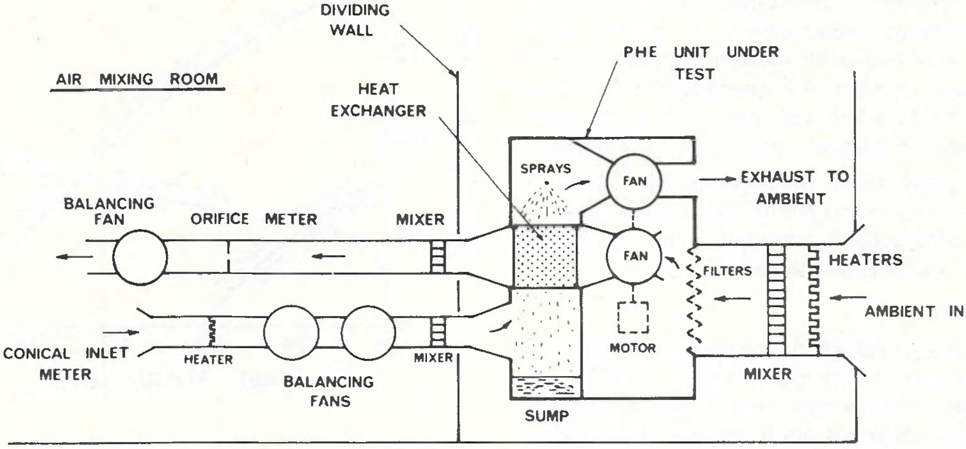


Fig. 7 — Diagram of PHE Testing.

PERFORMANCE IN THE LABORATORY

Some test results with the prototype PHE unit are given in Table 1. The exhaust flow is normally made less than the supply flow in order to slightly pressurise the building and reduce infiltration. The cooling effectiveness is not significantly affected until the flow ratio is reduced below 0.80. The variation in cooling effectiveness shown in Table 1 was caused by variation in volume flow of supply air. This effect was treated in detail by Pescod (Ref. 4).

Cooling effectiveness ϵ_w is determined by the equation

$$\epsilon_w = (t_{hi} - t_{ho}) / (t_{hi} - t_{ciw})$$

where t_{hi} is the dry bulb temperature of the hot ambient air,

t_{ho} is the dry bulb temperature of the cooled air to the room, and

t_{ciw} is the wet bulb temperature of the return air from the room.

The test results show high values for effectiveness, indicating that the wetting of the plates was adequate. The local variations in effectiveness appear to be related to variations in air velocity through the plates.

The effect of circuit pressure drop on air flow and sensible cooling capacity is shown in **Fig. 8**.

When comparing the cooling capacity of a PHE unit with that of a conventional refrigeration unit, three differences must be taken into consideration:

- With the PHE system, the heat removed from the supply air is much higher than with most conventional systems. For convenience of selection, this supply air cooling load has been deducted from the "gross sensible cooling capacity" in Table 1 to obtain "net sensible cooling capacity".
- Data for conventional refrigeration is usually for "total cooling capacity", and the latent heat of condensation of water in the evaporator must be deducted to obtain gross sensible cooling capacity, from which the net sensible cooling capacity may be calculated, knowing the ventilation rate.
- When the outside temperature is high, the PHE unit uses a higher air circulation rate than conventional refrigeration. Robeson and Downie (1977, Ref. 5) have shown that increased air movement improved the sensation of comfort. Alternatively, a higher room temperature with higher air movement could give the same degree of comfort. A higher room temperature reduces the heat load in the room, and at the same time increases the cooling capacity of a PHE cooler.

Typically, a conventional refrigerated unit requires a total cooling capacity rating about 50% greater than the net sensible cooling capacity rating of a PHE unit for the same degree of comfort in the room.

INSTALLATIONS

Trial PHE cooling installations are now operating in the Caulfield Telephone Exchange, Victoria, and in the Balranald Telephone Exchange, New South Wales. The PHE units at both locations are fitted with deep bed air filters to satisfy Telecom filtering requirements, and will have three speed fans for variable air flow. The third trial

SUPPLY			
Flow m³/s	0.72	0.87	1.32
Duct Pressure Pa	+180	+160	+70
EXHAUST			
Flow m³/s	0.71	0.71	1.00
Duct Pressure Pa	−67	−65	−1
FLOW RATIO	0.99	0.82	0.76
COOLING EFFECTIVENESS			
Mean	0.88	0.84	0.82
Min.	0.83	0.80	0.71
Max.	0.92	0.90	0.89
FAN POWER kW	1.21	1.28	1.68
RATIO			
Fan Power/Supply Air Flow	1.68	1.47	1.27
SENSIBLE COOLING CAPACITY * kW			
‡ Gross	17.6	19.9	29.2
Net	5.30	5.70	8.20

* Standard Reference Conditions: 35°C outside db
27°C inside db
19°C inside wb

‡ Gross sensible cooling capacity is the sum of the sensible heat removed from the supply air and from the building.

Net sensible cooling capacity is the sensible heat removed from the building only.

Table 1 — Performance of Prototype PHE Cooling Unit

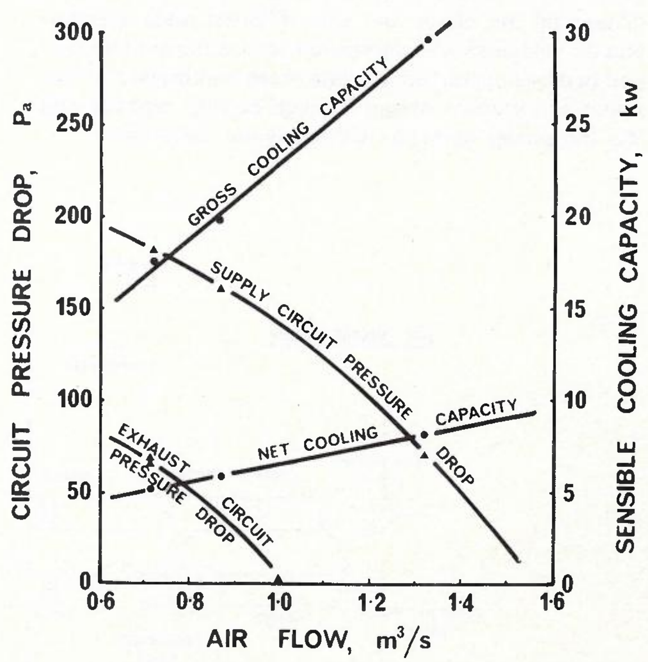


Fig. 8 — Effect of Circuit Pressure Drop on Air Flow and Cooling Capacity.

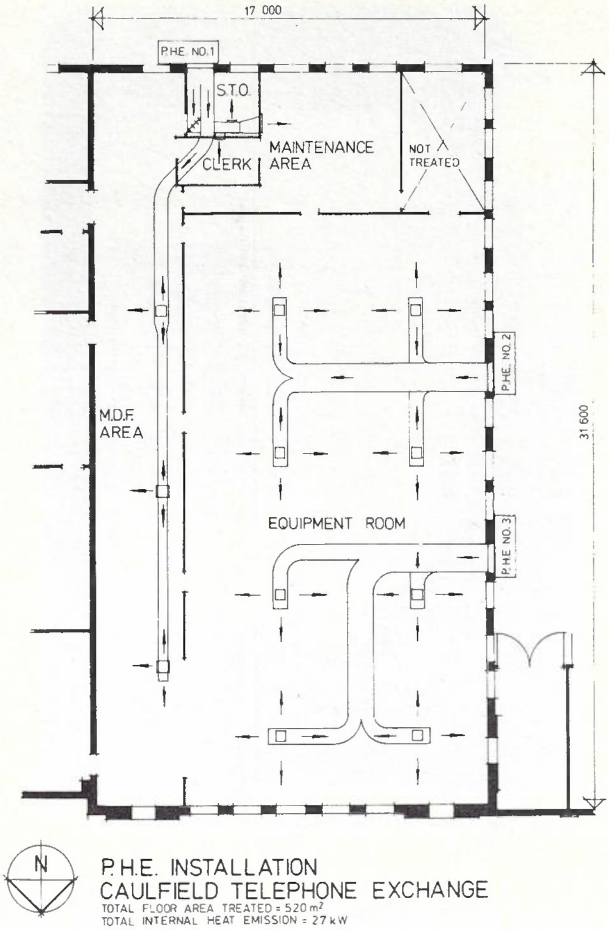


Fig. 9 — Plan of Caulfield Exchange.

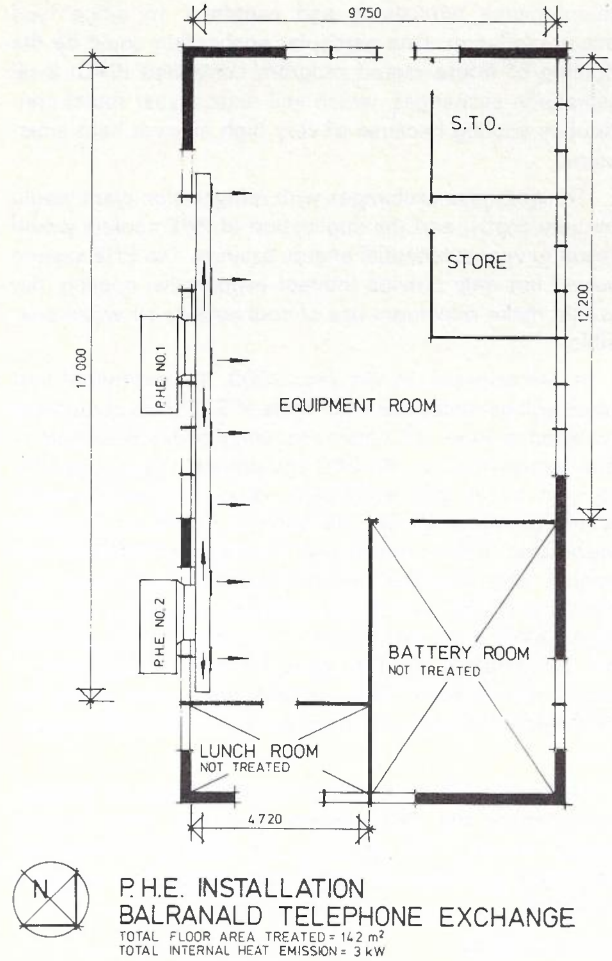


Fig. 10 — Plan of Balranald Exchange.

PHE installation is now progressing for the Maitland Telephone Exchange, South Australia.

For each installation the standard reference condition inside the conditioned area is 27°C dbt and 19°C wbt with 37°C dbt outside.

To satisfy Telecom comfort conditions it is necessary that 29°C should not be exceeded on more than 10 days of the year.

Caulfield Installation

The PHE installation at Caulfield Exchange uses three 1.4 m³/s commercial type package PHE units, with each unit reticulating cool air into the building via dedicated ductwork (see **Figs. 3 and 9** for illustrations of the installation). Two PHE units are located on the west wall, and cool the telephone equipment room. One PHE unit located on the south wall cools the office area, maintenance control room, and the main distribution frame area. All PHE units are mounted on steel platforms outside the building. The building originally was fitted with a ducted heating and ventilation system which proved inadequate on hot days.

The exchange building is constructed from double brick walls, tiled roof, with 100 mm mineral wool ceiling insulation and liberal fenestration.

The total floor area treated is 520 m². The total internal heat emission from telephone switching equipment and lighting is 27 kW. The exchange is normally occupied by nine staff from 7 a.m. to 5 p.m.

Balranald Installation

The PHE installation at Balranald uses two 1.4 m³/s PHE units blowing cool air into a common duct system. It is possible for both or either one of the PHE units to blow air into the duct system. Both units are mounted on concrete slabs on the south-east side of the building. Balranald is situated 34.7°S latitude and 143.6°E longitude. The summer conditions experienced are very hot and dry.

The building has 25 mm of mineral wool insulation in the roof space and walls, with fenestration comprising 40% of the wall area. External walls have aluminium cladding; the low gable roof is covered with 6 mm asbestos cement sheets and the ceiling is lined with caneite. The floor consists of vinyl tiles over a concrete slab on the ground; the conditioned area is 142 m². The total internal heat emission from lighting and telephone equipment is 3 kW. For a general layout of the building and PHE units see **Figs. 10 and 11**.

In Telecom there is a wide variety of applications where the PHE could be used as a cooling system, ranging from all types of telephone exchanges, line depots, maintenance workshops and canteens, to office type accommodation. One particular application could be the cooling of future stored program controlled (SPC) local telephone exchanges, which will require year round continuous cooling because of very high internal heat emissions.

To cool these exchanges with refrigeration plant would be very costly, and the application of PHE coolers would result in very substantial energy savings. The PHE system would not only provide indirect evaporative cooling, but would make maximum use of cool outside air when possible.

As an example, by the year 2000, it is estimated that there will be about 3.3×10^6 lines of SPC local equipment installed around the nation, totalling about 9500 kW of heat emission from the SPC equipment. The energy cost to cool all of this equipment using refrigeration plant would be about $1.6m per annum; if PHE type cooling were used, then it would only cost about $120,000 per annum. This assumes that refrigeration plant has a performance coefficient of 2.5, and that electricity will cost 5c per kWh. If we look directly at energy savings, then for the refrigeration plant to cool all of this equipment it would require about 32×10^6 kWh per annum, while the PHE system would only use about 2.4×10^6 kWh per annum.

Outside of Telecom there are multitudes of applications where the PHE system could be used to save national energy. For example, the cooling of hospitals, schools and all types of public, commercial and industrial buildings.

FIELD TESTS

At both Caulfield and Balranald Exchanges the first objective of the field tests was to gather sufficient data to enable the performance of the PHE systems to be determined. The second objective was to make an estimated comparison of energy consumption between the PHE system and a comparative refrigeration type system.

The results of the field tests will be presented at the conference.

Instrumentation has been provided to record the following data, for each PHE installation:

- Outside dry bulb temperature.
- Outside wet bulb temperature.
- Solar radiation.
- Room return wet bulb temperature to each PHE unit.
- Room discharge dry bulb temperature from each PHE unit.
- Hours of operation of water pumps and fans at each speed.
- Energy consumption.
- Water consumption.

For the Caulfield installation thermocouples wired to a potentiometric chart recorder are used to measure dry bulb and wet bulb temperature of outside air, dry bulb temperature of room discharge air and wet bulb temperature room return air into each PHE unit. Several thermohygrographs are located within the exchange to give general records of humidity and dry bulb temperature.

Because of the remoteness of the Balranald Exchange from the Telecom PHE project engineer based in Sydney,

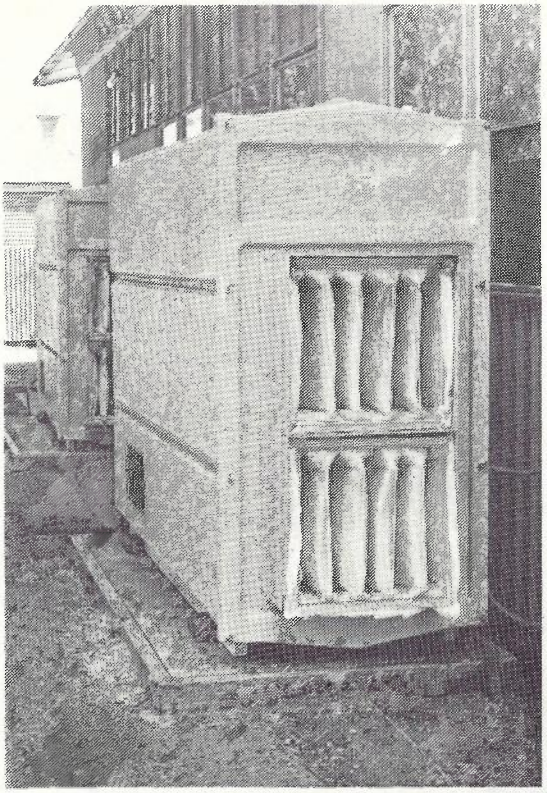


Fig. 11 — Installation at Balranald.

a special monitoring system has been installed. This system incorporates a Honeywell data gathering panel which enables relevant test data to be relayed from Balranald to the project engineer via a single telephone circuit and a 300 baud casette recorder. Data processing will be executed on the Telecom Honeywell 66/80 computing system.

Software has been prepared to enable energy cost and performance data to be printed out in graphical and tabular form.

CONCLUSIONS

The PHE system provides cooled fresh air in ample quantities for equipment and human comfort, with one-fifth to one-thirteenth the energy usage of refrigeration, for most parts of Australia. Air is not recirculated through the system.

The system also allows substantial recovery of heat from the exhaust air during cold weather when space heating is normally required. Laboratory tests and field tests have confirmed the predicted performance of commercial units. A range of models incorporating various improvements are expected to be available in the future.

Large scale application of the PHE system could make a major contribution to national energy conservation.

REFERENCES

1. Elms, L. D. (1979): 'Energy Aduits', Australian Institute of Refrigeration, Air Conditioning and Heating; Energy Conservation Seminar, Paper No. 2.
2. Pescod, D. (1974): 'An Evaporative Cooler Using a Plate Heat Exchanger'; CSIRO Division of Mechanical Engineering, Technical Report No. TR2.
3. Pescod, D. (1976): 'Energy Savings and Performance Limitations

with Evaporative Cooling in Australia'; CSIRO Division of Mechanical Engineering, Technical Report No. TR5.

4. Pescod, D. (1979): 'A Heat Exchanger for Energy Saving in an Air-conditioning Plant'; ASHRAE Trans., Vol. 85 (part 2).

5. Robeson, K. A. and Downie, R. J. (1977): 'A Method for Rapid Assessment of Relative Thermal Strain on Workers in Hot Environments'; CSIRO Division of Mechanical Engineering, Technical Report No. TR10.

6. Wooldridge, M. J., Chapman, H. L. and Pescod, D. (1976): 'Indirect Evaporative Cooling Systems'; ASHRAE Trans., Vol. 82 (part 1), pp. 146-155.

Addendum:
Results of Tests from the Trial PHE Cooling Installations.

Laboratory testing at CSIRO and field testing by Telecom during the summer of 1979/1980 confirm that suitable conditions for equipment and personnel are provided by the PHE system with substantial energy savings when compared with conventional refrigerated type building cooling systems.

In Brief

FIBRE OPTICS — A CHANCE FOR LOCAL INDUSTRY

The optical fibre is the medium through which the message of the future will flow.

Without continuing development of the technology of optical fibres the full benefits of the computer age will not be fully realised.

This is the view held by the Australian Telecommunications Development Association, the major body representing the local electronics and telecommunications manufacturing industry.

One of the most significant technologies to emerge since the transistor, optical fibres, are glass tubes about the diameter of a human hair which are capable of carrying thousands of messages at the speed of light.

After decades of theory and research they have emerged as a realistic communications vehicle at a time when the world's communications systems are searching for more channels. They offer exciting and wide possibilities for governments, commerce, industry and the ordinary citizen.

By replacing conventional telephone lines with optical fibres a whole new array of systems may become available to every phone subscriber.

The huge capacity of optical fibres will give the average home or business vastly increased telecommunications capacity.

Interconnecting TV screens between offices or homes, electronic letter delivery by means of telex or facsimile machine, immediate stock exchange reports and facsimile newspapers and other advanced devices could be made available by converting the public telephone network to optical fibres.

Things which now require special and expensive high capacity communications lines will be routinely available in every home — for instance, cable video services which will turn a TV set into a terminal for a huge electronic library.

In the field of defence it looks like the medium which will guarantee security of communications of national importance.

The physical advantages of optic fibre cables are that they are smaller, lighter and easier to install above and below ground. They are made basically from silicon, the most abundant element in the earth's crust. This makes them potentially very cheap when fully developed as compared with the relatively expensive, less flexible and limited traffic volumes offered by our current steel and copper communications lines.

Qualitatively, they offer even more. Light waves are not easily affected by electrical interference. As a result, crosstalk and fading signals on telephone lines will be significantly reduced.

The first Australian uses of this phenomenal technology are expected to be in city and suburban telephone exchanges, within power stations, the defence forces and commuter transport systems.

Since its creation in 1975 Telecom Australia has been deeply involved in the development of fibre optic technology.

Consequently, that body will lead the way in commercial applications of this unique tool. It is expected Telecom will introduce the first optical fibre channels into our telecommunications network later this year.

The fibre optic cable will eliminate the use of intermediate switching equipment by linking one suburban exchange direct with another through high speed digital transmission systems.

Large scale application is predicted within five to ten years.

In the transport field, freedom from electro-magnetic radiation is the key benefit and research is being directed at their use in carrying communications signals data in equipment located close to electrified vehicles such as trains and trams.

Several member companies have been significantly involved in researching, manufacturing, and conducting field trials of the technology in collaboration with Telecom and the Department of Defence.

One communications cable currently in use in Australia contains six optical fibre elements and is the size of a finger. It has the capacity to carry more information than a conventional copper cable as large as an arm.

There is now worldwide interest in optical fibres in communications. The Australian experiments are significant and advancing rapidly.

It is a revolutionary technology and one in which the Australian electronics industry must become expert — in every sphere of manufacture and the research and development of new and even more efficient applications.

Social Needs and Technology — A Partnership for Future Telecommunications Developments in Australia

D. M. ROWELL

A description of the business of Telecom, some of the social impacts of its technology, and ways in which Telecom is trying to come to grips with them. The paper is particularly orientated towards **Telecom 2000** and related endeavours.

In looking at technology and the future it is important to recognise the relationship between social needs and technology. In doing so it would be presumptuous to give the impression that a complete, unique or totally defensible picture of the world is being presented when dealing with such a complex relationship. This, however, is insufficient reason to avoid broaching the topic and thus failing to further stimulate thinking and debate.

Telecommunications has — rightly or wrongly — attracted particular attention in what has become known as the 'technology' debate and it needs to be seen in the perspective of its particular relationship with social needs to give some confidence in future developments in this field.

It is a natural reaction for man to move towards satisfying his basic social needs by the development of technology — to protect himself he developed the mouse-trap; to be mobile he developed the wheel; to communicate he sent smoke signals. It is well known what nature did for the 'smartness' of the mouse. In its attempt to build on the wheel to satisfy man's mobility needs, society has developed the motor car — with all its social consequences; to conquer the bounds of time, space, clarity, complexity, convenience, privacy and accountability society has progressively developed telecommunications technology to today's high level of sophistication. What are the social consequences, how do we identify them, and how do we learn to cope with them — can society adjust?

Technological advancement is a phenomenon which society has applied to its own ends to meet perceived social needs. With the satisfaction of new needs has come new social consequences. It would be a rare situation where the consequences had been properly identified and thought through before the advancements have been accepted by society. In the main it has adjusted progressively. There was a time when a bell and flag were necessary to forewarn of the movement of a motor car; now we require a series of sequentially controlled coloured lights to regulate their inter-movement. In adjusting the motor car to match our desire for changing social needs, the social consequences have been recognised progressively, and have become more complex and more external to the system involved.

Pollution, noise, freeways, road carnage, drink-driving, fuel dependence and its impact on national economics all figure in the social impact of the motor car and society is in the process of adjustment. A similar process has occurred with telecommunications. This, however, does not, in itself, give cause for concern because the benefits will outrough the problems.

RESPONSIBILITY FOR TELECOMMUNICATIONS DEVELOPMENT

If we wish to look at the way in which future telecommunications developments in Australia are affected by the relationship between social needs and technology it is necessary to understand the way Telecom Australia, the major actor in this development, manages this relationship. In particular, a knowledge of the forces which constrain its actions, the nature of its business, the common carrier role and the way it sets about managing technological change are important.

Under the Telecommunications Act 1975, the Australian Telecommunications Commission (Telecom Australia) has the common carrier responsibilities to 'provide, maintain and operate telecommunications services in Australia which best meet the social, industrial and commercial needs of the people of Australia'. Telecom therefore has a major responsibility to manage the balanced and effective development of telecommunications.

The legislative constraints under which it operates are derived from the enabling Act and several other Acts such as those relating to Wireless Telegraphy, Ombudsman, Administrative Appeals, Trade Practices, etc. Administrative arrangements such as Loans Council Approvals, Forward Estimates, Administrative Services guidelines and Public Service Board guidelines are developed as part of its interface with the various Government Departments and these also provide some boundaries for its decision-making and the timing of its actions.

THE TELECOM BUSINESS

Telecom Australia provides, maintains and operates telephone, telex, telegram, data and other telecommunications services for Australia. It has a fixed asset of about $6,560M, annual earnings of about $1,900M, annual borrowing of about $180M and an annual capital expenditure programme of about $950M. With a staff of about 87,500 it maintains about 5,600 telephone exchanges providing telephone services to about 4.2 million customers. The telephone density is about 43.5 instruments per 100 population. Telecom maintains 32,500 public telephones, 22,700 telex services and 19,300 datel services. It provides for additional new telephone services at a rate of about 280,000 per year and its investment per additional service is about $3,500. Its return on investment (after interest) is about 2.8% p.a.

The Corporate Plan sets out an approach to the development of its services which among other achievements, will result in a telephone in 9 out of 10 Australian homes by 1987. A rough measure of the productivity level planned for in 1987 is reflected in the ratio of nine full-time staff per 1,000 telephone instruments. While exact comparisons are not possible similar staffing ratios were achieved in USA (AT&T) in 1960, in Canada in 1965 and in Sweden in 1970. The Real Output Growth of the telecommunications network, calculated from the growth rates of the major telecommunications products, is currently expected to be about 8.5% p.a. to 1987. The Overall Business Productivity calculated as the ratio Output (Earnings at constant tariffs) to Input (Expenditure at constant prices) is planned to be about 5.6% p.a. to 1987.

THE COMMON CARRIER BALANCE AND RURAL/REMOTE NEEDS

What appears to be a delightful business monopoly situation is not what it seems. The advantages as normally conceived concerning a monopoly are balanced by the Act which requires Telecom to:

- 'make its services available throughout the country so far as is reasonably practicable'

and that

- 'revenue must cover current expenses each year and provide no less than one-half of capital requirements'

and that

- 'services are to be kept up to date and operated effectively and economically with charges as low as practicable'.

In a sense it is a 'Catch 22' situation and this is where the real management challenge starts.

The Telecom management challenge, therefore, is to balance the 'rough' with the 'smooth' — to be sure that its non-profitable services are adequately balanced in its development plans and programmes with its profitable services. The major area of non-profitable services is the vast rural/remote areas.

The real social needs for telecommunications in rural/remote areas are not clear, particularly when seen against relative priorities for other services and the costs involved. A representative of the Isolated Parents Association at the Domsat 79 Conference conducted in Canberra last year set out the service priorities as:

1. Reliable 24 hour telephone service
2. Education
3. Radio
4. Television
5. Medical Assistance

Telecom is undertaking continuing social research into this vexed question of needs so that priorities can be established for its planning.

A cross-subsidy of about $40 to each country telephone service or 4 cents for each telephone call is necessary. This subsidy must come from profitable metropolitan subscribers in the form of a component of their accounts. This additional charge amounts to about $19 on each metropolitan telephone service or 1.6 cents on each telephone call (based on a 1975/76 survey).

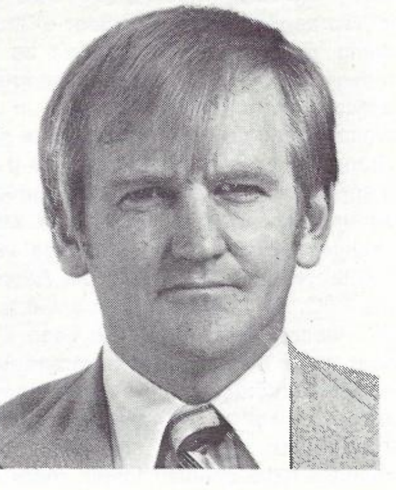
Despite the progress made to date in the rural area

DOUGLAS M. ROWELL is nominally the Manager of the Policy Research Branch, previously the National Telecommunications Planning (NTP) Branch of the Planning Directorate, Telecom Australia. NTP was the multi-disciplinary policy research and planning unit within Telecom which produced the report **Telecom 2000** in 1975 and **Outcomes from the Telecom 2000 Report** in 1978.

Prior to taking up this position, he was Chief Planning Officer in the team which set up corporate planning in Telecom and produced its first Corporate Plan.

Mr. Rowell is qualified with an Associateship Diploma of Communications (RMIT) and has studied at the Australian Graduate School of Management, at the University of N.S.W. in the Development Program for Managers. He has a broad range of experience covering domestic and international services employing telecommunications, broadcasting and satellite technologies both in Australia and Papua New Guinea. He was Deputy Director of the Deep Space Tracking Station at Woomera during a Mariner Mass mission phase and was instrumental in setting up the international telecommunications organisation in the independent Papua New Guinea.

Mr. Rowell is currently acting Director, Planning, in Telecom Australia Headquarters.



there remain quite formidable problems in completing a modern telephone service throughout the less closely settled areas of Australia. Telecom, however, adopted the objective of completing the upgrading of the manual services to full automatic working by 1990. The total cost of this programme is expected to be not less than $300M at present prices. A further investment in excess of $100M could be necessary to extend the telephone network into areas now served by outpost radio. Studies are still in progress on how best to identify and provide for the social needs of these areas. A technological breakthrough to bring the cost of provision of service in these areas below $40,000 per customer would be most welcome if these social needs are to be served.

In spite of the application of the best available technology and careful planning it will be difficult for Telecom to fund these programmes — there are no easy solutions to meeting the rural challenge. These funds can only come, in a simple analysis, from increased borrowings which has an inherent long-term interest commitment, increased charges which will, in the main, derive an increased absolute contribution from metropolitan customers, a decrease in the rate of development of the non-rural aspects which would increase deferred applicants and would be somewhat self-defeating in reducing the source of profitable revenue, or by a reduction in operating costs, the major component of which is staff costs.

The social needs of Australians for telecommunications are diverse and often complicated by distance, terrain and consequently costs. The common carrier responsibility of Telecom renders these needs as a commitment. The costs, however, have to be carried by someone. However, if technological developments reduced the costs of a telephone service for example, by satellite or reliable, private, low cost radio services, the meeting of these social needs in remote areas would be more achievable.

CHANGE AND TELECOMMUNICATIONS

Change has been a constant feature of telecommunications since the technology was first available to provide the service and since society first began identifying needs which could be fulfilled by such services. Since that time there has been a continuous interactive process which has developed the telecommunications of today and is likely to do so for tomorrow — smoke signals, drums, morse code, manual switchboards, mechanical switching, computers. As each new technology emerged it was applied with the object of improving the service, doing something that couldn't be done before or to reduce the cost of service. These interactions have been similarly responsive to changes in the environment in which telecommunications plays a part. Living with this change has proved a challenge to the effective development of the Australian telecommunications systems and an understanding of the nature and effects of future changes will help Telecom cope with future developments. Historically in Telecom Australia and previously the APO, the change from manual to automatic working of telephone exchanges has been a continuing component of its development programmes since 1911. This activity continues into the more remotely located areas of service as well as the operation of long distance services, international services and customer enquiries. These changes have enabled faster, more efficient services to be provided to more people and enabled costs to be maintained at a level which has made the services acceptable to more people. Changes in the technology of automatic interconnection of telephone customers have occurred from step-by-step to crossbar in the early sixties and more recently from crossbar to processor controlled exchanges. These technology changes have achieved significant steps in switching efficiency and reliability as well as providing for additional facilities such as subscriber trunk dialling (STD) and international subscriber dialling (ISD). The inbuilt efficiency and reliability resulting from such design factors as a reduction in moving parts and a shift from mechanical working to electronic working reduced the need for staff levels to grow in proportion to network growth and this has produced commensurate savings to customers.

With the advent of the transistor in the 1950s, significant changes commenced in the design and construction of telecommunications equipment. Notably the advent of more sophisticated multiplexing and radio equipment have enabled transmission systems of high capacity and reliability to be developed between major centres. Changes in this area have resulted in reductions of the order of 200:1 in the unit cost of components and this has made it possible for modern telecommunications to expand over the vast distances of the Australian continent at reasonable costs.

Many of the changes involved in telecommunications developments are external to the systems involved and it is necessary to recognise the importance of these influences. The part played by telegraph services in the 19th century in the build up of industry and transport, and in the development of countries like Australia is well accepted. The advent of the telephone, particularly since it has become a household amenity, has affected society both in an overall and in a very personal way.

Not only are the changes external in nature but also are the social consequences. Just as with the motor car we have learned that the impact of the technology is not only on those who use it or derive a direct benefit. The social consequences can be complex and are often external to the telecommunications system. The advancement of telecommunications has impacts which are broader than those on Telecom's customers and some of the social questions it raises are worthy of debate.

The Distributional Consequences of Product Changes and Tariff Policies

There are alternative ways of developing telecommunications services which extend the network further at the expense of providing new facilities or of updating the equipment to be more reliable. Tariff policies can shift the cross-subsidisational balances. People who already have good access to information sources or facilities or the 'information rich' can get richer and the 'information poor' can get poorer.

Privacy Implications of More Sophisticated Information Handling and Storage

There are those who would argue that Automatic Message Accounting (AMA) on trunk calls is an infringement of basic privacy. Many of these may well be people who are not responsible for paying the accounts and these people constitute the majority of telephone users. Junk advertising by telephone can be a threat and source of customer annoyance.

The Effects of Telecommunications on Social Communication Patterns

While privacy of conversation is an important attribute in a telecommunications system, the very basic non-private high frequency radio systems and party lines used in remote areas forms an important part of their social fabric. Changes from manual to automatic working, which brings with it many technical and facility advantages, often brings about a change in the social communication patterns of the area.

Economic Effects of Telecommunications on Business Efficiency

With more sophisticated telecommunications technology the logistics, contactability, flexibility, availability and management techniques of the infrastructure of business can be changed for more efficient working. The shift of 'staff share' resulting from the wage movements of the early '70s attracted business to more automatic and less labour-intensive installations.

The Balance of Cross-Subsidisation

It is not possible in any business to maintain a uniform balance of priority and profitability over all products. The way in which these balances are managed produce economic and social effects for the users of the products. Developmental, reliability, service levels, technology, staffing and financing issues are involved. To what extent does the customer of today pay for the network the customer of tomorrow will use; or to what extent is the customer of today living off the network provided by the customer of yesterday.

The Management of a Vital National Resource

The telecommunications services of a nation constitute a resource which helps to form the infrastructure for its social, industrial and commercial life. Its strengths and weaknesses, its privacy, reliability and efficiency interact with the society which goes to make up that nation. The way telecommunications services are developed can determine the way in which the country fits into the wider society of the world. It is important to look closely at who should manage such a resource and how it should be managed. This is one of the many complex issues underlying the domestic satellite debate.

Employment Considerations

Man looks for productive satisfying work and telecommunications has provided such employment over the years and will continue to do so. Job satisfaction is not provided by idleness, underemployment or by retarding technological development. We do not find the man with the bell employed in front of the car these days. He is employed designing, building, installing and maintaining the sequentially controlled coloured lights.

Technological change in the telecommunications field as in others will require social adjustments as a result of the employment considerations and they will come in areas not yet perceived. Who would have perceived that breathaliser manufacture would develop as an employment outcome of the motor car? If these adjustments could include changes in societies' interpretation of the work ethic on a global basis to suit a world where the shorter working week and working life and job sharing will be progressively introduced.

The social, economic and industrial adjustments involved appear to require a dimension of change which would need to be planned on a world wide basis.

Telecommunications and Energy

The costs of oil and consequently the costs of energy for the purpose of mobility in the form of petrol have doubled in the last few years while telecommunications costs have remained substantially constant over the same period. This brings into striking relief the possible substitution of telecommunications for energy in the form of mobility. It is difficult to see one being a complete substitution for the other because of the intangible benefit of the personal interaction which come with mobility. The trial system of confravision between Sydney and Melbourne has not received the anticipated level of market acceptance for these sorts of reasons. Indications are that the cost differential will continue to increase with oil prices continuing to climb and the price of telecommunications in real terms continuing to fall. Such trends must attract managers to confravision, teleconferencing and other telecommunications facilities which reduce the need to absorb energy in the interest of mobility. A nine cent call makes a lot of economic sense if it can obviate the need to pay a dollar to travel 15 kilometres for a discussion.

International Data Storage and Accessing

There is a growing awareness of the importance of information as a resource whose production occupies a major part of the economy. In recent years economists have been developing methods to classify, measure and account for the significance of the information sector, this being classified as a fourth sector in addition to the primary, secondary and tertiary sectors of the economy. If this sector is of such significance what effect does it have on an economy if such a product is shifted or otherwise traded. What costs are involved, what security or dependence are at stake, what controls or regulations are necessary. Similar questions, although less tangible in nature, can be raised concerning personal data storage and accessing on an international basis. These questions are currently being broached at the international level by a special group of the OECD.

SOCIETY AND CHANGE

It is meaningful to ask what will be the shape of society in the long-term future and what part will advancing technology in the telecommunications sphere play in this future. Speculation covers a wide range of possibilities and this in itself underlies the difficulties involved in planning within this sphere.

The new and developing technologies could offer a broader range of products with new and improved forms of information to simplify our home and work life. The environment provided by communications under such a scenario could serve to strengthen democracy by providing greater access for participation by the community in government decision-making and promote what might be perceived to be the 'good life' and self-realisation. Alternatively, the decentralised, multi-functional, self-contained, independent nature of services which could be provided by the new technologies may lead to a dehumanisation of society. Each of these views on change and its effects on society can be argued but neither provides a simple solution of comfort generally to telecommunications planners. They do, however, define some boundaries in regard to the debate which has now emerged over technological change at a time of low economic growth, a growing fuel crisis and high unemployment.

MANAGING CHANGE

It could be considered that every decision is concerned with change and the arrangements for putting decisions into practice constitute the management of change. The characteristics of the change can have many dimensions and these will influence the perspective, relativities, authority, influence and impact of the decisions made. These dimensions usually characterise a shift in value positions but the parties involved with the characteristics of the change can be diverse and the relationships are rarely simple. This lack of simplicity is inherent in the management of change and the degree of difficulty is greatest when the potential or real change is great as is the case for telecommunications.

Some decisions are internationally far-reaching, some are long term, some have immediate impact, some cause the on-going concern of staff, management, customers or society generally, some influence related industries and the Australian economic scene generally. Telecom, therefore, in managing the development of telecommunications, is involved in a dynamic far-reaching changing environment. To cope with this change it undertakes broadly based research and planning looking at long as well as short term horizons.

STRATEGIC PLANNING

In developing and applying the technology of telecommunications Telecom Australia has adopted at the corporate level planning processes of a strategic nature which encourage the partnership between technology and social needs. These processes have involved longer term perspectives, scenario development, an improved awareness of environmental influences, an increased recognition of its social responsibilities and increased interaction both inside and outside the organisation. In so doing the mood of technological development has changed towards a perspective which recognises more specifically the people aspects along with technology.

Three major strategic planning processes used by Telecom to guide the future of telecommunications developments in Australia are:

- **Telecom 2000** — An Exploration of the Possible Directions of Long Term Development of Telecommunications in Australia.
- **The Corporate Plan** — Objectives, Specific Strategies and Typical Major Projects for the Next 10 years.
- **Research, Development and Innovation (RDI) Strategic Guidelines** — A 5 Year Guideline to the Programming of RDI Resources.

These processes have contributed extensively to policy development and priority setting throughout the organisation by virtue of their effect on the interrelated network of plans and programmes which contribute towards the fabric of operational development of telecommunications in Australia.

TELECOM 2000

In 1973 the National Telecommunications Planning (NTP) Branch was set up within the then Australian Post Office. Its broad objective was to undertake an exploration of the possible directions of long term development of telecommunications in Australia. The need to set up such a group was a manifestation of a growing awareness of new technologies and new telecommunications services which were under consideration around the world and the rapidly changing environment. Widely discussed concepts such as "the wired city", "the global village", "the information based society", "the home office" suggested that telecommunications was on the threshold of a new era.

Many of these new services involved much more than simple extensions of the present telecommunications facilities, and could involve large investments just to establish a new network. It was possible that changes carried social implications for future society no less than those stemming from the invention of the telephone in 1876. It was recognised that telecommunications development required new policies and strategies to cope with the possible changes in the coming 25 years.

Thus NTP was set up as a multi-disciplinary group, not to duplicate the work of the existing planners, but to complement it. Their role was to examine future possibilities as they related to telecommunications, and provide information and advice to Telecom Australia to help in policy formation.

The NTP multi-disciplinary team set about this examination with the interactive assistance of users, academics, industry, Telecom people and others by way of seminars, discussion, consultantships and correspondence. A product of this planning exercise, **Telecom 2000**, was published in 1976. The general spirit of the report is captured by these words from the Introduction to that Report:

> "Society's needs, technology, and the social effects of technology are all interacting parts of a continuous process — a sort of complex chain reaction. There is nothing novel in emphasising the uneasy partnership that exists between technology and society; in emphasising the complex and often ambivalent effects of much technological development — some good for society, some bad. Basically, the ambivalence stems from the very nature of the two systems. To strike a sharp distinction — technology can be described as rationally based, scientific, logical. The social system is a human, living system; one in which large measures of irrationality, illogicality and unpredictability are likely to be encountered in its development.

The recommendations of **Telecom 2000** provided the basis for the required broader perspective for the setting of technology priorities into the future. In addition, they set up the tools to enable an on-going form of technology assessment process to be established. These tools are broadly defined by the following selected recommendations:

Telecom Australia should —

- "sponsor studies to identify and (where practicable) quantify the broader social and economic benefits of telecommunications";
- "support an open planning strategy and investigate both existing and new additional ways of facilitating interaction between itself and communities of interest";
- "implement a programme of field research into new and developing facilities";
- "commit itself to the development of advanced telecommunications facilities only after substantial field research data has been secured";

- "strengthen existing organisational machinery to monitor and study the interaction of social and economic environments with telecommunications and make the information generally available";
- "support interdisciplinary planning processes both within Telecom Australia and between it and other interdependent institutions (e.g. urban planning, transportation bodies)";
- "support an on-going programme of multi-disciplinary studies of future telecommunications";
- "conduct a programme of field research into new telecommunications concepts, facilities and equipment . . ."

OUTCOMES FROM THE TELECOM 2000 REPORT

Early in 1976 the report **Telecom 2000** was distributed for consideration and discussion within Telecom Australia. It was also decided to have the report distributed widely to organisations and individuals outside Telecom Australia. The aim was to tell people affected by Telecom Australia's services and policies about the issues involved in long term telecommunications planning. Comment on the issues raised in the report was invited. Responses to the report, both written and verbal, have been collected by NTP through 1976 and the early months of 1977.

Thirty thousand copies of the report were distributed, commencing in March 1976. A special distribution list was prepared to make the report available to all sectors of the community. The list included members of the Federal and State legislatures and judiciary; Federal, State and Local Government Departments and Authorities; educational institutions; industrial; professional, business and social organisations; and many private citizens involved in community and social activity. The public was invited to obtain copies.

Written responses totalled 210 ranging from formal acknowledgement to comments in depth.

The writers of the 111 more substantial responses could generally be identified with some professional or business source. Only 12 could be classified as "individuals". The single dominant source of responses was tertiary institutions (41). Other major sources were business (19) and government (18).

The major issues raised in responses involved only six subjects: open planning, community involvement, social theory, value position, competition and data policy. Each of these received comment from over 20 respondents. A further 15 subjects received comment from over ten respondents.

The responses received, however, were mainly of a high calibre, introducing a wide range of complex issues. An analysis of the responses and the recommendations as accepted by management are set out in the publication **Outcomes from the Telecom 2000 Report**.

RESEARCH, DEVELOPMENT AND INNOVATION (RDI)

Telecom pays particular attention to Research, Development and Innovation and manages specifically directed processes and programmes to ensure the effective and timely introduction of technology for the purpose of providing for new growth, providing new required facilities and for the replacement of obsolete equipment.

Each year it directs about 950 man-years of its resources on RDI. The distribution of this resource is determined by a corporate process which annually yields a rolling three-year programme. This programme covers a large number of projects and on-going activities which could find applications in the various components of the telecommunications network up to 20 years hence.

To enable priorities to be set within a number of categories relating to type of technology and the broad time of application the following criteria are used:

- Corporate Commitment
- Customer Orientation
- Financial and Resource Considerations
- Personnel and Industrial Relations
- Corporate Image

In the application of these criteria management judgement is required. Inherent in the process, however, is the opportunity for non-technical aspects relating to social needs to be taken into account.

OPEN PLANNING

The **Telecom 2000** report sets out discussion and recommendations about the desirability of involving the people affected by the actions of Telecom in the process of arriving at particular decisions. This was referred to as open planning. The report itself and the exercise involving evaluation of responses was in effect an open planning exercise. In view of the extent to which **Telecom 2000** was distributed, the number of written responses was less than had been expected within Telecom. On balance, however, it was considered to be a successful and useful overture into this mode of planning but it was clear that further thought and additional work would be necessary if the implementation of open planning was to effectively fulfil the expectations of all concerned.

The inherent change in attitude as well as the required changes in processes necessary to implement open planning must inevitably take time — one respondent to **Telecom 2000** suggested 10-15 years as being realistic. Telecom may not necessarily agree with this time-scale but it does signify a recognition by others of the difficulties involved.

THE CORPORATE PLAN

The need for formal corporate planning was recognised by the consultant to the Vernon Commission of Inquiry, Cresap, McCormick and Paget Incorporated (CMP) and is expressed in Section IV of its report which is published in volume 2 of the Report of the Commission of Inquiry into the Australian Post Office in the following terms:

> (p. IV-2) ". . . because development of a comprehensive strategic plan must be co-ordinated across several divisional lines, it is almost impossible under the present arrangements to provide co-ordinating leadership at a senior level other than in the office of the Director General . . ."

It was against the background of this statement that CMP recommended that the Managing Director be provided with "an immediate staff tailored to his external and strategic orientation" (p. IV-11). As a result of this recommendation the Planning Directorate with a Corporate Planning role was created at Vesting Day (July 1, 1975). The consultant broadly specified the role of the Corporate Planning Branch as:

(p. IV-13) "This long-range business planning activity should include financial, technological, marketing, manpower, organisational and profit planning components, to ensure that plans exist for all necessary resources."

In this way the social, industrial and commercial needs of the people of Australia for telecommunications services can be considered in a comprehensive and ongoing manner and accordingly consideration of the impact of technology is part of the broad package which constitutes Corporate Planning.

Since the setting up of Telecom Australia in 1975 a small group of corporate planners has been working with the various elements of line management to develop a Corporate Plan to bring about the top-down orientation seen as necessary to the future viability of the organisation and improvement in service to the customers.

Recognising the **Telecom 2000** recommendation concerning "open planning" it was also considered important as part of the Corporate Planning Process that Staff Associations be given the opportunity to comment. A draft was distributed and responses were received which assisted the preparation of the final document. The major changes which resulted concerned the role of women in the workforce and a more specific recognition of the important role that Staff Associations perform in negotiating industrial matters on behalf of Telecom Australia's employees. Staff Associations expressed concern that they should be involved much earlier in the development of future Corporate Plans.

Some of the interactions involved in developing this first Plan have proved less than ideal and will require refinement during future cycles of the process. To this extent, it is important to emphasise that the Corporate Plan is a "living" document subject to regular review and updating. These shortcomings are consistent with the recognised need to learn more about "open planning".

The Plan has been made available to the public on request and an abridged "Highlights" version has been distributed to all staff.

The Corporate Plan as currently developed broadly consists of three parts:

- the basis for corporating planning;
- the broad strategy to be adopted over the next five years;
- the Planning Guidelines for a ten year horizon.

To establish a basis for corporate planning a set of corporate objectives has been derived from a study of the statutory responsibilities given to Telecom Australia in the Telecommunications Act and a knowledge of what is required to improve the utility, reliability and economy of telecommunications services as seen by the people of Australia.

To assist in achieving these objectives the Corporate Plan sets a broad strategy for the next five years of adopting Corporate Thrusts and Actions. Four Corporate Thrusts have been identified by management:

- Quality of Service
- Efficiency
- Staff Relations and Development
- Technological Improvement

The need to assess the priorities to be accorded to technological improvement against the complete picture presented by the four Thrusts is inherent in the Plan. This is referred to in the definition of the Technological Improvement-Corporate Thrust.

"To use new and improved technology in a timely and efficient manner to reduce operating and overhead costs and to ensure that new services and improvements to existing services are available when required. As technology is basic to telecommunications, this thrust underlies much of the action possible to improve responsiveness to customer requirements and also to improve efficiency."

Corporate Actions are defined for each Corporate Thrust and these set out more specifically the manner in which the thrust is to be fulfilled.

The Technological Improvement Corporate Actions are:

- Development of the telephone switching network;
- Reliability of customer equipment;
- Computers in management;
- Rural services.

Each of these is defined to give further guidance to the operational planners. The importance of privacy and integrity of communications is also taken into account.

POLICY RESEARCH

Telecom undertakes policy research work employing interdisciplinary groups. Included in the range of studies are such subjects as the impact of the external environment, policy involving generally its ability to apply technology to fulfilling social needs — in particular those of its customers, and the behavioural requirements of the internal organisation in fulfilling its responsibilities. Policy research, as a prerequisite for policy review and formulation, is now performed on a much broader base with the involvement of the major functional areas and the use of consultants as necessary.

A social science research seminar on "Social Research and Telecommunications Planning" was held in late 1979. It was organised and funded by Telecom and the participants were Telecom staff and invited academics and practitioners in the social science disciplines who had previously shown an interest in telecommunications planning. The overall objective was to explore the role and contribution of the social sciences in the planning and provision of telecommunications services. Outcomes of this first seminar provided for the commencement of specific research projects, the provision of guidance for priorities in future research or changes in the purpose or participation of subsequent seminars. The seminar was an interactive participative process commencing prior to the event. The range of topics explored at the seminar included.

- Social Trends and Communication Patterns
- Distributional Consequences of the Provision of Specific Services
- The Information Economy
- Planning — Theory and Practice
- Technological and Social Interactions
- International Developments as they affect Australia's Telecommunications Planning

OECD ACTIVITIES

The programme of work being undertaken within the Committee for Scientific and Technological Policy (CSTP) of the OECD and its various working groups reflects the nature of telecommunications technology and its impact on social needs in a manner consistent with the spirit of **Telecom 2000**. Many of the projects being researched in many countries around the world involve analysis of the broader environment for telecommunications. The depth of research available and in progress on an international scale, therefore, is of value in providing the perspective necessary to assist in Telecom's planning. Out of study and participation in the work of OECD should come a better understanding of the social needs for telecommunications of today and tomorrow.

Recognising the reciprocal nature of a telecommunications service (it is to be rung as well as to ring!) Australia must see itself as part of the wider world network of telecommunications and plan accordingly. Some of the projects of the CSTP of interest to Telecom at this time include:

- Science and Technology in the New Socio-Economic Context
- Technical Change and Employment
- The Utilisation of Social Sciences in Policy Making
- Public Involvement in Decision-Making Related to Science and Technology
- Transborder Data Flows and Protection of Privacy
- Policy Implications of Data Communications Network Developments
- Economic Analysis of Information Activities and the Role of Electronics, Telecommunications and Related Technologies
- Implications of Microelectronics on Productivity and Employment
- Growing Vulnerability of Society Stemming from the Widespread Use of Computer and Telecommunications Systems
- Government and Information Policy

INTERNATIONAL FORCES

From the point of view of economics of production on an international scale and the increasing international nature of private as well as industry and commerce demand, there is a need for international compatibility of services. Such aspects are bandwidth, frequency, signalling, delay time, error rate, speed of transmission, modulation and multiplexing modes, all require international standards to enable effective interconnections to take place. Once such standards are set, manufacturers produce according to these specifications. If Telecom purchases equipment for a given service it is often constrained to new generation equipment designed to fulfil social needs which have been determined at the international level. If Telecom wishes to ensure that it communicates with the rest of the world, it can be necessary to ensure that it purchases the latest generation equipment.

SUMMARY AND CONCLUSION

It has been stressed that there is nothing new or mystic about technology or technological change — it is a natural reaction for man to move towards satisfying his basic social needs by the development of technology. In satisfying these social needs, there will be social consequences to which society will adjust. To satisfy the social need to communicate at a distance, telecommunications was developed and it has continued to develop with increased social needs.

Telecom Australia as the common carrier has a major responsibility for the introduction of new telecommunications technology. How can it best fulfil this responsibility and be sure that it continues to meet society's changing needs of the future? It has several constraining forces by way of statutory requirements and administrative arrangements which restrict its activities.

Over the years Telecom has operated in a field of continuous change from manual to automatic, step-by-step to crossbar and crossbar to computer controlled exchanges. It has had to develop research and planning processes which encourage a partnership between social needs and technology in its telecommunications developments.

The **Telecom 2000** report surveyed social needs to the year 2000 and discussed the technology which would be available to satisfy those needs. It put forward the concept of open planning which would involve the people affected by its actions in the process of arriving at particular decisions. It was followed up with **Outcomes from the Telecom 2000 Report** which discussed the reaction of society to **Telecom 2000** and set out the recommendations as accepted. As part of its strategic planning processes Telecom has produced a Corporate Plan and associated processes so that the social, industrial and commercial needs of the people of Australia for telecommunications services can be considered in a comprehensive and on-going manner. It also sets priorities for the application of resources to Research, Development and Innovation based on broad perspectives involving a large number of projects which could find applications in the various components of the telecommunications network up to 20 years hence. It undertakes policy research based on multidisciplinary studies and involves itself in and monitors international activities which recognise the partnership between social needs and technology.

Just as the mouse is given credit for adjusting its smartness to match that of the smarter mouse-trap we must give credit to the ability of society to adjust to the changing social implications of new telecommunications technology. Recognition of the significance of the broader social issues involved will manifest itself in a realisation of the necessity of the partnership of social needs and technology for future telecommunications developments in Australia. This realisation will prompt increasing calls for open planning and public participation in planning processes generally. Telecom as the common carrier of telecommunications in Australia has made a start by recognising this partnership and developing some processes to make it work. Like all partnerships, however, continuous understanding and adjustment will be necessary to ensure that social needs and telecommunications technology proceed into the future hand in hand.

Alice Springs — Tennant Creek: A New Approach to Radio Relay Systems

A. J. MENCEL

The need to extend the broadband communication network to the centre of Australia provided Telecom Australia engineers with the challenge to design a terrestrial radio relay system which would be specifically suited for installation and operation in remote areas. By making use of the recent development of low power consumption equipment and the availability of photovoltaic solar cells to power such equipment, and by careful attention to design, a system was developed which shows considerable savings in capital and maintenance costs when compared with earlier installations.

This article discusses the concepts involved in the design of radio communication systems for remote areas and describes the system installed between Alice Springs and Tennant Creek in the Northern Territory of Australia.

In 1872, a single iron wire provided one telegraph circuit across Australia from Adelaide to Darwin, a distance of some 2600 km and although additional wires were added over the years to provide for telephony and additional telegraph circuits, the overhead construction remained in service for 100 years when the Tennant Creek—Darwin section was replaced by a microwave radiocommunication system (Ref. 1 and 2). This system gave Darwin its first broadband link with the capital cities in the south. In 1979, a further section of the open wire route was withdrawn from service when Alice Springs and Tennant Creek were joined by a microwave radio relay link.

The design of this latest, long-haul broadband radiocommunication system to the centre of Australia provided engineers with an unique challenge to design a system which would overcome many of the difficult problems associated with systems previously provided in remote areas.

The system installed involves 13 repeaters between Tennant Creek and Alice Springs, employs low power drain equipment of very high reliability installed in underground shelters, makes use of torsionally stabilised masts and is believed to be the first major long-haul microwave system in the world in which all repeaters are solar powered.

DESIGN PHILOSOPHY

The design philosophy for remote area broadband radio relay systems rests on four main, mutually dependent points as shown in **Fig. 1**. These are:

- Use of low power consumption radio equipment — The first and most important factor that makes the system concept possible is the recent development of low power consumption, highly reliable microwave radio relay equipment. Such development has been fairly general and equipment of this type is now offered by many manufacturers.
- Solar power — As a consequence of using low power consumption equipment it becomes economic, considering capital costs alone, to use solar energy to provide primary power for loads of up to about 140 watts.
- No airconditioning — Given the above two points, it follows that no other site facility should dominate power consumption requirements. In particular, the need to provide airconditioning must be avoided.
- Underground equipment shelters — Performance of radio relay equipment is improved if it is presented with a constant temperature environment. Having ruled out the provision of airconditioning, the need for underground or similar heat dissipating and temperature averaging shelters becomes imperative.

Adoption of the above four points leads to further advantages and cost savings in other areas of system provisioning and maintenance:

- Installation costs — Considerable cost savings can be achieved by extensive 'pre-installation' of equipment in transportable shelters before their transportation to remote sites.
- Operating Costs — Liquid or gas fuel charges with their uncertain cost and supply structures are completely avoided.
- Maintenance costs — Use of solar cells eliminate costly maintenance of rotating power generating equipment and fuel delivery charges.
- Site access roads — Savings in costs of access roads can be achieved by specifying a standard of road con-

sistent with infrequent site visits and access by four-wheel drive vehicles only.

Applying these points to the design of the Alice Springs — Tennant Creek radio relay system, together with other considerations determining the type of antenna support structure, power shelter and solar array support, resulted in an installation which is well suited to conditions such as are encountered in Central Australia. The type of station established at repeater sites is shown in **Fig. 2.**

SYSTEM DESCRIPTION

The system, between Alice Springs and Tennant Creek in Central Australia, comprises a 960 circuit telephony bearer, a 'protection' bearer with provision for non-priority television transmission and an undirectional television bearer from Tennant Creek to Alice Springs. It consists of two terminals and thirteen intermediate solar powered repeaters. The average path length between stations is 36 km. The system operates in the 4GHz band and was designed to meet the usual transmission specifications applicable to broadband radio relay systems.

At Tennant Creek, the system interconnects with the existing Telecom broadband network. Telephony circuits are extended to Darwin and eastwards to Brisbane and beyond, while television programs originating in Brisbane and relayed to Darwin are split and fed to Alice Springs.

Route

The system traverses 500km of sparsely populated arid country and follows closely the route of the Stuart Highway as shown in **Fig. 3.** The terrain consists of scrub and grass plains with occasional rocky, spinifex covered ranges of low hills.

In selecting repeater and terminal sites, environmental issues were very much to the fore, especially in the Alice Springs area where every effort was made to minimise interference to the natural grandeur of the surroundings. In line with the wishes of environmental protection authorities who wish to avoid proliferation of structures on the range of hills surrounding the town, an agreement was reached with the Department of Transport to share the existing hill site at West Gap, just south of the township. A new equipment building was constructed, recessed against the hill and is not visible from Alice Springs. The existing light-duty tower was replaced by a stronger structure capable of satisfying, in the Alice Springs area, the radiocommunication needs of Telecom Australia, the Department of Transport and other authorised parties for many years to come.

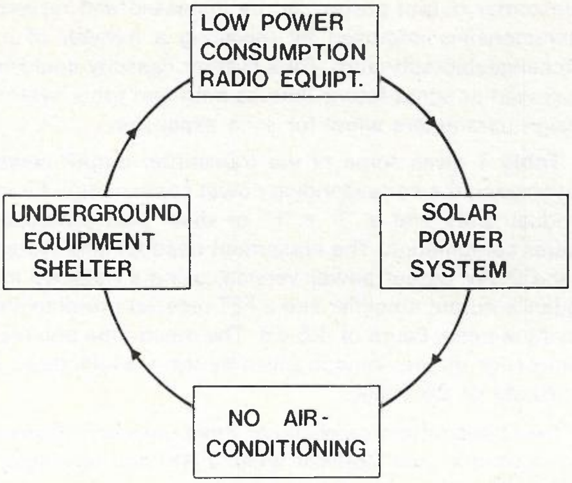


Fig. 1 — Interdependence of Design Factors for Remote Area Radio Relay Systems.

Radio Equipment

The concept adopted in the design required that low power consumption, highly reliable radio equipment be selected for this system. Also it needed to be of modular construction requiring only a minimum time to be spent in field visits for restoration of faults.

The equipment selected meets these requirements. In addition, its configuration is such that, if required,

ANTON MENCEL joined the Australian Post Office in 1957 as a Technician's Assistant and was appointed Trainee Engineer in 1962. After graduating from the South Australian Institute of Technology with a Bachelor of Technology Degree in Electronic Engineering in 1964 he was engaged in the installation of telephone switching equipment in the Adelaide metropolitan area.

In 1968, he transferred to radiocommunication equipment installation duties and was involved in projects in South Australia and the Northern Territory. He was appointed project co-ordinator of the Alice Springs — Tennant Creek radio relay system installation and was responsible for the introduction of subscriber trunk dialling to Alice Springs. At present, he is the Senior Engineer for radiocommunication installation projects.

transmitter output power can be increased and receiver characteristics improved by replacing a number of interchangeable sub-units. Thus system capacity could be increased at some future time as path and other system design parameters allow for such expansion.

Table 1 gives some of the transmitter output power options and the corresponding power consumption for individual units and a '1 + 1', or main plus protection bearer combination. The equipment used for this system is the 0.5W output power version, using a negative impedance output amplifier and a FET receiver pre-amplifier having a noise figure of 4.5 dB. The mean time between failures for the equipment, given by the manufacturer, is in excess of 25 years.

Two transmitters/receivers or three diversity receivers are housed in one 260mm wide, 2100mm high equipment rack.

Supervisory Equipment

In line with the need to minimise power drain at repeater stations, low consumption supervisory equipment was selected. The equipment which operates in the frequency shift key (FSK) mode extends alarms, consisting of 32 indications per station, to the route control station in Darwin. Of the 32 indications, 16 are used to monitor radio equipment performance, 11 to extend power equipment alarms and such miscellaneous alarms as waveguide pressure and door alarms, while five are presently spare and available for system expansion. The status of an alarm is displayed locally by low power light emitting diode (LED) indicators.

Telecontrol facilities from the route control station at Darwin to repeaters are not provided.

Equipment Shelters

The location of the system is in a hot, arid zone where large diurnal and seasonal variations in temperature occur. In order to increase system reliability and improve performance it was essential to reduce temperature extremes and temperature cycling to which the equipment would be exposed. Since mains power for airconditioning was available at terminal stations only, the decision was

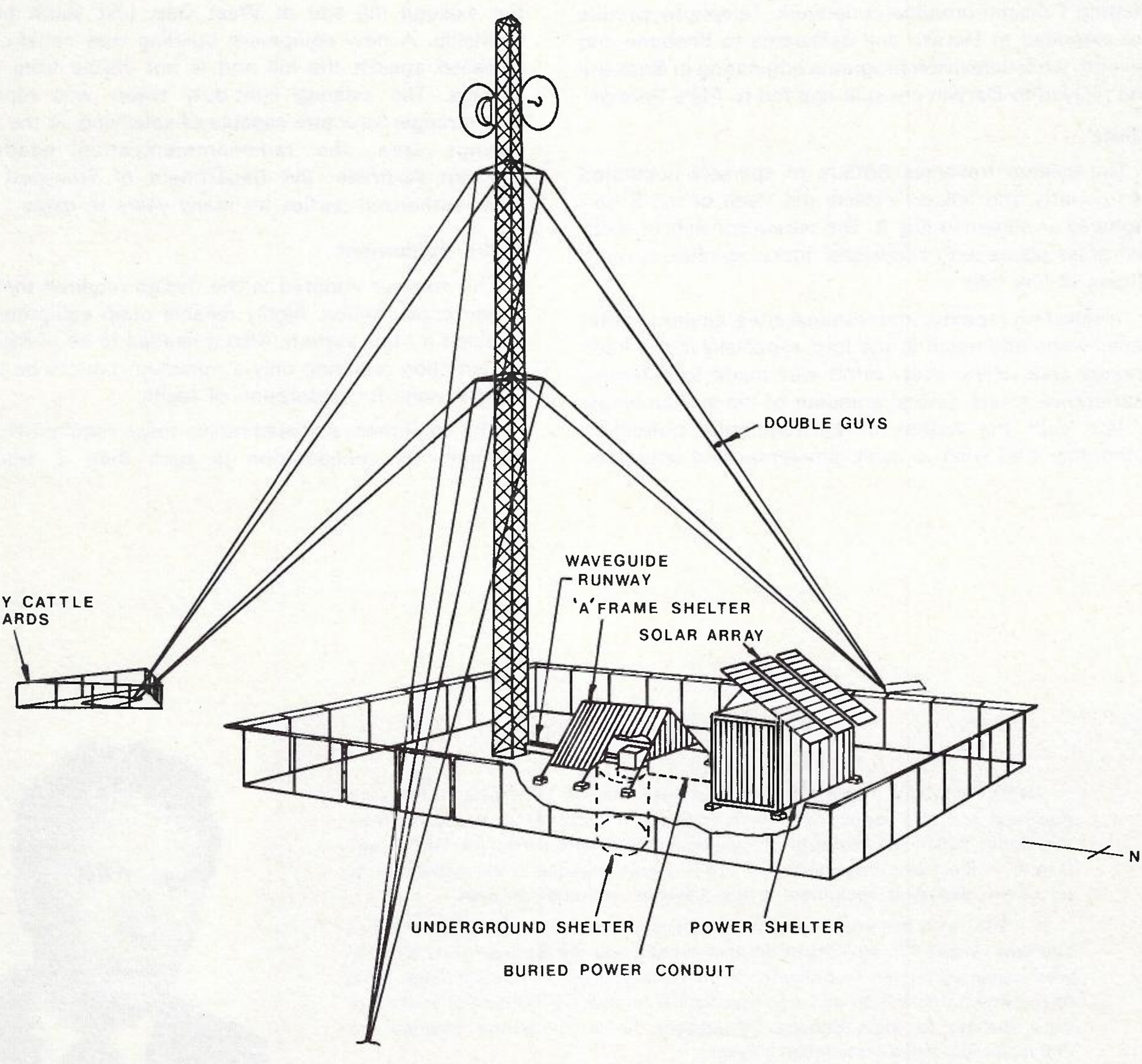


Fig. 2 — Typical Repeater Station Site Layout.

made to house the equipment at repeaters in underground shelters. Heat generated by the equipment is dissipated into the surrounding soil and stable temperature conditions are achieved without the use of airconditioning. This method is considered satisfactory for an equipment power dissipation of up to about 15 watts per sq. m. of shelter wall in contact with surrounding soil.

A steel shelter was designed to provide sufficient space for up to four both way radio bearers and a total power dissipation of 400 watts. The shelter, manufactured from 6mm steel plate, is a cylinder 2400 mm in diameter and 2600 mm high and is buried in the ground to a depth of about 500 mm. Protection against corrosion is provided by a coating of coal tar epoxy paint and a sacrificial cathodic protection system. Access to the shelter for personnel and equipment is by a ladder within a rectangular 800 mm by 900 mm entrance 'conning tower' which protrudes about 900 mm above the surface of the ground. A lockable aluminium entrance hatch lid prevents unauthorised entry and a separately hinged polycarbonate insect screen seals against dust and creates an airlock to reduce heat transfer. Attached to the outside of the conning tower is an air intake fan housing and fan. This provides ventilation via a duct extending to the floor of the shelter when staff are in attendance. Portion of the ceiling where antenna feeders enter the shelter is raised above ground level to facilitate sealing against entry of moisture.

A simple steel 'A'-frame structure above the underground shelter acts as a sunshield for the exposed parts of the shelter and provides an anchorage point above the entrance for a pulley system for lowering equipment into the shelter.

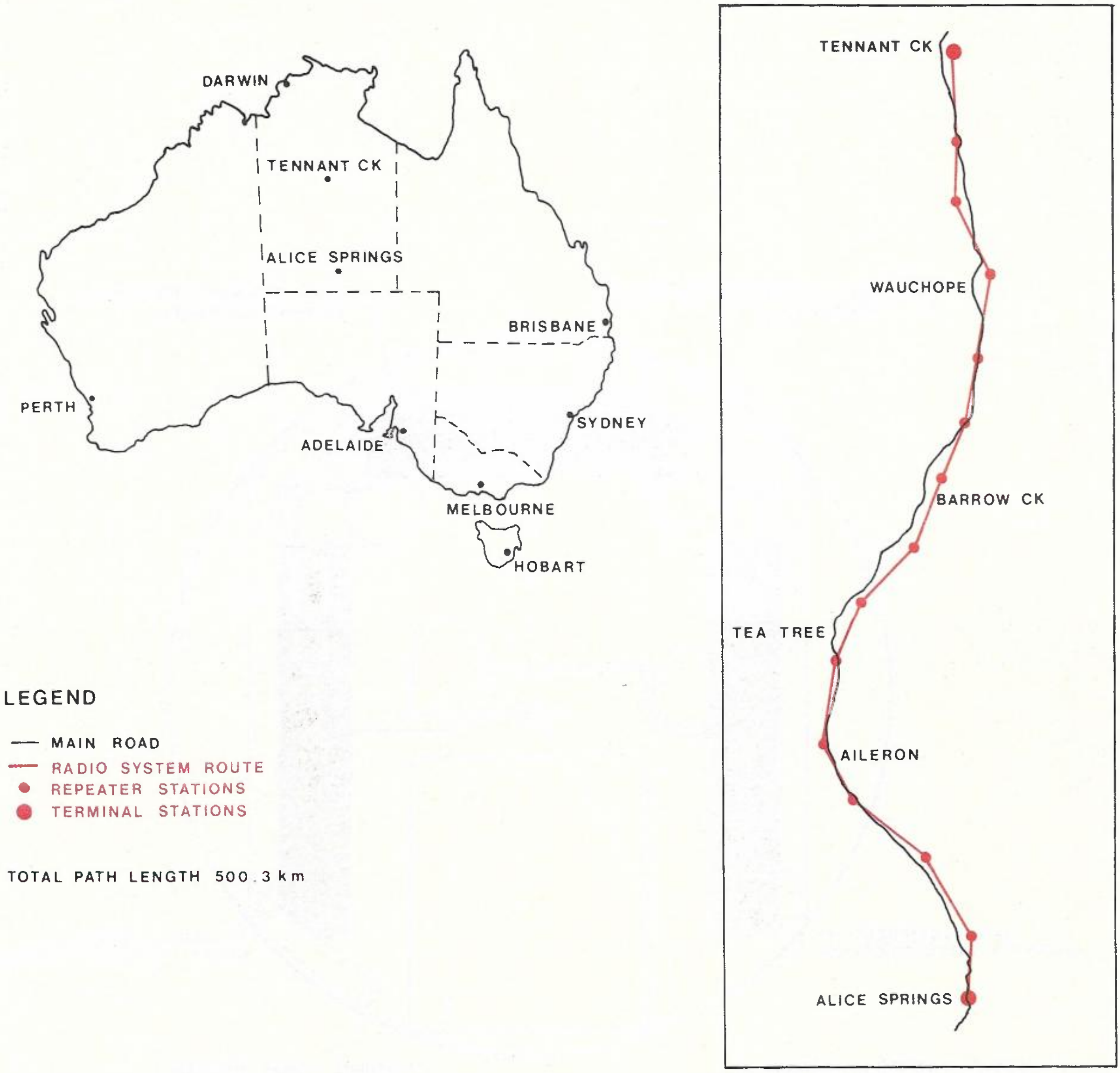


Fig. 3 — Alice Springs — Tennant Creek Radio Relay System Route.

POWER CONSUMPTION AT -20VDC

TRANSMITTER OUTPUT POWER	+20dBm (0.1W)	+27dBm (0.5W)	+30dBm (1.0W)	+37dBm (5.0W)
TRANSMITTER POWER CONSUMPTION	7W	12W	17W	50W
RECEIVER POWER CONSUMPTION	5W	5W	5W	5W
REPEATER (I.F.) FOR A 1+1 SYSTEM	48W	68W	88W	220W

Table 1 — Power Consumption of Broadband Radio Relay Equipment.

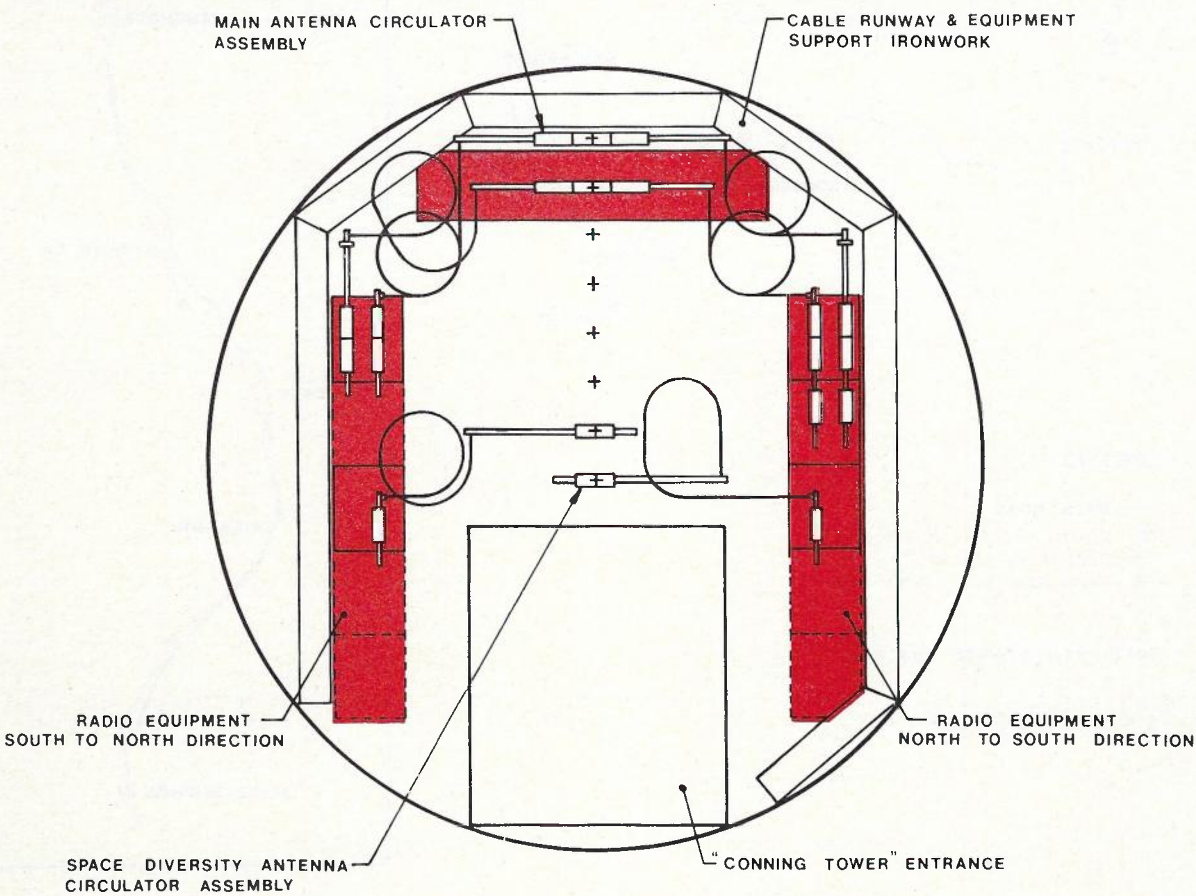


Fig. 4 — Repeater Station: Layout of Equipment in Underground Shelter.

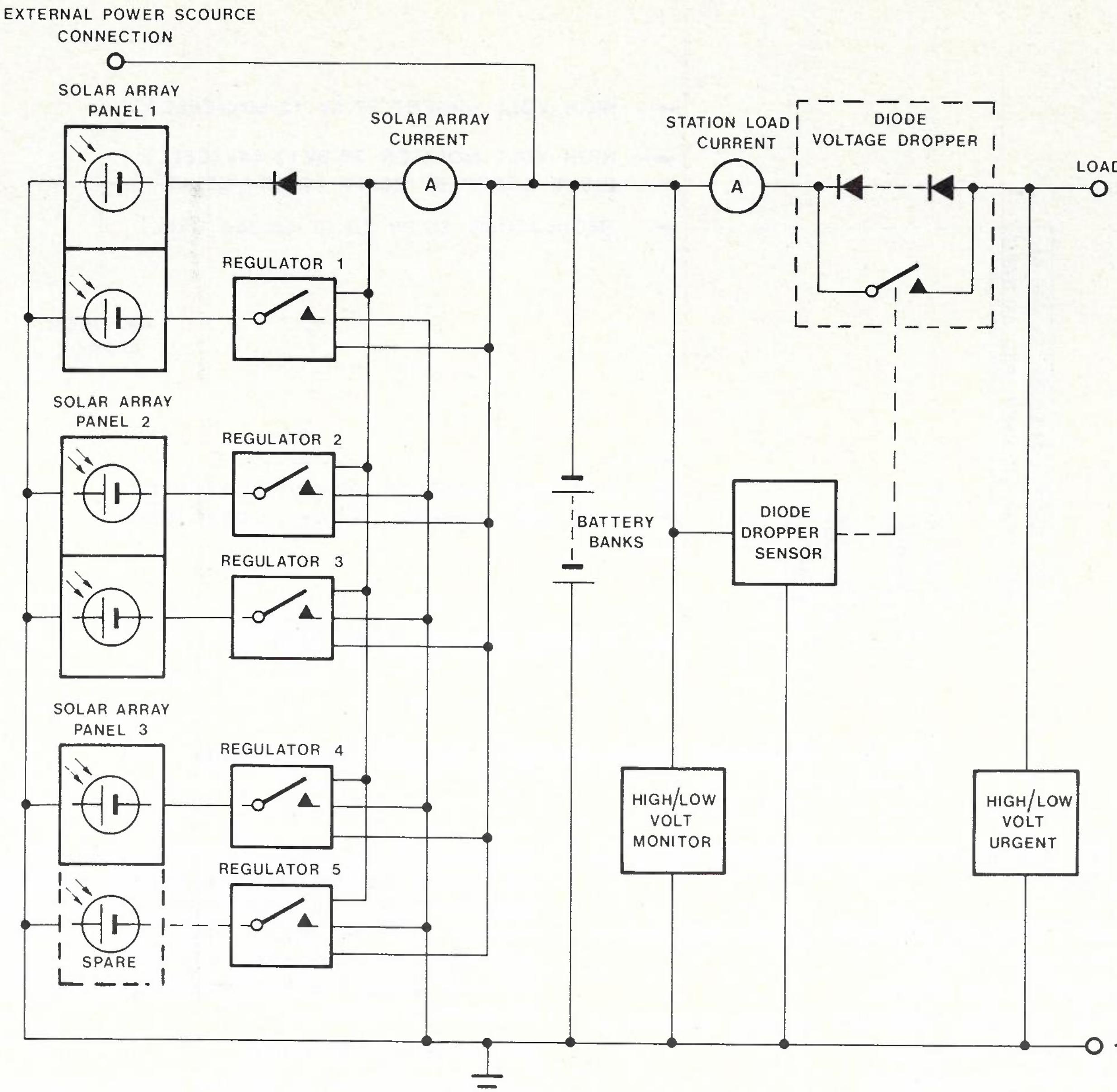


Fig. 5 — Block Diagram of Solar Power Plant.

Equipment Layout

Fig. 4 shows the equipment layout at repeater stations. The radio equipment is arranged in two 1300mm long suites, the two directions of transmission being on opposite sides of the shelter. Supervisory equipment, waveguide dryers with air distribution, and a power distribution panel are housed on two racks opposite the entry hatch. A 102 mm by 76 mm 'U' channel running at rack height along the walls of the shelter doubles as a support for the equipment racks and cable runway.

Power Supplies

For a number of years Telecom Australia has been using small solar power systems, comprising photovoltaic cells, storage batteries and control circuits, to power single channel subscriber radio equipment. With the advent of low power drain broadband radio relay equipment programs were initiated to develop systems capable of supplying loads of up to 150 watts.

Design considerations and the plant developed for use on the Alice Springs-Tennant Creek system were described in Ref. 3. The design is based on a standard 6100 mm x 2500 mm x 2500 mm steel shipping container as a power shelter, with an array of solar panels giving 850W peak power mounted on the roof. Three, 22 volt banks of 500 AH batteries, control cubicle and staff amenities are housed within the container. **Fig. 5** shows a block diagram of the power plant.

For control purposes the array is divided into six sections, five of which are equipped initially. Each section, except the first, is controlled by an open circuiting regulator which removes the output of that particular part of the array once the preset battery voltage is reached. Although each regulator is set to the same nominal value, incremental operation of the control circuit as a whole is ensured by normal component spread. Section 1 of the array is permanently connected across the batteries.

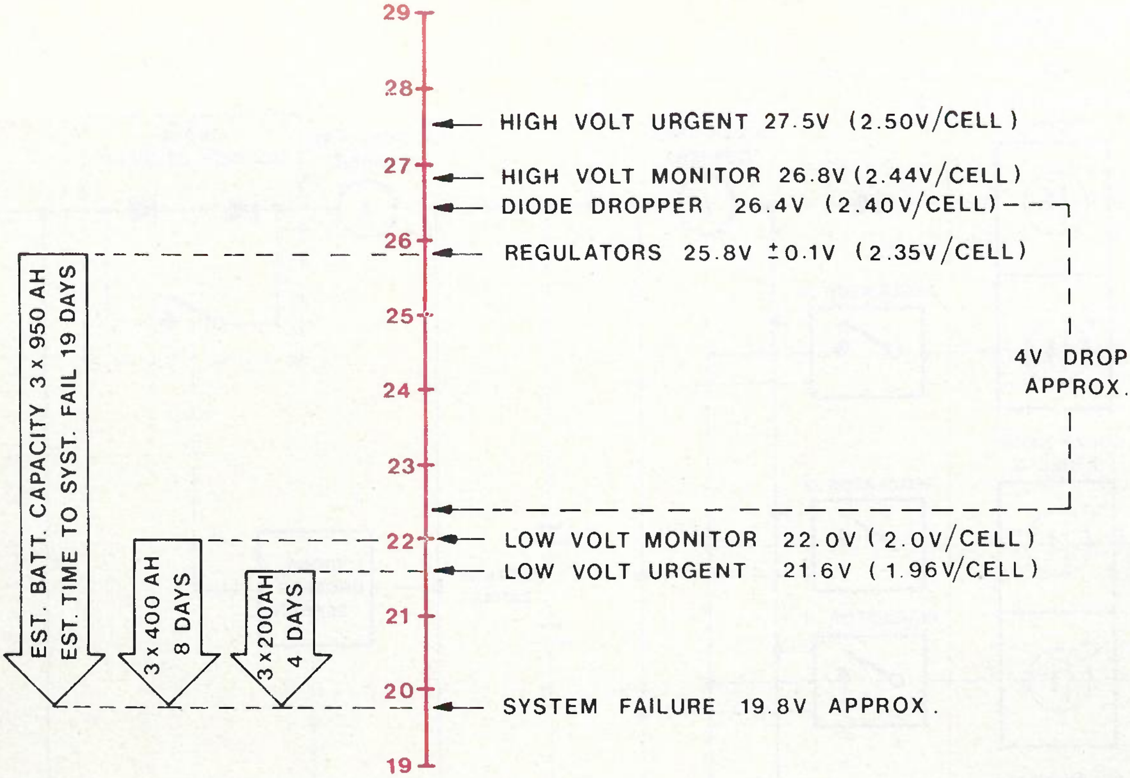


Fig. 6 — Solar Power System: Setting of Alarm and Monitor Points

The control circuit provides the following alarms and indications:

- HIGH VOLTAGE MONITOR, an early indication of rising output voltage;
- HIGH VOLTAGE URGENT;
- LOW VOLTAGE MONITOR, an early indication of falling output voltage;
- LOW VOLTAGE URGENT;
- LOCAL INDICATIONS ON, local indications and meters are normally switched off as part of the need to conserve power;
- FUSE ALARM;
- POWER SHELTER DOOR ALARM.

All these indications are extended to the control station in Darwin.

A safeguard has been built into the system to protect the radio equipment from high voltages in the event of failure of the regulators. It consists of a number of series connected diodes which can be inserted, under the control of a voltage sensing circuit, into the output lead feeding the radio equipment. When operated, this lowers the output voltage by approximately four volts.

Setting of the alarm and monitor points is shown in **Fig. 6** together with expected battery reserve and estimated time to system failure at these points in the event of a complete failure of the solar array.

Connection of power to the equipment in the underground shelter is by cables run in galvanised iron pipe between the two shelters. To prevent high voltages which could be experienced due to heavy earth currents and resulting potential differences between the shelter earths in the event of a lightning strike at the site, surge protector diodes are fitted to earth from each of the cables linking the two shelters. This precaution is in addition to the bonding together of the earthing systems of all the structures on site.

Antenna Support Structures

In calling tenders for antenna support structures, prospective suppliers were given two alternatives — self supporting towers or torsionally stabilised guyed masts, each to support up to four 3.7m diameter shrouded parabolic antennas mounted at heights of up to 75m above ground level. Design calculations were to be based on wind velocities of 48m/sec at a height of 10m above ground with an allowance for increase in velocity with height ranging to 57m/sec at 70m above ground. A further requirement was that the tilt and twist of each structure should be such that the radio beam would not deflect by more than 0.65 degree from true bearing in azimuth and in elevation for wind velocities of 30m/sec. The sway of the structure from vertical, under maximum design wind load, should not exceed 0.75% of the height of the structure.

On the basis of costs and because masts have a lesser impact on the skyline than free-standing steel towers a tender was accepted offering torsionally stabilized latticed steel guyed masts for repeater stations and a self supporting steel tower for the Alice Springs terminal; space limitations at this site precluded a guyed structure. At Tennant Creek use was made of the existing 54m tower.

The necessary stiffness of the 1m square section guyed masts is achieved by fixing double guys to outriggers adjacent to each antenna mounting position as can be seen in **Fig. 7**. The type of guy anchors used was dependent on the nature of the ground at each site, being mass concrete type at sandy sites, and rock anchor or wedge type at rocky sites. Up to two levels of guys are fixed to each guy anchor.

Antennas and Feeders

Spun aluminium parabolic reflectors, 3.7m in diameter, are used as main antennas at all stations; diversity antennas are 3.3m in diameter. The antenna feeder is 4GHz elliptical waveguide.

For ease of installation the vertical run of the feeders is on the outside of the mast with the horizontal gantry consisting of enclosed trays. Entry into the underground shelter is vertically and the waveguides terminate in circulator assemblies located just below the ceiling, along the centre line of the shelter. Flexible coaxial cable tails complete the connection to the radio equipment. (refer Fig. 4).

DC operated waveguide air dryers located in the underground shelters provide pressurization of the antenna systems.

Access Roads

The proportion of total costs of radio relay systems represented by the cost of access roads has been rising steadily in recent years. It has therefore become very necessary to pay close attention to the type and cost of roads to be specified.

The decision to power all repeater stations with solar energy has removed the requirement for fuel deliveries to sites. This fact combined with the expected high reliability of the equipment means that only very infrequent visits by maintenance staff should be necessary. In designing the system it was therefore considered that a substantial saving in costs could be achieved by specifying site access roads of a lesser standard than was normal for such roads in the past. Access roads were specified to provide:

- Two-wheel drive access during normal (good weather) conditions;
- Four-wheel drive access during abnormal (wet weather) conditions;
- Road running width of 3.0m.

These relaxed specifications have all but removed the need to transport road making material over more than short distances. Sufficient material could usually be found close to each site resulting in considerable cost savings.

Typical Site Layout

Fig. 2 shows a typical repeater station layout. Structures have been arranged generally along a north-south line with the mast being at the southern end of the site and the power shelter with its roof mounted, north facing solar panel array at the northern end. Depending on the direction of fire of the antennas and the topographical layout of the site, and hence on the orientation of the mast guys, the power shelter is moved either east or west of the north-south line in order to reduce shading of the array by the guys. The distance between the mast

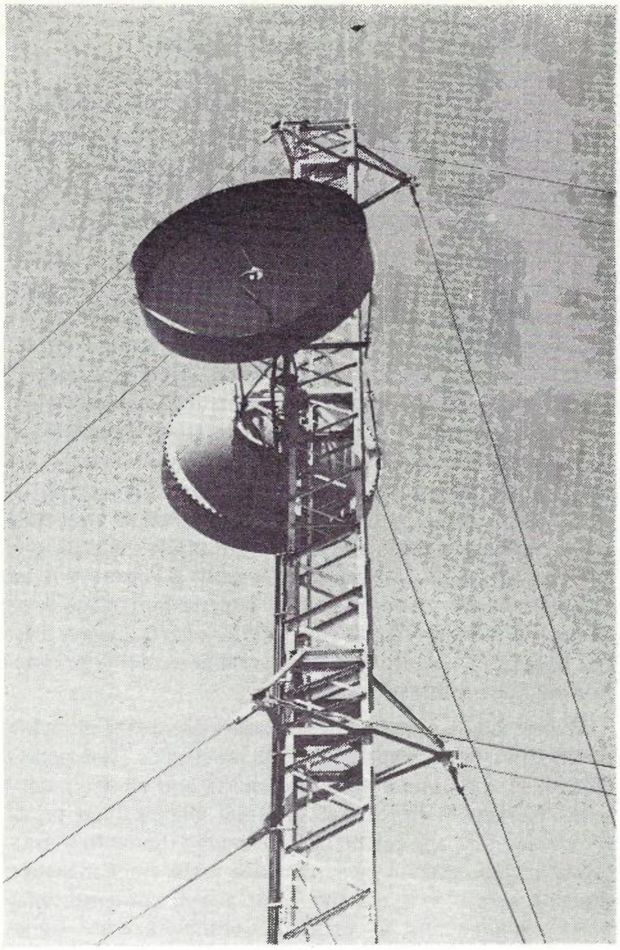


Fig. 7 — Guyed Mast Fixing Arrangements

and power shelter is approximately 12m, this distance having been determined by the need to avoid shading of the array by the mast and antennas during the summer period when the sun passes to the south of the site. All sites on this route lie north of the Tropic of Capricorn.

A 2m high, man-proof fence surrounds the structures; guy anchors, which mostly lie outside this fence are protected by steel guard rails.

IMPLEMENTATION

Because of the limited time available for implementation of this project, tight co-ordination of the various phases of the work was required. Just under three years were allowed for the provision of the system which involved detailed system planning, preparation of schedules for purchase of material and services, examination of tenders, letting of contracts, manufacture of equipment and material, installation by contractors and Telecom staff and, finally, commissioning of the system.

Separate contracts were let for:

- Provision of site access roads and site preparation;
- Supply and erection of masts and towers, supply and installation of underground equipment shelters and 'A'-frame sunshields, and the provision of foundations for power shelters;
- Supply, installation and commissioning of solar power plant;

- Supply and erection of site fencing;
- Supply only of antennas and waveguides;
- Supply only of radio and supervisory equipment;
- Supply only of waveguide pressurization equipment.

Installation of the radio, supervisory and waveguide pressurization equipment, and the antennas and waveguides was carried out by Telecom Australia personnel, as was overall commissioning of the system.

Field activities, except for construction of site access roads lasted just over 12 months, the actual construction phase being completed within nine months. Field work commenced with provision of the underground equipment shelters. The shelters were manufactured in Adelaide and all cabling and wiring, and some equipment was installed before transportation to sites. Also fitted in the shelters were rack plinths and all ironwork necessary for fixing of equipment. Shelters were transported by semi-trailer, three at a time, and unloaded at individual sites. After excavation and placement of the underground shelter, the mast, power shelter and 'A'-frame shelter foundations were poured at each site starting at the Alice Springs end of the route. This activity was followed, after the necessary curing time of foundations, by mast erection and assembly of 'A'-frames.

Power plant installation followed progressively after completion of structural work at each site. The power plant was manufactured in Melbourne and all equipment was installed in the modified, steel shipping container power shelters and tested before leaving the factory. Batteries in their special packing cases were stacked within the containers as were the solar arrays complete with solar modules and all cabling. Containers were transported on semi-trailers and placed on the already prepared foundations at each site. Solar arrays were then unloaded and hoisted onto the roof, batteries were placed on racking installed in the container and connected. Battery charging, using transportable generating equipment, testing and commissioning of the plant completed the power installation.

Installation of radio and supervisory equipment, antennas and feeders followed closely on the provision of power plant. Because of the lack of storage facilities at the sites, equipment was transported to a site, uncrated, lowered into the shelter by pulley and fixed in position. A second team of technicians followed, completing cabling and wiring, and fitting antenna branching networks to the terminated waveguides and pre-terminated flexible coaxial cable tails. Small portable petrol driven alternators provided power for test equipment.

Site fencing was provided after all work requiring access by heavy transport had been completed.

The various phases of the field work were tightly scheduled and progress was closely monitored to ensure minimum interference among the various activities. Accordingly work on the different phases commenced progressively and its sequence maintained from site to site. In general, installation went as planned except for some delays in mast construction caused by material shortages when heavy rains in Central Australia cut all roads and the rail line to the south of Alice Springs for several weeks.

POWER SAVING TECHNIQUES

A designer contemplating use of solar power will find strong inducements to the saving of power beyond the mere use of low power drain equipment.

The installed cost of the solar power supply for this system is approximately $300 per watt of load. To increase available capacity beyond the present 140W would incur a cost penalty of about $120 per additional watt. Thus a saving of one watt of power consumption at each of the 13 repeater stations results in an overall saving of about $1500 of capital investment.

Power saving techniques have been adopted to reduce consumption wherever possible. Thus:

- All local indications are switched off when staff are not in attendance and **'INDICATIONS-ON'** condition is alarmed to prevent them being left on inadvertently;
- Orderwire access equipment is switched off when not in use. This is under the control of a timing circuit which is activated by the door switch. A four minute delay after all doors are closed allows control station to recall staff before they leave the site. The external loudspeaker and associated amplifier are also switched off after four minutes together with the timing circuit itself;
- Alarms on all light switches when in the 'ON' position;
- Alarm and mechanical timing switch on the fan to prevent it being left running after staff leave the site.

COST SAVINGS AND PRODUCTIVITY

Planning and provision of the system took place at a time when Telecom Australia, in line with many other large business organisations in Australia, was experiencing the effects of the tight monetary situation prevailing in the country. Thus a major consideration in the design and implementation of the system has been, even more so than in the past, the need to keep capital and operating costs as low as possible.

The factors resulting in reduced capital costs can be summarised as follows:

- Use of transportable equipment shelters in place of buildings constructed on site;
- Use of below ground equipment shelters to obviate the need for airconditioning;
- Extensive pre-installation of equipment in shelters before transportation to sites and corresponding reduction in on-site work;
- Use of low power consumption equipment and attention to power saving techniques resulting in smaller and cheaper power supplies;
- Use of guyed masts in place of self-supporting towers. The average cost of an erected guyed mast is about three quarters the cost of a tower supporting the same head load;
- A standard of site access road consistent with expected usage. Cost savings achieved due to the reduced requirements were approximately 20% when compared with roads provided for earlier radio relay systems.

Overall the capital cost savings achieved resulted in the actual cost of the system being held to the cost estimated in 1972 based on prices ruling in that year for conventional broadband radio practices.

Maintenance costs will be kept low by:

- Use of highly reliable equipment whose performance will be further improved by the stable environment provided by the use of underground shelters;

- Use of equipment of modular construction so that time spent in the field on fault clearance will be short;
- Use of solar cells as primary power source has eliminated costly maintenance of rotating power generating equipment, and fuel and fuel delivery charges;
- Eliminating usually expensive maintenance of airconditioning plant;
- Eliminating access road maintenance to the extent that four-wheel drive vehicle access only needs to be ensured.

Although no figures are yet available on the cost of operating this system there is a firm expectation that substantial savings will be possible when compared with other established radio relay systems.

THE FUTURE

Application of recent advances in technology and the changing economics resulting from it has enabled this system to be the first of a new generation of broadband radio relay systems. Now in operation, it can be considered the prototype of systems specifically suited to remote areas. Although only experience gained in operating the system over an extended period of time can confirm its advantages, a number of points regarding future development in radio communication systems can be made now:

- Indications are that the high reliability and low maintenance requirements of solar power supplies should match that of the radio relay equipment. If this is in fact confirmed then solar power will become the standard power source for radio communication systems in remote areas especially as costs of solar panels can be expected to be reduced in the future.
- In high temperature remote areas with primary power limited to that available from solar sources, below ground shelters are seen as presenting the best solution for temperature control problems. However in some locations, especially those subject to flooding, above ground, enclosed, fully insulated shelters with inbuilt heat exchangers should also prove satisfactory.
- Torsionally stabilised guyed masts will be used extensively in areas where space is available for guy anchor placement.

Costs of masts increase approximately linearly with height whereas costs of towers increase exponentially. It therefore follows that use can be made of high masts to obviate the need to locate stations on hill tops, especially where access is difficult and road construction costs would be high.

REFERENCES

1. WOODROW B.E. and TODD R.M.: 'A Century of Telecommunication in the Northern Territory'; Parts 1 and 2; Telecom Journal of Aust., Vol. 22, No. 3, 1974, pp 167-182.
2. KIMBER M. J.: 'The Darwin — Mt. Isa Radio Relay System'; Telecom Journal of Aust., Vol. 24, No. 1, 1974, pp 44-53.
3. MACK M. R.: 'Solar Power for Telecommunications'; Telecom Journal of Aust., Vol. 29, No. 1, 1979, pp 20-44.

A Performance Monitoring System for Data Transmission Circuits

N. Q. DUC, B.E. (Hons.), Ph.D., M.I.R.E.E. (Aust.), M.I.E.E.E. (USA), R. B. COXHILL, K. S. ENGLISH, B.E. (Hons.), and R. I. WEBSTER.

As part of an investigation into the performance of data links which may be used in the proposed Telecom Australia Digital Data Network (DDN), tests are being conducted on selected intercapital wideband data loops. These are performed with the aid of a fully-automatic microprocessor-controlled data test set developed by Telecom Australia Research Laboratories. The performance is based on a concept known as "error-free second", a transmission time interval of one second over which no data bit error is detected.

This paper considers the concept of error-free second (EFS) and describes the functions and capabilities of a test set developed around this performance parameter.

As part of an investigation into the performance of data links which may be used in the proposed Telecom Australia Digital Data Network (DDN) (Ref. 1), tests are being conducted on selected intercapital wideband data loops. These are performed with the aid of a microprocessor-controlled data test set developed by the Research Laboratories of Telecom Australia. The performance is based on a concept known as "error-free second", i.e., a transmission time interval of one second over which no data bit error occurs. This parameter is therefore independent of the data block sizes that may be used over the communication channel. The performance can be then described jointly as availability and percentage of error-free seconds (%EFS). The first parameter refers to the duration of time over which the transmission channel is deemed to operate satisfactorily. The latter gives an indication as to the quality of transmission when the channel is available. These concepts will be explained in more detail in the next section.

In addition to monitoring the data transmission performance according to availability and percentage of error-free seconds, the test set allows several other transmission-related parameters to be recorded, such as modem-detected carrier failures, microwave radio bearer alarms, etc. This facility can be helpful in the indentification of the various factors which may affect data transmission over radio bearers. The information thus collected by the test set is subsequently analyzed on TACONET (Telecom Australia Computer Network) and the results are presented in the form of tables and histograms together with other parameters of interest.

As the basic unit of measurement is the time interval of one second, any bit rates (currently up to 2048 kbit/s) can be accommodated. Several interchangeable commonly-used line interfaces are provided, allowing the test set to be used over a wide range of applications. One such application is the study of performance of primary-level PCM (Pulse Code Modulation) line transmission systems. In addition to digital telephony, these bearers can carry a wide range of services such as data, text, video, etc.

DATA TRANSMISSION PERFORMANCE PARAMETERS

Traditionally, the performance of a data transmission circuit is expressed in terms of bit error rate (BER) and block error rate (BKER), where

BER = Number of received bits in error/Number of transmitted bits

and BKER = Number of received blocks in error/Number of transmitted blocks

The BER parameter, however, does not give an accurate estimate of the data circuit performance, except only for the case where bit errors occur in a random fashion. To overcome this deficiency, block error rate is used in conjunction with bit error rate. A knowledge of the data block size is required in order to evaluate the block error rate. This is therefore not satisfactory in view of the variety of block sizes adopted by data users. Furthermore, in the estimation of the above two performance parameters, no distinction is made as to whether the data circuit is operationally available.

With the introduction of public data networks in recent years (see, for example, Ref. 2), there is a need to express the performance of a data circuit in such a way that it is meaningful to both the data users and the network

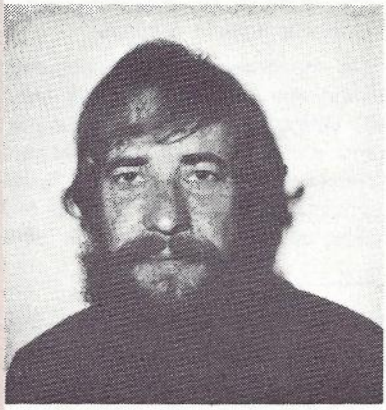
NGUYEN QUANG DUC was born in Gia Dinh, Vietnam, on June 23, 1947. He came to Australia in 1964 on a Colombo Plan Scholarship sponsored by the Australian Government. He received the B.E. (Honours) and the Ph.D. degrees in Electrical Engineering from the University of Queensland, Brisbane, in 1969 and 1973, respectively.

From 1969 to 1972, he was a Tutor in Electrical Engineering and in Pure Mathematics at the University of Queensland. He then joined the Telecom Australia Research Laboratories, Melbourne (then part of the Australian Post Office), working on various transmission aspects of digital line systems and data communications. He is presently a Senior Engineer with the Switching and Signalling Branch studying packet switching data networks, integrated services digital networks, communication protocols and common-channel signalling. Between June 1976 and May 1977, he was a Visiting Associate Professor at the School of Computer and Information Science, Syracuse University, Syracuse, NY, USA.

Dr. Duc is a member of the Institution of Radio and Electronics Engineers (Australia) and of the Institute of Electrical and Electronics Engineers (USA).

RICK COXHILL joined the Australian Post Office in 1963 as a Technician-in-Training. On completion of this training he was appointed as Technician in the Line and Data Systems Section of the Australian Post Office Research Laboratories.

Since then he has worked on various projects to study transmission related aspects of the Australian Communications Network. He is currently employed as a Senior Technical Officer and is engaged in developing hardware and software for instrumentation to study the quality of data transmission within Telecom Australia's Communications Network.



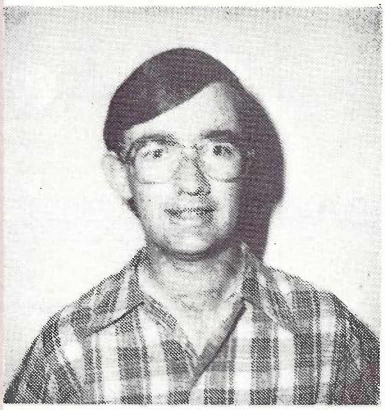
KEVIN ENGLISH was born in Melbourne in 1952 and received the B.E. (Honours) degree inElectrical Engineering from Monash University in 1974. He has worked in the Computer Applications and Techniques Section of the Telecom Australia Research Laboratories since 1974, involved in studies of adaptive echo cancellation and computer analysis of experimental data.

Since September 1979, he has been working in the United Kingdom, on a two-year GEC Overseas Fellowship.

RON WEBSTER became a staff member of the Research Laboratories of Telecom Australia in February 1969. As a Technical Assistant, he obtained on-the-job training in various facets of the Research Department's investigations as well as continuing further formal studies.

In 1973, he became a Technical Officer in the Line and Data Systems Section of the Transmission Branch of Research. He participated in various aspects of the Section's work, but in particular, digital, line transmission test equipment development.

Currently, he is employed as a Senior Technical Officer and is working on microprocessor based test equipment for characterizing long haul data transmission circuits.



operating organization. The performance can be assessed in terms of two parameters, namely, availability and quality.

- Availability. A data circuit is said to be available when its service is deemed to operate satisfactorily[1]. Periods of unsatisfactory operation (e.g. loss of circuit, intolerable numbers of errors in received data, etc.) constitute unavailable time or outage time.
- Quality. When the data circuit is available, its quality or error performance can be then gauged in terms of a quantity called error-free second (EFS) (see, for example, Refs. 3-5). This is defined as a transmission time interval of one second in which no data bit error is present. It is therefore independent of the users' data block sizes[2]. The performance is then quantitatively expressed as a percentage of error-free seconds (%EFS). This percentage is obtained from the ratio of the number of error-free seconds to the circuit available time in seconds.

On the other hand, the one-second intervals which contain one or more bit errors are called error-seconds (ES). Unavailability or outage time can be then expressed in terms of error-seconds. In this paper, an event of 10 or more ***consecutive*** error-seconds is defined as contributing to unavailability and this event is referred to as an error-second outage (ESO) or simply outage.

[1] This does not necessarily imply that the transmission is error-free.

[2] Note that an arbitrary time frame of 1-second intervals is now imposed on the data.

THE MICROPROCESSOR-CONTROLLED DATA TEST SET

Parameters Measured

The test set has been developed in such a way that the availability and error performance of a given data circuit can be evaluated according to the parameters discussed in the previous section. These are basically:

- Total number of error-free seconds (EFS) over a measurement period and
- Total duration of error-second outages (ESO).

Since short-term error performance is as important as long-term error performance, the measurement period is subdivided into time intervals of 15 minutes. Furthermore, in order to gain some insight into the transmission characteristics of the test circuit, the following information is recorded by the test set.

- The frequency distribution of the bit error counts for each error-second (BEC/ES) within a 15-minute interval.
- The frequency distribution of error-free-second runs (EFSR) within the 15-minute interval above.
- The start and finish times (to the nearest millisecond) in real time of any externally detected alarm conditions (e.g. modem-detected carrier failures).
- The start and finish times (to the nearest second) in real time of any events of 10 or more ***consecutive*** error-seconds (or error-second outages).

Functional Description

A functional block diagram of the test set is illustrated

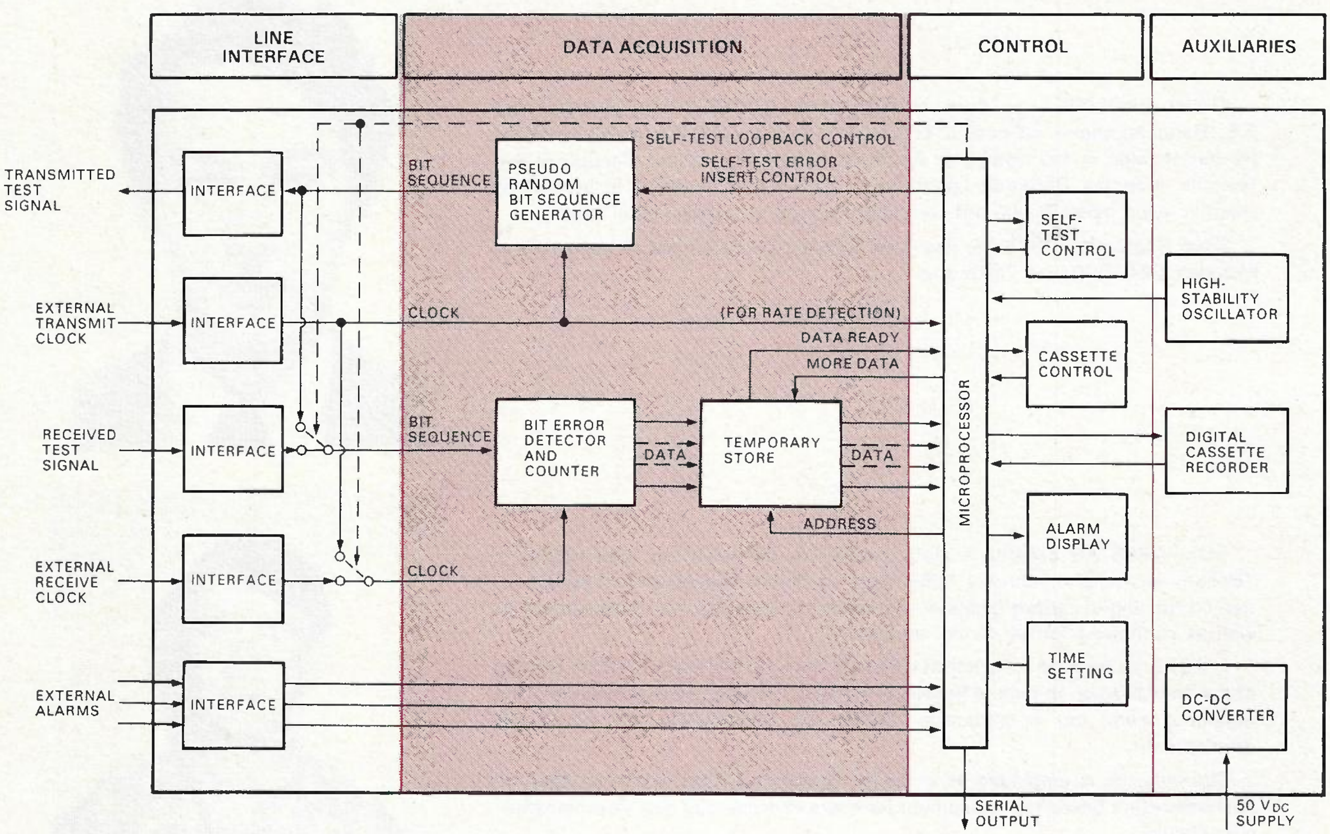


Fig. 1 — Functional Block Diagram of the Data Test Set.

in **Fig. 1**. It consists of four main sections:

- Line interface
- Data acquisition
- Control
- Auxiliaries.

The first three sections are implemented on individual plug-in cards so as to allow maximum flexibility in the use of the test set. The line interface is a special-purpose module that can be readily interchanged to suit a particular interface requirement. As the basic unit of measurement is one second, any data signalling rates can be accommodated using an appropriate line interface. The only constraint then is the hardware speed limitations imposed by data acquisition section. At present, the following interface options are provided: CCITT[3] Recommendations V.24, V.35, V.36, G.703-64 kbit/s and G.703-2048 kbits/s.

The data acquisition section consists of independent transmit and receive sub-sections. The transmitter generates a pseudo-random bit sequence which is transmitted as a test sequence over the data link via the line interface. In the receiver, an error detector with automatic synchronization checks for bit errors in the incoming data stream and increments an error counter for each error detected.

Under microprocessor control, each 15-minute measuring period is quantized into 1-second intervals. This timing is provided by a software clock driven by a high-stability oscillator. At the end of each 1-second interval the current content of the error counter is fed to the microprocessor and the counter is then reset to zero. The microprocessor processes the bit error count for each error-second, categorizes this according to **Table 1** and increments the corresponding bin content by one. This process is repeated for each 1-second interval of a 15-minute measuring period. Similarly, the length of error-free-second runs is categorized as in **Table 2**. If an error-free-second run follows on from, and/or extends into, the previous or the following 15-minute periods respectively, then additional information is added to the collected bin information denoting this. At the end of the 15-minute period, the resulting information is stored on a digital cassette recorder and all bin contents are reset to zero. If any runs of 10 or more consecutive error-seconds (ESO) are detected by the microprocessor, the start and finish times of these events are stored on the digital cassette as they occur. Similar action is taken for any externally detected alarm conditions (e.g. modem-detected carrier failures). Three external alarms inputs are provided and these can be used according to the user's requirements.

The information obtained above is encoded as an easily interpretable sequence of ASCII[4] characters. Time of day information derived from the clock in the microprocessor is periodically added to the collected data. The resulting information is also available via a serial output from the test set, allowing optional on-line monitoring of the recorded data using a printer or a visual display unit (VDU).

[3] Consultative Committee on International Telegraph and Telephone.

[4] American Standard Code for Information Interchange.

Bin Category	Range of Bit Error Count per Error-Second (BEC/ES)
a	1-2
b	3-4
c	5-8
d	9-16
e	17-32
f	33-64
g	65-128
h	129-256
i	257-512
j	513-1024
k	1025-2048
l	2049-4096
m	4097-8192
n	8193-16384
o	≥ 16385

Table 1: Categorization of Bit Error Counts per Error-Second

Bin Category	Range of Error-Free-Second Run (EFSR)
A	1-2
B	3-4
C	5-8
D	9-16
E	17-32
F	33-64
G	65-128
H	129-256
I	257-512
J	513-899
K	900*

(* Maximum EFSR within a 15-minute interval)

Table 2: Categorization of Error-Free-Second Runs

Owing to the complexity of the test set internal operation and the importance of long-term measurements, an automatic self-test mode for one 15-minute interval of each day is provided. In this mode, the test set is internally looped between transmit and receive parts and predetermined bit error patterns generated by the microprocessor are injected into the test data sequence. The rate at which these error patterns are inserted is adjusted automatically according to the particular data rate used. The information recorded during this self-test mode can then be checked via the analysis programs (described in the next section) for any deviation from the preset pattern.

COMPUTER ANALYSIS OF THE RECORDED INFORMATION

The information recorded on the digital cassette is transferred to the Telecom Australia Computer Network (TACONET) for analysis and the results are summarized on a weekly basis. To help the reader follow the method by which the data transmission performance is evaluated, **Fig. 2** illustrates the relationships of various parameters used. The following processing steps take place in the analysis:

(1) Any periods of time over which no measurement was made or the recorded data is invalid are ignored. This may be caused by:

— planned withdrawals of transmission bearers
— local loopback tests
— test set malfunctions

The remaining time is then labelled as valid time. The corresponding percentage is calculated.

% Valid Time = (Valid Time/Weekly Period) x 100

where all times are expressed in seconds.

(2) The unavailable time is determined by the total duration of all error-second outages. The percentage of available time is then:

% Availability = (Available Time/Valid Time) x 100

(3) The percentage of error-free seconds (%EFS) within various time intervals of interest (e.g. 15-minute, 1-hour, 1-day, 1-week, etc) is evaluated.

(4) The percentage of time intervals having a %EFS equal to or better than a given error performance objective for the circuit under test is evaluated. In this calculation, any intervals containing error-second outages are weighted according to their individual availability percentages.

The results derived from calculations (1)-(4) are summarized in a weekly performance table (as exemplified in **Fig. 3**). In addition to the summary table, the following secondary results are available which can be used to further characterize the performance of the data link:

- Percentage histogram of bit error counts/error-second (as exemplified in **Fig. 4**).
- Percentage histogram of error-free-second runs (as exemplified in **Fig. 5**).
- Listing of the total duration of error-second outages in each 15-minute interval.
- Listing of the number and total duration of any externally detected alarm conditions in each 30-minute interval.

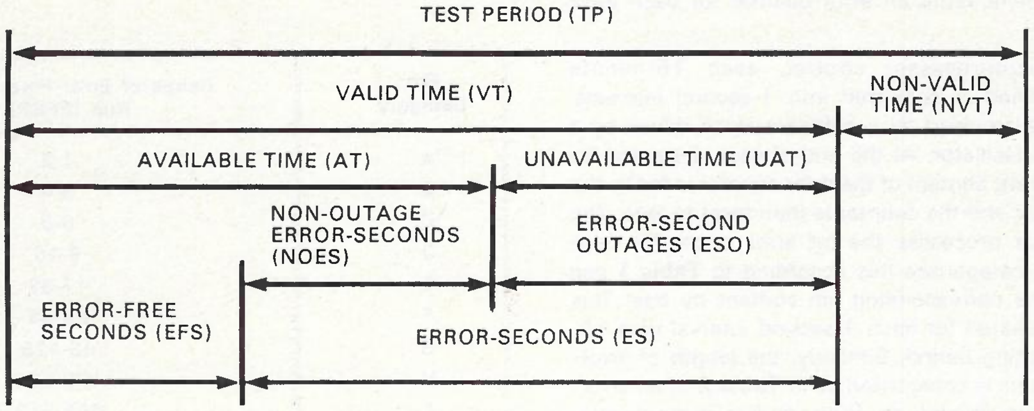


Fig. 2 — Relationships between Various Parameters Used in Determining Error-Free Second Performance.
(Notes — Time unit = second
— The definitions of the terms used are given in the Appendix).

MELBOURNE-ADELAIDE (LOOPED) 72KBIT/S				% OF TIME INTERVALS (T) FOR WHICH ERROR PERFORMANCE OBJECTIVE WAS MET (*)		
WEEKLY PERIOD	% VALID TIME	% AVAIL-ABILITY	% ERROR-FREE SECONDS	T = 15 MIN	T = 1 HOUR	T = 1 DAY
8/3/79-14/3/79	98.36	99.96	99.89	97.86	98.75	99.96
15/3/79-21/3/79	99.70	99.89	99.83	95.34	95.77	99.89
22/3/79-28/3/79	100.00	99.97	99.91	97.90	97.60	99.97
29/3/79- 4/4/79	90.33	99.98	99.91	97.69	98.67	99.98
(*) . . . IN THIS CALCULATION, ANY INTERVALS CONTAINING ERROR-SECOND OUTAGES ARE WEIGHTED ACCORDING TO THEIR AVAILABILITY PERCENTAGES.						

Fig 3 — Sample Summary Table of Availability and Error Performance (Redrawn from Original Computer Print-Out).
(Note — In this example, the error performance objectives have been taken as %EFS ≥ 99.0 for both 15-minute and 1-hour intervals, and %EFS ≥ 99.5 for 1-day intervals).

With the above additional information, some insight can be obtained as to the type of errors (random/burst), the distribution of error-free seconds, and the occurrence of error-second outages and external alarms (e.g., modem-detected carrier failures). The latter two events can also be checked against the analogue performance results of radio broadband bearers monitored by some Telecom State Administrations. In addition, to gain some insight into the short-term 15-minute performance, a sensitivity analysis is also available for a range of % EFS criteria.

In order to estimate the long-term (e.g. 1-year) performance characteristics, the total durations of valid time, available time and error-free-second time for the week are appended in the percentage histogram plots. The median range of bit error counts per error-second is also indicated to allow the estimation of bit error rate from error-free-second performance (Ref. 6). Note that the histogram **median** value is determined in preference to **mean** value in view of the non-linear nature of the range categorization.

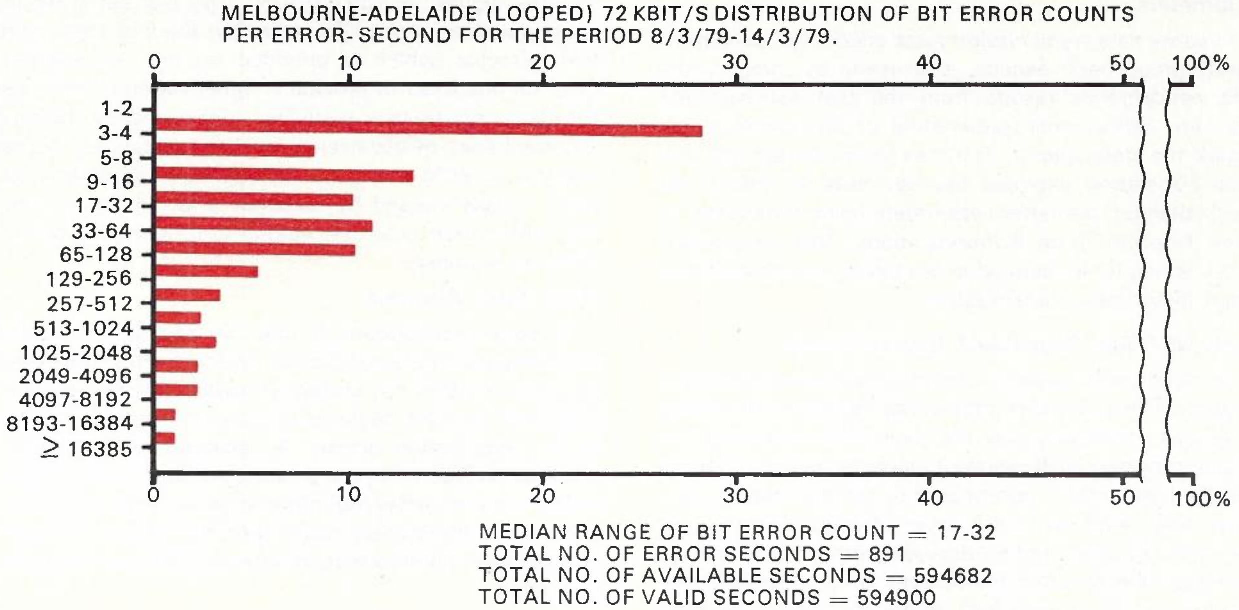


Fig. 4 — Sample Percentage Histogram of Bit Error Counts per Error-Second (Redrawn from Original Computer Print-out).

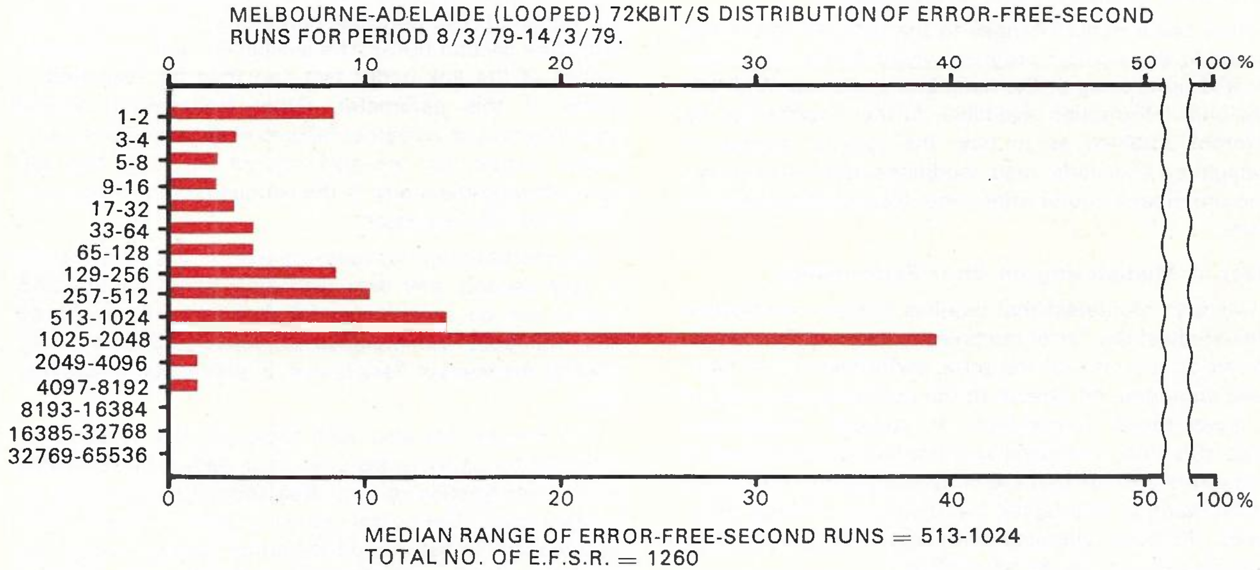


Fig. 5 — Sample Percentage Histogram of Error-Free-Second Runs (Redrawn from Original Computer Print-Out).

DISCUSSION AND APPLICATIONS

The test set has been designed to be a flexible performance monitoring instrument. Operation at any data signalling rates up to 2048 kbit/s can be achieved with only a change of the line interface card. Thus the range of usefulness of the instrument also extends into the area of Pulse Code Modulation (PCM) line transmission systems. Together with the computer analysis program, the test set constitutes a complete package for studying the short-term and long-term performance of a data or digital transmission path. Some of the specialized applications of the test set are now discussed below. These make use of the facilities that have already been implemented or will be implemented in the near future.

Correlation between Analogue and Data Performance Parameters

In some data transmission tests conducted over intercapital group-band circuits, it is useful to compare the data performance results from the test set with the analogue performance parameters of the bearer which carries the data circuit. This has been carried out and good correlation between the two sets of results has been obtained, the latter parameters being monitored by some Telecom State Administrations. This comparison could be helpful in identifying the bearer parameters that might affect data transmission.

Study of Radio Broadband Bearer Alarms

All radio bearer systems are equipped with supervisory equipment that provides information regarding the status of various conditions over the route. This information is usually provided in the form of alarm signals that can be classified as urgent, non-urgent or for information purposes only. Any one or a number of these alarms could be readily encoded and multiplexed with the information normally collected from the test set. Only minor software changes would be required in the test set to accommodate the additional information. This can be carried out by simply replacing a PROM (Programmable Read-Only Memory) which contains the necessary programming information for the microprocessor in the test set. At the analysis stage, the additional alarm information would have to be extracted and processed.

Thus, some minor changes to the software in the test set and to the analysis program would enable the collection and processing of the radio bearer alarms. With this additional information available, further insight can be therefore obtained as to how the varying microwave propagation and traffic load conditions associated with a radio broadband bearer affect data transmission over the bearer.

Effect of Multiplexing on Error Performance

One area of interest that requires further investigation is the study of the "error multiplexing factor". This can be defined as the ratio of the error performance of a high-speed aggregate bit stream to the performance of one of its lower-speed component bit streams. Parameters which affect the multiplexing factor include the nature of burst errors and the method of demultiplexing. Estimates can be made of this factor, but owing to a lack of information on burst characteristics and other parameters, these figures are yet to be verified.

In order to conduct this study, a "pseudo-demultiplexer" switchable option is provided in the test set. This facility allows the recording of the digital transmission performance parameters of one individual 64 kbit/s channel within an aggregate 2048 kbit/s stream, without having to demultiplex completely the latter signal. With the additional use of a second test set in parallel, the performances of the above two signals can be simultaneously monitored, thus allowing the error multiplexing factor to be evaluated.

Performance of PCM Line Transmission Systems

Another area of application is the long-term study of the performance of primary-level 2048 kbit/s PCM bearers. This work is recently attracting interest as it is desirable for the digital performances for both data and telephony to be compatible in the evolution of integrated services digital networks (ISDN). The test set is readily suited for this purpose. In particular, the line code violation detector (which is provided on the line interface card) can be used to provide a signal via one of the test set alarm inputs, thus providing information on the time and frequency of occurrence of these violations. As the majority of PCM errors are reflected as line code violations, mainly caused by crosstalk and impulsive noise, this information could be helpful in determining the interfering sources.

Burst Error Analysis

In some applications it may be desirable to know detailed burst characteristics of detected error events. As the test set does not currently provide this information, additional facilities could be included in a similar manner as for radio bearer alarms. A separate microprocessor could be configured to pre-process the detected bit errors with a view to obtaining information on error burst patterns. This information could then be coded and multiplexed with the information normally obtained from the test set.

CONCLUDING REMARKS

Long-term monitoring of transmission performance of data links requires an instrument whereby the measured parameters are recorded in an efficient manner for subsequent analysis. This paper has described the functional capabilities of one such data test set. Although bit errors are detected, the principal parameter of interest is the error-free second (EFS). The availability and error performance of the link under test can then be evaluated in terms of this parameter. Other transmission-related parameters such as carrier failures of data modems, radio bearer alarms, etc. are also catered for in the test set, thus allowing the study of the various factors which may affect data transmission.

As the basic unit of measurement is the time interval of one second, any data signalling rates (up to 2048 kbit/s) can be accommodated. Several commonly-used line interfaces are provided on interchangeable cards, making the test set flexible over a wide range of applications.

The test set has also been shown to be a versatile instrument for applications other than data. One such area is the investigation of error-free second performance of primary-level PCM bearers which may carry data as well as telephony in the immediate future, and other services (e.g. text, video . . .) in the context of integrated services digital networks (ISDN).

Together with the computer analysis programs, the test set describes provides a useful and versatile package for monitoring the performance of data and digital transmission channels and for providing other related information which may be helpful in the identification of those bearer parameters that affect the overall transmission performance.

REFERENCES

1. Gannon, D. J. and McKenzie, A. J.: 'Digital Data Network Overview'; Radio Research Board Symposium on Digital Communication Systems, Proceedings, Sydney, 5-7 December 1977.
2. Duc, N. Q.: 'Data Transmission Developments and Public Data Networks'; Telecom Journal of Australia, Vol. 29, No. 3, October 1979, pp. 194-205.
3. Horton, D. J. and Bowie, P. G.: 'An Overview of Dataroute: System and Performance'; International Conference on Communications, Minneapolis, Minnesota, 17-19 June 1974, pp. 2A/1-2A/5.
4. Snow, N. E. and Knapp, N., Jr.: 'Digital Data System: System Overview'; Bell System Technical Journal, Vol. 54, May-June 1975, pp. 811-832.
5. CCITT Study Group VII: 'Report of the Meeting in Geneva, 19 April-2 May 1979, Part V: Report of Working Party VII/4 (Transmission Maintenance and Quality of Service)'; Contribution No. 372, 4 May 1979, ITU, Geneva.
6. Duc, N. Q.: 'Estimation of Bit Error Rate from Error-Free Second Performance'; Australian Telecommunication Research, Vol. 13, No. 2, November 1979, pp. 50-52.

APPENDIX

GLOSSARY OF TERMS

Available Time (AT). This is the transmission time over which no error-second outage (ESO) was encountered.

Error-Free Seconds (EFS). These constitute one-second transmission intervals over which no bit error was detected.

Error-Seconds (ES). These are one-second transmission intervals over which bit errors were detected.

Error-Second Outages (ESO). These are events of 10 or more **consecutive** error-seconds. They are also simply called outages.

Non-Outage Error-Seconds (NOES). These are events of less than 10 **consecutive** error-seconds.

Non-Valid Time (NVT). Time over which no measurement was made or the recorded data is invalid (15 minutes minimum). This may be caused by:

— planned withdrawals of transmission bearers
— local loopback tests
— test set malfunctions

Test Period (TP). Period over which performance test was conducted (1 week minimum).

Unavailable Time (UAT). This corresponds to the total duration of events of 10 or more **consecutive** error-seconds (or error-second outages).

Valid Time (VT). Time over which recorded data is considered for computer analysis.

The International Electrotechnical Commission Quality Assessment System for Electronic Components

G. FLATAU F.R.M.I.T.

The International Electrotechnical Commission has set up a Quality Assessment System for electronic components, which aims to standardise the quality assurance procedures, as well as the performance specifications, for a wide range of components. Australia intends to fully participate in this System, and this paper describes the history, content and scope of this scheme, and the expected benefits to its participants.

The next few years will see the introduction of an international quality assessment system for electronic components, which should bring significant benefits to the users of what is often termed "professional grade" electronic components. This type of component is usually called for in telecommunication, defence, computer and safety related equipments, and generally would be expected to have a higher reliability, and be manufactured to tighter tolerances, than components used solely for domestic consumer products such as the television set. The decision on which type of component to use in manufacture, is mainly one of cost, with reliability, maintainability and availability requirements considered; but the increasing sophistication of many consumer items, such as in automotive, leisure and entertainment equipment is likely to result in more frequent use of higher grade components also in these fields.

The International Electrotechnical Commission (IEC) Quality Assessment System for Electronic Components, (IEC/Q), has been in the planning stage for several years, and as will be described, follows in the footsteps of some earlier schemes of a national or regional nature. The great advantage of such a system is that the components are manufactured to a common, widely accepted specification, under clearly defined quality assessment conditions, so that the user receives a produce which is virtually independent of its origin, providing it is certified as complying with the System. As a result, incoming inspection procedures can be relaxed or even omitted, second sourcing of components is facilitated and the availability of certified test records gives a basis for reliability predictions.

The background to the IEC/Q System, what it requires of its participants, and the role Australia will play in such a System, will be discussed in this article.

THE INTERNATIONAL ELECTROTECHNICAL COMMISSION

The IEC was formed in 1906, with the task of coordinating and unifying electrotechnical standards, which at that time existed only in a variety of national forms. The early work was, for obvious reasons, entirely in the electrical engineering area, mainly in the power field. Over the years the IEC has become involved in many other activities, and today it has more than 70 Technical Committees, creating specifications dealing with a very wide range of electrotechnical equipment, materials and components, as well as safety aspects, specialised test methods, terms and definitions etc. The IEC is affiliated with the other major international standardisation body, the International Organisation for Standardisation (ISO), which deals with all products of a non-electrical nature.

More than forty countries are members of the IEC, compared with about 70 in the ISO. Both bodies have their headquarters in Geneva, with similar but separate administrative structures, and are financed by annual contributions from member countries. All specifications are produced by specialist technical committees, which every member country is free to join. As these specifications are produced on the basis of substantial concensus, their production rate is relatively slow, and it normally requires several years to go from first draft to publication.

Australia is a member of both IEC and ISO, and actively participates in many technical committees and the management bodies of both organisations. Australia is represented by the Standards Association of Australia (SAA), in the IEC specifically by the Australian Electrotechnical Committee (AEC), which consists of representatives from electrical and telecommunication engineering interests. Because of Australia's remoteness it is impossible to have representation at all technical meetings, which mainly take place in Europe or the USA, but efforts are made to attend the more important meetings, by either SAA staff, or experts from Industry or Government whose visits are funded by their own organisations. Most Technical Committees (TCs) of the IEC have a corresponding committee in SAA, and many IEC specifications (or to be more precise recommendations) are adopted as Australian standards with little or no technical change.

THE DEVELOPMENT OF COMPONENT SPECIFICATIONS

The first attempt to produce true standards for the electrical component industry occurred around the turn of the century, but progress was very slow until the late 1930s, except for some defence applications.

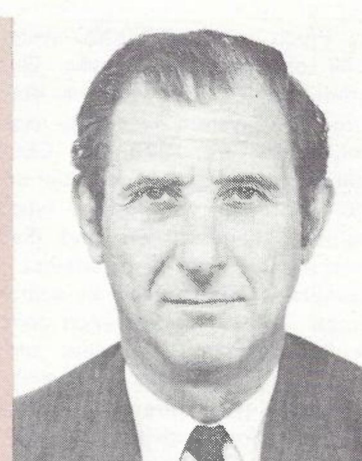
During the early 1940s, largely as a result of the needs of the Armed Services during World War II, it became evident that the increasing complexity of electronic and electrical equipment required components of an assured quality, and that in order to produce and maintain large volumes of such equipment it was essential that components made by different manufacturers, or at different times, were readily interchangeable, both in parameters and dimensions. It soon became clear that this could only be achieved by having agreed national standards, which would clearly define the required properties, as well as the test methods to be used to ascertain compliance with these standards. Recognising that test equipment and testing time is costly, it was considered necessary to aim, wherever possible, for common test methods covering a wide spectrum of components; for instance climatic and mechanical test requirements should be similar for all components in a given application. In drafting such specifications, it was usually found necessary to achieve a compromise between the demands of the users, and the ability of the manufacturer to produce such an article at a reasonable cost. It became evident that the requirements for reliability, close electrical tolerances in parameters, and ability to withstand environmental factors were widely different for such diverse users as the Armed Services, public or private utilities and the private consumer, and that this could only be satisfied by having either separate standards, or otherwise offering a range of "severities" within the one standard. Important applications requiring high reliability demanded more stringent testing with consequent increase in unit costs.

Recognition of these requirements produced the early "MIL" specifications in the USA, from 1947 onwards. The MIL system grew during the 1950s into a vast complex of specifications, assessment procedures, reliability demonstration techniques etc., and was widely adopted by the defence services of the western world, as well as some users of sophisticated equipments on the commercial side. The major drawback of MIL standard components was their high cost, caused by their extensive testing requirements, and the fact that the specifications were somewhat uniquely written around USA manufacture. Many of the quality and reliability assessment techniques called for by these specifications were only feasible for very high production volumes.

Electronic component standardisation had also made progress in other countries during the early 1950s, in particular in the UK, and as international trade increased, and with the growth of international political and military alliances, it became evident that there was a need to rationalise the standards used by the various participant nations. An early example was NATO, where common specifications were essential in order that weapon systems designed in one country could be manufactured, or at least maintained, in all member countries. The dominance of the USA in this alliance and the technological lead it had, at least in the early days of NATO, resulted in the large scale adoption of MIL standards. The newly constituted European Economic Community (EEC) also saw the need for international standardisation as a means of eliminating non-tariff trade barriers, and began to exert pressure on ISO and IEC to expedite work on specifications acceptable to all EEC members. As a result the Technical Committees of IEC began to issue quite a number of component, material and parts specifications. However, these IEC recommendations are not binding on IEC member countries, irrespective of whether the particular country had voted for acceptance of the recommendation or not in an IEC committee, and hence it was still necessary for each individual country, through the agency of its national stan-

GERRY FLATAU joined the PMG Research Laboratories, after qualifying as a Physicist, in April 1951. He was for many years engaged in material evaluation and component reliability studies, and has published many reports and papers on these subjects. Until 1973, he was in charge of the Physics and Polymer Section in the Laboratories, and since then has been Staff Scientist for the Applied Science Branch, with responsibility for overall technical co-ordination.

Mr Flatau has been very active in both national and international standardisation activities for a long time, and has been deeply involved in the planning and management of the IEC Quality Assessment System since 1971.



dardisation body, to publish the text under its own imprint. However, at the time most countries did not possess an organisation capable of assessing conformity with a specific standard.

COMPONENTS OF ASSESSED QUALITY

In 1961 the British Ministry of Aviation set up a committee under the chairmanship of Rear-Admiral G. F. Burghard, with a membership comprising representatives from industry, government and the British Standards Institute (BSI), to examine the possibility of creating a component specification system which would be acceptable to all users, including the defence sector. A final report by the Burghard Committee was issued in May 1965 and was accepted by both the British government and industry the following March. The principal recommendations of the report were that:

- a system of common standards for electronic parts, suitable for both civil and military use, should be introduced under the control of the BSI.
- specifications should be prepared by BSI Technical Committees and wherever possible conform to IEC recommendations. These specifications should contain the requirements for acceptance and reliability testing on a sampling basis, and should include long term tests to be done at less frequent intervals.
- all test results should be accumulated over six-monthly periods, and the results made available to customers as Certified Test Records.
- the system should prescribe the procedures for the approval of manufacturers, test houses and stockists.
- there should be an independent inspection authority, which would grant parts qualification approval, manufacturers' inspection procedure approval and supervise those activities delegated to the manufacturer.
- qualification approval to be obtained prior to a part being supplied as conforming with the specification. A Certificate of Conformity (Release Note) should accompany delivery.

The necessary organisation was then set up and commenced production of what has since become known as the BS 9000 series of specification.

In Europe the European Electrical Standards Coordination Committee (CENEL), comprising countries from the EEC and the European Free Trade Association (EFTA) had been set up and in the late 1960s turned its attention to electronic components. Basing its efforts very much on the BS 9000 system, the Europeans in 1970 set up the Cenelec Electronic Components Committee (CECC), with the objective of creating a harmonised system for quality assessment of electronic components. By 1979, the CECC system was well established and had 11 member countries, listing nearly 900 approved component types, and about 150 approved manufacturers and distributors. The CECC system is regional in its interest, and has rebuffed all attempts for membership by countries outside Western Europe. CECC members exert considerable influence in the IEC Technical Committees, and the CECC prefers to use IEC specifications whenever they are available. However, the inherent inertia in international standardisation activities, caused by the need for concensus, the difficulties of holding meetings at frequent enough intervals, and the fact that Technical Committees consist of volunteers with other, pressing duties, often result in specifications taking many years to reach publication. For that reason the CECC has been forced to also develop many specifications of its own, in particular in terms of quality assessment requirements.

THE DEMAND FOR AN INTERNATIONAL CERTIFICATION SYSTEM

With the advent of the CENEL system of approved components in Europe, and the operation of the BS 9000 scheme in the UK, the USA component industry faced a prospective sales loss, estimated then at $40 million per annum, as these markets would in future be virtually closed to non-members. In response to its industry's urging the USA raised the matter of non-tariff barriers to trade within GATT and in 1969 managed to have a working group set up to look at the whole matter of standards as potential trade barriers, and to set guidelines for international harmonisation and certification agreements open to all. A GATT Code of Conduct to prevent technical barriers to trade was finalised in 1979, and the Australian Government at the time of writing is considering if, and when, to accede to this Code. The USA National Committee of the IEC exerted strong pressure at the 1970 IEC General Meeting for a start to the preparation of guidelines for the harmonisation of component certification. As a result, a Working Group was set up to study the requirements necessary for "The development of a national certification system which can be adopted by any nation and be harmonised into an international plan".

This Working Group, on which Australia was represented, produced a draft outline for an IEC Certification System which was basically identical with the European System. The proposed system was submitted to the Committee of Action of the IEC in 1971, where it was agreed that the IEC should accept overall responsibility for the establishment of an international certification scheme for components.

By late 1972, it had been decided to set up a Provisional Management Committee (PMC) to prepare the basic documentation for the initial operation of the scheme. It was agreed that this Committee should be financially self-sufficient, e.g. it should be financed from contributions separate to those member countries made to the IEC itself. An initial joining fee of Swiss Fr. 5000 was stipulated. The PMC held its first meeting in January 1973 with 12 prospective member countries present, including Australia. During the succeeding 2½ years, the PMC met five times and developed the two basic documents for the system, the Basic Rules and the Rules of Procedure. The Basic Rules were submitted to the formal IEC voting procedures in 1975, and having been accepted the following year, the Certification Management Committee (CMC) was set up with overall responsibility to create the framework and documentation necessary for the system to become operational. The CMC held its first meeting in November 1976, with 19 countries, including Australia, in attendance, all having paid a Swiss Fr. 10 000 entry fee. The CMC first turned its attention towards finalising the Basic Rules, and then to such matters as dues assessments, the special conditions for starting up the system, the way manufacturers from non-IEC countries may gain entry to the system, the structure of specifications suitable for the system, and most importantly to develop acceptable Rules of Procedure. These tasks progressed sufficiently to permit the setting up of the Interim Inspection Co-ordination Committee (IICC) in January 1978.

After the 5th meeting of the CMC and the 3rd meeting of the IICC, in Sydney during June 1979, the Rules of Procedure were finally considered sufficiently complete to be submitted to vote by member countries. Most other contentious matters had also been sufficiently defined to raise hopes that after another meeting, in April 1980, steps to formally assess candidate members could proceed, with the prospect of the system actually being ready to operate in 1981. By this time membership had risen to 20, as follows:

Australia, Belgium, Canada, **Denmark, France, Germany, Hungary, Ireland, Israel, Italy, Japan, Korea, Netherlands,** Norway, Poland, Sweden, **Switzerland, UK, USA,** USSR (bold type denotes countries which have indicated that they wish to become full, e.g. certifying, members).

DESCRIPTION OF THE IEC/Q SYSTEM

The objective of the System is to facilitate international trade in electronic components of assessed quality. This is to be achieved by defining and implementing quality assessment procedures in such a way that their equivalence in application, in all member countries, is assured by the use of common component specifications. Components released in a participating country will carry a certification of their conformity with the requirements of the applicable component specification, and hence should be acceptable in all other member countries without the need for further testing.

The System is open to all member countries of the IEC which have established National Authorised Institutions and National Standards Organisations and who agree to:

- Publish and implement the Rules of the System in their country
- Recognise without discrimination the approvals of manufacturers, including their testing laboratories, independent distributors and independent test laboratories and the qualification approvals of components released in other participating countries according to the System.
- Agree to certain financial obligations that enable the System, at an international level, to be self-financed and non-profit making.

In addition procedures are being developed which will enable manufacturers in countries which are not members of IEC to produce components under the System.

Each member country must have a national organisation consisting of a National Authorised Institution (NAI) to manage the System at the national level, and a National Standards Organisation which prepares and issues national standards. Furthermore, if the participating country wishes to carry out quality assessments and certification under the system, it must possess a National Supervising Inspectorate (NSI) which is responsible for the surveillance of all testing and inspection procedures by manufacturers and distributors of components under the System. A certifying country must also have available a recognised calibration service for verification of measurement standards.

The international organisation, operating under the auspices of the IEC Council, consists of the Certification Management Committee for Electronic Components (CMC) which has the management responsibility for the System, and its Inspectorate Co-ordination Committee (ICC), which is responsible for the approval of the National Supervising Inspectorates and the uniform application by them of the Rules of Procedure concerning quality assessment and certification. The System is based on the use of IEC Standards which have been prepared in the normal manner by the appropriate Technical Committees and formally adopted by the Certification Management Committee for use within the System. These standards will include the necessary provisions for inspection and will be implemented, when needed, through national standards of the participating countries, for all electronic components to be certified within the System. The participating countries may rewrite the IEC Standards, if necessary, in accordance with the rules of their national system, but without altering the technical content. However, in the absence of an applicable IEC Standard, use can be made provisionally of other documents which must however, first be submitted by National Authorised Institutions to the Certification Management Committee. The documents may not necessarily include completed detail specifications. These will be prepared by the involved parties in accordance with the Basic Rules and Rules of Procedure of the System.

Assurance that components conform to the requirements of the applicable specification is given by a Certification of Conformity granted under the supervision of a NSI. This assessment is carried out in a number of steps. First the NSI evaluates the organisation and facilities of a manufacturer desiring to deliver components under the System, and when these are deemed acceptable, the manufacturer is approved as such.

For each type of component to be delivered under the System, the manufacturer can then apply for Qualification Approval, on the basis that:

- A component detail specification, acceptable under the System is available.
- The component, and each manufacturing step, is clearly identified. When it is partly manufactured outside his factory, the manufacturer must assume responsibility for the total quality assessment procedure.
- Tests can be made to show that the components meet the requirements of the specification. These tests may be carried out especially for the purpose of qualification approval, or they may form part of a quality conformance inspection carried out by the manufacturer on that type of component, before it is delivered under the System.
- The NSI has the right to be represented at any or all of these tests.

The manufacturer's application gives the NSI the opportunity to check whether the manufacturer's approval is actually valid for the component type in question. If all requirements are satisfied, qualification approval is granted by the national organisation. The manufacturer must appoint a Chief Inspector, who assumes full responsibility for the correct application of inspection and testing procedures in the manufacturer's premises, and for the application of the Certification of Conformity. This Chief Inspector is the link with the NSI, and his ability and integrity are key factors in making the System acceptable.

After qualification approval has been obtained, the manufacturer is responsible for ensuring that no significant technical changes are introduced in the product without a re-qualification, and that the quality conformance inspection prescribed by the specification is carried out. This inspection is divided into two parts: that carried out lot-by-lot and on which the release of the individual lots is based, and that (containing the time-consuming and more expensive tests) carried out on a periodic basis. All quality conformance inspections are subject to surveillance by the NSI, and the NSI will periodically take samples for audit testing in its own Laboratories.

As proof that the components delivered under the System come from lots released by the procedure described above, the manufacturer either issues an appropriate Certificate of Conformity with each shipment, or he places a Mark of Conformity on each component or on the sealed packing. Apart from identification of the component type and the specification against which it is delivered, the certification will allow reference to be made to the test records of the manufacturer. The manufacturer issues periodically (e.g. every six months), in concise form, the accumulated results of tests made by him for lots which were released under the System. This document will also be authenticated by the NSI, and is known as a Certified Record of Released Lots. A customer can use these records to estimate the reliability of his purchases, and as the results refer to the total production lot, as distinct to the quantity he buys, an enhanced statistical confidence is provided.

Similar detailed requirements are laid down for independent distributors and independent test laboratories who wish to obtain approval to operate under the System.

In order to gain admission to the System as a certifying country, the candidate country must submit a document called a National Statement of Surveillance Arrangements (NSSA) to the ICC, in which he describes his national organisation, and the detailed procedures to be implemented by his NSI to carry out its quality surveillance function. When this NSSA is deemed acceptable, the candidate's NSI is visited by an examination team comprised of representatives from other NSIs, who check that all arrangements set out in the NSSA are in fact satisfactory, and that the candidate NSI possesses the requisite resources and experience to carry out its task.

The National Supervising Inspectorates approved under the System, exchange information on experience gained, in order to ensure continued existence in the uniformity of application of quality assessment procedures, and in general they maintain close liaison by their membership in the ICC.

Complaints regarding the quality of components which arise between a manufacturer and user (or buyer and seller) within a country, will be settled in accordance with the relevant procedures established within that country, as set out in the NSSA. The Certification Management Committee is drafting a procedure for examining complaints or appeals referred to it, where more than one country is involved, and how to arbitrate in such disputes. Each participating country retains its right to appeal to the IEC Council regarding any decision which it feels to be unreasonable or unfair.

AUSTRALIAN PARTICIPATION IN THE IEC/Q

As noted above, Australia has been involved from the start in the planning and development of the System, and was a foundation member of the CMC and interim ICC. Participation in the activities was directed by the Australian Electrotechnical Committee (AEC), which has been designated by the Standards Association of Australia as the Australian National Committee for the IEC. The AEC established a special committee to manage the System on a national basis. This committee, ET/4, is made up of representatives from Government Departments and Authorities, electronic component and equipment manufacturers, testing authorities and other users of electronic components. ET/4 after careful deliberations agreed in 1978, and confirmed in 1979, that Australia should continue its membership in the System and should seek to become a certifying country. Both users and manufacturers of components could see advantages in such a step and agreed to financially support the Australian participation. Some of the advantages were: for the manufacturer, the ability to compete with overseas imports for local sales and the possibilities of export opportunities; for the user, the savings in incoming inspection, the greater confidence in the quality and reliability of assessed components irrespective of their origin (e.g. in second sourcing) and the benefits in procurement by common specifications. The formula adopted for financial support was for the Commonwealth Government to contribute one half, the Australian Electronic Industry one third, and Telecom Australia one sixth. The total amount was $18 000 per annum, but will rise to $60 000 when the Australian NSI is set up. The contributions are administered separately from the normal SAA funds, and are used to finance Australia's membership fee in the CMC, attendance by delegates at CMC and ICC meetings, general expenses, and in due course the activities of the Australian NSI.

In November 1978, Australia submitted a draft NSSA to the interim ICC, which in common with those of other applicants was incomplete, but nevertheless was conditionally accepted. Because of some uncertainty regarding the availability of funds, no updated NSSA was submitted to the next meeting in May 1979. However, in December 1979, all problems having been resolved, a complete NSSA was dispatched which, it is hoped, will be accepted by the ICC at its April 1980 meetings, in which case Australia will be subject to an examination visit at the same time as all other applicants, in late 1980.

Whilst the Australian component industry has been seriously diminished in the last few years, there are still a number of manufacturers interested in becoming approved under the System, in such areas as printed wiring boards and connectors, capacitors, resistors and possibly some semiconductor devices. In addition, after the introduction of the System, it seems likely that various distributors will seek approval for a wide range of components. The Australian NSI will be located within SAA, but with its own separate staff and funds, assisted as required by testing and quality assurance specialists and facilities in Government Departments and Authorities, such assistance being provided on a fee for service basis.

THE FUTURE

Unless there are unforeseen delays, the Rules of Procedure of the System should be agreed to in 1980, and although there are still a number of contentious issues to be settled, and some further documentation needs to be produced, the ICC should come into being in early 1981. The ICC may at that time have at least 14 "full" members, many of which will have already had experience, and considerable trade in assessed components, in the related CECC scheme. It seems probable that the first international trade in IEC/Q assessed components will take place during 1981. The extent of such trade will be very dependent on the availability of specifications approved for use under the system. At this time such specifications are still lacking or in the draft stage for most components, except resistors and capacitors, and recourse will almost certainly have to be had to other, provisionally approved specifications (e.g. BSI, CECC, MIL), until suitable IEC specifications are published. The admission of provisional specifications to the System requires a number of procedural steps and hence is likely to be slow. For this reason it will probably be at least 1982 before a substantial volume of components can be released under the System.

The progress of the System in Australia will depend largely on its acceptance by end users. Telecom Australia has declared its active support for the implementation of the scheme in Australia, and undertaken to encourage the use of IEC quality assessed components, wherever possible, by its suppliers and in its own equipment specifications. It is to be hoped that other large end users of "professional grade" equipment such as the aviation and computer industry, and the defence services will take a similar approach.

The latter are of course at this time still strongly bound to the MIL system, but possibly the USA itself may eventually swing in some areas from MIL to IEC because of commercial pressures. It is possible that the increasing sophistication in certain types of consumer goods and automotive electronics will also lead to increased requirements for high quality components. If the IEC/Q system finds world wide acceptance, Australian manufacturers, to be export competitive, will have to be able to offer equipment containing assessed components.

The next few years should tell to what extent the scheme will be successful, and if it can cope with the new generation of components, such as solid state switches, microprocessors etc., now rapidly replacing discrete components in many applications. It would be not surprising, if the scheme achieves its objective of facilitating trade, to see similar systems being set up to deal with quality assessed equipments.

Near-End Crosstalk in the Broadband Network

R. A. J. REYNOLDS B.E., M. Eng. Sc.

The broadband network has grown from its beginnings more than 20 years ago and it now provides a very large proportion of Australia's telephone trunks and other communications services. Some limitations in the performance of the network are sufficiently understood as they apply to the usual types of services. With the advent of new uses for existing equipment, such as data and time-sharing of channels, one limitation in performance unexpectedly has proved to be a problem. Whilst the mechanism of near-end crosstalk is not a mystery in such a network, the crosstalk magnitude, and the relation to frequency are not well understood. Calculations and measurements based on terms which are crosstalk averages have been used previously and are now proving inadequate in the measurement and prediction of crosstalk in the network where some new types of services are concerned.

The purpose of this paper is to examine the mechanism of near-end crosstalk in sufficient detail to give a broad understanding of the problem and to state a couple of results which permit the measurement of crosstalk of this type in practical situations. Readers wishing to examine in detail the theory leading to these results should study reference 2, where the subject is treated using both higher mathematics and computerisation.

The mode of crosstalk considered is shown diagrammatically in **Fig 1.** The mode may occur both within a system and between systems operating on the same route. Hence go-to-return and near-end cross talk are similarly modelled and are referred to as NEXT for brevity.

In general, NEXT is a problem when the go and return directions are provided as unidirectional channels. Then, what is only sidetone in a normal telephone channel becomes adjacent service crosstalk in the case of these special services. Naturally enough, a network which is quite satisfactory in crosstalk terms when only sidetone has to be considered may be quite unsatisfactory when the NEXT has to be considered as affecting the adjacent services.

The Australian network is dominated by radio bearers and coaxial cable bearers. The cable part of the network appears to contribute most to the problem. This does not mean that radio systems do not cause crosstalk, but that, in general, crosstalk within radio systems arises at repeater stations. These are few, and worst case cumulative effects permit convenient specification of equipment for satisfactory operation. However, in a cable system, a route of 1000km will involve typically 250 repeaters, each of which will add to the overall NEXT in a way indicated in Fig 1. On a route composed of a number of systems in tandem, provided that the go and return directions at each repeater are at the same frequency, then each additional repeater will add to the overall NEXT.

In the past, it has been generally recognised that if the NEXT at a specific frequency adds at each repeater on a route so that the phase of each reflected exposure is identical when it arrives at the near end station, then the crosstalk will add in voltage terms. Nevertheless, over a wide frequency spectrum it is quite easy to demonstrate that phase identity cannot be maintained and that the average NEXT must add in power terms. Observations on

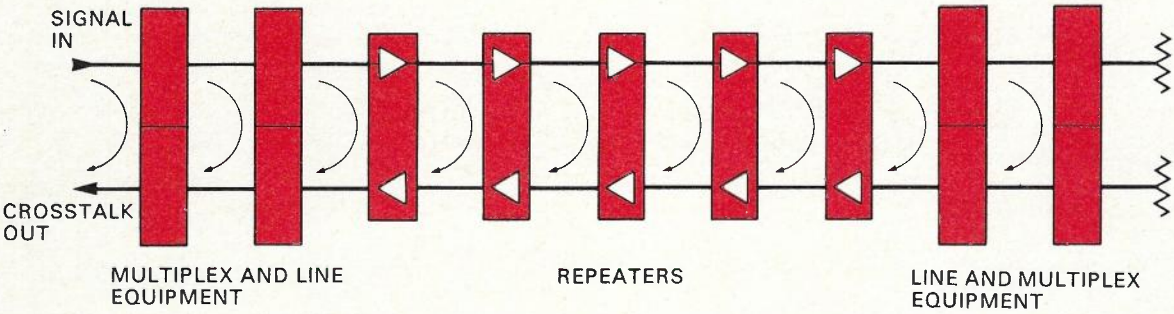


Fig. 1 — Considered Generation of High Frequency NEXT

real systems indicate that the pure voltage addition is not observed at any frequency and that the frequency response of NEXT is a very complex function with peak values which are somewhere in between power and voltage addition, and with averages over wide bandwidths that follow power addition. It is now realised that these peaks are at most some 12 dB above the average crosstalk.

Fig 2 gives a typical response over a 4 kHz channel bandwidth of the Sydney Melbourne 12 MHz cable route CX2, summarised in **Fig. 3** and **Table 1**.

Fig 4 shows the complexity of the response and its near random properties over a 48 kHz spectrum.

The problem is: "What is the nature of the frequency response of the NEXT arising from an arrangement such as Fig 1, and in particular, what is the average NEXT in, say, a VF channel on a given route?"

EVALUATION OF THE CROSSTALK MODEL

From a theoretical point of view, there is no convenient way of obtaining an exact solution, since the position of each repeater, the amplitude of each exposure and its phase are not known with sufficent accuracy. Indeed, it would be surprising if such a solution could be found since some one thousand parameters would have to be known with accuracy of which none could be independently measured for the Sydney Melbourne route of Fig 3, for example.

However, a solution to the problem does exist, although it of necessity makes use of some of the results of studies in the field of stochastic processes and in this case leads to a result which predicts the magnitude of the NEXT peaks in terms of measurable quantities with high accuracy. More importantly, the study relates the number of peaks in a given bandwidth that exceed some test level to the average NEXT over that bandwidth.

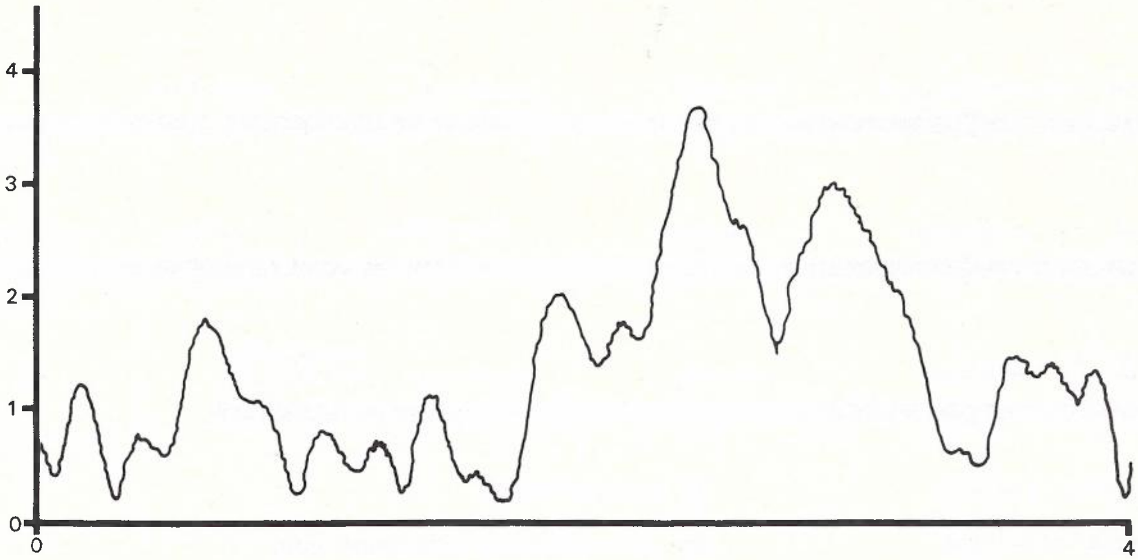


Fig. 2 — NEXT Frequency Response over a 4 kHz Channel at a Line Frequency of 10 MHz on Melbourne-Sydney CX2 Coaxial Cable.

RODNEY REYNOLDS joined the APO in 1968 working as an engineer in Long Line and Radio Installation areas in Tasmania until 1973. He then transferred to Headquarters where he worked in the Long Line Equipment Construction Branch in the areas of equipment provisioning and installation engineering. He is currently a Senior Engineer in the Digital Design Section of the same Branch.

He received a B.E. degree from the University of Tasmania in 1968 and a M.Eng.Sc. degree from Monash University in 1980.

Consider the model of Fig 1 and the parameters as they are understood. The spacing of the repeaters is known in terms of the average spacing and the variability of that spacing. The amplitude of the crosstalk at each repeater is known as an average only over a number of repeaters and it is necessary to consider a number of possible statistical distributions. As it eventuates, it matters very little what the distribution of amplitudes is, and it also eventuates that the distribution of the spacing is not needed in the real case. All that is needed is the average spacing, the number of repeaters or exposures, and the total average NEXT in order to find out the behaviour of the peaks, that is, the relationship between their magnitudes and how many there are in a given bandwidth.

From the point of view of NEXT measured at one terminal, the crosstalk phases at each repeater are random and independent of each other. It has been argued elsewhere (Ref 2) that irrespective of the distribution of crosstalk amplitudes found at each repeater, including high individual amplitude at the terminals and main repeaters, it can be assumed that the amplitudes are sufficiently close to being Rayleigh distributed for our purposes. It has also been argued and verified by example that measured values of NEXT at different frequencies which are sufficiently far apart are random.

The Rayleigh distribution mentioned above will turn up again shortly and needs some explanation. Any event that may or may not happen in nature is said to have a probability function which predicts the probability that it will happen. For instance, the toss of a coin can be either heads or tails in the simplest case. Either outcome is equally likely and it is said in this case that

$$P\text{ (heads)} = P\text{ (tails)} = \tfrac{1}{2}$$

If it is considered that successive tosses are independent then the probability of two heads in two tosses is

$$P\text{ (2 heads)} = \tfrac{1}{2} \times \tfrac{1}{2} = \tfrac{1}{4}$$

In general, for n heads in n tosses

$$P\text{ (n heads)} = (\tfrac{1}{2})^n$$

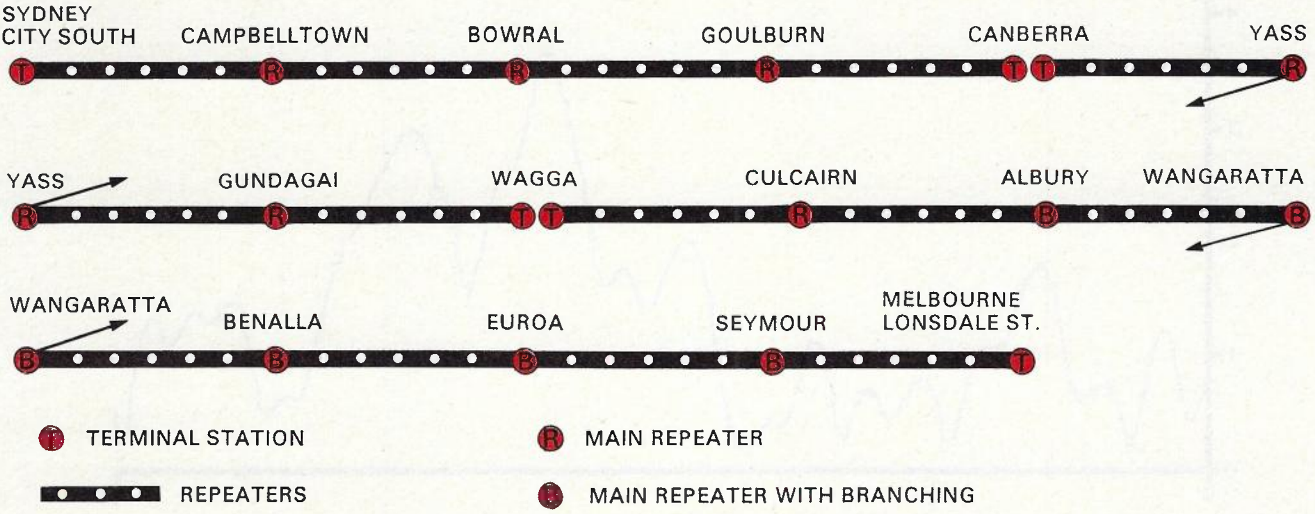


Fig. 3 — Route Layout, Sydney-Melbourne Bearer CX2.

Section	No. of Repeaters	Section Length	Mean Spacing	Stand. Dev. of Spacing
SYDNEY Campbelltown	11	51.700	4.308	0.161
Campbelltown Bowral	14	66.496	4.433	0.272
Bowral Goulburn	17	80.547	4.475	0.114
Goulburn Canberra	22	94.621	4.114	0.551
Canberra Yass	11	53.705	4.475	0.159
Yass Gundagai	22	101.783	4.425	0.192
Gundagai Wagga	18	76.621	4.033	0.513
Wagga Culcairn	17	78.949	4.386	0.183
Culcairn Albury	11	52.148	4.346	0.208
Albury Wangaratta	16	72.794	4.282	0.301
Wangaratta Benalla	9	41.803	4.180	0.226
Benalla Euroa	10	44.822	4.075	0.357
Euroa Seymour	13	54.322	3.880	0.253
Seymour MELBOURNE	22	96.886	4.212	0.368

(All distances in kilometres)

Table 1 — Statistics of Route Sydney-Melbourne Bearer CX2.

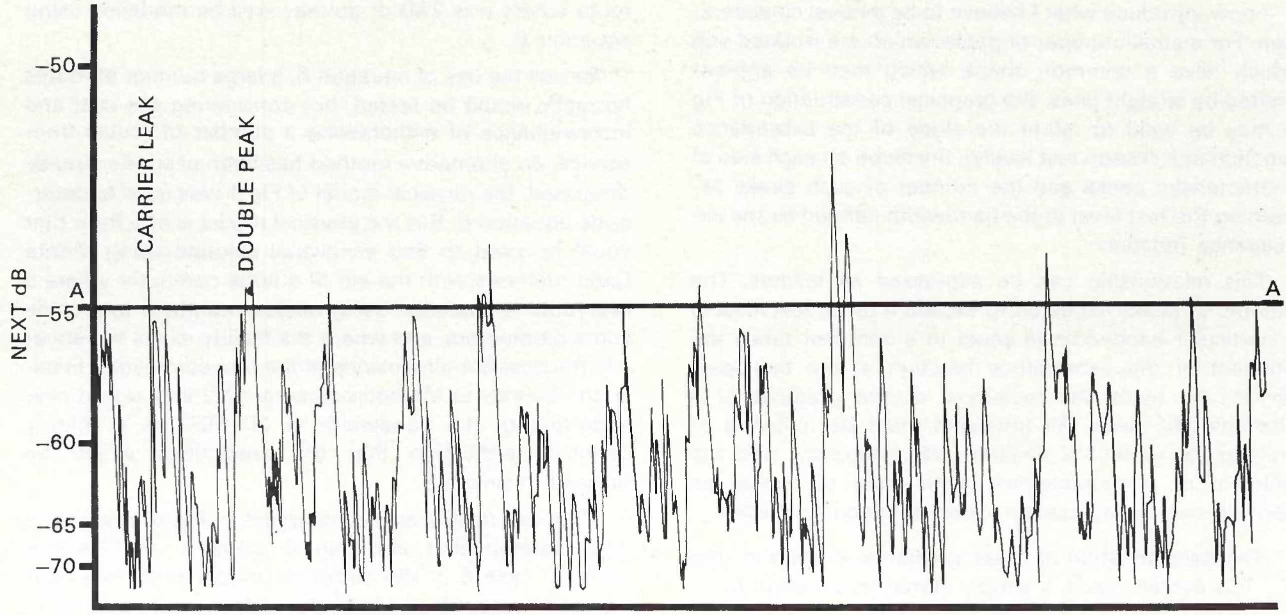


Fig. 4 — NEXT Frequency Response over a 48 kHz Group at a Line Frequency of 10 MHz on Sydney-Melbourne CX2 Coaxial Cable.

This, then, is a discrete probability function. Similar functions exist for all the other possible outcomes and their total adds up to unity (1). A single function which gives all these functions is called a probability density function and there are a number of natural phenomena, from a drunken man walking randomly to the fading behaviour of a radio path, which give rise to what is known as a Rayleigh distribution (Ref 1) which for our case here is, for a large number of repeaters,

$$P(R) = \frac{2Rk^2}{n} \exp\left(\frac{-R^2k^2}{n}\right) \qquad -(1)$$

where n = number of repeaters
k = constant to be determined for each route
R = crosstalk testing level in voltage terms

The determination of this function is not trivial and is given in (Ref 2). Equation 1 assumes that the distribution of the amplitudes is also Rayleigh distributed and given by

$$P(A) = 2k^2A \exp(-k^2A^2) \qquad -(2)$$

where P(A) is probability density function for the amplitude of the crosstalk exposures at the repeaters and k is the same k as in equation 1.

If we consider another amplitude distribution by making the crosstalk amplitudes at the repeaters all equal to unity it can be shown (Ref 2) that

$$P(R) = \frac{2R}{n} \exp\left(\frac{-R^2}{n}\right) \qquad -(3)$$

which is very similar to equation 1 and is still Rayleigh distributed. So it would appear that a Rayleigh distribution will be obtained irrespective of the distribution of the amplitudes of the crosstalk exposures.

Now, using equations 1 and 2, it is possible to find a new parameter which is of use to us, X, for which I have coined the word exceedance, which describes the bandwidth in a testing bandwidth F where the crosstalk exceeds a testing potential V. The normalisation of V is such that the level V = 1 corresponds to the average NEXT power. Then —

$$X = F \exp\left(\frac{-\pi V^2}{4}\right) \qquad -(4)$$

This equation might be used directly, using graphical integration techniques on graphs such as that of Fig. 4, extending over some 48kHz at the frequency of interest. While this method could well be used in a once only exercise, its repetitive use in field applications is out of the question since the graphical scale and accuracy required to give reliable results would create a large quantity of work. However, a convenient alternative is available.

Observation of Fig. 2 will show that all of the peaks in the frequency response of the NEXT are essentially distinct and have slopes which have similar values, provided that levels are considered where the crosstalk value is more than about twice the mean value. Now, consider a special route layout where the repeater spacings are all equal and have spacing equal to ℓ, where the repeater crosstalk amplitudes are equal and unity and where the crosstalk phases are all zero at each repeater. In this particular case it has been shown (Ref 2) that —

$$X = \frac{\sin(2\pi \ell fn/c)}{\sin(2\pi \ell f/c)} \qquad -(5)$$

where f is the frequency of transmission and c is the velocity of propagation. This, then, is sufficient to define the shape of a peak in the real case.

I now introduce what I believe to be a novel consideration. For a small number of peaks which are isolated and which have a common shape which may be approximated by straight lines, the graphical construction of **Fig 5** may be used to relate the slope of the exceedance function at a chosen test level q, the slope on each side of characteristic peaks and the number of such peaks exceeding the test level in the bandwidth defined by the exceedance function.

This relationship can be expressed as follows. The number of peaks expected to exceed a given test level in a particular bandwidth is equal to a constant times the gradient of the exceedance function at the test level divided by twice the reciprocal of the gradient of a characteristic peak. All gradients must be in terms of voltage (or current if desired) and frequency, and the gradient of a characteristic peak must of course be derived after normalisation when equation 5 is used.

The determination of these gradients is given in (Ref 2). The overall result is simply stated in equation 6 —

$$N_V = 0.34 \text{ anBFV } \exp(-\pi V^2/4) \qquad -(6)$$

where N_V = number of peaks exceeding the test voltage V

$a = 2\pi l/c$

n = number of crosstalk exposures

B = empirical factor = 0.83

l = mean repeater spacing (metres)

c = velocity of propagation in the cable (metres/sec)

F = width of the test spectrum (Hertz)

The empirical factor B is the constant referred to earlier and is required since in the construction leading to equation 6, the peaks were considered as triangles. The realised value of 0.83 is not unreasonable as discussed in (ref 2). Values of n exceeding 30 are large enough for sufficient accuracy, so certainly a long coaxial cable route where n is 250 or so may well be modelled using equation 6.

To test the use of equation 6, a large number of routes normally would be tested, but considering the cost and inconvenience of withdrawing a number of routes from service, an alternative method has been used. As already discussed, the physical model of Fig 1 was used to determine equation 6. But the physical model is of a form that could be used to find an overall solution using Monte Carlo methods with the aid of a large computer where a real route is modelled using random numbers to provide some parameters, and where the facility exists to vary at will the possible dimensions of the repeater layout. Finally, the Sydney to Melbourne bearer CX2 was tested over a portion of the bandwidth at 10 MHz as a solitary detailed verification that the predictions would be realised in practice.

All these results are summarised in **Fig 6** where it is demonstrated that equation 6 gives a valid testing method. Case 6 of the computer model involves a considerable amount of cophasor additon, not realised in practice, but plotted here to demonstrate the effect of violation of the hypothesis that the phase distribution at the repeaters is random.

MEASUREMENT PROCEDURE

The application of the testing method to measure the average NEXT on a bearer is straightforward. A graphical representation of the NEXT is required at the frequency of interest. Fig 4 is typical, so consider this as an example to be evaluated using the method. The scales are unimportant provided that the vertical scale is calibrated at the testing level chosen. In order to obtain the plot a very slow scan is required and 15 minutes is typical for a 48 kHz scan. The existence of noise on the bearer will modify the plot obtained but not the result if the noise is 5 to 10 dB below the testing level with the receive filter used. In general zero send level OdbmO and 400 Hz receive filters are adequate.

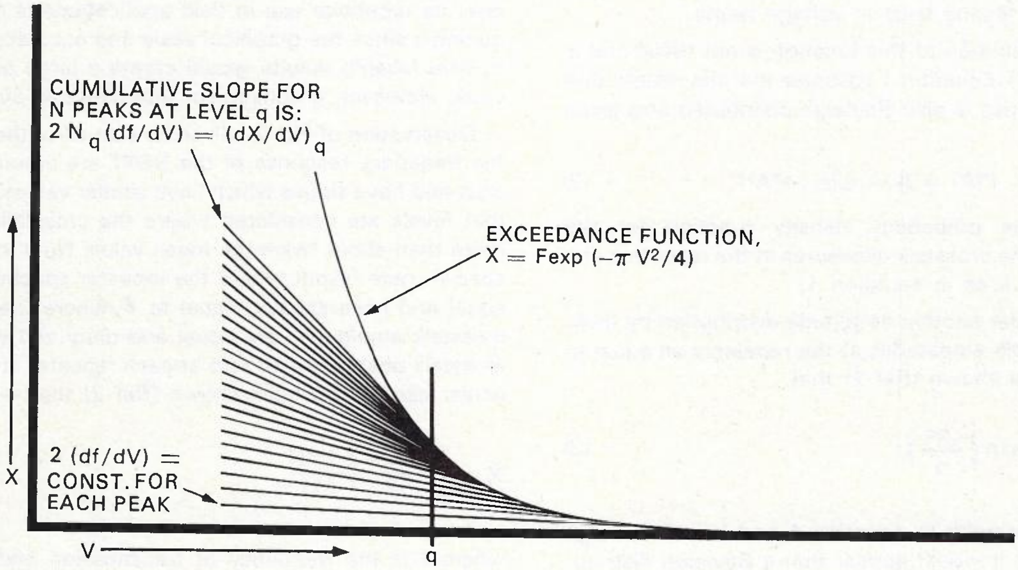


Fig. 5 — Geometric Construction to Predict a Count of Peaks Above a Test Level.

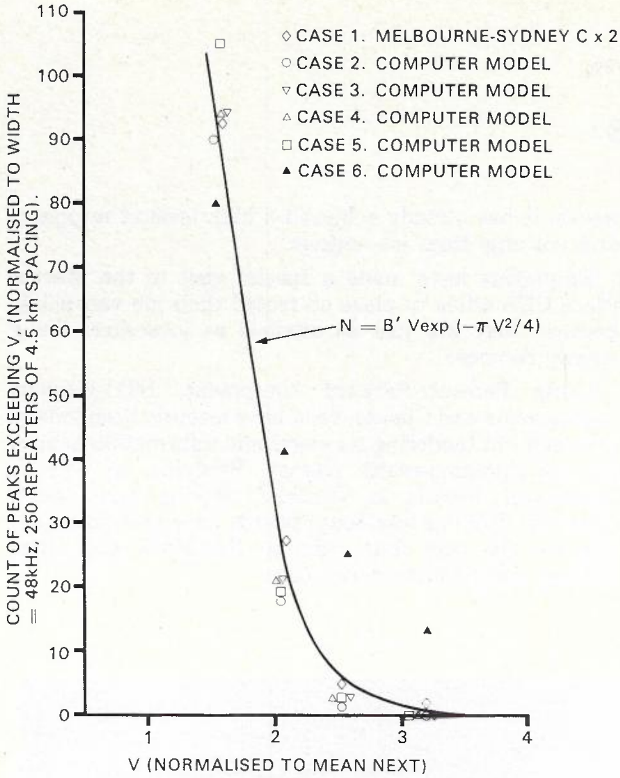


Fig. 6 — Graphical Comparison of Normalised Results.

However, the slow scan requires the facilities provided in synthesised sweep sets and while lower cost equipment might be used, the operator expertise will affect the overall result.

Once the plot has been obtained a line is drawn so that approximately 10 to 20 peaks are intersected, eg, the line AA at -55 dB on Fig 4.

Spurious responses are ignored such as the sharp line shown. These responses are easily seen if a background noise and carrier leak plot is obtained first. The count must then be normalised to 250 repeaters and 4.5 km average spacing if Fig 6 is to be used. In this case from the route layout there are 228 exposures and the mean spacing is 4.261 km. So the corrected count for the 13 counted intersections at -55 dB is

$$N_V = 13 \times \frac{228}{250} \times \frac{4.261}{4.500}$$

$$= 11 \text{ approximately}$$

The corresponding value of V is read from Fig 6 which is in this case V = 2.26. Then simply as this is a voltage reading and we require the dB equivalent, the average NEXT is —

$$X_T = -55 - 20 \log 2.26$$

$$= -62.08 \text{ dB}$$

Modified graphical integration methods give —

$$X_T = -62 \text{ dB}$$

A simple form of graphical integration which makes use of an independence property of NEXT with frequency can be used to give a pessimistic result due to the existence of system noise. By measuring the NEXT voltage at, say, 20 frequencies, the average NEXT voltage may then be used as a measure of the average NEXT over the band. Some care must be taken in the choice of the 20 frequencies. Frequencies having spurious content must be avoided and no attempt should be made to look for frequencies of high NEXT. In other words, choose a set of frequencies, say, at 1 kHz spacing, starting at a frequency which is removed from a carrier leak by, say, 500 Hz. Send levels of +5 dBm0 should be used with a receive filter width of 50 Hz to lessen noise effects. Use of this method results in errors which indicate NEXT values up to 2 dB worse than actual.

CONCLUSION

Previous to this investigation, operators have tended to read NEXT on practical routes by finding the peak values. The results here show that the mean NEXT is of the order of 10 dB removed from the peaks on average. Ref 2 goes further to demonstrate that the mean NEXT on a 4 kHz channel is variable but is removed from the peak value over a group width, say, by 8 to 16 dB. In the course of this investigation it has been determined that the NEXT is Rayleigh distributed for all reasonable repeater crosstalk amplitudes provided that the phases of the individual crosstalk interferes are essentially random.

Of particular interest in the Australian network, those routes like the Sydney-Melbourne CX2 which have been considered as possessing unsatisfactory NEXT performances are somewhat better in this respect than previously thought.

REFERENCES

1. Rayleigh, J. W. S. Baron, **On the Resultant of a Large Number of Vibrations of the Same Pitch and of Arbitrary Phase**, Philosophical Magazine X pp 73-78, 1880.
2. Reynolds, R. A. J., **The Characterisation of Go-to-Return Crosstalk on Long, High Capacity, Broadband Coaxial Cable Communication Links**, Monash University, 1978 (with References). Telecom Australia Research Library Reference 621.391.827 MON.

In Brief

DEBUT OF ELECTRONIC CLASSIFIEDS

An electronic signboard which advertises job vacancies is the latest application of joint expertise demonstrated by STC-Cannon Components Pty. Ltd. and Claude Neon Ltd.

As a community service, the two companies have lent the equipment necessary for the electronic signboard to the Commonwealth Employment Service (CES) office at Martin Place and Elizabeth Street, Sydney, where it is now being evaluated.

The signboard is electronically fed by computer, displays jobs as they become available, deletes them as they are taken up and is continually updated.

Though the signboard has been operating for only two weeks, it has already achieved a high level of response, and not only from job seekers.

Employers have made a special visit to the Martin Place CES office to place on record their job vacancies, because they are just as anxious as jobseekers for a speedy response.

Using Ferranti-Packard equipment, STC-Cannon Components and Claude Neon have recently been jointly successful in tendering for electronic information boards for the Commonwealth Games, Brisbane, as well as totalisator boards at Gosford, Wyong and South Australia. Similar totalisator boards have been in operation for the past four years at Randwick and other Sydney metropolitan racecourses.

The Electronic Signboard which Advertises Job Vacancies, on show at the Martin Place CES Office.

Plastics Encapsulation of Integrated Circuits

G. G. MITCHELL, B.Sc.(Hons), M.Sc.

A factor which is sometimes overlooked when choosing an integrated circuit is the influence the packaging may have on reliability. This article aims to provide background information about the various aspects of plastics packaging of integrated circuits. The structure of the common plastics encapsulated dual-in-line packaged IC is outlined and its strengths and weaknesses discussed as they influence reliability. The potential for further reliability improvements in plastics packaging is described. Although some problems remain, penetration of high quality plastics encapsulated ICs into telecommunications applications will increase.

Integrated circuits (ICs) are manufactured by and available from a wide range of sources using production techniques which are being continually subjected to change. This article aims to provide the reader with a background of information about plastics encapsulation of ICs. The various production techniques and reliability implications are discussed. Where comparisons with hermetic packaged ICs are drawn, data on the CERDIP (Ceramic dual in line package) is generally cited.

The introduction of dual-in-line plastics packaged (plastic DIP) ICs in the 60s made available low cost, high volume ICs for the industrial and consumer markets. The early plastic packaging technology, however, resulted in significant reliability problems through chemical and physical incompatibility of some of the materials. Since then a lengthy process of gradual improvement in materials and techniques has taken place.

Most development of IC technology takes place in the US and Europe, and it becomes essential to monitor developments and accept only those new techniques which meet specific performance requirements. With the wide range of packaging technology and the diversity of sources currently available, the choice of what to adopt, and from whom, is not an easy one.

THE STRUCTURE OF ICs

The functional requirements for any semiconductor package include provision for electrical connection to the interior, electrical isolation between leads, suitable heat transfer capability and the package must also provide an environment compatible with device performance and reliability. Protection from outside influences such as chemicals, temperature, and humidity is required. It may also be necessary to provide protection from light or other radiation, magnetic fields, etc. Fire retardancy is also a desired property.

The dual-in-line package (DIP) configuration is compact and convenient for assembly and handling, whilst being able to meet the other functional requirements. The general construction of a plastic DIP IC can be seen in **Fig. 1**, which shows a partially decapsulated device. The IC chip is mounted on a metal heatsink which is part of the metal skeleton, or lead frame, of the IC. Fine bonding wires are used to connect the lead frame to the metallised pads on the chip. The lead frame and chip are then encapsulated in one or more resins. Once the lead frame is supported by the body of the package the leads may be trimmed, and bent into their final shape.

The construction of a common hermetic package, the CERDIP, can be seen in **Fig. 2**. In this package the chip is mounted on a ceramic (usually, alumina), preform base, electrical connections are made to the lead frame with bonding wires and then the package is completed with a ceramic preform top. The whole package is held together by a low melting point glass frit.

Both plastic and hermetic packages take many forms, but the plastic DIP and CERDIP have become the most common types.

IC CHIP MANUFACTURE

In considering the packaging of ICs, the structure of the IC chip itself must be considered as some of the processes applied to the chip form the beginnings of the packaging process.

ICs are produced en masse on silicon wafers by means of photo-lithographic, diffusion and oxidation processes. The interconnection pattern is generally made with evaporated aluminium. The final processes must provide electrical connection and chip protection. Protection is usually provided by depositing a thin layer of silicon dioxide (SiO_2), or silicon nitride (Si_3N_4), on the chip surface and then removing this "passivation" from the areas where connecting pads are required. The metallisation of the pads must be chosen so that it is compatible with both the chip and the bonding wires. In the case where aluminium bonding wires are used, aluminium metallisation is compatible. This is the case in CERDIPs.

Plastic DIPs generally use gold bonding wire, and in this case direct connection of the gold to aluminium may, at temperatures above 150°C, give rise to the formation of brittle intermetallic compounds and subsequent bond failure. To overcome this problem alternate metallisation systems have been developed, such as RCA's titanium, platinum, gold trimetal process. This provides compatibility with the bonding wires and is also corrosion resistant (Ref. 1).

A further development in chip technology involves modification of the connecting pads to permit more highly automated assembly methods.

This involves preparing raised metal beams or bumps on the chip so that connection to the lead frame can be performed simultaneously and automatically. The completed wafers are inspected and then diced into individual chips, usually by scribing and breaking. The chips are

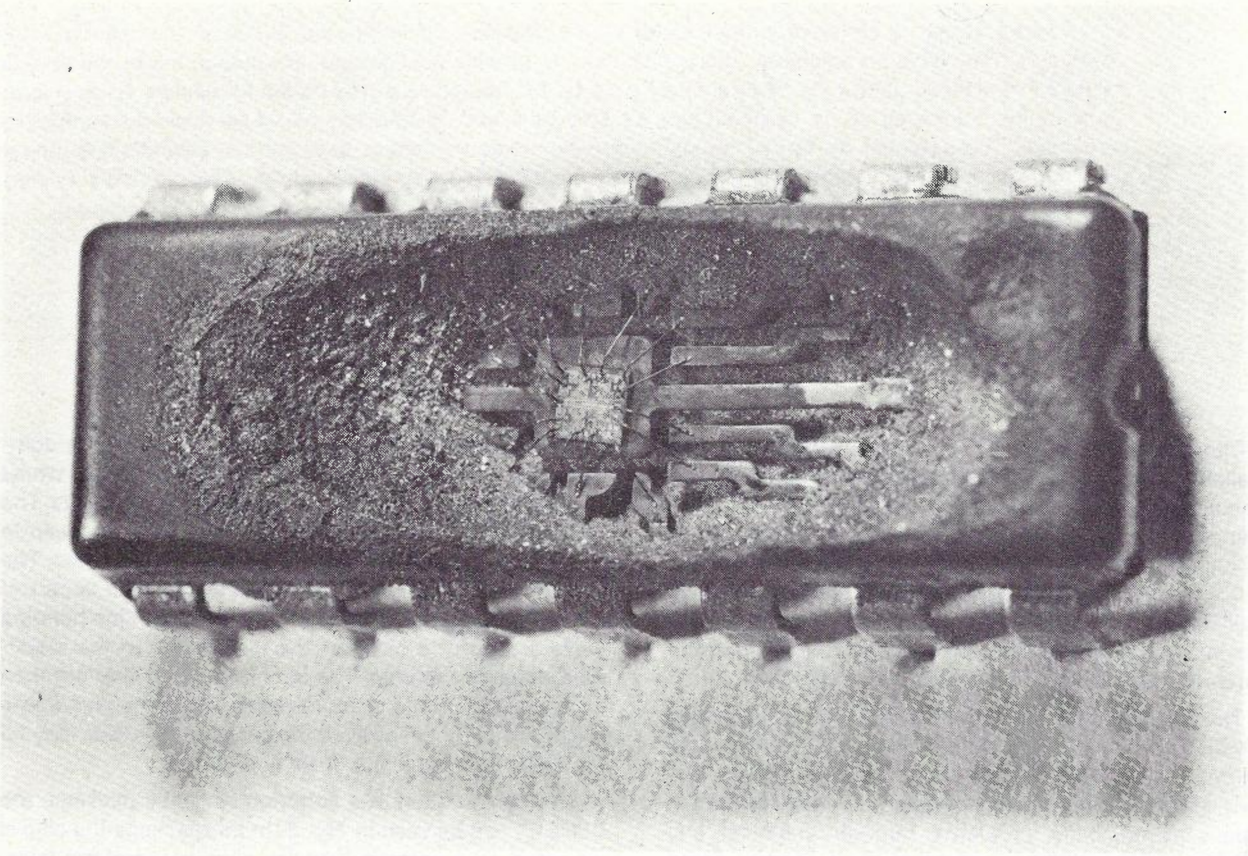
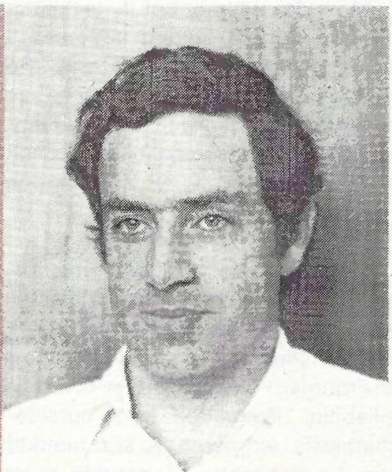


Fig. 1 — A Partially Decapsulated Plastic DIP IC.

GEOFF MITCHELL graduated from the University of Melbourne as a Master of Science (Physics) in 1968. After two years on military service with the Royal Australian Signal Corps he joined the Telecom Research Laboratories to work in the field of component reliability. He is currently a senior scientist with the Reliability Studies Section.



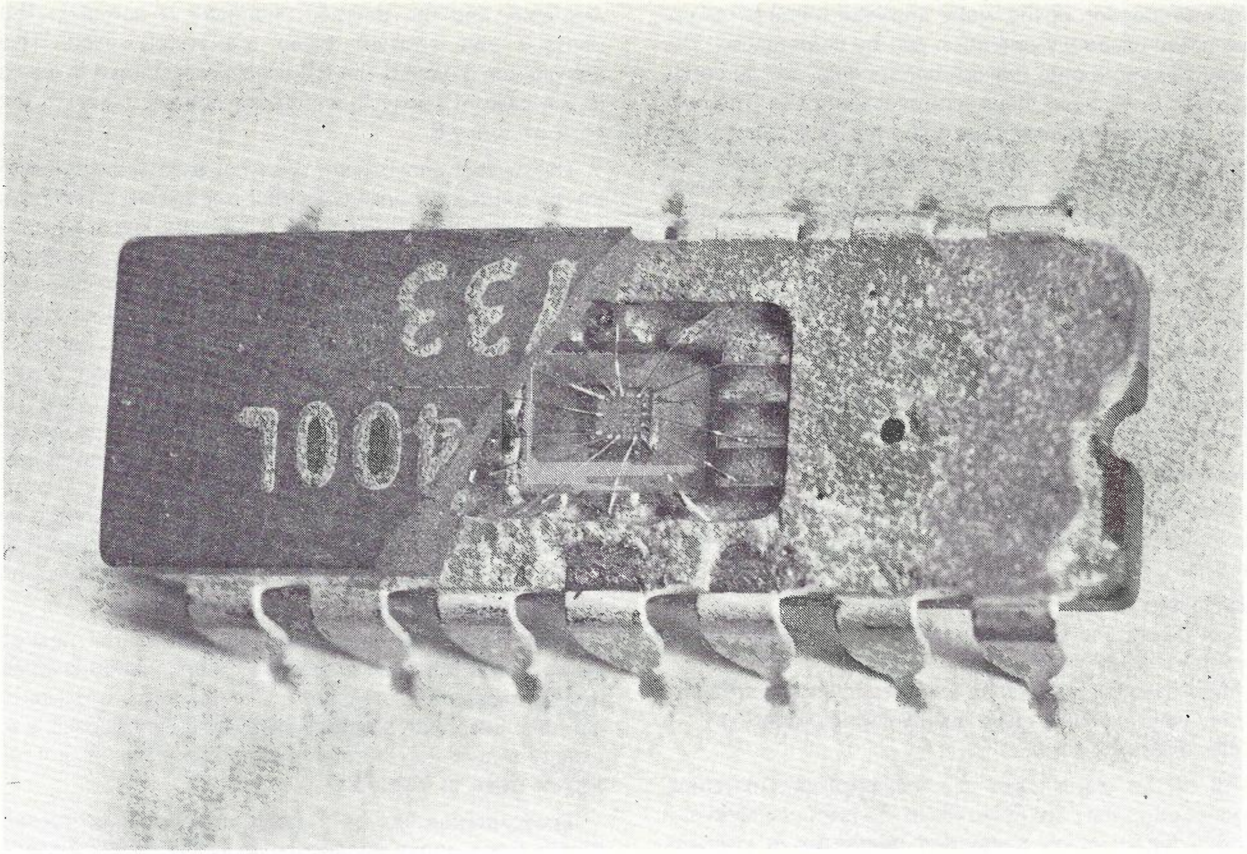


Fig. 2 — A CERDIP IC with Part of the Top Removed.

then cleaned and mounted on the leadframe heatsink. This attachment is made by soldering, alloying or by means of an adhesive.

Bonding Wires and Lead Frame

The bonding wires and lead frame serve three main functions: electrical connection, heat sinking and mechanical support.

The lead frame is generally made of Kovar (a Ni-Co-Fe alloy which has a temperature coefficient of about 6 x 10^{-6}/°C, compared with Si, 4 x 10 $^{-6}$/°C). **Fig. 3** shows lead frames from four different plastic DIPs. Some have provision for better physical locking into the encapsulant, and longer internal pathways to reduce the likelihood of moisture penetration along the leads. The inner ends are prepared to accept the bonding wires, i.e. they are usually aluminium or gold finished.

The bonding wires (usually 25μm gold or 35μm aluminium) are attached to the chip and lead frame by thermocompression and ultrasonic welding.

In the quest to produce cheaper, more consistently reliable devices, the trend is towards increasing the automated content of the manufacturing process. Conventional manual wire bonding may be cheap in terms of equipment costs, but it requires a significant level of operator skill. In a 16 lead IC, 32 placement decisions are required per device. Automated ganged wire bonding reduces this to one decision, the positioning of the chip,

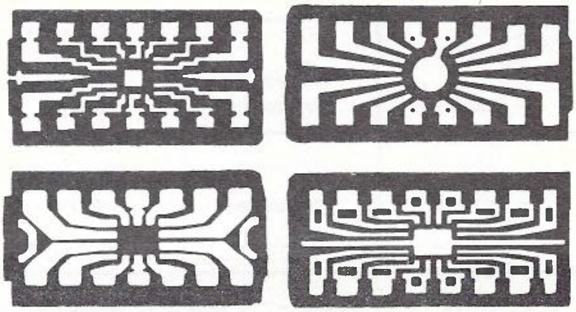


Fig. 3 — Examples of Lead Frames used in Plastic DIP ICs.

as all wire bonds are then made automatically and simultaneously. Throughput can be increased from about 60 devices/h to about 1000 devices/h for the same labour costs.

Tape automated bonding system (Ref. 2) are a further advancement. Here the wafers are "bumped" with raised connection pads, adhered to a substrate (usually glass), and sawn into individual chips (rather than scribed). The inner lead frame is prepared using etched copper leads on polyimide film with sprocket hole location. The inner ends of the copper leads are usually plated to suit the metallisation of the connection pads. Once the appropriate location of the wafer and lead frame is set up, automated assembly operation can be commenced. The frame is lowered onto the appropriate chip, and all bonds are made by a single thermocompression head. The heat from the process releases the chip from its substrate, and the lead frame with chip is removed and the next chip and lead frame are advanced. Throughputs of 5000 devices/h can be achieved with one operator controlling several machines.

Once on the tape, chips can be tested without the need for individual probing. Depending on lead frame design, it also becomes possible to carry out burn-in of the chips before encapsulation. The main drawback of tape automated bonding is the extra cost of materials and equipment.

Encapsulants

The most commonly used resin for encapsulation is the family of epoxies. They are popular for the following reasons:

- shrinkage is low
- they have good adhesive properties, particularly to the metal lead frame
- they have good resistance to environmental extremes
- they have excellent electrical insulating properties
- they are easily cured

All of the resins used are thermosetting materials. Before curing they are generally in the form of a solid or a viscous liquid which melts and decreases in viscosity upon the application of heat. When combined with a catalyst or curing agent the neighbouring resin molecules are cross-linked and a solid block of resin is formed which cannot be remelted.

The number of possible resin formulations is considerable, and the detailed chemistry is complex. The epoxy A and epoxy B types are widely used. This designation indicates the long chain epichlorhydrin resins in the case of epoxy A, and epoxy novolac resins in the case of epoxy B.

The perfect encapsulant does not exist since some of the properties required are either impossible to achieve, or mutually exclusive. For example, very low water absorption and ionic impurity content require a non-polar resin. However, good adhesion requires a chemically active polar resin, preferably free from filler and mould release agents. Yet without filler there is no chance of matching the thermal coefficients of expansion of the other parts of the IC, and a mould release agent is desirable to assist in freeing components from the mould. Any encapsulant is thus of necessity a compromise. Several important properties of encapsulants are compared in Table 1. Some resins may have better individual properties, but the phenolic modified epoxies (epoxy B or epoxy novolac) have the best all round performance and are used most widely.

All encapsulants are "filled" to achieve the desired physical and chemical properties. Fillers include crushed quartz, asbestos, glass fibre and other forms of silica or alumina. Even with around 75% fillers it is not possible to exactly match the thermal coefficients of expansion, as can be seen in **Table 2**.

Encapsulation can be a single or two stage process. Single stage epoxy encapsulation is the most common technique, although in some cases the chip and an inner lead frame are encapsulated first. This package is then attached to an outer lead frame and encapsulated to bring the package to the usual DIP size. The most common two stage encapsulation involves placing a drop of room

Property / Resin	Water Absorption	Conductivity of aqueous extract	pH of aqueous extract	Adhesion to silica	Adhesion to metals
Expoxy A	adequate	poor (high)	poor	adequate	good
Epoxy B	adequate	adequate	adequate	poor	adequate
Silicone	adequate	good (low)	adequate	good	poor

Table 1 — Relative Performance of the Most Common Encapsulants

Property	Glass Transition Temp, Tg: +°C	Thermal coefficient of expansion, α x $10^6/^{\circ}C$			
		at 50°C	at 100 °C	at 150°C	above Tg
Epoxy A	140	25	30	60	
Epoxy B	140	25	35	80	
Silicone	220	27	33	33	130

Silicon has an α of $4 \times 10^{-6}/^{\circ}C$

Table 2 — Typical Values of Glass Transition Temperature and Thermal Expansion Coefficient for Common Encapsulants.

temperature vulcanising (RTV) flexible silicone resin over the chip and bonding wires and then encapsulating with a solid, filled silicone resin.

If a mould release agent is used the encapsulant to lead frame interface may be affected. Some manufacturers use a backfill plastic impregnation operation to seal any gaps along the plastic-lead interface.

PROCESS CONTROL

Virtually all devices are subject to batch or periodic sampling at all important stages of manufacture. Electrical and visual inspections are performed prior to encapsulation and mechanical, electrical and environmental screening carried out subsequent to encapsulaton.

The testing serves to not only maximise process yields, thereby keeping costs down, but also to ensure that process control is maintained. Quality and reliability are a function of proof of process capability and maintenance of process control.

Much of the testing is automated. Even so, it is not possible to fully test all possible functions of LSI chips. In some circumstances specialised test structures are incorporated on wafers containing complex chips so that process quality can be assessed more easily. If the test structures are faulty the whole wafer is discarded.

Encapsulant Testing

Specifications such as those produced by the British Post Office (Refs. 3, 4) can be used to set performance requirements which must be met by encapsulants. Important requirements include low content of mobile ions (both positive and negative), low water absorption, low water vapour permeability, low coefficient of expansion and high adhesion to all surfaces. Other requirements affecting the manufacturing processes must also be met, e.g. defined ranges of melt viscosity, gel and cure times.

Encapsulant testing is performed on both bulk material and finished devices, containing transistors or ICs of well established performance.

The epoxy B resins are the preferred material for encapsulating low power components for use at ambient conditions of temperature and humidity. The epoxy A resins have better adhesion, but usually contain greater amounts of mobile ionic contaminants which make them suspect in humid environments. Their preferred use is with devices operating continuously above ambient temperature and in dirty environments where good adhesion is valuable. The silicones have only one major weakness — poor adhesion to metal lead frames. This restricts their use to clean environments or high temperatures, where there is little chance of penetration by moisture or pollutants along the lead frame to resin interface.

Final Testing

Following encapsulation finished ICs must once again be subjected to testing to assess reliability levels. It is reported that manufacturers generally do not follow the progress of all lots thoroughly, except for special high reliability runs. Lot identity is lost as the chips are usually taken off-shore to a low labour cost country for assembly and encapsulation. Testing is required to establish process yields and overall reliability.

Obviously the work involved in testing adds to the cost of finished devices. As the scope of applied tests increases, the cost of plastics packaging moves closer to hermetic packaging. As it is wasteful to have the ICs tested before leaving the manufacturer, and again on being received by a user, these factors which influence cost are generally brought into balance as a result of supplier-user agreement.

Many of the tests used for hermetic packaged ICs can be applied to plastics packaged ICs and are described in documents such as MIL-STD-883. However, some important requirements relating to moisture and temperature failure modes have not yet been formulated in an entirely satisfactory way, although progress is being made in the creation of acceptable national specifications covering all requirements for qualification approval and ongoing monitoring of performance (Refs. 5, 6). The general objective is to produce a series of screening tests to cover different application categories.

ACCELERATED TESTING OF ICs

Accelerated testing is used to assess and compare new materials and processes, and also to monitor the process control of established methods. In order to amass sufficient device hours for a satisfactory confidence level, stress acceleration is used. The test results can then be extrapolated back to field conditions with a significant gain in device test hours.

The testing of plastic DIP ICs involves using a wide range of tests, but three types of test are considered the most important in evaluating the influence of plastics encapsulation on IC reliability. These are:

- High temperature with Electrical Bias
- Temperature-Humidity-Bias Testing, and
- Temperature Cycling

High Temperature-Bias Testing (Life Testing)

One of the most significant effects early plastic encapsulants had on silicon chip reliability resulted from ionic contaminants in the resin. This contamination, usually in the form of positive mobile ions such as sodium, resulted in the formation of inversion layers on the chip surface, with a corresponding degradation in device characteristics when voltage was applied for long periods. High temperature (typically 125°C) reverse bias testing is used to reveal the presence of this failure mechanism. Fortunately, the development of very pure resins and the use of a protective layer, such as silicon nitride passivation, over the surface of the chip, have been largely successful in eliminating this type of failure.

The same type of test is also performed as an accelerated life test to seek out failures due to chip fabrication defects or design weaknesses.

Testing of hermetic packaged semiconductor devices has shown that elevated temperatures will accelerate failures and that the behaviour follows the Arrhenius relationship:

$$R(t) = Ro(t)e^{-\theta/kT}$$

where R(t) is the reaction rate function

Ro(t) is a constant (with respect to temperature)

t is the time

$\varnothing$ is the activation energy in eV

k is Boltzmanns constant
T the temperature in K

The activation energy, Ø, is the energy threshold of a particular reaction or failure mechanism. Values quoted for Ø range from 0.2eV to 1.3eV, however, most evaluations use an overall Ø of 1.0eV. It is worth noting that extrapolation of results from elevated temperature to ambient conditions is greatly influenced by the choice of the activation energy value. For example, a 0.1%/1000 h failure rate at 125°C becomes 0.01%/1000 h at 25°C for a Ø of 0.2eV and 5×10^{-7}%/1000 h at 25°C for Ø of 1.3eV.

The ability to accelerate failure mechanisms in plastic DIP ICs is limited by the rapid deterioration of the polymer resins at relatively low temperatures. Consequently, testing for long term reliability has to be carried out for extended periods at moderate temperatures to ensure that no new failure mechanisms are introduced by the testing.

Some manufacturers have produced results showing that under this type of testing plastic DIP ICs are as reliable as hermetic packaged equivalents, with about 0.0012%/1000 h failures at 50°C. This has resulted in claims or inference of equal reliability in service. It should be borne in mind that for plastic DIP ICs this is not a representative life test as it does not explore important weaknesses of plastic packaging, namely, the susceptibility to moisture induced failures and to a lesser extent failures resulting from thermal mismatching.

Temperature-Humidity-Bias Testing

A major weakness of plastic DIP ICs is that moisture can penetrate the package and transport contaminants, both from outside and from within the resin, to the chip where corrosion of the aluminium metallisation occurs, with subsequent failure of the device. Moisture can reach the chip either through the bulk resin or along the interface between the resin and the lead frame. In early plastic DIP ICs moisture penetration along the leads was predominant. With backfilling techniques and generally improved matching of encapsulant and lead frame materials this factor has been reduced to near the levels of bulk penetration.

The test conditions most commonly used to assess moisture resistance are steady state 85°C, 85% RH with electrical bias applied to give minimum power dissipation, but maximum voltage gradient between adjacent connection pads on the chip.

Despite intensive work using different temperature and humidity combinations on similar ICs, no agreed acceleration factor has yet been determined relating accelerated test results to field failures. The vapour pressure, $(RH)^2$ and other factors have been postulated as the prime variable by which the accelerated test conditions can be correlated to field conditions.

Most theoretical approaches use the general log-linear form $R(t) = A.E.e^{-B/F}$ where R(t) is the failure rate function under particular conditions, A and B are constants, E is the electric field present and F is a function of temperature and/or vapour pressure or relative humidity. Acceleration factors between 50 and 10^6 have been reported (Ref. 7). This uncertainty together with reports of different resins having different sensitivities to this test, and speculation that time may be a predominant factor independent of humidity, means that the long term reliability of plastic encapsulated devices based on laboratory evaluations is still in doubt, and likely to remain so.

Despite the lack of an adequate experimental or theoretical link between test and field conditions great progress has been achieved in improving moisture resistance. It is clear from our own work, and that reported elsewhere, that some plastic DIP ICs can now withstand several thousand hours of exposure to 85°C, 85% RH and reverse bias, with few failures. Even with a pessimistic extrapolation to field conditions a satisfactory service life is highly probable for devices which are located in controlled environments, and dissipate significant amounts of power.

Unfortunately, it appears that further major advances in encapsulant hermeticity are unlikely. Thus attention has turned to making the chip impervious to the moisture which will inevitably reach it. The trilayer metallised passivated chip, in theory at least, should be unaffected by moisture (Ref. 8).

Temperature Cycling

Another major failure mode of plastic DIP ICs has been intermittent or open internal connections resulting from the thermal mismatch of the plastic resin, the IC chip, bonding wires and lead frame. All plastics encapsulated devices are susceptible to this failure mechanism although very significant improvements have been achieved through careful selection of materials and manufacturing techniques. To produce fracture of weak bonds and detect open circuits, temperature cycling (in air) tests are used. Conditions vary but typical temperature limits are —65°C to +150°C with 10 or more cycles being performed.

Other Tests

Generally plastics encapsulated devices (PEDs) have shown excellent performance under mechanical shock, vibration and acceleration. The mechanical stresses that a PED can withstand are generally higher than for their hermeticaly sealed counterparts.

Salt spray testing and industrial atmosphere testing have been reported to adversely affect PEDs by introducing ionic contamination. However, the deleterious effects, are brought about by moisture transporting contamination to the chip and hence moisture stress testing is more important than these other tests.

FIELD TESTING

Laboratory test data, whilst valuable, cannot substitute for data from field failures. Information is obtained from analysis of failures occurring in in-service equipment, or by special field testing such as the US Army Electronics Command's (ECOM) test program in tropical areas (Ref. 9). The results generally show wide variations and conclusions reached as to failure rates must be treated cautiously. However, it is fair to say that plastic DIPs have improved, and that the best appear to be as good as CERDIPs. ECOM has collected data on ICs exposed to average conditions of 30°C, 90% RH for several years. Their reported failure rates for epoxy B plastic DIPs span the range 0.17 to 2.12%/1000 h. For CERDIPs rates between 0.10 and 0.68%/1000 h are quoted. These failure rates are well above the failure rates of around

.030%/1000 h, determined from field failures occurring in benign (low moisture) operating environments.

Various data banks such as the US-based Reliability Analysis Centre and Europe's Exact System and France's CNET are further sources of information about IC failure rates.

FAILURE DETECTION AND ANALYSIS

As encapsulants are improved and ICs become more complex increasing sophistication in analytical techniques is required to identify failure phenomena and causes.

Electrical Failures

The main failure modes in plastic DIP ICs appear as open circuits, excessive leakage current, or changes in junction characteristics. Open circuits may result from mechanical failure (e.g. bonding failure or chip fracture) or corrosion. Excessive leakage current may be the result of internal or external corrosion or metal migration. More subtle are changes due to temperature-contaminant effects on the chip.

Measuring IC performance against specification is generally straightforward, however, advanced LSI devices have a high function to external connection ratio and this can severely limit their testability, both in terms of functions which may be numerous, and degradation of electrical characteristics of sections of the device remote from the IC terminals. The application of automated test equipment is essential and the use of techniques such as noise injection (to cause a measurable level of errors in digital circuits) is increasing.

Mechanical Defects

Despite careful control of manufacturing conditions, failures still occur due to mechanical causes. Chip fabrication, chip attachment to the lead frame and wire bonding to the chip all introduce mechanical stresses. Encapsulation can deform the bonding wires and add further stress. Subsequent environmental stresses can promote failure through wire bond or chip damage. Internal stress can also alter electrical characteristics of the circuit, especially resistances (up to $\pm 15\%$). Cracks or voids in the encapsulant or passivation can assist moisture penetration, and adhesion of the encapsulant to the chip is very important in preventing a film of moisture forming on the chip surface.

The flexible silicone resin sometimes applied over the chip and bonding wires adheres to the silicon chip more strongly than epoxy resins, and being flexible provides a degree of protection from the stresses of the subsequent solid encapsulation.

Decapsulation Techniques

Satisfactory failure analysis can only be carried out if close examination of the interior of failed ICs is possible. In the case of PEDs the encapsulants used are thermosetting resins and cannot be readily removed by heat or solvents. With ageing the resins become more difficult to remove. Decapsulation is possible, however, through a combination of mechanical and chemical techniques. Although there are chemical agents which will induce stress cracking and gradual breakdown of the resins, decapsulation by this means takes a long time and can result in damage to wire bonds. More rapid decapsulation can be accomplished with hot (120°C) sulphuric and/or nitric acid. Provided the technique is carefully controlled, decapsulation can be accomplished without damage to the bonding wires or chip.

Another method of epoxy removal is through radio frequency, oxygen plasma-etching, which causes slow, low temperature burning of the resin.

Instrumental Analysis

Once a satisfactory decapsulation has been achieved the cause of failure may be readily apparent, e.g. in **Fig. 4** electrical overload has occurred, and in **Fig. 5**, corrosion. In other cases, it may be necessary to apply microbeam techniques (e.g. scanning electron microscopy coupled with a suitable surface analysis technique such as energy dispersive x-ray spectrometry and secondary ion mass spectroscopy) to identify defects.

Another instrumental technique used in assessing internal defects is x-ray radiography. This non-destructive technique can be used to detect misplaced bonding wires, internal voids or inclusions of foreign material.

As well as analysis of failed devices, characterisation of materials and processes used in manufacture can play a major role in assessing the suitability of PEDs.

HERMETIC PACKAGE TYPES

The prime motivation behind plastics encapsulation is to lower costs. The prime objective of hermetic packaging is high reliability. Over the years developments in packaging technology have aimed at achieving both low cost and high reliability in a single package. The result has been the production of a spectrum of packages for ICs.

The main hermetic packages are:

- metal-glass cans

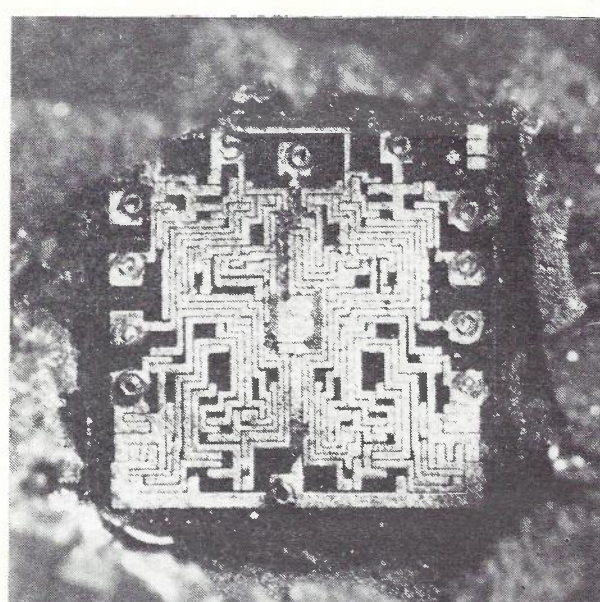


Fig. 4 — IC Chip Damaged by Overvoltage Between V_{CC} (top centre) and Ground (bottom centre).

- metal-ceramic flat packs, and
- ceramic dual in line (CERDIP)

The metal-glass type offers highest hermeticity with matched metal-glass, and welded seals, but is limited in lead numbers and is not a compact package. The metal-ceramic types use matched seals with brazed joints. They are compact but expensive, and the leads are generally easily damaged. The CERDIP is the most cost competitive with plastics, but requires very well controlled firing of the glass frit.

FACTORS AFFECTING PACKAGE SELECTION

Until plastics encapsulation can be proven the equal of hermetic packaging, IC users must make an individual judgement whether the reliability available with plastic is acceptable for their particular applications.

The type of IC can influence the choice of package, as can the environment in which the equipment will operate, and the reliability level demanded by the designer. Low power technologies, such as the MOS family, generally dissipate insufficient power to exclude moisture from the chip, whereas linear devices, dissipating say 20 mW continuously, can reasonably be expected to be free of moisture related failures provided, of course, that moisture was not introduced into the package during manufacture. If the equipment operates in a controlled environment, moisture related failures would be less likely.

A further factor is the relative proportion of the total cost which is represented by the packaging. A long run, small scale integrated (SSI) chip costs less than its package and the total cost of the device may be as little as 10 cents. A large scale integrated chip may itself cost several dollars and the cost difference between plastic and hermetic packaging may be relatively insignificant.

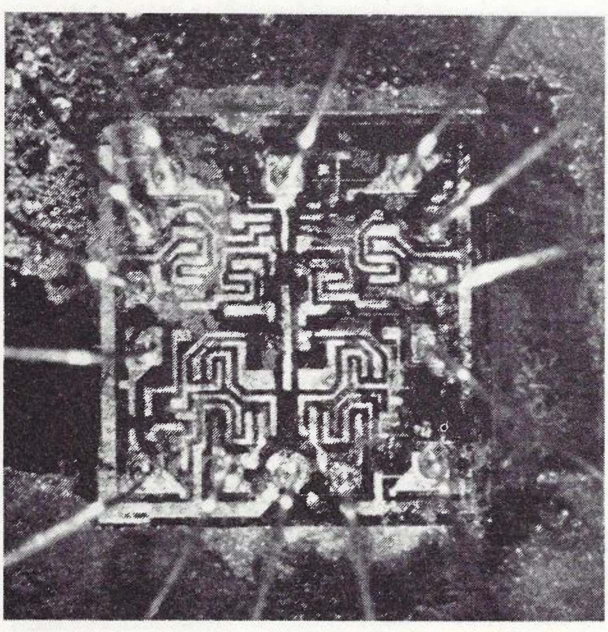


Fig. 5 — An IC Chip which has Suffered Corrosion Damage as a Result of 85°C/85% RH Testing.

The anticipated repair costs of equipment also need to be considered when selecting packaging. Assuming a typical failure rate of about 100×10^{-9}/h for hermetics, plastic DIP ICs are expected to have a fialure rate starting at about 150×10^{-9}/h for benign environments, and the failure rate may reach several times that of hermetics as the environmental stress is increased. The extra cost for repair, over the expected service life of the equipment, can be calculated and compared with the extra initial capital cost of hermetic packaging.

The rapidity with which technology is advancing favours the use of plastics. In some instances equipment may not be in service long enough for IC failures to occur before it is rendered obsolete!

It is generally considered essential to apply 100% screening to ICs before assembly into equipment. The implementation of acceptance screening has led to reports of rejected batches of ICs being sold elsewhere to "less fussy" customers. The possibility of receiving a reject batch of perhaps, relabelled ICs makes a knowledge of the source of supply of ICs equally as important as information on the reliability of the device.

Most major manufacturers have production facilities in a number of countries. The IC assembly may be carried out in any one of several low labour cost countries, sometimes on behalf of an equipment manufacturer and stamped with his brand. This applies to both hermetic and plastics packaging. The level of testing applied by a manufacturer may vary depending on the maturity of the processes and previous results. Screens may be relaxed until a process change is made or excessive faults are detected, indicating that control over the final product needs extra attention. Accordingly, procurement specifications must cover not only service environment and device type and function, but also require accelerated testing, a capability for assessment of the manufacturer's processes and materials specifications.

CONCLUSION

As a result of design and process improvements plastics encapsulated semiconductors have shown substantial growth in reliability. The failure mechanisms and the stresses required to accelerate these mechanisms are now well known. The technology is still evolving, and as new materials and techniques are developed, higher reliability should be obtained. The highest reliability plastic DIP ICs can be expected to have chip protection which makes the chip in effect a metal-glass package in itself, a tape automated lead bonding system, and a silicone encapsulant which results in a strong encapsulant-lead frame bond (the latter is yet to be achieved).

It is expected that approval of plastic DIP ICs will be achieved by appraisal and approval of manufacturing capability and quality assurance schemes, on a selective basis. This is because a general demand for low cost, unproven quality, ICs will remain, and not all ICs will be made to the same quality levels.

It seems that approval by Telecom of the use of plastic DIP ICs, in selected application categories, is becoming feasible. However, the extent of such approvals is likely to be limited, and only apply to well established types from manufacturers known to apply strict quality and process controls.

REFERENCES

1. Khajezdah, H. and Rose, A. S.: 'Reliability evaluation of trimetal ICs in plastic packages'; International Reliability Physics Symposium, April 1977.
2. Keizer, A. and Brown, D.: 'Bonding Systems for Microinterconnect Tape Technology'; Solid State Technology, March 1978, pp. 59-64.
3. BPO THQ Specification M219 for 'Thermosetting Moulding or Casting Material for the Solid Encapsulation of Silicon Integrated Circuits'.
4. BPO THQ Specification M220 for 'Thermosetting Moulding or Casting Material for the Secondary Encapsulation of Silicon Integrated Circuits'.
5. BPO Procurement Specification for Bipolar Logic Integrated Circuits, D3000.
6. Taylor, C. H. and Roberts, B. C.: 'Evaluation of a UK Specification for the Procurement of Plastic Encapsulated Semiconductor Devices for Military use'; Microelectron. Reliab., 1978, Vol. 18, pp. 367-377.
7. Reich, B.: 'Acceleration Factors for Plastic Encapsulated Semiconductor Devices and their Relationship to Field Performance'; Microelectron Reliab., 1975, Vol. 14, pp. 63-66.
8. Gallace, L. J., Jacobus, L. A., Pfiffner, E. J. and West, C. A.: 'Accelerated Reliability Evaluation of Trimetal Integrated Circuit Chips in Plastic Packages'; IEEE Transactions on Components, Hybrids and Manufacturing Technology, June 1979, Vol. CHMT-2, No. 2, pp. 172-179.
9. Hakim, E. B.: 'US Army Panama Field Test of Plastic Encapsulated Devices'; Microelectron. Reliab., 1978, Vol. 17, pp. 387-392.

In Brief

AUSTRALIA'S LARGEST COMMERCIAL SOLAR POWERED COMMUNICATIONS SYSTEM INSTALLED

Lucas Industries Australia Limited have completed the installation of Australia's largest commercial application of solar power for the communications system along the new 831 km Tarcoola-Alice Springs' Railway.

In 1979 the Australian National Railways awarded Lucas the contract to supply solar power for 23 radio repeater stations in the integrated microwave-VHF radio system along the railway. This communication system will enable train crews and track maintenance gangs to have continuous radio contact with train control centres in Alice Springs, Tarcoola and Port Augusta.

The use of solar power for the communications was selected by Australian National Railways to eliminate costly diesel fuelling and maintenance procedures on the new line.

Specifications of Installations

Each of the sites comprises a specially designed weather resistant shelter, which houses the communication equipment and batteries, a 70 m tower and solar array. Twenty-three of the 26 repeater stations have their own solar power system each with a peak output of approximately 1300 watts. The equipment load is expected to reach 200 watts continuous at 24 Volts dc all year round, when the communication system reaches its 72-channel capacity.

Each of the solar powered sites consists of solar arrays utilising 40 Lucas Solar Power Modules, Model G12-361. The power from the array is fed into a single regulator, then to the batteries. Also included in the power system is an automatic high/low voltage alarm system which continuously monitors the state of charge of the storage batteries. The solar arrays at each site are computer designed to provide the correct angle of tilt from horizontal with orientation to true north. A feature of the solar array design is the clever division of the array into sub-arrays which can be lowered individually to facilitate ease of servicing and maintenance.

Technical Details for a typical site

Load	200 Watts continuous
Voltage	24 Volts dc

Solar System and Ancillary Equipment

Array designation	G24-40-361 (see Specification A)
Modules	G12-361 (see Specification B)
Regulator	BSR24-48

2000 AH of storage at 24 Volts providing 10 days storage.

Specification A

Array Tilt	40°
Charging Current	40 Amps
Charging Voltage	27.2 Volts
Charging Power	1088 Watts
Peak Power Point	1258 Watts
Peak Power Current	38 Amps
Peak Power Voltage	33 Volts

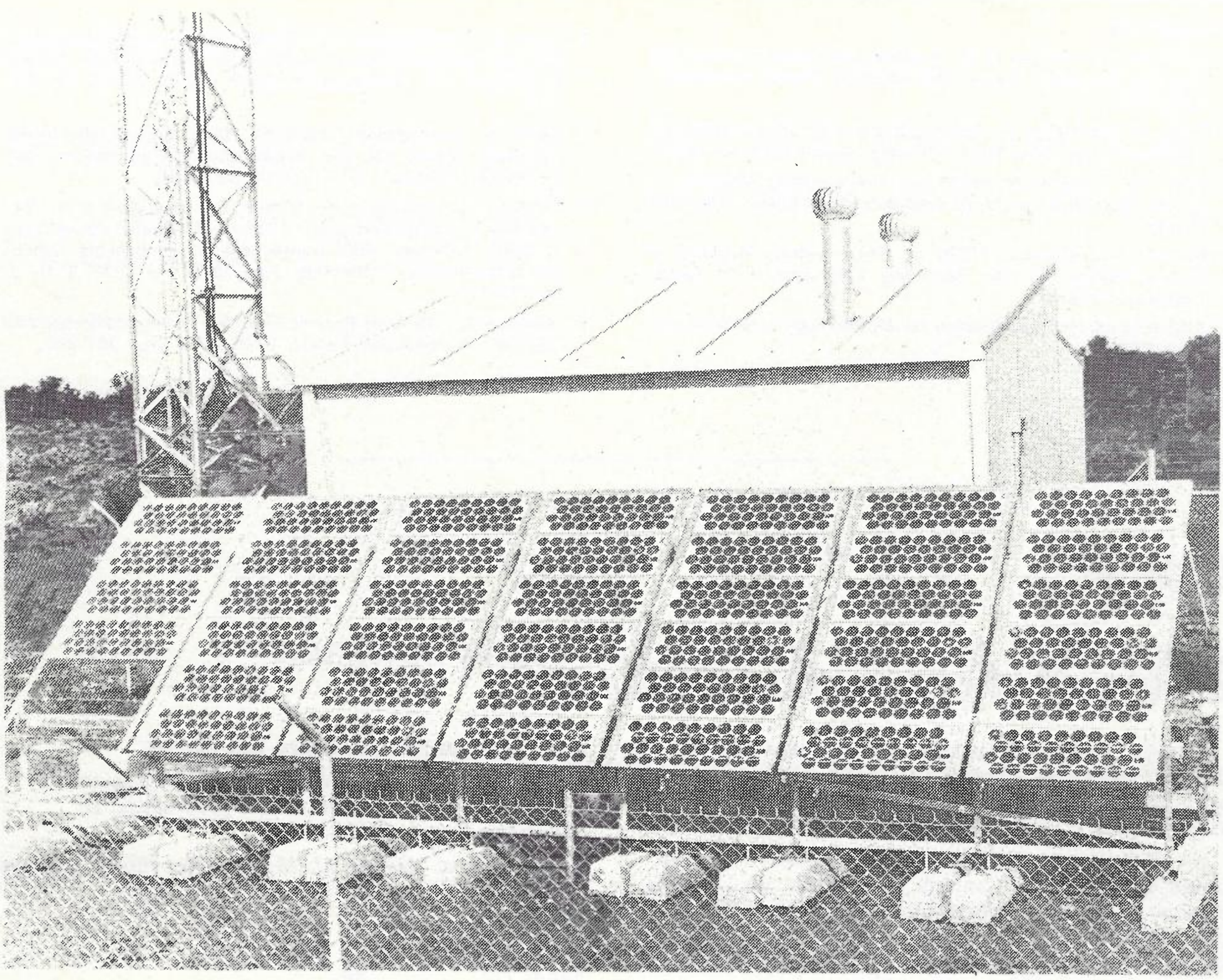
Specification B

Model G12-361 Solar Module:

The Model G12-361 solar module consists of thirty-six. 100 mm diameter silicon solar cells connected in series in a module package that features a glass-top module surface. The top module surface material is a low iron, high transmission tempered glass that provides a smooth and durable cover. The glass surface gives the module the capability to withstand salt spray, sand storms, hail stones, and attack by birds and vermin with minimal degradation of electrical performance.

Low iron glass was selected for its characteristically high light transmittance. Tempering increases the impact strength of the glass. The top surface of the glass module is smooth, thus preventing the buildup of debris on the module.

The solar cells are bonded to the glass sheet with silicone rubber. The silicone seals the solar cells and the electrical interconnections from the environment. Silicone has been chosen for various reasons including high light transmission, long term environmental stability, excellent electrical insulation properties, and the ability to resist degradation due to UV radiation. The silicone/solar cell combination is covered at the rear surface by a white plastic film.



Solar Array at one of the Radio Sites.

The 100 mm diameter solar cells are produced from high purity, single crystal silicon wafers. The wafer initially doped with an "n", or negative, charge donor impurity has a "p" or positive, charge donor impurity diffused into the top layer of the wafer to form the p-n junction. Electrodes are attached to the top and bottom surfaces of the solar cell to collect the electrical energy.

The bottom surface is completely covered by an electrode which improves energy collection and reflects unabsorbed photons towards the junction. The electrode pattern used on the top surface of the 100 mm solar cell consists of a number of small conductor "fingers" crisscrossing the wafer and connecting to a tapering bifurcated main bus. This pattern has been designed to provide maximum surface area for light collection while providing a low resistance, efficient electrical conductor, and completely redundant cell-to-cell electrical interconnections.

Individual modules are supplied with an output cable and blocking diode, or bypass diode, or both as required. The diodes and the connectors to the output cable are sealed in a glass reinforced phenolic junction box located in the rear of the module. (An optional galvanized steel screen is available to cover the rear of the module to protect the encapsulants from damage due to animals or birds.) The module is supplied with an anodised aluminium support frame. The glass, solar cell and silicone assembly is held in the glass frame by a one-piece silicone gasket. The gasket isolates the glass assembly from shocks transmitted through the frame.

ELECTRICAL SPECIFICATIONS

CHARGING POINT		PEAK POWER POINT		PEAK POWER
Volts	Amps	Volts	Amps	Watts
13.8	2.15 ± 10%	16.5	2.05 ± 10%	33.8

Output rated at 28°C cell temperature and 100-mW/cm² incident sunlight. The charging point is based on the voltage of a 12-volt lead-acid battery near full charge. Peak power point values do not include output cable and blocking diode losses.

Exchange Traffic Simulator

G. CONROY and J. DAVIS

A new item of Telephone Exchange test equipment, the Exchange Traffic Simulator is discussed. The Traffic Simulator generates up to 64 erlangs of simulated telephone traffic and can be used to test Telephone Exchanges both before and after cutover. The article details the hardware and software aspects of the equipment, how the machine is operated and its use with Statistical Acceptance testing tables.

An Exchange Traffic Simulator has been designed and developed to Telecom specifications by Information Electronics, an Australian firm based in Canberra. The equipment will be used to acceptance test new telephone exchanges and extensions. In some respects it will replace the current electromechanical 10 line load tester but will generate calls from a maximum 64 lines terminating into a maximum 64 lines.

Unlike the load tester the Exchange Traffic Simulator will generate calls randomly in a similar way to live traffic. The birth and duration of each call will be programmed to follow the standard Traffic Engineering formulae.

The Traffic Simulator generates a traffic component of up to 64 erlangs and prints out on an associated teletype details of failed calls as they occur. After testing, a measure of the grade of service can be obtained. Each exchange is designed primarily as a machine to carry a particular amount of traffic at a particular grade of service and it will be exactly this criterion which will determine whether the exchange can be put into service.

The equipment consists basically of three units.

- A processor controlled random call generator (sender unit).
- A portable called number answer set (receiver unit) and
- A portable teleprinter to interface with the processor.

The teleprinter control will enable the equipment to be used to generate the required traffic or number of calls per hour for a small country ARK exchange up to the high calling rate lines of metropolitan exchanges. The likely applications of the equipment would include

- Exchange debugging aid during installation.
- Exchange check-out before cutover.
- Indication of the grade of service of an operational exchange.

DESCRIPTION OF UNIT — HARDWARE

Figs 1 and 2 show the sender equipment with associated control unit and teleprinter and the separate receiver equipment. Each unit is designed to be portable and all equipment fits easily into one of the Commission's standard stationwaggon vehicles.

Sender and Control Unit (Fig 1)

The control unit is designed around the Intel 8080A (8bit) micro-processor, standard Intel bus, bus extender, 1K Read Only Memory ROM) and 16K Random Access Memory (RAM) boards. The RAM memory is used for temporary storage and contains all the information being used by the processor in the setting up of a call such as the number dialled, sender used, holding time of call etc. The ROM contains the program used including random number generator code listings to enable simulated traffic conditions to be achieved. The numeric displays consist of a seven segment light emitting diode display to indicate the total calls generated, the number of failures and the number of calls in progress. This facility enables the operator to make a quick check of the progress of the tests without using the teletype facilities. A Motorola MC14408 "binary to phone pulse converter" is used for dialling.

Teleprinter

The teleprinter used with the Exchange traffic Simulator is an ITT type "Teletype 43". The unit is portable and weighs only 25 kg and a paper tape reader facilitates the speedy entering of a call programme into the unit. The sender equipment contains 16 Quad Sender Boards. Each quad sender board simulates the sending capabilities of four telephones. In other words the board loops an exchange line, tests for dial tone, dials out decadic digits and detects answer tone generated by the receivers. Careful design of the dial tone detector was necessary to cater for the wide variation of dial tone levels and frequencies generated in the network. During development of the Exchange Traffic Simulator extensive studies of the range of dial and other service tones in the network were made. It was necessary also to allow for the expected introduction of new service tones into the network such as the 425Hz dial tone.

Monitoring facilities are available in the sender equipment which enables any sender line to be connected to an audio amplifier and speaker. Progress of calls on any line can then be monitored above the level of normal exchange noise, by exchange staff who may be working some distance from the unit. The sender equipment also contains sender tester equipment which can be used to replace the exchange and receiver equipment to do tests on a suspected faulty sender in isolation. The sender tester board supplies dial tone and receiver answer tone for tests. Once a faulty sender board is located it is replaced by a spare and no further investigations are necessary on site.

Receiver Unit (Fig 2)

The Receiver unit contains sixteen Quad Receiver Boards. Each Quad Receiver Board contains equipment to simulate the receiving characteristics of four telephones. A receiver detects ringing current sent by the exchange and returns two bursts of answer tone at 820 Hertz. In addition a receiver disconnects from the exchange line when it receives busy tone indicating that the simulated calling subscriber has hung up. The receiver unit is separate from the rest of the equipment to enable network testing with senders and receivers in separate exchanges to be done. A reset button on the front panel enables all receivers to be reset should a receiver fail to disconnect from a line at the end of a call.

A receiver tester board enables a suspected faulty receiver to be tested in isolation. This board effectively replaces the exchange and sender equipment for the tests. Front panel lights indicate whether the receiver under test has detected simulated ringing current and whether it has disconnected from the line at the end of the call.

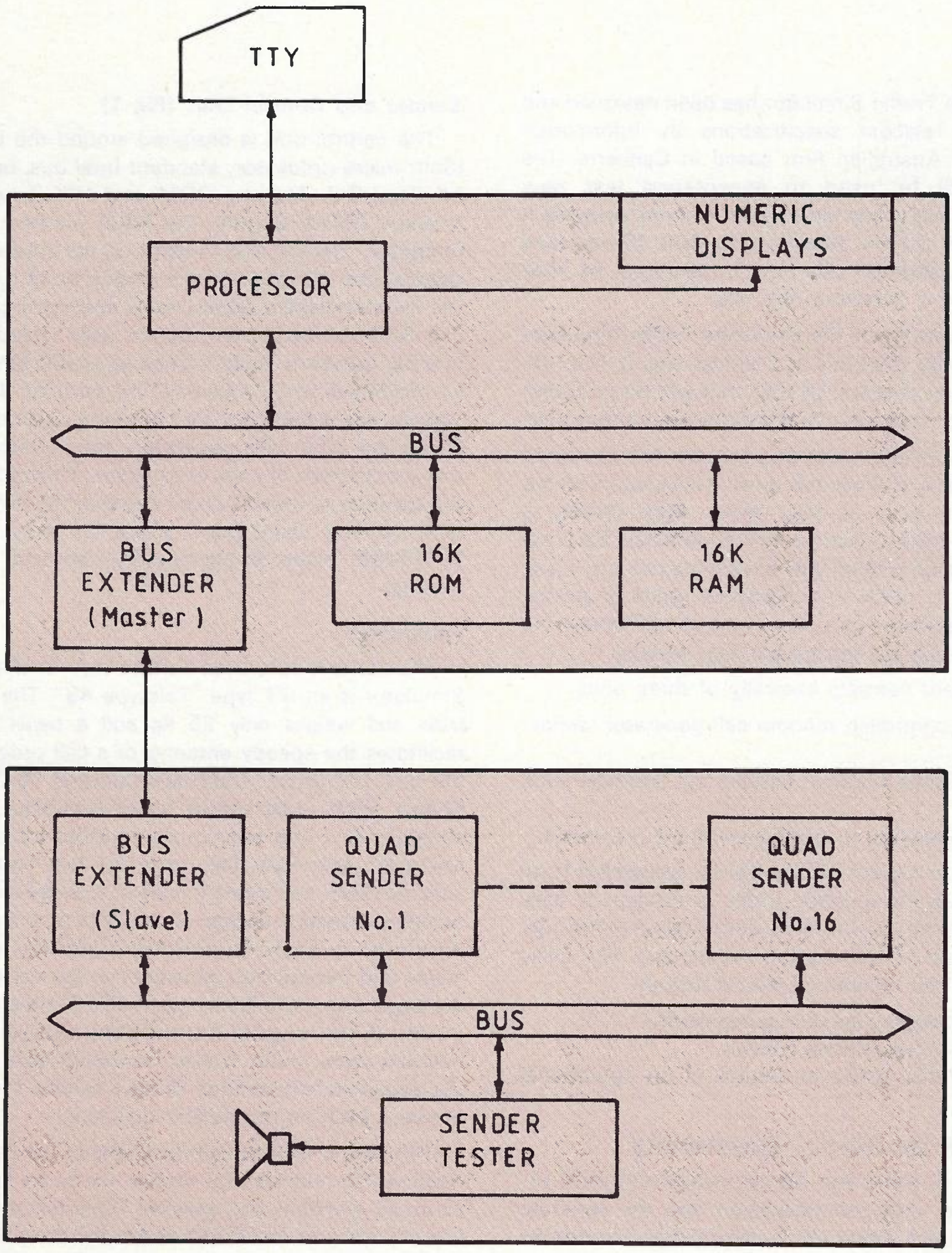


Fig. 1 — Exchange Traffic Simulator at Belconnen Exchange, Canberra.

SYSTEM SOFTWARE DESCRIPTION

The exchange traffic simulator exploits the flexibility inherent in a software based design (as opposed to hardwired logic). The program for the microprocessor is held in Read Only Memories (ROM's) mounted on the program memory board, and variable data is held in Random Access Memory (RAM) mounted on the data memory board.

The software is fully interrupt driven and at power up time (or reset) the program is started at location "O" to initialise the various parts of the system, which includes all the registers in the sender subsystem. Interrupt driven software means that the program in the microprocessor is interrupted when it is necessary to transfer information between the processor and an external device such as a sender register.

"Initialise" is the procedure for setting various parts of a stored program to starting values so that the program will behave the same way each time it is repeated.

All the digits in the numeric displays are set to "8" at power up to check that all the segments are working and a test is made on the program memory to check if the memory checksum calculated in the test agrees with the checksum loaded in the memory. A message is sent to the teletype if there is an error. A test is made on the data memory using both fixed and random data and if any errors have occurred a message is sent to the teletype.

A real time clock at one second intervals, causes all the senders to be polled (their states to be recorded consecutively by the processor) and appropriate action is taken according to a state flow procedure.

The teleprinter input and output channels can interrupt to transfer characters from the keyboard or to the printing mechanism of the teletype. The sender testing hardware can be interrupted by one of higher priority. The interrupt handlers have four levels of priority, the real time clock has lowest priority followed by the teletype keyboard, the teletype printer and the sender dialling tester which has highest priority.

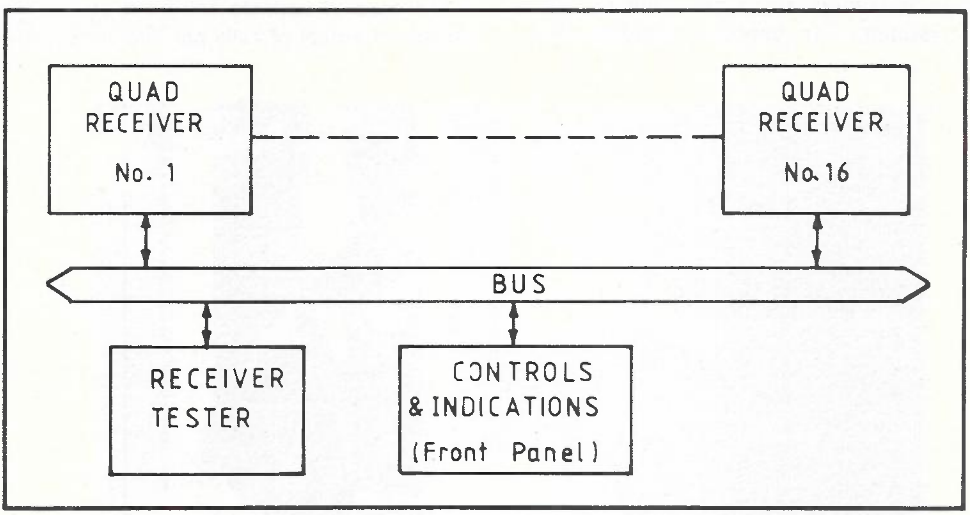
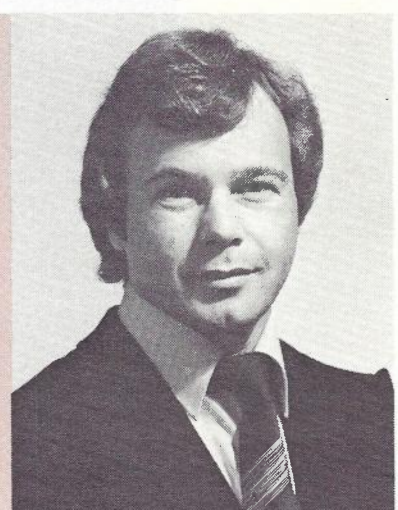


Fig. 2 — Receiver Equipment.

JIM DAVIS graduated with a B.E. (Electrical) from the University of N.S.W. in 1972. Prior to joining the P.M.G. he spent a year teaching at a Technical College.

He worked in the Cable Protection Section (now Lines Practices and Protection)for four years before travelling overseas for a year. On his return to Australia he joined the Trunk Service Section and has been involved with special projects in the switching field.

A profile of G CONROY appears in Volume 26 No 3 of the Telecommunication Journal of Australia.



After the operator has completed the entry of the data and commands to be used in a run, the programme moves into a background mode, carrying out various self-testing routines. In the first test the system buses are checked by sending known data to the port on the sender test board and reading the data back. If there is an error a message is sent to the teleprinter. In the second test a known calculation is performed using some of the more frequently used instructions of the microprocessor and, as before, if an error is detected a message is printed.

The program can be interrupted at any time by any device and it is at this point that the operator would type the word "RUN" to begin testing the exchange.

OPERATION OF EXCHANGE TRAFFIC SIMULATOR

Setting Up

Prior to connection of the exchange traffic simulator an examination of the trunking diagram of the exchange is made to determine the testing parameters. One of three main areas of the exchange may be loaded: the subscribers markers, the registers or the exchange speech paths. On the other hand, the exchange may be tested as a whole. The method of testing used is determined by the operator facility selected. The operator facilities can enable calls to be generated in quick succession for loading markers or registers and would use short call birth times (Ref. 1). Calls however which load speech paths would have longer call holding times.

Once the nature of the tests is determined the equipment is powered up and initialised using the teletype control. Initialisation is done by a question and answer routine wherein the operator supplies the necessary information for the run.

Some of the questions are as follows:-

- Enter time of day as "HHMM" (24 hour format)
- Enter calling numbers
- Enter hold time
- Constant hold time?
- Enter number of calls

Four main types of tests are available:-

- Constant call birth (and/or holding) times
- Variable call birth (and/or holding) times
- Constant traffic into common equipment
- Constant traffic through speech paths

The times are selectable in general in 1 second steps. In the case of variable call birth and holding times the pattern of arrival of calls per line is described by the fol-

Fig. 3 — Simulator in use.

lowing probability density function stored in memory (Ref. 1)

$$f(x) = 1/m \exp(-x/m) \qquad x \; 0$$

where x is the period between calls in seconds m is the average period between calls.

The pattern of holding times is described by the following similar probability density function:-

$$f(x) = 1/h \exp(-x/h) \qquad x \; 0$$

where h is the average holding time in seconds and x is the holding time in seconds.

Typical values for m and h entered during initialisation are 300 seconds and 240 seconds respectively.

In the constant traffic into common equipment mode a stable number of calls are being set up over a period of time. For example, if the common equipment traffic is set at 10 then for any time in this particular run ten calls are being set up.

As soon as one of these calls is set up another starts to be set up keeping the common equipment traffic constant at 10. Similarly for the constant traffic through speech paths a stable number of calls are being held over a period of time.

The number of calls to be generated can be determined using standard statistical acceptance testing tables such as in Australian Standard 1199. A typical statistical operating curve (Ref. 2) might provide for a sample size of 20 000 calls with an acceptance figure of 50. Thus, if the exchange is manufactured and installed so that an average failure rate of 2 calls per 1000 is to be expected, the risk of accepting a particular exchange with a failure rate of 3.4 calls per 1000 or more is less than 1%.

The exchange manufacturer's or installer's risk (Ref. 2) of having an exchange wrongly rejected when its true performance is better than 2 calls lost for 1000 is 5%.

Different operating curves hence sample sizes and acceptance numbers are used when using the ETS to test an exchange as a whole, a group of registers, a group of markers or a new extension. **Fig. 3** shows the exchange traffic simulator in use in Belconnen Exchange in Canberra.

CONCLUSIONS

It is expected that the simulator will more accurately determine whether an exchange should be put into service. Experience with this type of equipment overseas (Ref. 3) has shown that faults are found, particularly in electronic exchange installations, which would not be found in any other way. Faults existing after cutover can often be very costly in terms of maintenance manhours. Overseas experience has also shown that much of the detailed time consuming functional testing of exchanges at installation can be eliminated in favour of simulated traffic testing in conjunction with a study of the exchange indicators. The authors wish to gratefully acknowledge the assistance of Information Electronic's Engineers in the preparation of this article.

REFERENCES

1. Rubas J. and Harris, R. J.: "Introduction to Traffic Engineering"; Footscray Institute of Technology.
2. Standards Association of Australia, Australian Standard 1057 "Glossary of Terms Related to Quality Control".
3. Mackie, R. H.: "An Electronic Automatic Call Sender for Testing New Telephone Exchange Installations;" Post Office Electrical Engineers Journal, Vol. 61, page 165, Oct. 1968.

In Brief

IRELAND CHOOSES ERICSSON'S AXE SYSTEM FOR MODERNIZATION OF ITS TELEPHONE NETWORK

The Irish Department of Posts and Telegraphs has decided to embark on a £650 million programme to expand and progressively develop the country's telephone network using digital switching and transmission systems at all levels in the network. The decision is internationally significant in terms of the scale and speed of the planned transition.

The Department has chosen L. M. Ericsson's digital AXE switching system for an important part of this ambitious programme of expansion and modernization.

Through this decision, Ireland becomes the 23rd country in the world to select Ericsson's advanced AXE system.

L. M. Ericsson's subsidiary in Ireland, L.M. Ericsson Ltd., will manufacture AXE hardware at its factory at Athlone. The company will also establish a software design facility in Athlone. The new facilities are planned to come on stream early in 1981.

L. M. Ericsson has been a prime supplier of telephone switching equipment to Ireland since 1957 when the company installed its first crossbar telephone exchange in the country.

A Brief Review of Electrical Power Sources at Remote Coastal Navaids

M. B. KOMESAROFF, Dip.Eng., Grad.Dip.Mgt., F.R.M.I.T.

A brief review of current practices in the provision of electrical power supplies for minor, unattended navigational aids. Department of Transport field experiences are mentioned as are the Department's current development projects.

This paper was originally presented to the Diamond Jubilee conference of the Institution of Engineers, Australia, held in Perth during 1979. The Institution's approval to reproduce it here is gratefully acknowledged.

The Australian Department of Transport provides a system of navigational aids to ensure the safety and efficiency of coasting vessels. Apart from a small number of daymarks, all these navaids consume energy and most of them are a long way from mains electricity supplies and roads. The electrical power required for a coastal navaid varies from about 1 W (average) for a flashing light on a buoy to about 20 kW for a manned station whose electrical load might consist of various items of radio equipment as well as the lighthouse and the domestic load of two or three dwellings.

Although this paper is concerned only with sources of electrical power, it must be remembered that this is not the only form of energy used. For instance solar hot water units, stoves and heaters fired with distillate or LPG, and acetylene lights are all in common use at light stations. Mains electricity is always used where it is economically available but this source of supply is also excluded from detailed treatment in this paper.

The distribution of power supply systems operated by the Coastal Services Division of the Department of Transport is summarised in Table 1.

The normal requirement in marine navaids is for a high reliability coupled with low maintenance. This is not an unusual specification for a power supply, however the remoteness and expensive logistics of marine navaids means that the financial expenditure which can be justified is often greater than in other types of installation.

The unattended navaids which comprise the majority of installations have an unusual load characteristic in two aspects. This applies to electrically powered and acetylene powered equipments, but we will from now on only consider the electrical apparatus.

Firstly, the load is not connected during daylight hours. Depending on season and location, the load, ranging from a few watts to 1 kW, would be connected for between 10 to 14 hours in every 24.

	Mains-Diesel Standby	Mains-Battery Standby	Primary Diesel	Primary Cell	Acetylene	Wind Power	Total
Manned	16	—	26	—	—	—	42
Unmanned	22	9	4	96	125	1	299
Total	38	9	30	96	125	1	341

This table does not include radio aids operated by the Department for the use of coasting vessels.

Table 1 — Distribution of Visual Aids to Navigation Operated by the Australian Department of Transport

Power Source	Solar Cells	Wind Generator	Wave Activated Generators	Fuel Cells
Energy	solar	wind	wave	chemical
Capital Cost	high	medium	medium	high
Potential life in years	5-10	10-15	10-15	10
Output rating in watts	50	2000	100	50
Frequency of visits	moderate	low	low	low
Skill required	low	low	moderate	moderate
Advantages	no fuel no moving parts	no fuel	low maintenance no fuel	high conversion efficiency
Disadvantages	cost performance prediction energy storage cleaning	performance prediction energy storage	performance prediction energy storage	fuel transport expensive fuel need for peripheral equipment

Power Source	Primary Cells	Isotope Generators	Thermo Electric Generators	Thermo Mechanical Generators
Energy	chemical	isotopes	hydro-carbon	hydro-carbon
Capital Cost	low	high	medium	medium
Potential life in years	1-2	7-10	5-10	10-15
Output rating in watts	50	50	5-500	100
Frequency of visits	low	low	low	low
Skill required	low	low	low	moderate
Advantages	portable no moving parts	low maintenance predictable performance	low maintenance small installation no moving parts reliable	low maintenance
Disadvantages	low power density high cost environmental	high cost environmental	low efficiency fuel transport	low efficiency fuel transport

Power Source	Closed-cycle vapour turbine (CCVT)	Petrol Alternators	Propane Alternators	Diesel Alternators
Energy	hydro-carbon	petrol	L.P.G.	Dieselene
Capital Cost	medium	medium	high	medium
Potential life in years	5-10	3-5	3-5	8-20
Output rating in watts	100-2000	75-5000	75-5000	1000
Frequency of visits	low	very high	moderate	high
Skill required	moderate	high	high	high
Advantages	low maintenance	predictable performance low weight	predictable performance fuel handling and storage can be lightly loaded low weight	predictable performance low capital cost reliable
Disadvantages	low efficiency fuel transport	fuel transport maintenance fire and explosion hazard	maintenance fire hazard need for further developments	fuel transport maintenance

Table 2 — Commercially Available Power Sources

Secondly, when operating, the load is not necessarily constant and will vary from a load factor of 2% for a flashed light to 100% for a revolving light.

In the selection of a power supply system for use with an aid to navigation consideration is given to both technical and economic factors. Table 2 summarises the basic properties of some commercially available power sources which have been used in conjunction with marine navigational aids.

NATURAL ENERGY SYSTEMS

Solar Cells

The main interest in solar cells is due to the freely available energy from the sun.

Early solar cells were only about 1% efficient, however, the discovery of the silicon cell in 1954 has led to efficiencies as high as 14%.

The potential benefits of solar power have been of interest to marine navaids authorities world-wide. In the late 1950s the U.S. Coast Guard experimented with a solar-powered light for three years in southern California. A subsequent detailed theoretical study by the Coast Guard laboratory confirmed that because of economic considerations and wide variations in the availability of solar energy, solar power did not warrant further attention (O'Connell, 1970).

More recently the USCG has revised this policy and is using solar cells in operational field trials powering minor lights in both Alaska and Florida. The system used consists of a 4 watt solar panel with a blocking diode, a 12-volt 100 amp hour lead acid battery and a 15 volt zener diode as a voltage regulator. This system is then coupled to a flashed light comprising a 0.55 lamp operating on a 10% duty cycle. After nine months of operation, there had been no solar panel failure. However problems have been encountered with vandals who have either destroyed or stolen whole intallations (Ryba and Naus, 1976).

The results of evaluation by other lighthouse authorities (Richards, 1977, and Buzin, 1976) have not been as encouraging and indicate that —

- available output declines significantly with age and despite their semiconductor nature solar cells have a finite life of between five and eight years;
- despite advances in basic semiconductor technology the encapsulation of cells is a major factor contributing to poor reliability;
- the matching of solar cells to storage batteries is difficult. There is a requirement for a large capacity in the secondary battery to operate the light during winter months. The charging current in the battery is very low, C/500 to C/200 being typical. At the same time self discharge is low, about C/150[1].

Despite advances in technology the price of solar cells in Australia has declined only slightly in the last five years.

The Department of Transport has been conducting field trials of different solar panels at various locations around Melbourne. These trials have been fairly successful. However, it has been noted that some panels have performed satisfactorily but have discoloured with the result that available output has declined. This discolouration was the result of ultra violet sensitivity of the polycarbonate encapsulation and is an indication of its potential breakdown. Recent tests of cells which are laminated between layers of optical glass have not shown any signs of discolouration.

In 1979 the Department intends to install its first operational solar powered aid. Situated in Torres Strait the installation will consist of eight Philips BPX/47A panels feeding into a 12 volt, 1000 amp hour battery. The nightly load in this case will be a 1.35 amp lamp operating on a 25% duty cycle.

1. The letter C refers to the rated capacity of the battery and the figure in the denominator is the number of hours required to complete the full charge or discharge, the fraction being numerically equal to the charge or discharge current. Hence C/500 represents a current equivalent to 1/500 of the rated capacity so that if C = 50 Ah the current will be 50/500 = 0.1 A.

Wind Generators

Because of the abundance of wind at most navaid sites lighthouse authorities have been particularly active in exploiting this form of free energy.

In 1976 the Department commissioned a wind-powered system at Tasman Island, Tasmania. This installation comprises a Dunlite 2 kW wind generator feeding a 1500 amp hour battery bank. Twin 2 kW standby diesel alternators are incorporated and are designed to start up during prolonged wind lulls or when daily wind energy is insufficient to power the aid. The station load averages 550 watts during the hours of darkness (Clarkson and Komesaroff, 1975). Assuming 14 hours of darkness the monthly energy consumption is estimated at 240 kWh.

The minimum monthly average wind speed at Tasman Island is 21.7 km/h. With the Dunlite machine the minimum monthly energy output at Tasman Island is estimated at around 200 kWh (Komesaroff, 1978). Thus the wind generator supplies some 86% of the energy requirement.

In its two years of operation, apart from one incident involving propeller blade damage, the power supply has performed satisfactorily. Under normal conditions the diesel has been found to start every five or six days though periods of 10 days or more between starts are not uncommon.

Over the last five years the Service de Phares et Balises[2] has installed over 40 wind generators (Martin and Prunieras, 1975). These have generally been used to power minor aids but recently with the availability of larger sizes (e.g. 10 kW) the French authority has used wind generators to supply major (e.g. 500,000 cd and larger) lights. The French have also used wind generators to power small buoy systems. These are generally confined to protected waters such as harbour confines.

The Australian Department of Transport has purchased a 24 watt wind generator similar to the machines used by the French Service. This machine has been installed (October 1978) on an experimental basis in South Australia. A preliminary evaluation suggests that for navaid requirements the French machine has the following advantages:

- because of lower cut in and rated speeds it has a higher machine load factor (e.g. for the same size machines under identical conditions the French unit would generate about twice the power of other known units);
- the use of extruded symmetrical propellor blades improves dynamic balancing and blade reliability.
- the use of a permanent magnet generator and direct drive reduces internal machine losses.

The acceptance of wind generators particularly for larger loads (where major savings can be achieved) can be restricted due to availability of wind data. The Department of Transport is fortunate in this area in that at some 25 manned light stations the lightkeepers report the wind speed twice daily. These observations are taken at 0900

2. Service de Phares et Balises is responsible for the administration of navaids on the French coast.

and 1500 hours and provide a fair guide to diurnal variations. However there is a disadvantage with this data in that it is not continuous, i.e. it is based on two discrete samples. Thus the data prevents detailed analysis of short term variations. In marginal situations these variations are important and more precise data would be required.

The Department has attempted to gauge the available energy at various locations, by matching the wind data at the site to the characteristic of a particular wind generator (Komesaroff, 1978). The data manipulation for this assessment has been undertaken using a specially prepared computer programme. For each station and machine, computer output consists of:

- monthly summaries of
  - — available energy
  - — load factors
  - — average station wind speed;
- statistical summary of available energy;
- graphical presentation of available energy.

Some 13 stations have been analysed in this way and the results have highlighted three interesting facts.

The first is the poor suitability of northern sites for wind generation. Generally the better sites are located below latitude 35°S. This area coincides with the southern hemisphere anti-cyclone circulation zone. A unique combination of pressure differences in this area has the effect of channelling the weather patterns in an easterly direction. This lane of wind exists continually, its only seasonality being a summer-winter latitude change of a few degrees (Mullet, 1957).

Second, the seasonality of winds in the northern latitude makes these areas particularly unsuitable for wind power. Furthermore in some cases, e.g. north Queensland, the existence of cyclones is a threat to windmill reliability. In other cases, e.g. north-western Australia, the wind variation between seasons and overall average wind speed make reliable system design difficult.

Finally, for the two machines considered it was found that the relationship between load factor and average wind speed is linear over the range of 10 to 30 km/h. With 156 co-ordinates, conventional linear regression techniques gave co-efficients of determination of 0.98, i.e. less than 2% of variations are not accounted for by the regression equation. This relationship suggests that for a given machine the average wind speed can be accepted as a measure of load factor, i.e. energy output. This then simplifies estimates of wind power potential at other sites.

Wave Activated Generators

The operation of the wave activated power supply system is based on the principle of conversion of sea wave energy into electrical energy. Light buoys fitted with these units are provided with a long pipe through the buoy body. Wave motion affects the volume of air in this pipe and an electrical generator unit is arranged to utilize this air flow (Yogo, 1975).

The Japanese have been particularly active in developing wave activated generators and production units range up to 100 watts.

The application of wave activated generators by the Australian Department of Transport is likely to be restricted because —

- of the small number of buoys on our coastline;
- relatively high cost of wave activated generators compared to existing systems;
- lack of wave data with which to predict energy availability.

CHEMICAL SOURCES

Fuel Cells

The fuel cell consists of a number of cells in which hydro-carbon or hydrogen fuel is directly oxidised within an electrode system. Prompted by the combination of simple fuel handling with the efficiency of electric aids, a number of companies have put a great deal of development effort into fuel cells. However, it has been calculated that an aid consuming 60 watts for an average 14 hour day would require the annual provision of 200, 000 litres of hydrogen and 100,000 litres of oxygen in cylinders weighing over 2,000 kg (Graham, 1975). The oxygen is necessary because it does not seem to have been possible to use atmospheric oxygen. It is probably this fact which has limited the application of fuel cells to test installations. Indeed the U.S. Coast Guard have concluded that in the foreseeable future, fuel cells are unlikely to compete in cost and reliability with more conventional power sources (O'Connell, 1970).

Primary Cells

Primary cells consist of a cast, amalgamated zinc electrode and a porous carbon rod both immersed in a caustic potash solution. The top face of the carbon rod is exposed to the atmosphere permitting oxygen from the air to penetrate the carbon rod.

Here the oxygen serves as the positive pole and the zinc plates form the negative pole of the battery. The cell in other words utilizes oxygen from the air, the carbon rod serving primarily as the carrying medium. These cells may therefore be viewed as a zinc-oxygen electrode couple operating in a caustic electrolyte.

Normally cells up to 2,800 amp hour capacity are connected into banks of 12 volt to power minor lights (i.e. up to 2 amp) for up to 12 months.

Recently the Department's experience with primary cells has been disappointing, particularly in tropical areas where high temperatures and humidity have given rise to poor performance. Some years ago the U.S. Coast Guard experienced similar problems and after extensive investigation they attributed the problem to sulphation of the zinc plates due to atmospheric moisture. This investigation also showed that the shelf life of activated cells was superior to that of unactivated cells. As a result of this work the Coast Guard only issued pre-activated cells to tropical stations. More recently the Department of Transport has been using Australian assembled cells which because of their availability are installed well before the expiry of their shelf life.

With increasing community awareness on environmental issues the disposal of primary cells has become a major problem. In the United States federal legislation restricts disposal to designated areas in which the cells are buried in plastic bags to a minimum depth of one metre. Similar local ordinances exist in Australia. For this reason in Australia cells are returned for co-ordinated disposal.

Department policy has been to replace some of the existing 96 primary cell lights with natural energy systems such as wind generators and solar cells. Because of manpower and financial limitations, this policy will probably take some years to implement thus primary cells will still be used in significant quantities for some time to come.

Isotope Fuelled Units

Power supplies of this type usually use Strontium 90 as a heat source and are designed to have an unattended working life of five to 10 years.

Present installations are generally of a test nature and therefore of little direct interest to the Department at this time.

Isotope generators are an extremely expensive source of energy which could only be justified in locations with very high service costs. Since the high capital cost must be recovered by reduced running costs (i.e. maintenance visits), isotope generators put an additional premium on associated equipment, lights, radio beacons, storage batteries, etc.

Isotope generators installed some seven or eight years ago were designed for a five year service life but have generally exceeded this and current designs are based on a 10 year life expectancy (Graham, 1975).

The increasing awareness of environmental factors is another consideration that could restrict the future use of nuclear power supplies.

PROPANE POWERED GENERATORS

Thermo Electric Generators

The thermo electric generator is a heat engine which converts heat energy into electrical energy by maintaining a temperature difference across junctions of dissimilar materials.

The Department operates two thermo-electric generator (TEG) installations. In each case the load consists of a 50 watt radio beacon. The TEG is a 120 (peak) watt propane powered unit and feeds the load via a converter/limiter regulation unit.

Initially experience at these installations suggested that the maintenance claims advanced in favour of TEGs were questionable. The main concern was the burner orifice which required constant attention. Selective ageing of the thermocouples directly behind the burner was also encountered. However in later models these deficiencies have been corrected.

The TEG uses a heat sink to dissipate heat to the atmosphere on one side of the thermopile. Any variation in ambient temperature will alter the temperature differences across the pile and hence the output power level will change. For this reason TEGs are generally unsuitable for use in tropical climates where wide temperature variations are likely to occur.

The low efficiency ($< 5\%$) of TEGs necessitates large quantities of fuel for extended (i.e. 12 months) operation. Whilst the fuel is comparatively cheap, transport adds greatly to final running costs. This is particularly relevent where site access is limited to ship or helicopter.

Because of their low efficiency, use of TEGs by the Department of Transport is likely to be restricted to radio beacon installations where other conventional sources (e.g. diesel, solar cells, wind generators) are unacceptable.

Closed Cycle Vapour Turbines (CCVT)

The closed cycle vapour turbine is a hermetically sealed Rankine cycle electric generator consisting of a turbine coupled to an alternator. The turbine has only one moving part, the rotor.

As with TEGs the CCVT suffers from low efficiency necessitating large quantities of fuel. Additionally the capital cost of the machine is high.

Discussions by the author with one Australian user of CCVTs indicated that operational experiences are not encouraging. Problems encountered have included:

- faulty electronic circuitry;
- defective turbines;
- machines unable to regain full capacity after shut down.

The Department has no plans to evaluate these units.

Thermo Mechanical Generator (TMG)

The thermo mechanical generator was originally designed for use with nuclear isotopes by the Atomic Energy Establishment at Harwell, U.K. The rising price of isotopes and shortage of development funds forced the Establishment to terminate the project. AGA Pty. Ltd. of the U.K. has purchased the manufacturing rights to a modified (propane) version of the original design. To date AGA has only released a 25 watt unit though it intends to produce a 100 watt version.

The TMG is essentially a Stirling cycle heat engine. However unlike conventional engines it has no pistons, valves, cranks or bearings. Because it has only three moving parts which simply vibrate, without surface contact there is no frictional wear and no need for lubrication (AGA Ltd., n.d.).

Trinity House[3] has been evaluating an AGA produced TMG. It is anticipated that the results of this evaluation will be published in another 12 months.

ENGINE DRIVEN ALTERNATORS

Petrol Engines

At first glance, petrol and diesel driven alternators may appear to be competing for the higher loads. However petrol engines are not usually favoured because of the fire and explosion hazards associated with petrol. Furthermore their reliability, particularly when starting, is low in comparison with diesels.

From a Departmental point of view petrol engines are undesirable because of an existing commitment (fuel storage, parts, training, etc.) with a comparable range of diesels.

Petrol engines also have the disadvantage of:

- requiring more maintenance than diesels;
- electrical ignition.

Propane Powered I.C. Engines

In recent years there has been an increase in the use of internal combustion engines which run on LPG. A force behind this move has been the relative cost of LPG against dieselene and petrol. The difference in relative costs is due to the federal tax on conventional fuels. Being a federal authority the Department of Transport does not pay such taxes and little economy can be expected in fuel consumption.

3. Trinity House is the principal U.K. authority responsible for the administration of navaids on the English coast.

The advantages of propane engines are very real for unattended operation in isolated places or where servicing is difficult. Advantages include:

- simpler fuel transport and storage compared to dieselene and petrol;
- fuel burns cleaner thereby reducing maintenance on valves and piston rings;
- the engine can be operated efficiently and with no maintenance penalty at light loads.

Being basically similar in principle, the propane engine suffers from the same disadvantages as the petrol engine, i.e. reliability, maintenance, electrical ignition.

Whilst propane engines are being used in increasing numbers there has been little experience on extended operation as is likely to be encountered in a navaid system. Hence the application of propane engines to navaids would involve a costly development commitment for which only marginal benefits could be expected.

Because of :

- the limited application to the navaids network;
- the amount of development work required;
- the very real disadvantages (compared with diesel engines) which outweigh possible advantages.

present involvement with propane engines will probably be limited to monitoring general industry development and trends.

Diesel Engines

There can be little doubt that for larger loads (i.e. above 1 kW) diesel-alternators represent the most attractive power source. Two or more diesels can run alternatively and concurrently with the aid. If the operational set shuts down under a fault condition the other set will start up and assume the load.

A modification to this system incorporates a storage battery which is charged by the diesel alternator and in turn supplies the load. This modification has the advantage of:

- improving system reliability in the event of a diesel failing to start;
- serving as an electrical flywheel thereby reducing the need to start.

Many diesel alternator problems are associated with the start up. It is during this period that the prime mover experiences most wear and tear. Because most parts of the system, i.e. fuel pump, starter motor, batteries, etc. are called into operation at the one time during start up, reliability at this time is lower than normal. Thus the aim of a diesel-alternator system should be for a minimum of start ups. This in turn requires optimising with the increased fuel consumption arising from continuous running.

Maximum efficiency and reliability with diesel prime movers is obtained when they are run at full load. Because of the diurnal and fluctuating nature of a lighthouse load this is not always possible. For this reason a small dummy load is sometimes incorporated into the engine control unit. Taking the form of a radiator bar of 500 to 1,000 watt this load is connected during daylight hours. Often located in the lighthouse tower, the dissipated heat from the dummy load is used to maintain warm air circulation and control condensation in the tower.

Multiple primary generating installations associated with navaids are required to operate for extended periods without any attention. At these stations, and where near continuous running is required, special attention has to be paid to lubrication and cooling arrangements. Using a standard two machine system the maximum unattended period would be of the order of three to four months.

Since 1976 the Department has been conducting a series of field trials on continuously running diesel alternators (Crossing, 1978). The object of these trials has been to achieve —

- 8,000 hours operation between routine servicing, i.e. oil, filter and injector changes;
- 16,000 hours operation before requiring a major overhaul.

The tests have involved a standard Lister SR1 diesel engine and a Dunlite BIF10 brushless alternator rated at 7.5 kVA.

To reduce engine wear and tear and improve reliability the test engine was modified slightly. The most significant modification being to the lubricating system which was converted from a 'wet' to a 'dry' sump. In this system lubricating oil is piped to and from the engine to a (remote) tank of appropriate capacity. Usually, a dry sump arrangement requires two pumps — an oil supply and a scavenger pump (of larger capacity) to return the draining oil back to the tank. The Lister SR1 engine employs a piston type pump which is less sensitive to suction head than a gear type pump and it was considered feasible to place the remote tank below the engine and have the oil drain back to the remote tank by gravity.

The remote tank was constructed with a capacity of 112 litres. This gives the same proportion of oil capacity per hour between oil changes as with the standard engine, with the additional allowances for normal oil consumption.

After 3,000 hours of operation the engine was shut down and dismantled for visual inspection to determine the extent of wear. Generally speaking the engine was in good condition and the internal examination revealed the following (Crossing, 1978):

- No evidence of oil sludge or other deposits within the crankcase or valve gear area.
- Carbon deposits on the cylinder head and piston were very light and powdery. The piston skirt below the ring belt was clean, showing little sign of blow-by.
- The injector appeared to be in reasonable condition. There was a uniform layer of hard carbon around the nose.
- The only visible sign of wear was the area on the camshaft extension which had been in contact with the oil seal. It was difficult to accurately determine the extent of wear, but it was of the order of 0.05 mm. The wear had not lessened the effectiveness of the oil seal.
- The hone markings on the cylinder were still clearly visible. However, around mid stroke, the markings on the side thrust zones were about half the depth of the markings in other areas.
- The inlet and exhaust valves were lifted off their seats for a visual inspection. Both valve seats and cylinder head seats showed arcs over which considerable pitting had occurred. In the case of the inlet valve this extended for about 160°. For the exhaust valve, the arc was somewhat less.

These observations suggest that the objectives of the exercise can be achieved. The diesel is presently being returned to service with the intention that it run a further 8,000 hours before being touched.

CONCLUSION

The author has attempted a brief review of the power supply systems used by various lighthouse authorities and by the Australian Department of Transport in particular. It is suggested that some of the systems reviewed are still too exotic or costly for immediate and widespread application. Other systems such as solar cells and wind generators are likely to find increased use in the future. At the same time more traditional and proven sources including diesel alternators and primary cells are likely to find continued use.

ACKNOWLEDGEMENTS

The author is an engineer with the Coastal Services Division of the Australian Department of Transport. This paper includes opinions which are strictly his own and do not necessarily represent the policies of the Department. The author would like to thank the Department for permitting him to publish the paper.

REFERENCES

Aga Navigation Aids Ltd. (n.d.): 'Electric Power From Propane'. Bulletin No. 6/75.

Buzin, P. (1976): 'Electric Supply with Photocells'. IALA Bulletin, No. 4, pp. 11-17.

Clarkson, B. C. and Komesaroff, M. B. (1975): 'Wind Driven Generator Power Supply System and Light to Replace a Manned Lighthouse Facility at Tasman Island, Tasmania'. IALA Conference, Ottawa, Paper 4.5.1.

Crossing, A. E. (1978): Interim report on the operation of a diesel alternator modified for continuous running. Department of Transport, Planning and Development Report PD 1006.

Graham, G. W. (1975): 'Electrical Power Supplies for Navigational Aids'. IALA Conference, Ottawa, Paper 4.9.4. 6.

Komesaroff, M. B. (1978): 'Wind Power Potential at Selected Navaid Sites'. Department of Transport, Planning and Development, Report No. 21.

Martin, M. and Prunieras, J. (1975): 'A Summary of Experience with Wind Power Units in the French Lighthouse Service'. IALA Conference, Ottawa, Paper 4.5.3.

Mullet, L. F. (1957): 'Survey for Wind Power in Australia'. Journal I.E. Aust, Vol. 29, No. 3, March, pp. 69-73.

O'Connell, J. M. (1970): 'Power Supplies for Minor Aids to Navigation'. IALA Conference, Stockholm, Paper 4.6.3.

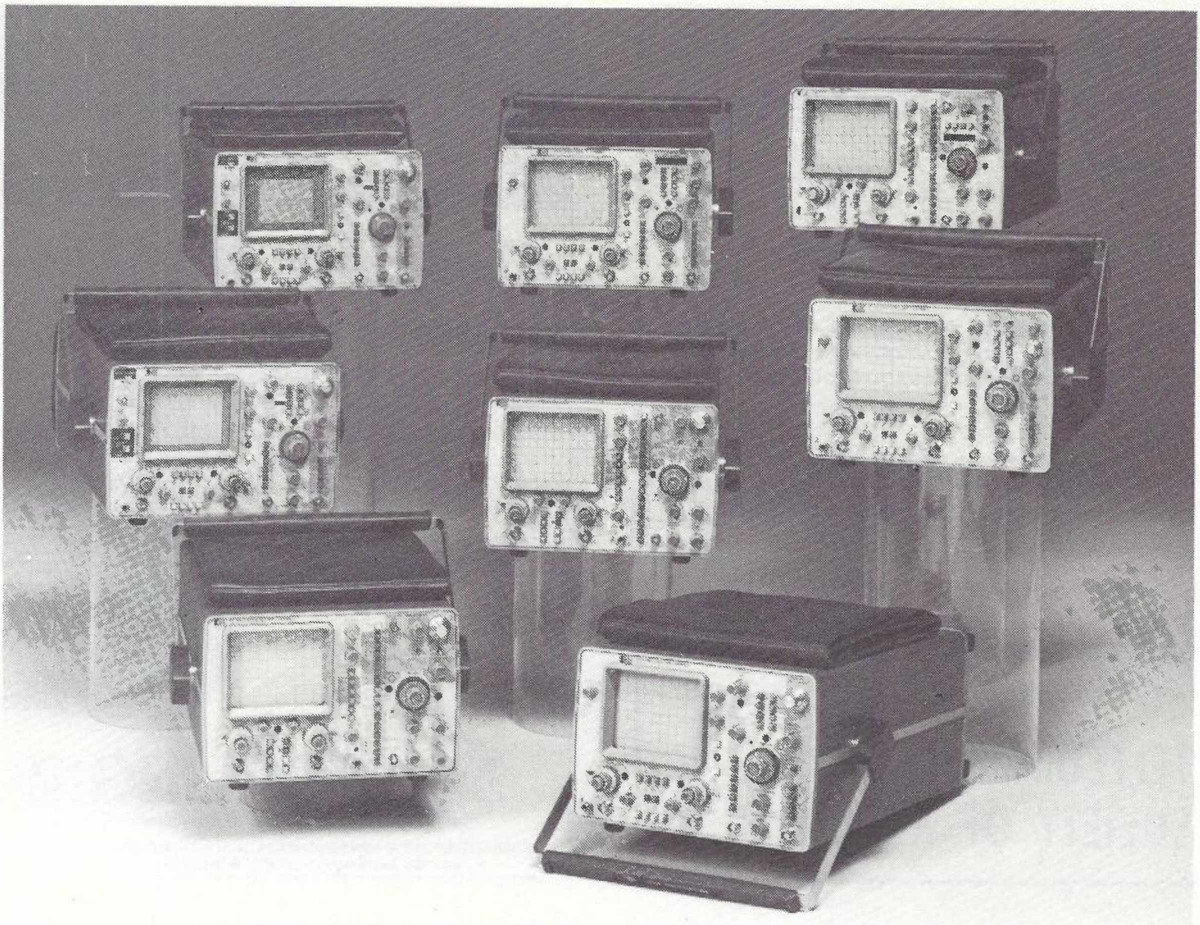
Richards, E. R. (1971): 'The Use of Solar Cells in the Lighthouse Service'. IALA Bulletin No. 4, pp. 25-31.

Ryba, J. and Naus, D. (1976): 'Laboratory Evaluation of Solar Power Units for Marine Aids to Navigation'. Department of Transportation, U.S. Coast Guard, Report No. CG-D-106-76.

Yogo, I. (1970): 'Wave Activated Generator Buoy'. IALA Conference, Stockholm, Paper 4.6.4.

MICHAEL KOMESAROFF graduated in 1968 with a Diploma of Electrical Engineering from the Royal Melbourne Institute of Technology. This was followed by a Fellowship Diploma in 1969 and a Graduate Diploma of Management in 1972. He is currently completing the final stage of a Masters degree in Administration at Monash University.

He joined the Bureau of Meteorology as a Technical Assistant in 1966. On gaining his engineering qualifications he was promoted to the Department of Civil Aviation. In 1970 he joined the Department of Shipping and Transport where he was involved in the planning and development of marine navigational aids. In 1976 he was promoted to Senior Engineer. In 1979 he was awarded a joint Confederation of British Industry Scholarship and Commonwealth Public Service Board Financial Assistance Award which permitted him to visit the United Kingdom to study aspects of marine nav aids.



Here's how HP Scopes solve the three most common scope measurement problems

Hewlett-Packard's 1700 Series oscilloscopes are designed to solve the most common measurement problems faced by scope users.

We've overcome the first big measurement problem, triggering, with a custom ECL triggering circuit. This proven circuit is even independent of vertical position controls, which means you can reposition the traces without having to re-establish trigger synchronization. It offers more reliable triggering than conventional tunnel diodes, which can drift due to temperature and aging.

The problem of dim traces is solved by our 1741A and 1744A variable persistence storage scopes. Variable persistence integrates repetitive signals for easy viewing. Practically any signal can be viewed as a sharp, bright trace regardless of repetition rate or speed.

The third problem — measurement of extremely fast pulses — is solved by the fast writing speeds of HP's storage scopes; 200 cm/μsec for the 1741A, and 1800 cm/μsec for the 1744A. Since the full writing speed is available in all three operating modes — variable persistence, auto-erase and auto-store — you have the freedom to pick the operating mode that matches your measurements.

For complete information on HP's 1700 Series Scopes and a copy of the Hewlett-Packard Oscilloscope Selection Guide, contact your local Hewlett-Packard sales office.

HEWLETT PACKARD

Adelaide 272 5911/Auckland 687 1591/Brisbane 229 1544/Canberra 80 4244
Melbourne 89 6351/Perth 386 5455/Sydney 449 6566/Wellington 87 7199

089/16 AUST

The Telecommunications Journal of Australia

ABSTRACTS: Vol. 30, No. 2.

CONROY, D. and DAVIS, J.: "Exchange Traffic Simulator"; Telecom Journal of Aust., Vol. 30, No. 2, 1980, page 141.

A new item of telephone exchange test equipment, the Exchange Traffic Simulator, is discussed. The Traffic Simulator generates up to 64 erlangs of simulated telephone traffic and can be used to test telephone exchanges both before and after cutover. The article details the hardware and software aspects of the equipment, how the machine is operated and its use with Statistical Acceptance testing tables.

DUC, N. Q. et al: "A Performance Monitoring System for Data Transmission Circuits"; Telecom Journal of Aust., Vol. 30, No. 2, 1980, page 110.

As part of an investigation into the performance of data links which may be used in the proposed Telecom Australia Digital Data Network (DDN), tests are being conducted on selected intercapital wideband data loops. These are performed with the aid of a fully-automatic microprocessor-controlled data test set developed by Telecom Australia Research Laboratories. The performance is based on a concept known as "error-free second", a transmission time interval of one second over which no data bit error is detected. This paper considers the concept of error-free second (EFS) and describes the functions and capabilities of a test set developed around this performance parameter.

FLATAU, G.: "The International Electrotechnical Commission Quality Assessment System for Electronic Components"; Telecom Journal of Aust., Vol. 30, No. 2, 1980, page 118.

The International Electrotechnical Commission has set up a Quality Assessment System for electronic components, which aims to standardise the quality assurance procedures, as well as the performance specifications, for a wide range of components. Australia intends to fully participate in this System, and this paper describes the history, content and scope of this scheme, and the expected benefits to its participants.

KOMESAROFF, M. B.: "A Brief Review of Electrical Power Sources at Remote Coastal Navalds"; Telecom Journal of Aust., Vol. 30, No. 2, 1980, page 146.

A brief review of current practices in the provision of electrical power supplies for minor, unattended navigation aids. Department of Transport field experiences are mentioned as are the Department's current development projects.

MENCEL, A. J.: "Alice Springs — Tennant Creek: A New Approach to Radio Relay Systems"; Telecom Journal of Aust., Vol. 30, No. 2, 1980, page 100.

The need to extend the broadband communciation network to the centre of Australia provided Telecom Australia engineers with the challenge to design a terrestrial radio relay system which would be specifically suited for installation and operation in remote areas. By making use of the recent development of low power consumption equipment and the availability of photovoltaic solar cells to power such equipment, and by careful attention to design, a system was developed which shows considerable savings in capital and maintenance costs when compared with earlier installations.

This article discusses the concepts involved in the design of radio communication systems for remote areas and describes the system installed between Alice Springs and Tennant Creek in the Northern Territory of Australia.

MITCHELL, G. G.: "Plastics Encapsulation of Integrated Circuits"; Telecom Journal of Aust., Vol. 30, No. 2, 1980, page 131.

A factor which is sometimes overlooked when choosing an integrated circuit is the influence the packaging may have on reliability. This article aims to provide background information about the various aspects of plastics packaging of integrated circuits. The structure of the common plastics encapsulated dual-in-line packaged IC is outlined and its strengths and weaknesses discussed as they influence reliability. The potential for further reliability improvements in plastics packaging is described. Although some problems remain, penetration of high quality plastics encapsulated ICs into telecommunications applications will increase.

PESCOD, D. and PRUDHOE, R. K.: "Application of CSIRO Plate Heat Exchangers for Low Energy Cooling of Telecom Buildings"; Telecom Journal of Aust., Vol. 30, No. 2, page 83.

Modern telecommunications equipment must be cooled to remove waste heat and maintain an acceptable temperature and humidity. Plate heat exchangers developed by CSIRO Division of Mechanical Engineering for use as coolers can provide the necessary cooling for both equipment and personnel with low energy usage and low capital outlay.

Existing air conditioning systems have relatively high operating costs, because of high energy usage and maintenance requirements. The new system, known as the PHE system, is now in commercial production. It uses water as a refrigerant and saves substantial amounts of energy by utilising the latent heat of vaporisation of water, and exhausting the vapour to the outside atmosphere, whereas other systems must recycle the refrigerant vapour by compression or absorption. Such systems may use up to thirteen times the energy requirements of the PHE system. With the PHE system, all circulated air is fresh and the mositure content of the air is not changed during the cooling process. In cooler weather, the heat exchanger recovers much of the heat from the exhaust air when combined with a building heating system.

Laboratory tests at CSIRO on a prototype have confirmed the performance as predicted from earlier experimental units. The first commercial installations are operating in the Caulfield and Balranald Telephone Exchanges. Large scale application of plate heat exchangers for low energy cooling of buildings could become a major contribution to national energy conservation.

REYNOLDS, R. A. J.: "Near-End Crosstalk in the Broadband Network"; Telecom Journal of Aust., Vol. 30, No. 2, 1980, page 124.

The broadband network has grown from its beginnings more than 20 years ago and it now provides a very large proportion of Australia's telephone trunks and other communications services. Some limitations in the performance of the network are sufficiently understood as they apply to the usual types of services. With the advent of new uses for existing equipment, such as data and time-sharing of channels, one limitation in performance unexpectedly has proved to be a problem. Whilst the mechanism of near-end crosstalk is not a mystery in such a network, the crosstalk magnitude, and the relation to frequency are not well understood. Calculations and measurements based on terms which are crosstalk averages have been used previously and are now proving inadequate in the measurement and prediction of crosstalk in the network where some new types of services are concerned.

ROWELL, D. M.: "Social Needs and Technology — A Partnership for Future Telecommunications Developments in Australia"; Vol. 30, No. 2, 1980, page 92.

A description of the business of Telecom, some of the social impacts of its technology, and ways in which Telecom is trying to come to grips with them. The paper is particularly orientated towards **Telecom 2000** and related endeavours.

THE TELECOMMUNICATION JOURNAL
OF AUSTRALIA

Volume 30, No. 2 1980

ISN 0040-2486

CONTENTS

COVER
INSTALLED PLATE
HEAT EXCHANGER

Printed by Standard Newspapers Ltd., 10 Park Rd., Cheltenham.

The Telecommunication Society of Australia

Subscription and Membership Rates, 1980

TELECOMMUNICATION JOURNAL OF AUSTRALIA

(Australia) Membership rate — See Note 3	$3.50
(Australia) Non-member rate	$6.00
Overseas subscription rate (post free by surface mail) — See Note 2	$9.00

Single copies (including back issues)

(Australia) Members	$2.00
(Australia) Non-members	$2.50
Overseas subscription rate	$3.50

AUSTRALIAN TELECOMMUNICATION RESEARCH

(Australia) Members — See Note 3	$4.50
Non-members	$9.00
Overseas subscription rate (post free by surface mail) — See Note 2	$12.00

Single copies (including back issues)

(Australia) Members	$3.00
(Australia) Non-members	$6.00
Overseas subscription rate — See Note 2	$7.00

AUSTRALIAN TELECOMMUNICATIONS MONOGRAPH No. 4

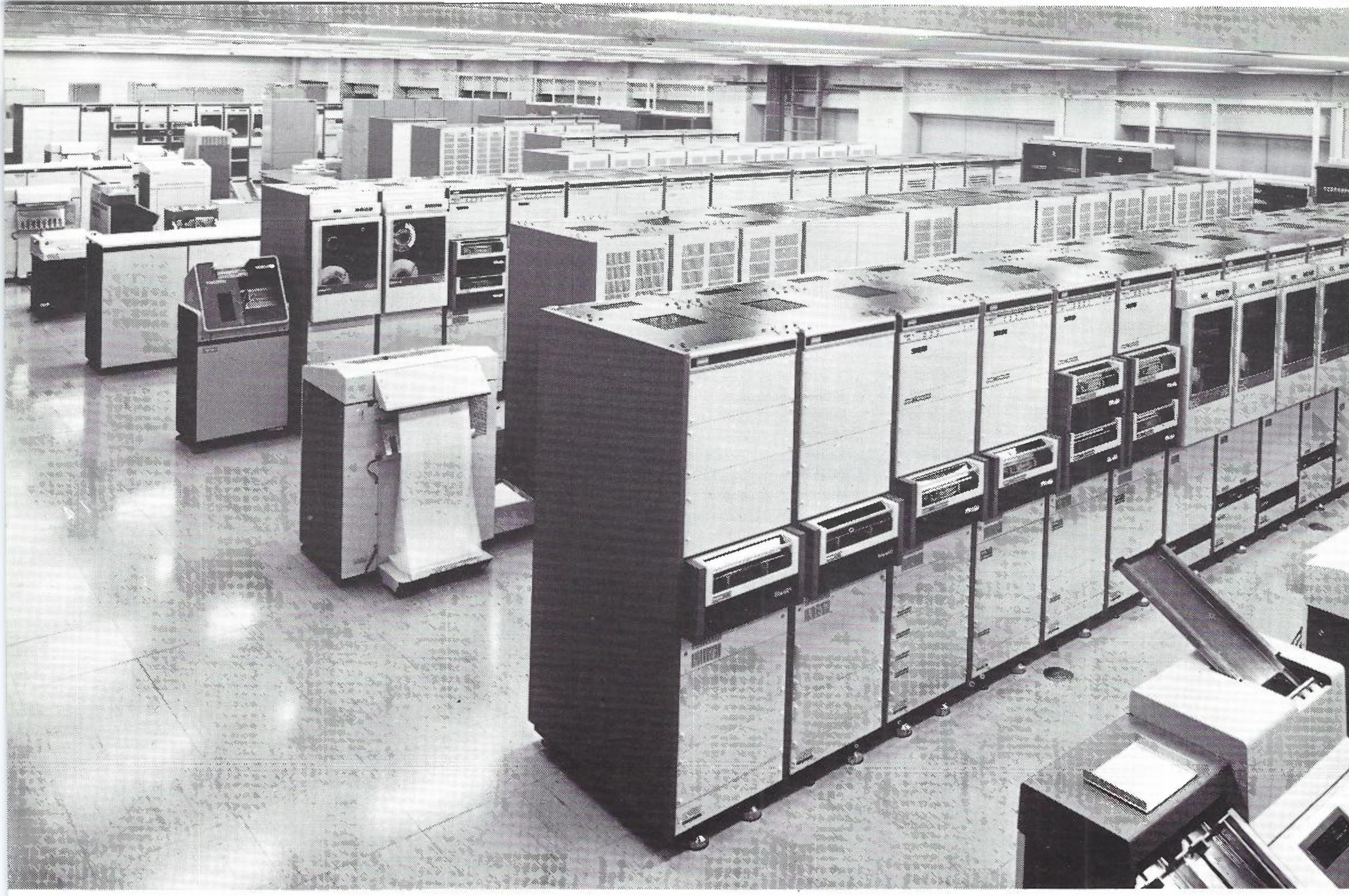
Automatic Telephony in the Australian Post Office

Members (Australia)	$2.00
Non-members (Australia and Overseas) — See Note 2	$4.00

Notes: (1) Subscriptions addressed to an office (e.g. Librarian, General Manager, etc.) cannot be accepted at membership rate.

(2) Overseas readers: Please note that the rates must be paid in Australian currency. Special rates for air mail postage are available on application.

(3) Telecom Australia employees should arrange to have their membership costs deducted from salary. Your local agent or State Secretary will advise procedures.



FUJITSU PACKET SWITCHING SYSTEM

A Giant Step For International Data Communications

Fujitsu's packet switching system represents today's most advanced integration of computer and telecommunication technologies. As the fulcrum for an international data communication network, it features versatility, speed and reliability. The first system has already been installed by KDD (Kokusai Denshin Denwa Co., Ltd.) for Japan's ultramodern international data communication service. Here are some of the features that make it the world's leading packet switching system.

- State-of-the-art technology including Looped Optical Fiber BUS and Maintenance-Free Software
- High Reliability
- Excellent Cost Performance

Developing this advanced system was the perfect challenge for Fujitsu. As a world leader in both the computer and telecommunication fields, we had the experience and technological capability to fuse them into a perfect blend with which to create our state-of-the-art system. We also have a wide knowledge of Australia's computerisation efforts. FACOM Australia Ltd. (FAL), Fujitsu's computer company in Australia, has been active in all areas of your country's computer growth and now FAL offers the next step into international data communications. Contact us today for a full presentation.

FACOM AUSTRALIA LTD
41 McLaren Street, North Sydney, N.S.W. 2060
Telephone: 922-1822 Telex: 71 25233

Manufactured by Fujitsu Limited, Japan

FACOM