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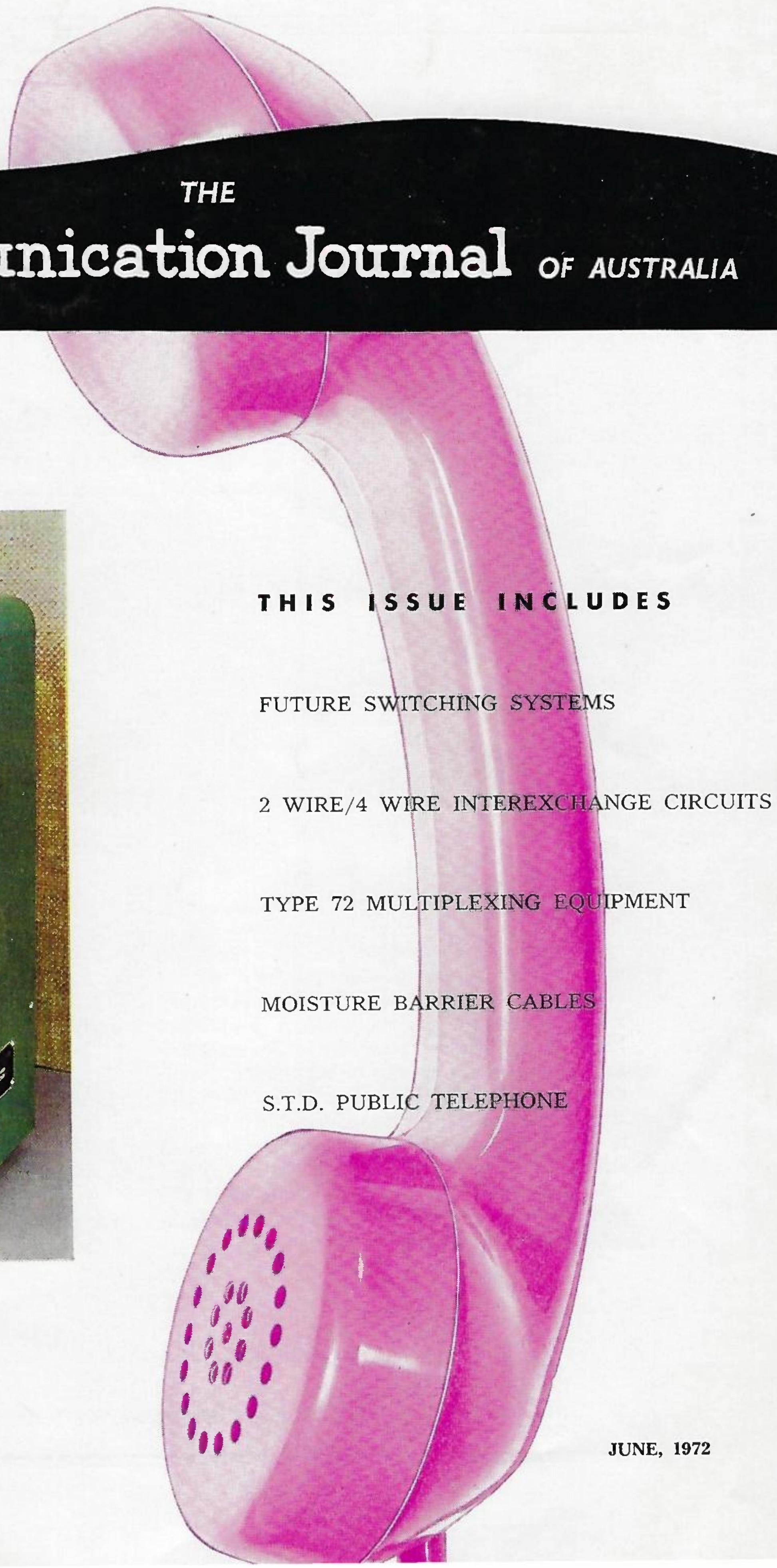

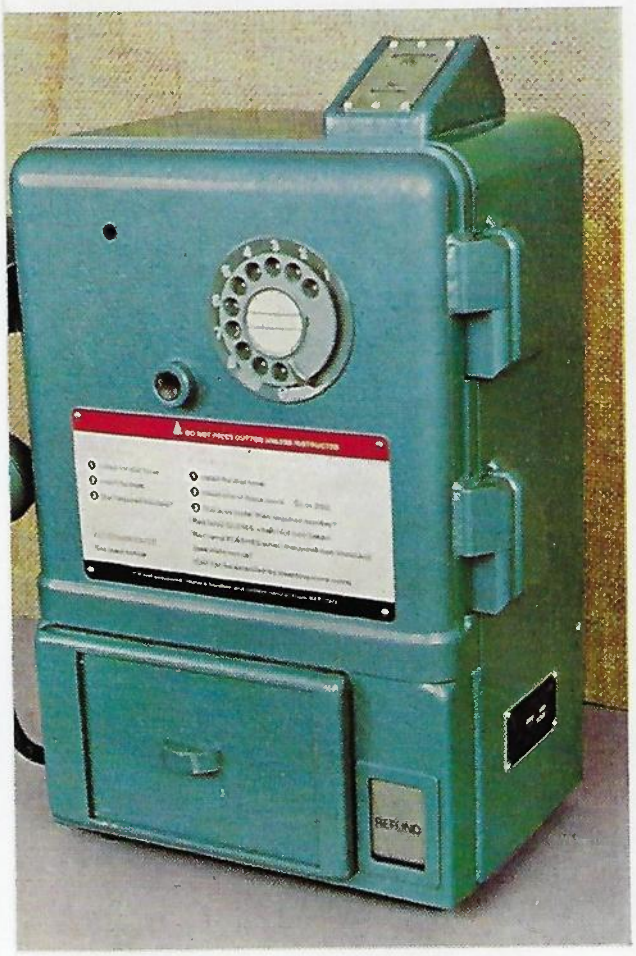

THIS ISSUE INCLUDES

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FUTURE TELEPHONE SWITCHING SYSTEMS

*S. DOSSING, M.Sc.E.E.(Hons.), M.E.E., F.I.E. Aust.**

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INTRODUCTION

Telephone communications are discussed in this paper although reference is occasionally made to other communications services, such as telegraph and TV, and in particular the general problems encountered in switching any subscriber to any other subscriber, perhaps in an entirely different part of the world.

The telephone systems of the future are placed in perspective by examining the past and present systems in relation to the needs of the community and the technological capabilities of the time.

HISTORY OF SWITCHING SYSTEMS

The first switching systems in general use were simple manual switchboards. On the simplest of such boards each subscriber's line had one appearance and could be connected via a 'cord circuit' under the control of the operator to any other subscriber associated with the same board. Such a switching system served the need of the community for some time but it was soon found desirable to enable subscribers associated with one switchboard to talk to subscribers on another and 'links' (junctions) were introduced between switchboards, making it possible for a subscriber on one to be connected, via two (or even more) operators to a subscriber on another switchboard.

This type of operation expanded and orderly switching rules were introduced to enable the expansion to take place in a logical and economical manner, in particular when long-distance communication became practicable on a larger scale by the introduction of electronic carrier telephone systems and radio in the field of transmission. The relatively high cost of manual operation, the limited size of board and traffic possible and the slowness associated with the setting-up of a multilink connection together with man's natural inclination to automate led to the invention of automatic switching systems, in which the subscriber himself could control at least part of the switching operations, although manual switching was, and still is, used comprehensively for long distance connections. The first automatic exchange in Australia was opened in Geelong (Victoria) in 1912 (Ref. 1).

At the present time 75% of the subscribers enjoy automatic service and with the introduction over the last few years of ELSA (extended local service area), which expanded the areas around the capital cities within which calls may be made at the same charge as a call within the one exchange, and s.t.d. (subscriber trunk dialling), a reasonably sophisticated and modern telephone system may be claimed to exist in Australia.

SWITCHING SYSTEM REQUIREMENTS

Cost

The subscribers and the Department are naturally cost conscious and any improvements in the new system must be weighed against the possible costs involved.

Costs are dependent on a number of complex factors, such as:

(i) The form of the telephone network as a whole (see Ref. 2).
(ii) Interrelation of the telephone network with the other communications services, such as: telegraph, telex data, 'private line networks' (that is, lines and perhaps associated switching facilities leased to 'private' users), radio and TV transmission and others. For economic reasons, there is a trend towards integrating these networks with one another.
(iii) The degree of sophistication of services offered to the users of the network (this topic is discussed in more detail in a later section).
(iv) The degree of quality provided; a 'perfect' telephone connection may naturally be more expensive to provide than one with a number of tolerable imperfections.

Currently the Department is investing about $30M. per annum on switching equipment. Consequently, new developments and trends are under continual surveillance and assessed with the objective of keeping expenditure down, whilst at the same time attempting to provide a more modern and versatile service.

Services Offered

Present System: Briefly speaking, the basic function of a telephone network is to allow interconnection of subscribers. The area within which this can be done in the automatic network is increasing, namely, the introduction of subscriber trunk dialling (s.t.d.) and international subscriber dialling.

There are however many other important services required by the public and which are catered for to a reasonable extent by the present telephone system. Some of these are:

(i) The facility for the installation at a customer's premises of a small 'local exchange' (p.a.b.x.), enabling calls between p.a.b.x. extensions to be made without the use of the public network and enabling various services to be rendered by the p.a.b.x. operator.
(ii) The facility to make local and trunk calls from coin-operated public telephones.
(iii) Various secretarial-type interception and transfer arrangements in smaller offices.
(iv) The facility to make calls to vehicles (mobile radio) and ships at sea.
(v) The facility to make special emergency calls (that is, police, fire), enquiry calls (that is, telephone numbers, trunk call rates) and recorded information services (that is, weather, sports, dial-a-prayer).
(vi) A variety of other services, such as: fixed time trunk calls, particular person trunk calls and credit card calls.

Future System: The variety of the services offered at present meets the requirements demanded by the majority of subscribers but there is an increasing demand, mainly from business subscribers, for a wider range of facilities. Some of these services can be provided on modern systems now being developed but not necessarily at an agreeable cost. Some of the facilities which are technically possible are:

Conference Facility: By dialling a 'conference' code and subsequently the numbers of, say, up to ten different subscribers, a telephone-conference on a nationwide and perhaps on an international basis can be set up.

Subscriber Controlled Transfer of Incoming Call: After dialling special 'transfer' codes followed by the number of the subscriber to which an incoming call is to be transferred, subsequent incoming calls will be transferred to that subscriber.

A number of possible different transfer arrangements can be foreseen, such as:

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(a) Immediate transfer, where the call is transferred to the pre-arranged number without the normal line being called at all.
(b) Dual calling transfer, where the normal and the pre-arranged number are called simultaneously.
(c) Delayed transfer, where the pre-arranged number is not called unless the normal line is not answered within a pre-determined time.
(d) Busy line transfer where the call is transferred to the pre-arranged number, if the normal line is busy.

Centralised P.A.B.X. Arrangements: In many cases a group of subscribers have common interests (for instance employees in a single firm) but they may work in widely separated premises. Under these circumstances it is feasible to integrate the p.a.b.x. switching facilities with the public telephone exchange whilst the operating consoles are installed in one of the premises.

The main advantage of this arrangement would be improved transmission performance for connections involving the public network, if some type of 'crankback' operation is introduced, but lower costs would possibly also be obtained.

Abbreviated Dialling: It is feasible to make special arrangements, enabling subscribers to use abbreviated dialling codes when calling frequently required numbers.

One possible way of doing this, is to equip the telephone with a push-button; depressing the button signifies that the exchange is to prepare itself to receive an abbreviated code, for instance a two-digit code which may represent any one of up to 100 different normal numbers.

Direct Call or Hot Line Service: As an extension of the above concept it is possible to arrange that upon lifting the receiver you are automatically connected via the public telephone network to a pre-determined number anywhere else in the network.

Ready Tracing of Malicious Calls: A speeding up relative to the present fairly slow and cumbersome methods could help to stamp out this nuisance.

Enquiry and Transfer: During an incoming or outgoing call the subscriber may make an enquiry call to another subscriber and consequently arrange to transfer the call to this other subscriber.

Call Back: If a number which is busy has been dialled, a 'call back' code may be dialled followed by the replacement of the handset. When the called number becomes free the exchange will establish the call.

Wake-up Service: A wake-up call to a specific subscriber can be arranged by dialling a 'wake-up service' code followed by the time of the day or night at which the wake-up call is desired.

Reverse Charges: Business houses may wish to offer to pay for the calls made to them. This would mean that the charge for the call, normally debited to the calling subscriber, would be 'reversed' and debited to the called subscriber.

Private Networks: Large business-undertakings with a considerable amount of traffic may wish a private network. This network could, as far as equipment is concerned, be integrated with the public network in such a manner that from the customers' point of view it would be indistinguishable from a genuine private network. The arrangement would be similar to a centralised p.a.b.x. but could be on a nationwide or an international basis rather than on a local basis. These networks could also be used for data transmission purposes.

Barring of Incoming Calls: It is feasible to bar a telephone, so that it will not accept incoming calls.

New Telephones: Telephone switching systems of the future may be required to work with telephones of new types. Three possible changes seen are:
(a) the replacement of the bell with a tone-calling device;
(b) the replacement of the present 10 i.p.s. (impulse per second) dial with a faster dial, say, 20 i.p.s.;
(c) the replacement of the dial with an array of pushbuttons, which are operated in a similar manner to the keys on a typewriter or cash register.

Data Transmission: Using the push-button telephone referred to above, it is possible to arrange for data transmission, using the pushbuttons to send the appropriate data codes. This type of data transmission could be useful, for instance, for commercial travellers contacting their head offices and for the housewife ordering deliveries from a supermarket.

Numerous other applications of a similar nature can be envisaged.

'Proper' data transmission at higher speeds, say, 600, 1200 and 2400 bits per second, is a growing requirement and it would obviously assist its penetration if the facilities for such data transmission could be integrated with the telephone network rather than establishing a completely separate new network for data subscribers only. Such an integration appears quite feasible with new telephone switching systems now being designed and studies in this direction are proceeding.

Meter Registration at a Subscriber's Premises: With a meter at his premises, operating in step with the meter at the exchange, the subscriber can at any time check on the number of meter-pulses chargeable to him. By noting the increment during a (long distance) call he can ascertain the cost of the call.

The facilities listed above would increase the range of services available to the subscriber and the Department is seeking attractive, low-cost solutions to the technical and administrative problems involved in their provision. There are however other problems to be faced in efforts to provide an economical service. Some of these are:

Larger Exchanges are required: To cope with the increasing number of subscribers and the increasing number of calls from each subscriber, the largest future exchanges are most likely to be about one order of magnitude bigger than present exchanges. Most types of present automatic large local exchanges have a capacity of approximately 10,000 lines.

Network Management: Manual operators have been able to supervise the performance of the network and have been able to initiate corrective action in case of minor and major troubles. With the disappearance (relatively speaking) of the operator, they must be replaced by automatic supervisors and the telephone system must be organised to take automatic corrective action. This feature is known as network management and typical actions may be:

Verbal Announcement: Perhaps these can be synthesised from words on a number of recorded tapes and relayed to subscribers, informing them, for instance, that calls to various exchanges or areas are not possible for the time being due to a major breakdown on a particular route.

Automatic Rerouting: In case of outage of a number of Melbourne-Sydney circuits, for example, part or all of the traffic could be rerouted via Canberra, Brisbane or Adelaide. In the non-busy hours, there might be enough unused circuits to enable this to be done without the subscribers detecting any abnormal delays or behaviour.

Automatic 'Busying' of Circuits: If a circuit or group of circuits becomes faulty, it is automatically busied and taken out of service. Calls are automatically rerouted over other suitable indirect routes. Automatic busying and rerouting is a feature of some present day systems.

Computerisation of Charges: The switching system should make the charging information available in such a form that it is suitable for direct input to a computer which in turn bills the customer.

Information and Enquiry Services: With the spread of s.t.d. a greater percentage of calls will be dialled by subscribers, and there is consequently an increasing demand for information and enquiry services (such as, number information, charge information and information concerning how to make proper use of the system). The trend is for such information services to be concentrated at regional centres.

Traffic Measurements: With the declining use of telephonists, fewer trunk dockets will be available for the determination of traffic quantities and growth of traffic. New automatic switching systems must be capable of yielding this information automatically.

FORM OF FUTURE TELEPHONE EXCHANGES

The telephonist has provided many of the services listed above. What made this possible from a technological point of view was that the 'intelligence' in the exchange was concentrated in one machine (the operator, or, in a more functional term, the processor), which controlled a fairly simple switching matrix (a cord type of switchboard). In the automatic system, which followed, it was too expensive (and technologically impracticable) to match the human intelligence and, as a result, we came to have an automatic system, which could cope with little more than bare essential tasks.

Most of the earliest automatic systems in common use were of the step-by-step type. In the step-by-step system each train of dial impulses is received and analysed by the control circuitry associated with a particular switch. The information contained in the train of dial-impulses is then used to set the switch connecting the calling subscriber through to the next switch. If the dial is 'spun' six times, each of the six trains sets six different switches, the control circuitry of each switch receiving, analysing and responding to one of the trains of impulses. Due to the vast number of switches there is a distinct upper economic limit to the amount of intelligence which can be associated with each switch.

In the common control switching systems, such as the present standard crossbar system, most of the intelligence (which used to be associated with each switch) is separated from the switches and grouped in common equipment. In the crossbar system, the common equipment functions are carried out by assemblies of electromechanical relays, known as registers and markers. This common equipment receives the incoming signals, translates them, selects the optimum routing and then sets up the call. Common control systems of the crossbar type offer facilities for alternate routing that are not available with the step-by-step system.

Under the alternate routing scheme, the exchange can route the call directly to a distant exchange if a direct route is provided. If a direct route is not provided or if all lines of the direct route are busy it can route the call via one or more indirect alternate routes involving transit-switching at one or more tandem exchanges. This facility is not obvious to the subscribers but they do nevertheless benefit in terms of lower cost than would otherwise be the case.

The 'next generation' switching systems, now in an advanced phase of development, make more pronounced use of common control than present so-called common control systems. This has been made possible by the advent of inexpensive and reliable electronic logic circuitry and memory systems. Briefly, most of these systems employ reed-relays or other mechanical form of contact for switching the call through the exchange, whilst virtually all intelligence, control and supervision is centralised in an electronic central control unit. This unit is often referred to as a 'processor'.

To obtain adequate reliability the processor is often provided in a replicated form, each unit of which is capable of performing all tasks without any assistance from the other. For the sake of completeness it must be mentioned that other arrangements are possible and perhaps even more attractive and that several processors may be necessary to carry out the multitude of tasks in a very large exchange.

The processor must be programmed to carry out the work expected from it. The simplest, but not necessarily the most attractive, solution is to wire the program into the processor. However, for flexibility reasons there is an increasing preference for computer-like processors operating under the control of software programs.

The speed at which the logical processes are carried out in electronic processors is inherently 1,000 to 10,000 times faster than that achieved by electromechanical common control equipment. Therefore, assuming the volume of control functions to be carried out is adequate to load the control equipment fully, we would appear to be able to reduce considerably the amount of control equipment and the total required switching equipment cost.

The savings are however to some extent offset by the necessity to provide extra equipment for the following reasons:

(a) Equipment must be provided to buffer the very fast processor to the speed of the much slower switching matrix and the even slower input from the dials.

(b) Likewise, power-buffering equipment must be provided to interface the processor to the switching matrix.

(c) Last, and probably most important, since the control equipment is so highly centralised, command, scanning and supervisory channels between the processor and the switching equipment proper must be provided.

(d) The need, from the point of view of reliability, to provide redundancy in the processor and the more important interface equipment. This is also to some extent applicable to present day electro-mechanical systems.

Telecommunications research and development teams all over the world, including the Research Laboratories, are deeply engaged in finding the most economical solution to these problems. A number of different approaches have been followed and new ones are being found. Some of the approaches have been developed to the extent where equipment embodying processor control is being manufactured and installed on a routine basis.

It is not the intention of this paper to review the different present approaches nor to postulate new ones but rather to illustrate the principles involved by describing one particular fairly readily understandable approach.

PROCESSOR CONTROLLED EXCHANGES

General Description

Two types of processor controlled exchanges were mentioned above, namely:

(i) hard-ware processor controlled, and

(ii) soft-ware (or stored program) controlled.

The latter has the advantage of much greater flexibility than the former and appears to be more widely preferred. The principle of operation of a stored program controlled exchange will therefore be described. Most of the exchanges now being developed employ space-division switching in the speech-path switching matrix, with a trend in the more forward looking

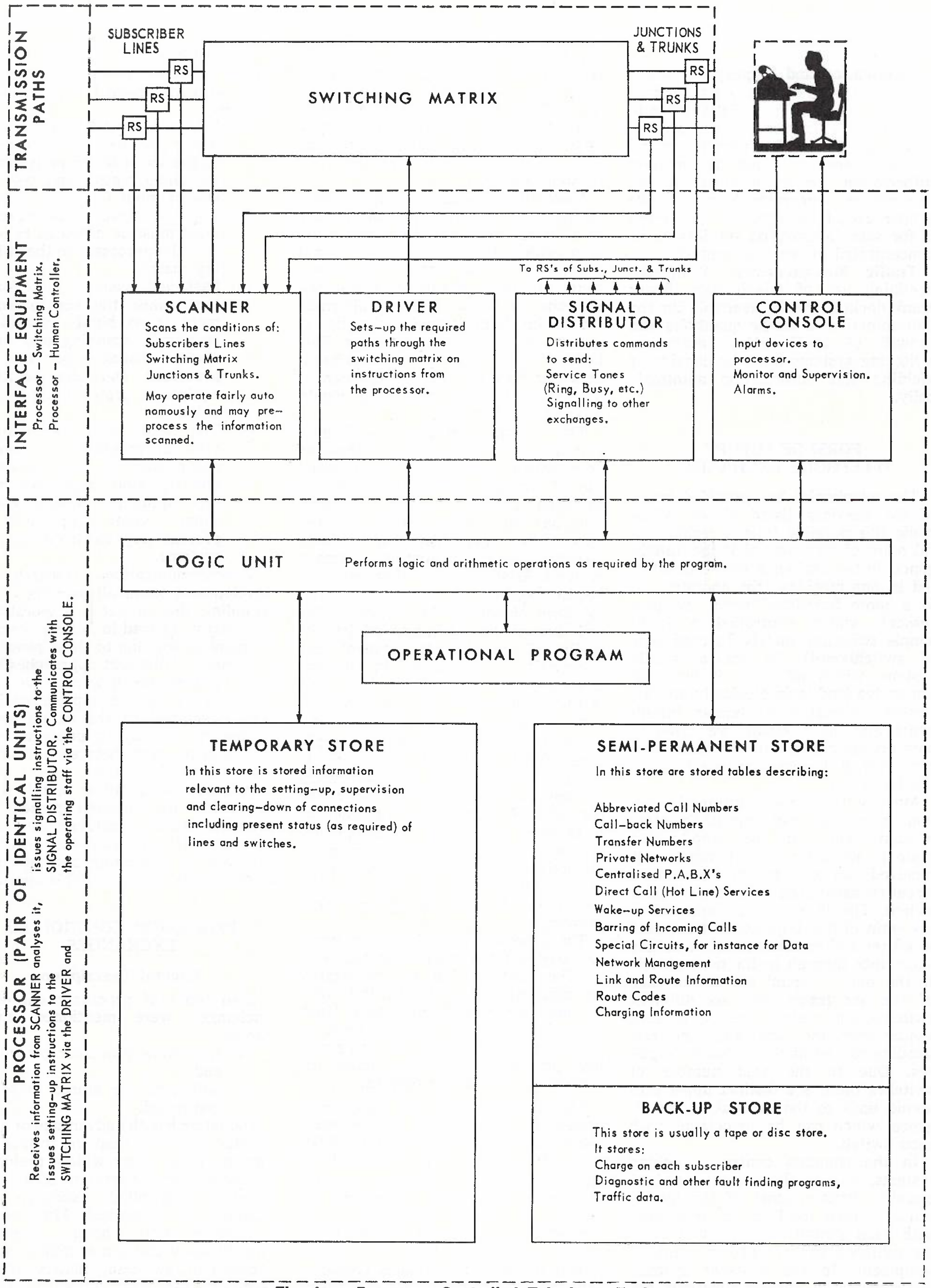

Fig. 1 — Processor Controlled Telephone Exchange.

TABLE I — ANALOGIES BETWEEN MANUALLY OPERATED EXCHANGES AND "PROCESSOR CONTROLLED" EXCHANGES.

Exchange type

Processor controlled	**Manual switchboards**
Switching matrix	Jacks and cords
Interface equipment	Vision and hearing processes and manual operations.
Scanner	Operators eyes and ears. Scans plug positions, lamps and indicators (vision), bells and instructions from subscribers (hearing).
Driver and signal distributor	Hands of the operator used for plugging-in of plugs and operation of dials, keys and push-buttons.
Processor	Brain and various tables, such as telephone and routing directories.
Operational program	Operational functions learned by the operator during training.
Temporary store	Operators short-term memory.
Semipermanent store	Operators long-term memory, telephone directory, routine directory, etc.

designs towards time-division multiplex (t.d.m.) switching. Space division (mostly reed relay) switching matrices will be assumed.

Fig. 1 shows a simplified block diagram of a possible arrangement for a stored program controlled exchange. The diagram has been arranged for simplicity of explanation and represents a possible rather than a preferred arrangement.

As may be expected, there is a close analogy between the operation of a processor controlled exchange and a manually operated exchange. For a system as indicated in Fig. 1, the analogies shown in Table 1 are quite striking. One paper (Ref. 3) states that 'some 80 conceptions have come to be known for switching systems using electronic devices and electronic switching techniques. 80% of these never got beyond the stage of laboratory experiments, . . .'. It is thus clear, if one looks at the picture in finer detail than that of Fig. 1, that a variety of detailed arrangements are possible. These will not be described but two pairs of alternatives will be discussed. These are: 'wired program versus stored program' and the 'feasibility of remote control of outposted smaller switching units'.

Wired Program Versus Stored Program

Whilst both types of programs no doubt will be encountered together in future exchanges, it is important that the right balance between the two be found.

Wired programs may be justifiable where the programs never have to be changed; this could, for instance, be true in the case of the programs which control the scanning operations associated with the scanner in Fig. 1.

Electronically alterable stored program control is seen as the only practicable concept capable of providing some of the facilities listed in the previous section (for instance, subscriber controlled transfer, subscriber controlled change of abbreviated dialling numbers).

It seems desirable that programs which are subject to change, and this appears to be all programs other than those associated with the scanning and driving operations, should be of the stored type. As in the case of computers, these programs may be changed electronically from a remote console. From Fig. 1 it is seen that most of the programs listed as being in the semi-permanent memory as well as the operational program are of a type which needs to be changed (updated) as the telephone network develops and expands.

An important point of controversy, not evident from Fig. 1, is the question of relay sets (labelled RS in Fig. 1). Many present types of relay sets perform a number of timing functions to determine, for instance, the lengths of signal elements as in our present T3 Type out-of-band pulse type signalling system (single E and M lead in each direction on trunks and junction lines). These relay sets are subject to frequent changes as the telephone network is expanded and developed and a large variety of types is required. In the present state such changes involve a significant amount of manual work and it is becoming more and more difficult to effect the changes simultaneously in the required number of exchanges whenever a more widespread change is involved. In a processor controlled exchange it is possible to embody the timing and other functions of the relay sets into the scanner or the processor proper.

This reduces the relay sets to a simpler form and by suitable design they can be made universally applicable to almost any type of line thus reducing the number of types required. The transfer of these functions away from the relay sets could possibly increase the cost of the scanner and/or the processor and possibly the total initial cost may be higher. However, a higher initial expenditure could well be off-set by subsequent operational savings. Furthermore, with universal relay sets and stored program control, changes can be made with ease, almost instantly and simultaneously in all exchanges involved in the change. Even if stored program is more expensive in terms of initial capital cost, it may still be more economical in the long run because of flexibility and the low costs associated with the program changes.

Outposted Switching Units

With present day state of technology and costs, stored program controlled exchanges tend to be uneconomical below a few thousand lines. The size at which they become economical is variously quoted but a maximum size of three to five thousand lines is at the optimistic end of the range. However, an economic need is seen, particularly in rural and country areas, for exchanges down to, say, about 100 lines. If processor controlled exchanges are to be applicable in this range a new breakthrough in components or technology will be necessary or, alternatively, it must be possible to employ remote control of small switching units outposted from a centrally located processor. In this way the small outposted switching units may benefit from the lower cost and increased versatility of stored program control. The use of centrally located processors raises a security hazard unless adequate steps are taken to safeguard the data link(s) interconnecting the processor and the outposted switching unit. Many approaches are being made to this problem which differs in large city and country areas. In city areas it is usually possible to provide one or two alternate routes for the control (data links) in case of failure of the regular control link(s). This is often not practicable in rural areas and the big question for application in these areas is therefore how many, if any, of the services between the lines connected to a particular outposted switching unit should remain operative when the control link to the central processor is severed.

In city areas, remote control of outposted switching units is likely to be common place in systems of the future (Ref. 2).

Extendability

Manual switchboards and the step-by-step automatic systems are readily extendable in small increments. Present day common control systems, such as the crossbar system, are also extendable in reasonably small increments.

Processor controlled systems tend to become uneconomical, as discussed in another section, in small sizes. It is possible, by appropriate systems design, to make such systems extendable also in reasonable increments, such as blocks of say 1000 lines. The control is also extendable but in larger blocks. This extendability is of paramount economic importance in a changing and developing telephone network.

MANUFACTURING INDUSTRY

The manufacture of present day electromechanical switching equipment requires a considerable amount of specialised production machinery and it is a multi-million dollar expenditure to set-up production facilities.

The next generation switching system will probably use reed-relays or some other type of electromechanical switch in the switching matrix. The manufacture of either requires expensive specialised production machinery. The manufacture of the processor and, to some extent, the interface equipment is, however, possible with the usual production facilities available in most electronics factories. This could lead to a saving in tooling costs and also provide the opportunity for manufacture to be spread readily over more factories than at present if this were found desirable. One could visualise an arrangement under which specified sub-systems could be manufactured in the same way as is done at present in the case of a large proportion of transmission equipment purchased.

With the introduction of pulse code modulation switching (p.c.m.) (Ref. 2) even the switching matrix could be made in 'ordinary' electronics factories.

The processors as well as p.c.m. switching matrices will make extensive use of integrated circuit techniques.

TRAINING

Processor controlled exchanges demand radically different skills than present day automatic exchanges in all phases of their execution, namely, design, installation and maintenance (manufacture having been dealt with separately above). As far as the operating administration is concerned, the requisite training must span from the technician level to the senior administrative level. The training must be undertaken well in advance so that the venture can be properly planned and executed, if maximum advantage is to be gained from the new technique. Universities and technical colleges should of course cover the basic concepts involved and this is already done to a large extent.

INTEGRATED SWITCHING AND TRANSMISSION

With space division processor controlled exchanges the traditional dividing line between switching and transmission is maintained. Advantages are however seen in integrating the two disciplines, arriving at what is known as an 'integrated switching and transmission system'. Such systems employ time division multiplex and a specific type of these is known as pulse code modulation switching.

CONCLUSION

A small number of processor controlled switching systems are already in service in various countries and a larger number are about to be put into service. The Department is actively examining and contributing to the various developments with the object of deciding on the right type(s) for Australian condition and the right time for its introduction.

ADDENDUM

After the preparation of this paper the Department placed a contract for a stored program control (s.p.c.) trunk exchange in Sydney, to become operative from 1973 onwards.

On the experimental side, the Department has provided a small s.p.c. electronic exchange (developed by the A.P.O. Research Laboratories) in Melbourne to work through a similar exchange at the O.T.C. in Sydney into the international network to test the practicability of a draft specification which has been prepared by the C.C.I.T.T. for a flexible new type of signalling system known as the C.C.I.T.T. Signalling System No. 6. These international tests commenced in 1971.

In the more advanced techniques area the Laboratories are developing an experimental integrated switching and transmission system, employing stored program control and scheduled to be installed on an experimental basis in the South-Eastern Melbourne Metropolitan Network in the latter part of 1972.

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TECHNICAL NEWS ITEMS

THE POST OFFICE ENTERS THE ELECTRONIC SWITCHING ERA

The Post Office entered the electronic switching era in September, 1969, when it was decided to purchase a stored program controlled trunk exchange to be placed in service in Sydney by 1973.

Studies commenced in 1966 indicated that it would be extremely difficult to switch economically the trunk traffic, expected to be generated in Sydney in the mid-1970s, using standard crossbar trunk switching equipment. Evaluation of tenders received in response to a world-wide request for offers of equipment for a very large capacity trunk exchange led to the acceptance of the proposal submitted by Standard Telephones and Cables Pty. Ltd., Sydney, for the supply of an I.T.T. Metaconta 10C stored program controlled four wire trunk exchange developed by the Bell Manufacturing Company, Antwerp.

On 1 July, 1970 the Central Board of Management adopted the following recommendation on the application of stored program controlled 10C trunk exchanges in the Australian network:—

"That the A.P.O. approves, as an alternative standard to the crossbar system, the use of the 10C system for trunk switching, manual assistance or automatic interception service."

The 10C exchanges use dry reed relays for speech path switching and are controlled by I.T.T. 3200 stored program controlled processors each of which is capable of connecting up to 290,000 calls per hour. Large capacity ferrite core memories are employed, as well as magnetic discs, magnetic tapes and teleprinters.

The 10C exchanges are being provided essentially for switching trunk calls dialled by subscribers (S.T.D.). Manual operating positions, where telephonists will connect calls for subscribers requiring assistance, will be associated with and controlled by the 10C exchanges.

The manual assistance positions will be the first of their type in the world and will incorporate an alphanumeric keyboard control and self-scan visual display system to indicate to the telephonist full details of each call. Call dockets will not be required as all information will be stored in the exchange processor system. The information required for accounting purposes will be recorded on a magnetic tape for processing by computer. The operation of the switchboards will be more efficient than existing types and the switchboards may be located remote from the trunk exchange if so desired.

Plans are well in hand to install similar exchanges in Melbourne and Adelaide for the commissioning during 1974. In subsequent years similar exchanges may be installed at Brisbane and Perth. The existing ARM exchanges at these locations (with the exception of Adelaide, which will be recovered) will then operate as secondary switching centres parented on the 10C exchange.

The extension of the 10C system to large provincial centres with reasonable growth of trunk switching requirements, together with a need for new manual assistance installations, is being considered.

OPTICAL FIBRES FOR BROADBAND COMMUNICATION

In December 1971, the Tribo Physics Division of the C.S.I.R.O. in Melbourne announced that it had manufactured optical fibres in lengths up to 1 km with measured attenuations of less than 20 dB/km. With further development, this figure is expected to fall to as low as 10 dB/km. This achievement is significant since overseas investigators have been unable to achieve losses less than several tens of dB/km, except in relatively short lengths of fibre.

The C.S.I.R.O. fibre consists of a drawn silica-glass tube containing an optically low-loss fluid rather than the more usual glass core. The diameter of this fluid core is large compared with the wavelength so that the bulk of the propagated energy travels in the core; in this condition a large number of modes can propagate and the fibre is said to be 'overmoded'. In contrast, most other effort has been directed towards constructing 'dominant-mode' fibres in which the diameter of the glass core is comparable with the signal wavelength. The glasses for these fibres must have extremely low impurity levels which are, in practice, very difficult to attain. The use by C.S.I.R.O. of a low loss fluid overcomes this difficulty.

The Research Laboratories of the A.P.O. has acquired lengths of the C.S.I.R.O. fibre and, in February 1972, demonstrated the transmission of analogue T.V. signals over a 400 metre length. The future programme of investigations will concentrate on determining the transmission capacity of the fibre and on developing suitable associated terminals and repeaters, with a view to specifying a possible system for the broadband network.

THE ACCURACY OF ELECTRICAL MEASUREMENTS MADE BY ELECTRONIC TECHNIQUES

*J. M. WARNER, B.Sc., M.I.E.E.**

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INTRODUCTION

About 40 years ago, the requirements for electrical measurement reached the stage where they could not be met by the indicating instruments of that time, although these were probably within one order of the limiting sensitivity and certainly the same order of accuracy as today's instruments. The measurement of alternating current, particularly at the higher frequencies, was becoming increasingly important and there were requirements of high impedance, extended frequency range and high sensitivity that the instruments of the time could not provide. These needs brought about the development of the first electronic instruments, vacuum tube voltmeters and, while the desirable features listed above were attained, the accuracy of the measurements declined. In the last 20 years, there has been a great increase in both the quantity and complexity of electronic instruments for making measurements of electrical quantities as well as those for measurement of other quantities, which are not the concern of this discussion.

It is known that we can often obtain an improvement in our product quality or output or our operational efficiency (depending on the type of industry concerned) by closer tolerance specification somewhere in our respective processes. Closer tolerance specification almost always requires higher accuracy measurement and with the introduction of automation into industry there arose the need for many of these measurements to be made automatically as well. This was for various reasons; so that information could be fed back into a process controller, so that the measurement could be made without operator error, for the results to be printed out or punched onto a tape for digestion by a computer for further calculation or other statistical purpose. As well as all this, the demand was for increasingly higher accuracy.

DIGITAL VOLTMETER ACCURACY

The most common automatic measuring instrument is the self balancing digital voltmeter which, with the appropriate accessories, is the basis for most data logging systems as well as a most convenient tool for investigations and general measurements.

Modern DVMs are among the most sophisticated measuring instruments made and have passed the stage where the accuracy is inferior to that of a good portable indicating instrument. Today, the accuracy claimed by some makers suggest that they could be used to replace the traditional potentiometer and standard cell in the standards laboratory. Instruments with a digital display are susceptible to a phenomenon that could be called the 'credibility effect'. Because there is no obvious reading error, all the digits are to be believed. When the first three digit instruments were made, the accuracy was usually limited by the finite resolution and an error of one digit was believable. Today, six and seven digit instruments are made and it should be apparent that the same limitations on accuracy do not apply.

When we wish to examine the accu-

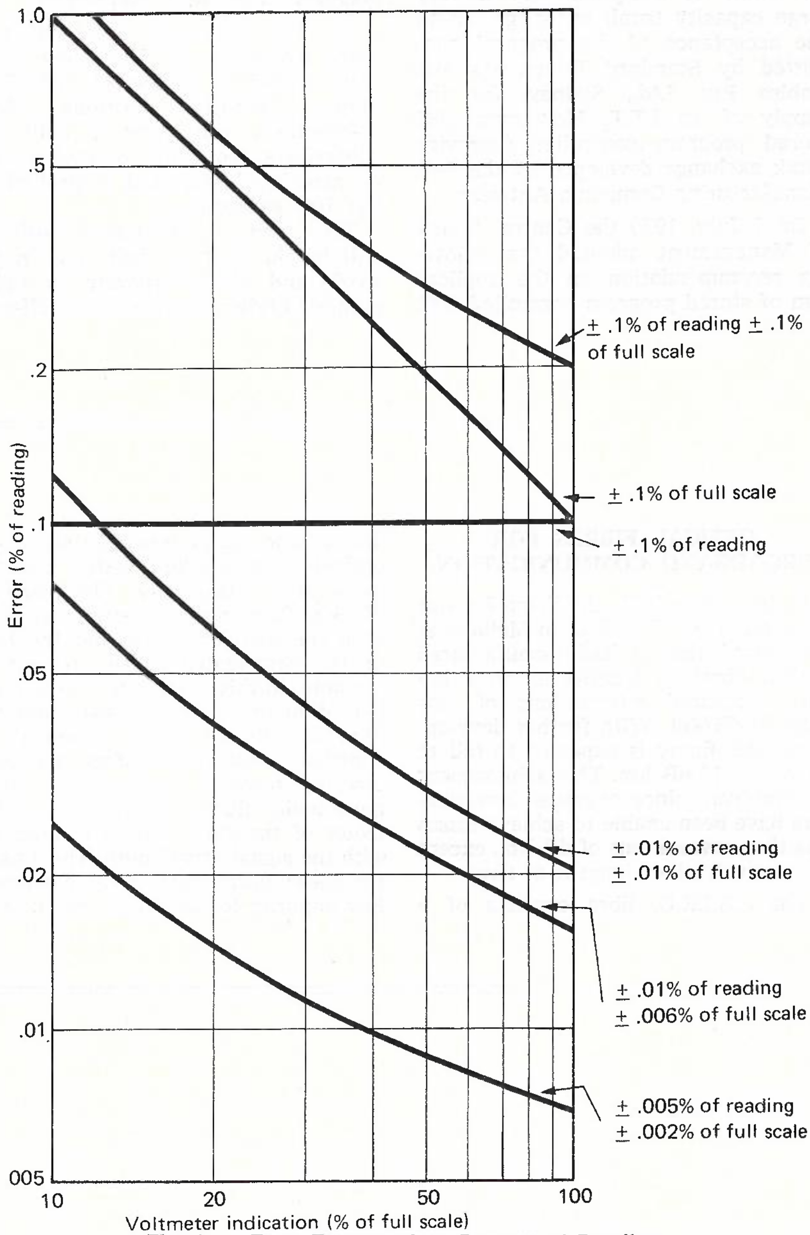

Fig. 1 — Error Expressed as Percent of Reading.

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racy of digital voltmeters and, particularly, to compare the published specifications of different manufacturers, we find some difficulty due to differing methods of writing specifications. (In what is a very competitive business there is also some advantage in skilful specification writing.) The method used differs from that almost standardized form that is used for indicating instruments, and the chances of misinterpretation are many. Errors are usually quoted in terms of the reading and range in combination, thus: ± X% of reading ± Y% of range. At full scale, this becomes ± (X + Y)% of reading but at the range change point, usually 1/10 of range, it becomes ± (X + 10Y)%. A typical 0.01% + 0.01% instrument has an error of 0.02% of reading at full scale and 0.11% of reading at 1/10 full scale. Fig. 1 shows the effect of various typical two-part accuracy specifications of error expressed as a percentage of the reading, which is what the user wants to know.

Over-Ranging

Some makers provide over-ranging by putting an '1' in front of the most significant digit, so that a three digit instrument can read up to 1999 instead of 999. Some people call this a 3½ digit instrument. There have been various over-ranges used, from 10% to 300%. Most manufacturers do not permit over-ranging on the maximum range (1000 volt). There is consequently a certain amount of doubt as to what is the 'range' for the purpose of calculating errors. On a 3½ digit instrument with 100% over-ranging is full scale 999 or 1999? Is the error 0.1% or 0.05% of range? There are marginal advantages for the specification writer (the maker's, not the purchaser's); four digits with 20% over-range has a one count error of 0.008% compared with 0.01% for a meter without over-range. Very few makers quote worst case accuracy (at the range change point) and certainly none headlines it.

Stability

The constancy of accuracy of digital voltmeters is usually given in the same two part form together with a time limit. Table 1 shows an extract from the catalogue of one maker.

Comparison with another maker's product is not simplified by the change in temperature range for the various entries. The more interesting question is that of the event occurring at zero time — the calibration of the DVM against an external standard, the uncertainty of which should be added to the figures above. There are very few laboratories in Australia that have the facilities for dc voltage measurement up to 1000V with an uncertainty less than 0.01%. For ac measurement, this would be even worse and, as will be shown later in this paper, there are difficulties with waveform. The calibration, every 90 days of even a moderately accurate DVM, is obviously outside the capabilities of the ordinary meter calibration laboratory and requires the very best in the way of standards and they will of necessity be the traditional potentiometer, volt box and standard cell.

A fairly common expression found in specifications is 'typical' as 'typical' accuracy, 'typical' stability and so on. 'Typical' accuracy is higher than 'guaranteed' accuracy by anything up to one order and is regarded with mistrust by some engineers because of the lack of definition of the expression, and the fact that in their past experience they had never been fortunate enough to have bought a 'typical' instrument.

TABLE 1. — AN ACCURACY STATEMENT

Accuracy (to 120% of range or 1100V maximum input)	
	For 24 hours (23°C ± 1°C)
0.1V range	± (0.004% of input + 0.005% of range)
1V	± (0.004% of input + 0.002% of range)
10, 100, 1000V	± (0.003% of input + 0.001% of range)
	For 90 days (18°C to 28°C)
0.1V range	± (0.005% of input + 0.005% of range)
1V	± (0.005% of input + 0.002% of range)
10, 100, 1000V	± (0.004% of input + 0.001% of range)
	For 1 year (18°C to 28°C)
0.1V range	± (0.02% of input + 0.005% of range)
1V	± (0.02% of input + 0.002% of range)
10, 100, 1000V	± (0.01% of input + 0.001% of range)

On the subject of stability, one maker (J. Fluke) has given the following definition of 'typical' stability for his 0.004% instrument:

> "Thorough error analysis studies into total instrument stability, taking into account the documented stabilities of individual components and utilizing probability and statistical methods, indicate that typical instrument stability (defined as a specification met by 80% to 90% of all instruments) is 40 ppm (0.004%) peak to peak per year. An instrument so categorized need be calibrated only once per year to meet all specifications".

Other makers might well follow this example.

Other Errors

The overall error in a DVM is the total of all or some of the following errors due to:

- finite resolution,
- non-linearity of basic range,
- range multipliers or attenuators,
- pre-amplifiers,
- internal reference,
- supply mains changes,
- effects of temperature,
- drift in zero setting,
- frequency of input,
- waveform.

There are also other effects that are not properly classed as errors but are capable of causing errors when the instrument is used in a particular manner, such as that due to the current fed out from the input terminals of self-balancing potentiometric type instruments.

If the specification is given for an overall error, it should list those causes that are included, but it is more common for the user to have to do his own arithmetic, particularly if the exercise is the comparison of allegedly similar instruments from different makers (as in the examination of public tenders). Accuracy statements such as the one quoted in Table 2 make such a comparison very tedious as all makers do not use the same form.

There is a tendency to make input resistances high to reduce internal heating as well as reduce circuit loading. It is well known that high valued resistors are less stable than lower valued and the makers provide adjustable trimmers that are adjusted at the 30, 60, or 90 day 'calibration'. Also, many instruments have a built-in reference, a zener diode or a standard cell against which the instrument is 'calibrated' at the user's demand by a front panel switch or button or even automatically in some cases. There is also a screw driver adjustment inside so that the change in this reference

TABLE 2. — AN A.C. ACCURACY STATEMENT

A.C. Accuracy

At 23°C ± 1°C (nominal calibration temperature), relative humidity less than 70%;

30Hz to 5kHz ± (0.05% of input + 0.0025% of range) from 0.001 to 500V ± 0.1% of input from 500 to 1100V.

5kHz to 10kHz ± (0.07% of input + 0.005% of range) from 0.001 to 500V ± 0.1% of input from 500 to 1100V.

10 kHz to 20kHz ± (0.15% of input + 0.01% of range) from 0.001 to 1100V.

Over the temperature range 13°C to 35°C (55°F to 95°F), relative humidity less than 70%;

20Hz to 5kHz ± (0.15% of input + 25μv) from 0.001 to 1100V.

10kHz to 20kHz ± 0.3% of input from 0.1 to 1100V.

20kHz to 50kHz ± 0.5% of input from 0.1 to 110V.

50kHz to 100kHz ± 1% of input from 0.1 to 110V.

10Hz to 20Hz ± (0.3% of input + 100μv) from 0.001 to 1100V.

5Hz to 10Hz ± (1% of input + 250 μv) from 0.001 to 1100V.

Outside the 13°C to 35°C temperature range, the above specifications may be derated at 0.003%/°C (below 5kHz) or 0.005%/°C (above 5kHz) to the extremes of 0°C and 50°C (32°F and 122°F).

with time can be compensated. In practice, the DVM is not 'calibrated' in the usual sense when sent to the standards laboratory but the internal trimmers are adjusted so that it reads correctly within a specified tolerance. Few users would be happy to receive a list of corrections to be applied — the normal result of a 'calibration' operation.

Temperature Effects

Several components in a DVM will be temperature dependent and the overall temperature dependence will not necessarily be linear. The designer will make it small over a small range about a normal ambient but outside that range it may be non-linear. He may quote an overall figure which may be quite large, or give the coefficient of each part, leaving the user to do his own statistics. Most makers have adopted the practice of quoting the accuracy first over a very narrow temperature range (23 ± 1°C for most instruments of American origin) and give additional errors for other temperatures. If the temperature coefficients differ for various input ranges, then a two part specification is often used (see Table 3).

In this example, the effect of temperature over the range 18-28°C is included in the statement given for accuracy and stability.

Unwanted Signals

Interference from a.c. signals has a greater effect on d.c. DVM operation than it has on VTVMs or any other indicating type instruments. The effect of series mode unwanted signals, which originate mainly from the supply mains, can be reduced by either a low pass filter or inherently by the integrating system used in some types of DVM. A low pass filter will reduce the reading speed to the extent that it may take ½ to 1 second to settle within 0.01% of the final reading, although the time without filter may be few milliseconds. The written specification may headline the time of the unfiltered performance and the rejection appropriate to filtered performance, which can be misleading. Slow balancing may not be important for some type of usage, in a laboratory for instance, but for data logging applications the high rejection of the integrating instrument is preferable.

It should be noted that, although it is possible to apply 100V a.c. on the 100V d.c. range without obtaining a change in reading greater than 0.1%, it is not reasonable to expect the same performance on lower ranges. In fact, low ranges which use pre-amplifiers frequently have clamping diodes for overload protection and these produce spurious signals when overloaded.

TABLE 3. — A TEMPERATURE COEFFICIENT SPECIFICATION

Temperature Coefficients (0° to 18°C and 28° to 50°C)

0.1V Range

± (0.0007% of input + 0.0005% of range)/°C

1V Range

± (0.0007% of input + 0.0003% of range)/°C

10, 100, 1000V Ranges

± (0.0005% of input + 0.0002% of range)/°C

A.C. MEASURING INSTRUMENTS

So far, the matters discussed in this paper may be taken to apply equally to instruments for the measurement of either direct or alternating quantities. There is an important source of error that affects the measurement of alternating quantities only: the relationship between the type of instrument and the waveform of the quantity being measured. The effect applies to *all* a.c. measuring instruments, ordinary indicating meters, all types of electronic voltmeter as well as differential and digital voltmeters.

The amplitude of an alternating wave may be specified by a single value provided the waveform is fully defined. The three well known parameters are the peak, average and root mean square (r.m.s.) values and they are interrelated as follows:

$$\text{form factor} = \frac{\text{r.m.s. amplitude}}{\text{average amplitude}}$$

$$\text{crest factor} = \frac{\text{peak amplitude}}{\text{r.m.s. amplitude}}$$

and for a sine wave these have fixed values of 1.1107 and 1.4142, respectively.

The significance of the difference between the three parameters is often overlooked. As the majority of measurements is concerned with energy and power, the r.m.s. value is the most important. For measuring the breakdown of insulating materials or calibrating an oscillograph, the peak value is more important, and for measurements of electrolysis, the average value is more appropriate. However, the r.m.s. value is always assumed to be specified unless otherwise stated.

Unfortunately, the r.m.s. value is the most difficult to measure in a practical manner. Dynamometer, thermocouple and electrostatic instruments all measure r.m.s. but suffer from limitations of sensitivity, frequency range, robustness and price as well as resolution. Peak rectifying diode voltmeters for the measurement of radio frequency voltage and average rectifying meters for lower frequencies are more practical. Although they do not measure r.m.s. values, but peak or average, the scales of these practical instruments are always scaled so that they indicate the r.m.s. value for a sine wave by applying either the crest factor or form factor and frequently declare on the scale 'R.M.S. of a Sine Wave'.

While the sinusoid may be simple to describe mathematically, it is rarely encountered in reality in the electrical field. The accuracy with which a peak or average responding r.m.s. voltmeter measures the r.m.s. value of a distorted sine wave voltage depends on the amplitude of the harmonics, their order, and phase relationship to the fundamental. It is not practical to calculate the correction for a particular amount of distortion because of the difficulty in measuring the phase relations. However, the errors can be calculated for the most unfavourable phase condition and this 'worst case error' used as a qualifying uncertainty for the measured value. The effects of harmonics differ with the type of instrument and are considered separately.

Peak Responding Instruments

For a sine wave with a single harmonic added the maximum error occurs when a peak of the harmonic coincides with that of the fundamental. The effect on the peak measurement will in this case be equal to the amount of the harmonic. The effect of several harmonics will be additive and in the worst case the error will be the arithmetic sum of the harmonic amplitudes.

Average Responding Instruments

The effects of even and odd order harmonics are quite different. The following summary is derived from an examination of the effects of harmonic influence given in Refs. 1 and 2 for the case where the amount of distortion is less than 5%.

Even-ordered harmonics: These can produce errors up to

$$(H^2/200) \text{ percent}$$

where H is the amplitude of the harmonic expressed as a percentage of the fundamental. The maximum error occurs when the harmonic is in phase with the fundamental. The error due to several even harmonics can be up to

$$(1/200)(H_2+H_4+\ldots)^2 \text{ percent}$$

The effect is small, 4% of 2nd harmonic producing less than 0.1% error.

Odd-ordered harmonics: These can produce the greatest errors up to

$$H_3/3+H_5/5+\ldots \text{ percent}$$

The error produced by the lower order odd harmonics is the worst and 3% of 3rd harmonic can produce an error in an r.m.s. measurement made with an average responding instrument between +1% and —1% depending on the phase relationship.

When the distortion in a supply is given only as a per cent harmonic content and the order of the harmonics is unspecified, then the worst case assumption is also that it is entirely 3rd harmonic.

The accuracy claims for a.c. measuring instruments also require a term to be added for the accuracy of the local standard and it should be noted that the Australian National Standards Laboratory calibrates true r.m.s. measuring devices for the frequency range up to 10kHz with an uncertainty at the present time of 0.01%. Consequently, a figure of at least that magnitude must be added to any maker's claims.

While the majority of a.c. DVMs is average responding/r.m.s. calibrated, there are some true r.m.s. instruments available as well as accessory type a.c./d.c. converters which are true r.m.s. operated. The true r.m.s. instruments use thermocouples and are much slower to reach final balance than the average responding types and, in general, are claimed to have worse accuracy than the average responding types. This will, of course, only be realized on sine waveforms of low distortion.

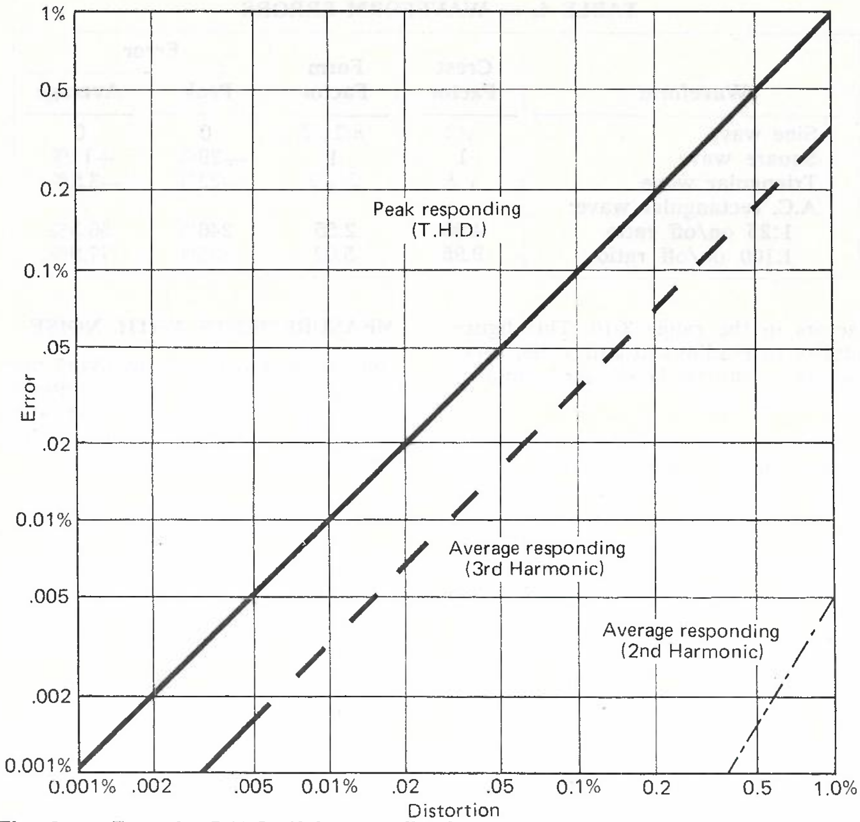

Fig. 2 — Error in R.M.S. Voltage Indication of Peak and Average Responding Instruments.

NON SINUSOIDAL WAVEFORMS

There are occasions when measurements have to be made of quantities where the waveform is not sinusoidal and r.m.s. responding meters are essential, whether digital or direct indicating is unimportant. Electronic instruments that are r.m.s. responding are invariably known as 'true r.m.s.' meters. There is however a limit to the departure from sine wave form beyond which the electronic 'true r.m.s.' meter will not operate correctly, as the peak amplitude may be many times greater than the r.m.s. value and overload the amplifiers causing clipping and inaccurate measurement. The ratio of peak to r.m.s. amplitude (crest factor) is usually taken as a measure of this departure and most instruments will cope with waveforms having crest

TABLE 4. — WAVEFORM ERRORS

Waveform	Crest Factor	Form Factor	Error	
			Peak	Average
Sine wave	$\sqrt{2}$	$\pi/2\sqrt{2}$	0	0
Square wave	1	1	—29%	+11%
Triangular wave	$\sqrt{3}$	$2/\sqrt{3}$	+22%	—3.8%
A.C. rectangular wave:				
1:25 on/off ratio	4.90	2.55	246%	56.5%
1:100 on/off ratio	9.95	5.03	605%	77.9%

factors in the range 3-10. This figure applies to readings at full scale, crest factors of 30-100 being acceptable at 10% of full scale.

Table 4 gives the crest factor of some common non-sinusoidal waveforms and the error that would result from measurement using peak and average responding r.m.s.-calibrated instruments. These errors are calculated from the crest and form factors of the waveforms and are given as an indication of the errors inherent in the mathematics of the peak or average responding/r.m.s. calibrated system that we employ. It should be noted that with rectangular or pulse waveforms there are two crest factors due to the different amplitudes of the positive and negative peaks. Conventionally the greater one is quoted but in practice measurements made with a peak responding meter will show two different readings depending on the polarity of connection. There is also a half wave average but it is the same for both positive and negative half cycles of an alternating waveform, that is one with no direct current component.

The value of the full wave rectified average is the value usually stated (the full wave average being zero of course) and this is twice the half wave average.

A peak responding r.m.s.-calibrated meter indicates an amplitude

$$Ai = Ap/\sqrt{2}$$

The true r.m.s. value of a waveform with crest factor Cf is

$$Ar = Ap/Cf$$

The error in the value indicated is

$$(Ai - Ar)/Ar = (Cf - \sqrt{2})/\sqrt{2}$$

Similarly the error in the value indicated for an average responding meter is

$$(\pi/2\sqrt{2} - Ff)/Ff$$

Where Ff is the form factor of the waveform being measured.

MEASUREMENTS WITH NOISE

Another measurement involving non sinusoidal waveforms is encountered when noise is present. Two types of noise can be considered, noise being defined as an unwanted signal.

Non Harmonically Related Periodic Noise

With average responding instruments the effect of a single interfering signal of value E_2 on the measurement of a signal E_1 results in the following reading

$$E_1\left[1 + \frac{1}{4}\left(\frac{E_2}{E_1}\right)^2 + \frac{1}{64}\left(\frac{E_2}{E_1}\right)^4 + \frac{1}{256}\left(\frac{E_2}{E_1}\right)^6 + \ldots\right]$$

According to the author of Ref. 3, from which this formula is quoted, this effect has not been previously subjected to rigorous scrutiny and consequently the results appear at first to be surprising. An interfering signal of amplitude 10% of the desired signal produces only 0.25% difference in the value read on an average responding instrument compared with 0.5% on a true r.m.s. instrument and 10% on a peak responding instrument.

Random Noise

The measurement of noise with peak responding instruments is open to many sources of error. The reading depends on the rectification efficiency of the diode which is rather uncertain and their use is not recommended.

The indication of average responding instruments to noise with a gaussian distribution can be calculated and for the usual r.m.s. scaled instrument the readings will be 11.5% low (1.05dB).

The measurement of sine wave signals in the presence of broadband noise has been simplified in the telecommunication field by the use of frequency selective instruments. Although these instruments respond to the average value of the fundamental, this is quite a good indication of the r.m.s. of a distorted wave. (The difference between the r.m.s. value of the fundamental and that of a distorted wave is only 50 parts per million for 1% harmonic distortion.)

For measurements made with wide band instruments the extent of the error due to random noise will depend upon the signal-to-noise amplitude ratio R and for ratios less than 10:1 is approximately

$$25\ (1/R^2)\ \text{percent}$$

for average responding instruments. For true r.m.s. instruments the error is approximately

$$50\ (1/R^2)\ \text{percent}$$

A rigorous examination of the effect of superimposed noise can be found in Ref. 4.

CALIBRATION

The calibration of a.c. measuring DVMs requires a signal source of very low distortion and high amplitude stability (because of the slow response of true r.m.s. instruments of the thermocouple type). The range multipliers (attenuators or voltage dividers) are usually provided with adjustable capacitors to compensate for changes of stray capacity distributions. The resistive trimmers for the multipliers are adjusted at a low frequency and the capacity trimmers at a high frequency — usually 100kHz. The supply of 1000V at this frequency with low distortion is probably the most stringent requirement for the signal source and its matching transformer, as the combined capacity of the DVM, circuit wiring and the calibration standard constitute a surprisingly high loading, even if it is reactive power.

CONCLUSION

Electronic measuring instruments are becoming increasingly used and they can possess particularly high short term accuracy. Although traditional calibration laboratories have no great confidence in digital voltmeters, they are acknowledged to be a very convenient tool.

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WARNER — Accuracy of Electrical Measurements

THE 2-WIRE/4-WIRE INTEREXCHANGE TELEPHONE CIRCUIT

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SUMMARY

The switched telephone circuit which terminates in a 2-wire switch at one end and a 4-wire switch at the other presents some interesting transmission problems. In this paper the network implications of the design of this type of circuit are examined. In particular, the paper examines the following factors:—

- transmission system loading
- asymmetry of loss in opposite directions in a connection
- data transmission implications
- national semi-loop loss
- noise
- national sending and receiving reference equivalents.

It is shown that when the circuit is required to introduce loss into a connection, such loss (relative to a zero-loss circuit) should be provided in the 2-wire receive path only.

INTRODUCTION

In any switched telephone connection including 4-wire switched circuits, there must be two circuits which are switched 2-wire at one end and 4-wire at the other. Such circuits may be provided between a (4-wire) secondary or higher switching centre and a (2-wire) primary or local exchange. Note: C.C.I.T.T. exchange terminology is used here; corresponding terms are as follows:

C.C.I.T.T.	Australia
Secondary	Secondary
Primary	Minor
Local	Terminal

The transmission design of these circuits is dependent not only on the send relative levels at the exchange in which they terminate, and the transmission loss they are intended to introduce into a connection, but also on transmission system loading and noise considerations. Furthermore, the two 2w/4w circuits must always be considered together; they are complementary, and neither can ever be used without the other.

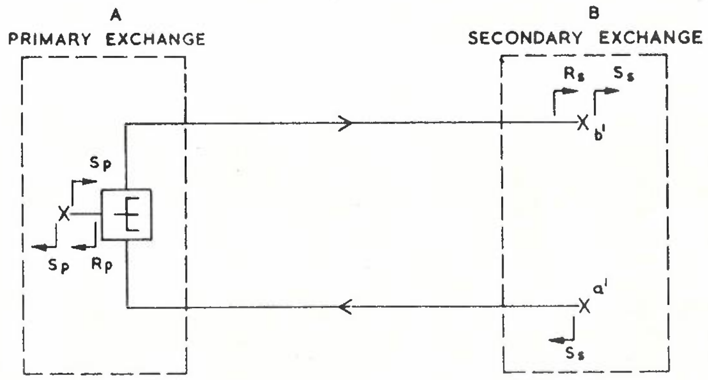
THE ZERO-LOSS CIRCUIT

The transmission design of circuits naving transmission loss is best introduced by consideration of a zero-loss circuit, which might be required, for example, between primary and secondary exchanges. (Fig. 1(a)).

Let the send relative level of all circuits at a primary exchange be S_p dBr, and let the send relative level of all circuits at a (4-wire) secondary exchange be S_s dBr. Note in Fig. 1(a) that the designation S_p to the left of the switch point in exchange A and the designation S_s to the right of the switch point in exchange B refer to the send relative levels of the circuits to which circuit AB may be switched. The S_p designation to the right of the switch point in exchange A and the S_s and R_s designations to the left of the switch point in exchange B refer to circuit AB.

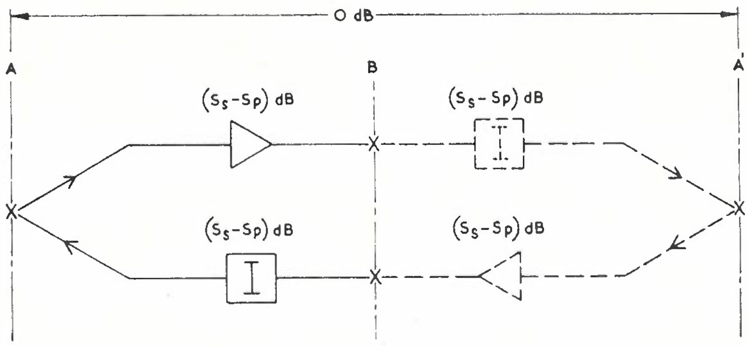
If circuit AB is to introduce no transmission loss in either direction of transmission when it is included in a connection, it follows that the receive relative level at each end should be the same as the respective send relative level of the circuits to which it is connected. For example, the circuit AB in Fig. 1(a) would have to have a receive level of $R_s = S_s$ at B and a receive relative level of $R_p = S_p$ at A.

It then follows that as far as the outside world is concerned, the zero-net-loss 2w/4w circuit AB must look like the solid lines of Fig. 1(b): a gain of $(S_s - S_p)$dB would be measured between switches in the AB direction and a loss of $(S_s - S_p)$dB would be measured in the BA direction, regardless of the actual make-up of the circuit between the exchanges. (The amplifier and pad symbols shown are appropriate for $S_s > S_p$; they would be reversed if $S_s < S_p$, and would each have the value 0 if $S_s = S_p$.) The dotted complementary circuit BA′ in Fig. 1(b) shows how an overall loss of OdB



NOTES:-
1. X DENOTES SWITCH-POINTS.
2. RELATIVE LEVELS UPSTREAM AT SWITCHING POINTS ARE RECEIVE RELATIVE LEVELS
" " DOWNSTREAM " " " " SEND " "
3. S IS FIXED FOR ALL CIRCUITS AT A GIVEN EXCHANGE. R MAY DIFFER BETWEEN DIFFERENT CIRCUITS AT AN EXCHANGE.

(a) SEND (S) & RECEIVE (R) RELATIVE LEVELS.



(b) EFFECTIVE CIRCUIT.

Fig. 1 — A Zero Net-Loss Circuit.

*Mr. Kitchenn is Engineer Class 4, Transmission and Line Planning, Headquarters. See Vol. 18, No. 1, page 67.

between 2-wire points is provided when two such circuits are connected 4-wire at B.

The concept of a circuit contributing no loss to a connection yet providing a loss in one direction and a gain in the other, requires careful explanation in installation and maintenance instructions. For the transmission planner, at least, it is convenient to regard the circuit just described as a zero-loss circuit, and one which contributes an effective X dB to a connection as an X-dB net loss circuit.

We are thus led to define the net loss of the circuit AB as the mean of A-B and B-A losses:

$$\text{Net loss} = \tfrac{1}{2}[S_s - S_p - (S_s - S_p)] = 0\text{dB in the example of Fig. 1.}$$

MAKING IT LOSSY

Adding Loss to Each Direction

What adjustments have to be made to the zero-net-loss circuit of Fig. 1 to enable it to contribute a net loss to a connection?

A first approach is to add that net loss to each direction of transmission. If circuit AB in Fig. 2 is to have a net loss of X dB, then the amplifier gain is reduced by X dB and the pad loss is increased by X dB. Fig. 2 also shows a complementary circuit BA′ with a net circuit loss of Y dB.

The receive relative levels of the circuit at A and B will each be lower than those indicated in Fig. 1 by the net loss of the circuit; they are shown in Fig. 2(b). The net loss of circuit AB is now:

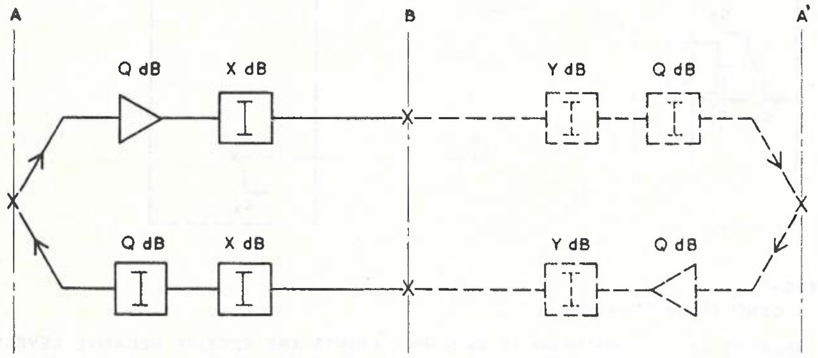
$$\tfrac{1}{2}[S_s - S_p + X - (S_s - S_p - X)] = X \text{ dB}$$

Similarly, the circuit A′B has a net loss of Y dB. Their 2-wire-2-wire sum is the same in each direction: (X + Y)dB.

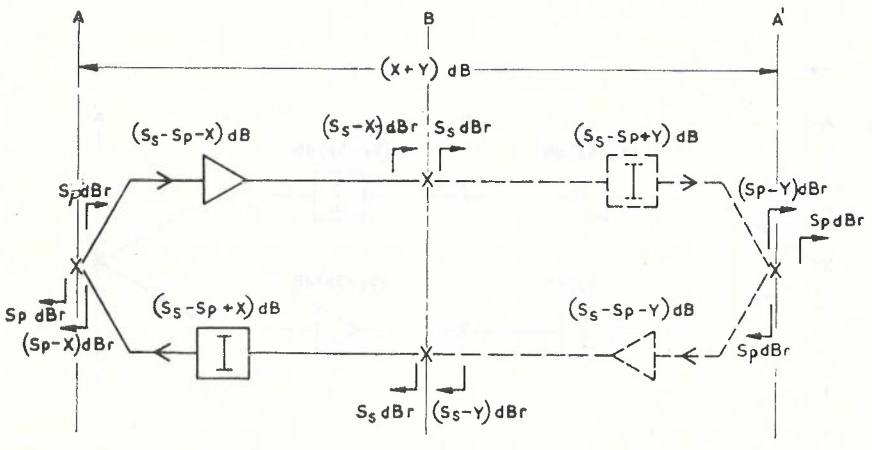
Adding Loss to Only One Direction

Suppose now that the loss of circuit AB in one direction of transmission remains independent of net circuit loss, and that all loss adjustments are made in the other direction only. In the first approach above, a net loss of X dB required the addition of 2X dB distributed equally between the two directions. In this second approach, we place the entire 2X dB in one direction, and Fig. 3 shows the effect of doing this, together with a complementary circuit BA′ which has a corresponding loss of 2Y dB added in one direction. The loss may be added in the 2-wire receive path (Fig. 3(a)) or the 2-wire send path (Fig. 3(b)).

It is clear from Fig. 3 that the overall loss between A and A′ is no longer the sum of the net circuit losses of the two circuits, and that unless X = Y, the loss will be different in opposite directions of transmission, the difference being 2(X ~ Y)dB. Following the same approach as previously, the 'net circuit loss' is found to be X for the circuits AB and Y for the circuits A′B in both Figs. 3(a) and 3(b). However, the sum of the losses is no longer X + Y in each direction, and application of the concept of 'net circuit loss' in a connection is less precise than in the previous arrangements.



(a) ADDING LOSS EQUALLY IN BOTH DIRECTIONS



(b) EQUIVALENT OF (a)

Fig. 2 — A Lossy Circuit: First Approach.

CHANNEL LOADING

The circuits such as AB in Figs. 1, 2 and 3 will generally be provided in f.d.m. carrier systems. The channels in such systems have standard input (send) and output (receive) relative levels (S_c dBr, R_c dBr respectively) which must be independent of the net losses of the circuits of which they are a part, to ensure controlled multi-channel loading of the systems (S_c) and standardized channel test procedures (S_c and R_c).

Fig. 4 shows the internal arrangements of a simple connection, when circuits are provided over f.d.m. carrier systems. In this Figure

(a) corresponds to Fig. 1(b);
(b) corresponds to Fig. 2(b);
(c) corresponds to Fig. 3(a); and
(d) corresponds to Fig. 3(b).

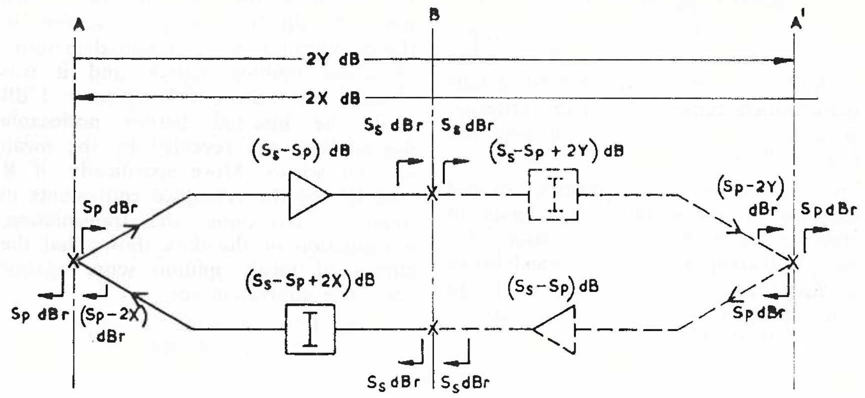
Note that the relative levels at the ends of the circuits in Fig. 4 correspond exactly with those of the earlier Figures. In practice, a complete connection could be extended to local exchanges over terminal circuits which could be provided by carrier systems switched 2-wire at each end, as shown in Fig. 5.

Let the carrier channels in Fig. 5 be identified in direction and location by their terminal letters; thus aA represents the channel from a to A, A′B represents the channel from A′ to B, and so on. Then for each case in Fig. 4 it is possible to describe the loading effects on the various carrier channels concerned. (See Table 1). The loading of channels aA and a′A′ is independent of the conditions in Fig. 4, and these channels are therefore not designated in the table.

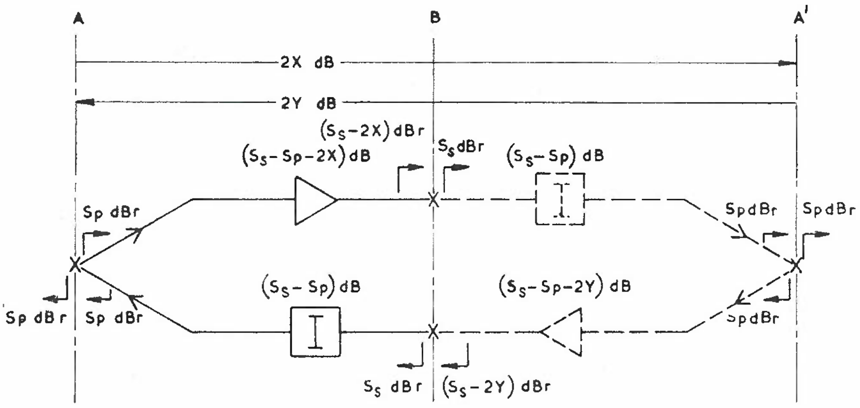
WHICH METHOD OF INTRODUCING LOSS?

Loss and Loading

We have seen that there are only three possibilities for designing 2w/4w circuits to provide a transmission loss.



(a) ADDING LOSS IN THE 2-WIRE RECEIVE PATH.



(b) ADDING LOSS IN THE 2-WIRE SEND PATH.

Fig. 3 — A Lossy Circuit : Second Approach.

TABLE 1: EFFECTS ON CHANNEL LOADING

Channel		Zero loss Fig. 4a	Two lossy circuits Fig. 4b	Fig. 4c	Fig. 4d
Direction aa'	AB	N	N	N	N
	BA'	N	L'	N	L''
	A'a'	N	L''	L''	L''
Direction a'a	A'B	N	N	N	N
	BA	N	L'	N	L''
	Aa	N	L''	L''	L''

Key: N = normal, or independent of net circuit losses.
L' = lower than normal by net circuit loss of previous circuit.
L'' = lower than normal by (a) twice net loss of one of the previous circuits, or (b) sum of net losses of both previous circuits.

They are (with respect to a circuit providing zero net loss):

(a) — add loss equally in both directions. (Fig. 2 (b)), or
(b) — add loss in the (2-wire) receive direction only. (Fig. 3(a)), or
(c) — add loss in the (2-wire) send direction only. (Fig. 3(b)).

Undesirable results attach to each method, either in respect of the overall connection loss, or in respect of carrier channel loading. In detail, these effects are:

(a) **Loss added in both directions (Fig. 2(b)):**

Loss addition: satisfactory
Channel loading:
(i) 2w/4w circuits: only 2 of the 4 channels in the connection are properly loaded; the others are underloaded by the net circuit loss of the previous circuit.
(ii) terminal circuits: primary-to-local channels underloaded by the sum of the net circuit losses of the 2w/4w circuits.

(b) **Loss added in 2-wire receive direction (Fig. 3(a)):**

Loss addition:
Unless the net circuit losses of the 2w/4w circuits in the connection are equal, there will be a difference in loss between the two directions of transmission. In an extreme case, this could could amount to 6 dB or more in an international conection, but this would be very rare.

Channel loading:
(i) 2w/4w circuits: all channels are properly loaded, and the loading is independent of net circuit losses.
(ii) terminal circuits: primary-to-local channels underloaded by twice the net circuit loss of one 2w/4w circuit at one end, and by twice the net circuit loss of the other 2w/4w circuit at the opposite end of the connection.

(c) **Loss added in 2-wire send direction (Fig. 3(b)):**

Loss addition: as for (b)
Channel loading:
(i) 2w/4w circuits: only 2 of the 4 channels in the connection are properly loaded; the others are underloaded by twice the net circuit loss of the previous circuit.
(ii) terminal circuits as for (b).

Channels in Terminal Circuits

Any connection in which net circuit loss is introduced into 2w/4w circuits will inevitably result in underloading of carrier channels in terminal circuits in the primary-to-local direction; the phenomenon is common to each of the methods (a), (b) and (c) above. The *degree* of under loading may be assumed to be much the same for all three methods, since the possible loading discrepancies ((X + Y)dB, 2X dB and 2Y dB) are statistically likely to have a common mean value over all possible connections.

Furthermore, other, non-carrier, terminal circuits connectable to a carrier terminal circuit at a primary exchange will also produce underloading if their loss is more than the difference between the send relative levels of circuits at the local and primary exchanges.

We conclude that the loading of channels in terminal circuits cannot be used as a criterion for choosing a preferred method of allocating loss in 2w/4w circuits.

Channels in 2w/4w Circuits

Only one method, (b), ensures proper loading of all channels. The other methods each result in underloading half the channels concerned. On this criterion method (b) is the preferred solution.

Loss addition:

Only method (a) ensures proper addition of losses and equal losses in opposite directions of transmission. Are the disadvantages of asymmetrical losses in method (b) sufficient to outweigh that method's advantages in respect of channel loading?

We must consider two aspects of bothway transmission: speech and data.

Speech:

The effect of difference in loss in opposite directions has been studied for telephony by the Swedish Administration. (Ref. 1) A telephone connection having a overall reference equivalent of about 12dB (about the value preferred by subscribers) was adjusted so that the loss in one direction was increased by X/2dB while the loss in the other was decreased by X/2dB, the difference in loss between the two directions then being X dB. Customers' reactions to these conditions were measured in terms of mean opinion scores, and it was claimed that values of X up to ± 17dB could be inserted before noticeable degradation was revealed by the mean opinion scores. More specifically, if R and R′ are the reference equivalents in opposite directions of transmission, examination of the data shows that the curves of mean opinion score against reference equivalent for:

(a) R′ = R and
(b) R′ = (24.3—R)

are virtually coincident over a range of 27>R>0dB (See Fig. 6).

On this evidence, there would be no observable disability to subscribers' conversations when presented with loss differences of the magnitude likely to result from the adoption of method (b) and we conclude that for telephony, the latter method is satisfactory.

Note: Since the preparation of this article, the C.C.I.T.T. has declared "....no great disad-

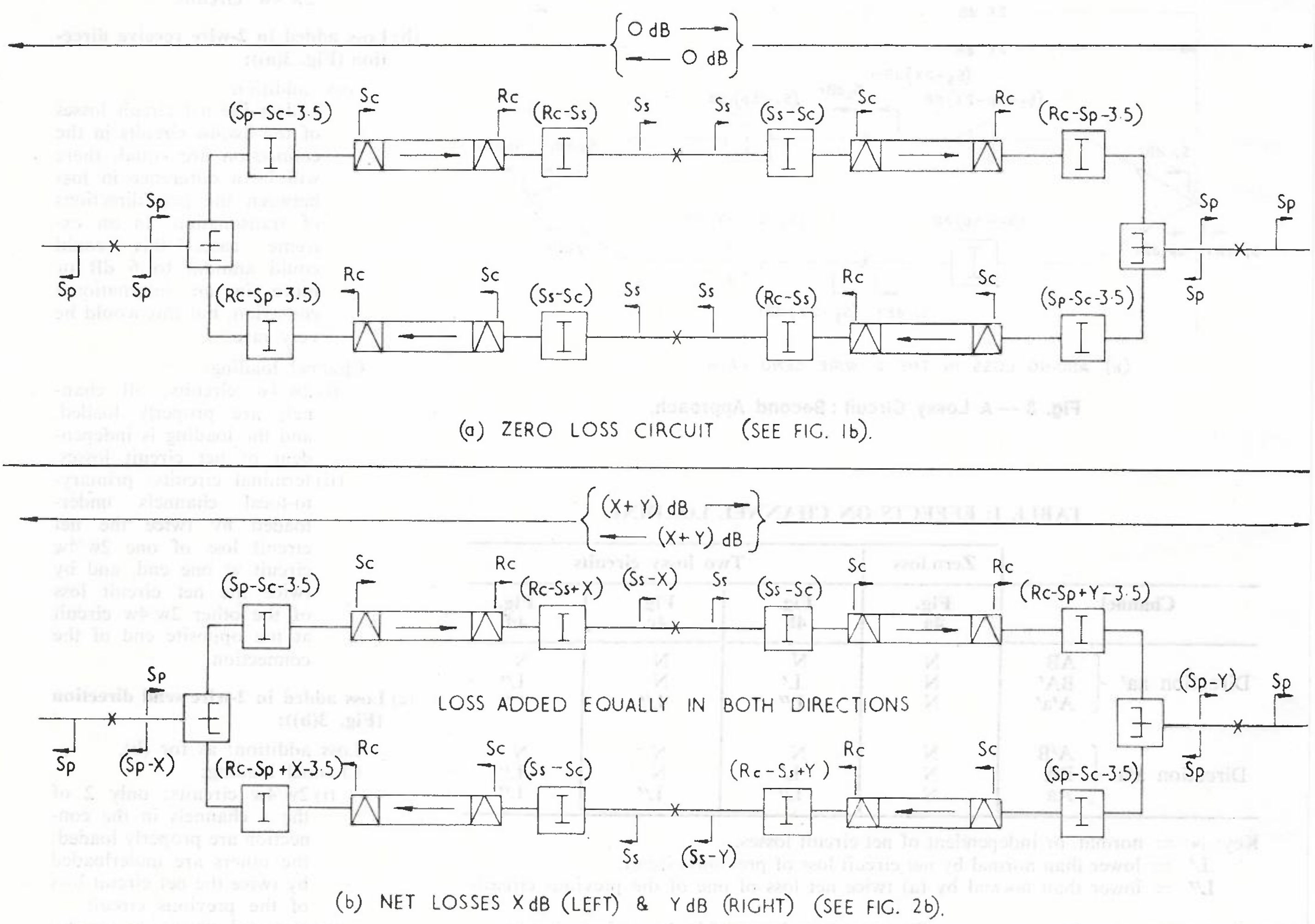


Fig. 4 — Circuits Provide

vantage attaches to any reasonable difference in nominal overall reference equivalent between the two directions. In consequence, there is no need to recommend a limit for this difference" (Ref. 2) ......

Data:

Data service over public telephone circuits is likely to be less critical with respect to difference of loss in opposite directions than telephony.

Data receivers are designed to accept a wide range of input levels (typically, a 2w-2w loss of 0 to 40 dB) and the operation in one direction of transmission is independent of that in the other. In principle, there is no reason why a data connection should not oper-

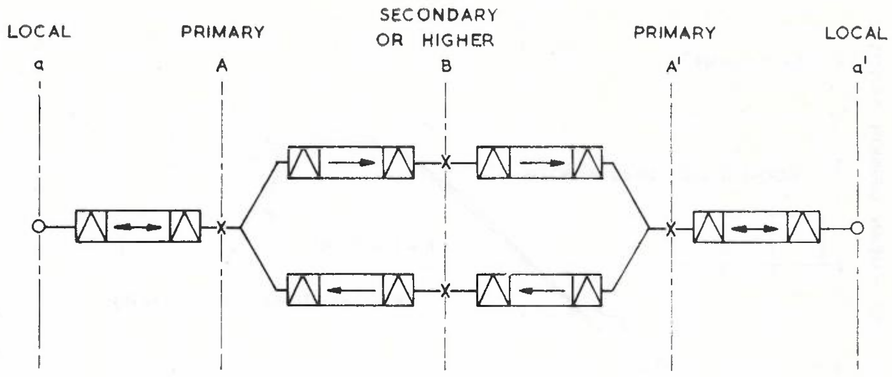
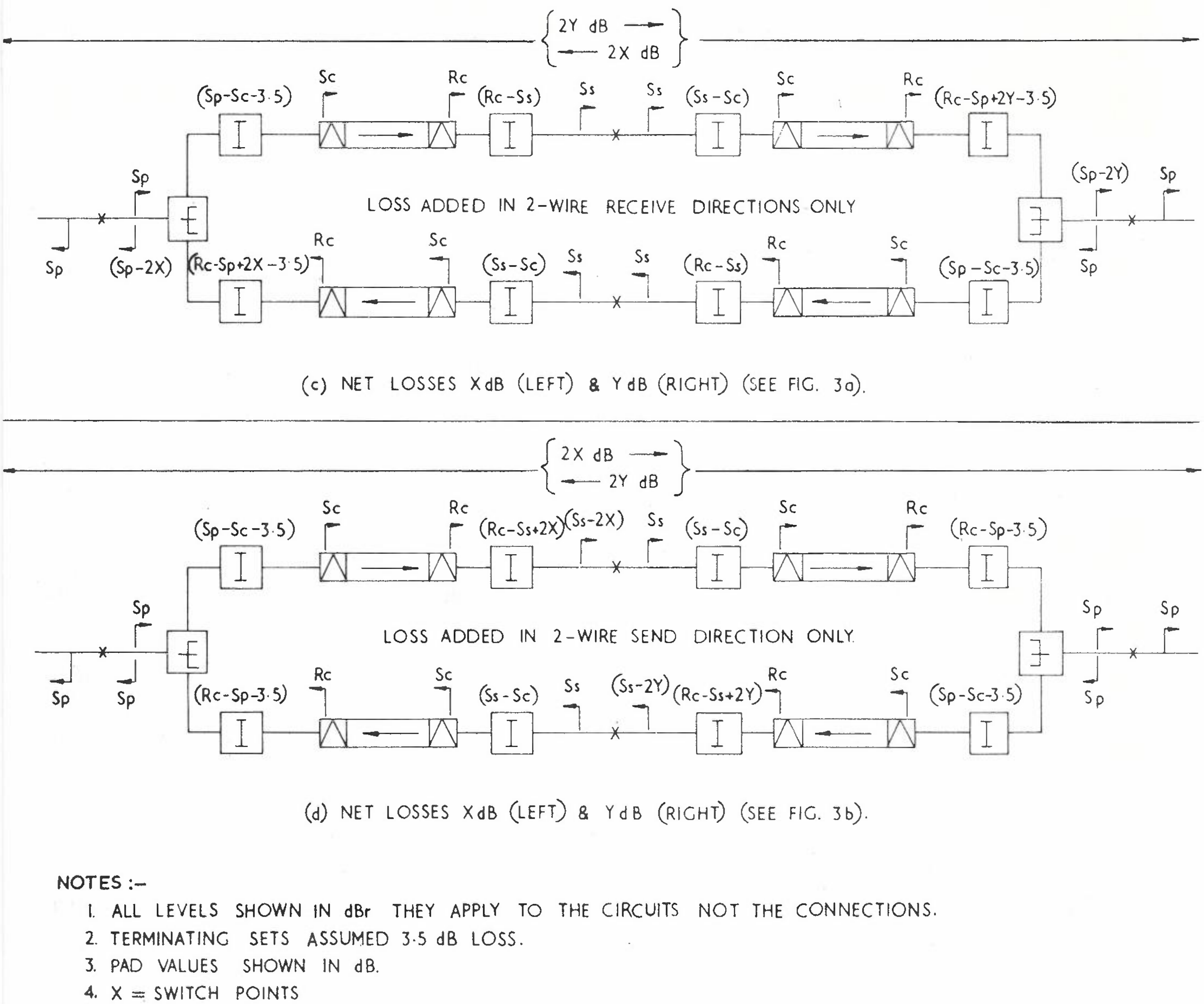


Fig. 5 — Simplified Connection between Local Exchanges, Using Carrier Circuits Throughout.



y Carrier Systems.

KITCHENN — 2 Wire/4 Wire Interexchange Circuit

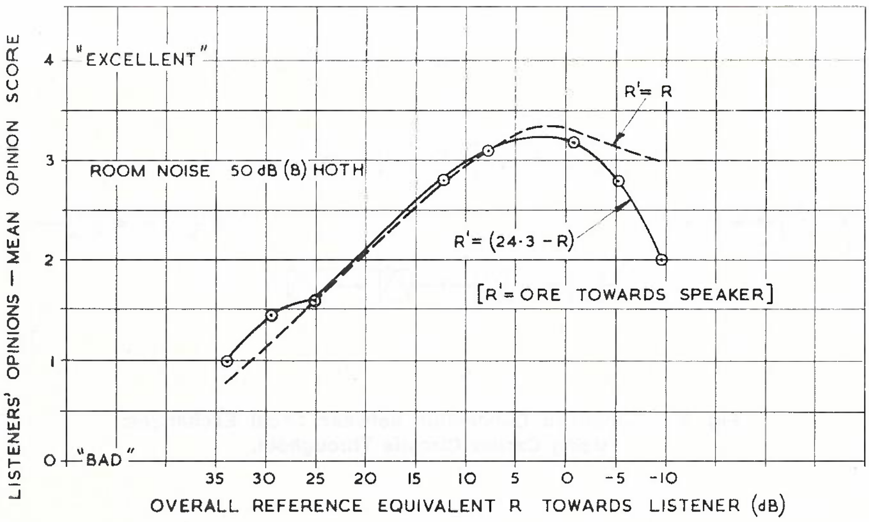


Fig. 6 — Effect of Different Reference Equivalents in Opposite Directions.

If the 4-wire/2-wire circuit has a net loss of X dB,

method (a) will add X dB to both sending and receiving national reference equivalents.

method (b) will add 2 X dB to the national receiving reference equivalent only and

method (c) will add 2 X dB to the national sending reference equivalent only.

Generally, the effect of microphone feed current loss in subscribers' local ends is such that the C.C.I.T.T. national sending reference equivalent limits are controlling, and there is still some margin before the national receiving reference equivalent limit is reached. In this case, there is obviously an advantage in adopting method (b) for introducing loss in the 4-wire/2-wire circuit, since this method introduces no sending reference equivalent penalty.

ate satisfactorily with a loss of 0dB in one direction and 40 dB in the other. The loss differential of method (b) is not a disadvantage to data transmission.

Semiloop Loss

For both national and international transmission planning, the national semiloop loss* is an important factor. The loss in the path a′ — A — b′ in Fig. 1(a) is an element in the national semiloop loss. How is the loss a′ — A — b′ affected in the three possibilities for loss addition described earlier?

To compare the three cases, we assume that the balance return loss BdB at exchange A is constant. Then the three losses to be compared are:

Method	Loss added	Fig.	Loss a′ — A — b′ (dB)
(a)	equally both ways	2b	B + 2X
(b)	in 2-wire receive path	3a	B + 2X
(c)	in 2-wire send path	3b	B + 2X

National semiloop loss is not affected by a choice between the three methods.

Noise

It may be assumed for this study that the absolute level of noise NdBm0 at the output of any of the carrier channels in Fig. 4 is the same for all channels. It may also be assumed that it is independent of small variations of signal level in the channels.

*Loss in the path a-t-b, as defined in C.C.I.T.T Rec. G.122.

The total noise received at either of the two-wire points in the connections illustrated in Fig. 4 is then sum of the noises attributable to the two carrier channels in tandem in the appropriate direction in the 4-wire path.

It can be shown (Appendix 1) that the arrangement of Fig. 4c (loss in receive path only; method (b)) produces an overall signal-to-noise ratio at the 2-wire points of the connection which is equal to or higher than that produced for the other arrangements, and equal to that provided by zero-loss circuits. Unlike the other arrangements, the signal-to-noise ratio is independent of the values of X and Y.

National Sending and Receiving Reference Equivalents

The method for providing the net loss of a 4-wire/2-wire circuit must also be chosen having regard to the requirements of C.C.I.T.T. Rec. G.121B (which specifies the maximum sending and receiving reference equivalents in a national network, referred to the international exchange) and the difference in sending and receiving reference equivalents of subscribers' local ends.

CONCLUSION

Six factors have been examined in respect of the planning of lossy 2w/4w circuits:—

1 — loading of carrier channels in terminal circuits
2 — loading of carrier channels in 2w/4w circuits
3 — loss differential in connections including 2w/4w circuits
4 — national semiloop losses
5 — noise
6 — national sending and receiving reference equivalents.

Of these factors, items 2, 5 and 6 were seen to be significant influences in determining a preferred method. On the first two of these criteria — loading of carrier channels in 2w/4w circuits and noise — there is an advantage in adopting a design which introduces all the required loss in the 2-wire receive direction. On information so far presented to the C.C.I.T.T., it seems likely that existing distributions of national reference equivalents (factor 6) are such that the sending limit is generally reached before the receiving limit. This is certainly true for Australia. This situation also favours the provision of 2w/4w net circuit loss entirely in the 2-wire receive direction.

REFERENCES

(1) Swedish Administration: C.C.I.T.T. SG.XII Dox. 21, March 1966.
(2) C.C.I.T.T. Study Group XVI, Geneva Nov./Dec. 1971: Temp. Doc. No. 14 (Draft note to be added to Rec. G.121-B).

APPENDIX 1

SIGNAL-TO-NOISE RATIO IN FIGS. 4a TO 4d

1. Introduction

The noise due to the carrier channel is taken as NdBm0 at the output of the carrier channel. Since this point has a relative level of R_c dBr, the absolute noise at each carrier channel output is $(N + R_c)$ dBm.

Taking the upper (left-to-right) path as illustrative of each arrangement in Fig. 4, we determine the noise level at the right-hand 2-wire point due to the combined effects of the noise contributions of the left-hand and right-hand carrier channels. At the 2w point each noise level $(N + R_c)$ dBm will be diminished by the loss between the carrier channel output and the 2-wire point; their sum N′ is the total noise.

The signal level may be characterised by the 2w-2w loss LdB of the connection. The signal-to-noise ratio is then proportional to -L-N′, the numerical value of which will be taken as a decibel-like indicator of signal-to-noise ratio.

Let the noise level at the right-hand 2w point due to the left-hand carrier channel = N_1 dBm and let N_2 dBm be the corresponding noise level due to the right-hand channel. Let their power sum correspond to N′ dBm.

2. Zero-loss circuits (Fig. 4a)

$N_1 = (N + R_c) - (R_c - S_s) - (S_s - S_c) - (S_c - R_c) - (R_c - S_p - 3.5) - 3.5$
$= N + S_p$
$N_2 = (N + R_c) - (R_c - S_p - 3.5) - 3.5$
$= N + S_p$
$N' = N_1 + N_2 = (N + S_p + 3)$dBm
$L = 0$

Then $S/N = (2) - (1)$
$= -(N + S_p + 3)$
$= -3 - (N + S_p)$ ... (1)

3. Loss X, Y, added equally in each direction (Fig. 4b)

$N_1 = (N + R_c) - (R_c - S_s + X) - (S_s - S_c) - (S_c - R_c) - (R_c - S_p + Y - 3.3) - 3.5$
$= N + S_p - X - Y$
$N_2 = (N + R_c) - (R_c - S_p + Y - 3.5) - 3.5$
$= N + S_p - Y$

The evaluation of $N_1 + N_2$ requires numbers to be assigned to X and Y. We will take four typical sets of values:

(a) $X = 1, Y = 2$
$N_1 = N + S_p - 3$
$N_2 = N + S_p - 2$
With 1 dB difference between N_1 and N_2, N′ is 2.5 dB above the higher power $N_2 : N' = (N + S_p + 0.5)$ dBm
$L = X + Y = 3$ dB
$S/N = -L - N'$
$= -3.5 - (N + S_p)$ dB ... (2)

(b) $X = 2, Y = 1$
$N_1 = N + S_p - 3$
$N_2 = N + S_p - 1$
With 2dB difference between N_1 and N_2 N′ is 2.1 dB above the higher power $N_2 : N' = (N + S_p + 1.1)$ dBm
$L = X + Y = 3$dB
$S/N = -L - N'$
$= -4.1 - (N + S_p)$ dB ... (3)

(c) $X = 0, Y = 3$
$N_1 = N + S_p - 3$
$N_2 = N + S_p - 3$
With equal power $N' = N + S_p$
$L = X + Y = 3$
$S/N = -L - N' = -3 - (N + S_p)$ ... (4)

(d) $X = 3, Y = 0$
$N_1 = N + S_p - 3$
$N_2 = N + S_p$
With 3 dB difference between N_1 and N_2, N′ is 1.76 dB above the higher power $N_2 : N' = N + S_p + 3$
$L = X + Y = 3$
$S/N = -L - N = -6 - (N + S_p)$ ... (5)

4. Loss X, Y, added in 2w receive direction only (Fig. 4c)

$N_1 = (N + R_c) - (R_c - S_c) - (S_s - S_c) - (S_c - R_c) - (R_c - S_p + 2Y - 3.5) - 3.5$
$= N + S_p - 2Y$
$N_2 = (N + R_c) - (R_c - S_p + 2Y - 3.5) - 3.5$
$= N + S_p - 2Y$
With $N_1 = N_2$,
$N' = (N + S_p - 2Y + 3)$ dBm
$L = 2Y$
$S/N = -L - N' = -3 - (N + S_p)$ ... (6)

This clearly holds for all values of X and Y.

5. Loss X, Y, added in 2w sending direction only

$N_1 = (N + R_c) - (R_c - S_s + 2X) - (S_s - S_c) - (S_c - R_c) - (R_c - S_p - 3.5) - 3.5$
$= N + S_p - 2X$
$N_2 = (N + R_c) - (R_c - S_p - 3.5) - 3.5$
$= N + S_p$
$L = 2X$

(a) $X = 1, Y = 2$
$N_1 = N + S_p - 2$
$N_2 = N + S_p$
With 2 dB difference, N′ is 2.11 dB higher than the higher component $N_2 : N' = (N + S_p + 2.11)$ dBm
$L = 2$
$S/N = -L - N' = -4.11 - (N + S_p)$ dB ... (7)

(b) $X = 2, Y = 1$
$N_1 = N + S_p - 4$
$N_2 = N + S_p$
With 4 dB difference, N′ is 1.45 dB higher than the higher component $N_2 : N' = (N + S_p + 1.45)$
$L = 4$
$S/N = -L - N' = -5.55 - (N + S_p)$ ... (8)

(c) $X = O, Y = 3$
$N_1 = N + S_p$
$N_2 = N + S_p$
$N' = N + S_p + 3$
$L = 0$
$S/N = -L - N' = -3 - (N + S_p)$ ... (9)

(d) $X = 3, Y = 0$
$N_1 = N + S_p - 6$
$N_2 = N + S_p$
With 6 dB difference, N′ is 0.98 dB higher than the higher component $N_2 : N' = N + S_p + 0.98$
$L = 6$
$S/N = -L - N' = -6.98 - (N + S_p)$ ... (10)

6. Summary

Since each of the expressions (1) to (10) is of the form $q - (N + S_p)$, the bracketed term being constant, we may take q as an indicator of signal-to-noise ratio in each case.

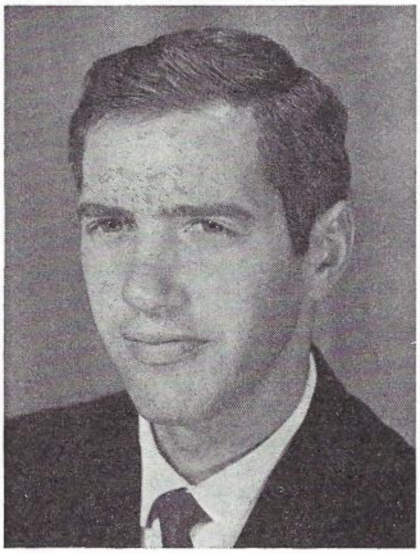
The table below collects the results for q in dB:

For comparison, the corresponding value of q for a zero-loss circuit (Fig. 4(a)) is −3dB.

It is clear that in all circumstances the signal-to-noise ratio on the connection of Fig. 4(c) is equal to or better than that provided by either of the methods of Figs. 4(b) and 4(d), regardless of the values of X and Y.

	X = 1 Y = 2	X = 2 Y = 1	X = 0 Y = 3	X = 3 Y = 0
Fig. 4(b) Loss in both directions	−3.5	−4.1	−3	−6
Fig. 4(c) Loss in 2w receive only	−3	−3	−3	−3
Fig. 4(d) Loss in 2w send only	−4.11	−5.55	−3	−6.98

NEW GENERAL SECRETARY



MR. N. G. ROSS

NEW GENERAL SECRETARY

The Council of Control has appointed Mr. N. G. Ross, B.E.E., to the position of General Secretary of the Society following the resignation of Mr. R. Kitchenn. Noel joined the Department in 1955 as a Cadet Engineer and completed the B.E.E. at the University of Melbourne in 1958, obtaining First Class Honours and the Dixson Scholarship. He is presently working in the Lines Branch of the Engineering Works Division at Headquarters and has contributed a number of articles to the Journal over recent years. The Society is confident that Noel will be a worthy successor for this important post.

MR. R. KITCHENN

THANK YOU RON KITCHENN

The Council of Control of the Telecommunication Society of Australia has regretfully accepted the resignation of the General Secretary, Mr. Ron Kitchenn. The evolution of the Journal to its present standard is due very largely to Mr. Kitchenn's work over the last 13 years. Ron was appointed Secretary of the Postal Electrical Society of Victoria in 1958, and it was mainly his initiative that led to the establishment of the present Telecommunication Society of Australia with its Council of Control and State Committees. As a result of this re-organisation, print orders rose from a level of 2,400 in 1958 to 6,600 in 1960/61. Ron was appointed to the new post of General Secretary of the Council of Control in 1959, which office he has retained up to the present. During his term of office, the Journal was placed on a sound financial footing, and it now has world-wide recognition. We say thank you to Ron Kitchenn for a job well done.

The Victorian State Committee has awarded Life Membership of the Society to Ron Kitchenn as a mark of appreciation of his contribution to the work of the Society.

TYPE-72 MULTIPLEXING EQUIPMENT FOR THE APO NETWORK (PART 1)

*R. J. SPITHILL, B.Sc.(Eng.), G. VAN BAALEN, B.Sc.(Eng.), and L. R. GREGORY, M.I.E.(Aust.)**

INTRODUCTION

The introduction of the A.P.O. Design Guide for Long Line Equipment (Ref. 1) setting out the special needs of the A.P.O., particularly in the realm of standardisation, has led to the development and production of a new range of equipment by Standard Telephones and Cables Pty. Limited (S.T.C.). This new range meets the requirements and embodies the philosophy of the Guide. For more than 30 years S.T.C. has been actively associated with the A.P.O. in local development of transmission equipment suitable for Australian conditions.

This article describes the new equipment and the techniques used to achieve optimum performance, consistent with the need to use components and circuitry of proven reliability. In many areas, adaptation and refinement of well established principles has resulted in developmental economies and contributed to an earlier realisation of the goals.

The article is in two parts. Part 1 of the article covers rack construction, channel translating equipment and channel carrier supply arrangements. Part 2 deals with group modems, group carrier supply and distribution, supergroup modems and carrier supply, automatic gain regulation, supergroup assembly equipment, master oscillator equipment, power supply and rack capacities.

The fundamentally important standardisation concepts of the Design Guide have been applied in the design to provide economies in installation, operation and maintenance.

In the realisation of an equipment design meeting the A.P.O. needs, the potentialities for export have not been overlooked, and in fact many of the A.P.O. requirements incorporated enhance the possibilities of sales in other areas.

CONSTRUCTION

The S.T.C. designed 72-type rack (Fig. 1) meeting the requirements of the Design Guide is a composite structure of steel and aluminium providing adequate strength with lightness. It weighs less than 50 kg (110 lbs); can be shipped knocked down, and only one man is needed for its assembly and raising to a vertical position. Where room to raise it from the horizontal is not available, it is possible to assemble the rack, from its few constitutent parts, in the vertical position.

Four levelling screws bear on an inverted tray in the base which protects the floor from damage and prevents the accumulation of dirt beneath the rack.

The previous CW97 rack system for subrack mounting, using spring-held loose nuts, fitted as required to rectangular holes in the rack uprights, has been retained because of its simplicity. The difficulty of inserting these nuts, and the protrusion of their springs onto the flat equipment-mounting surface, has been overcome by a better match of the material thickness in the

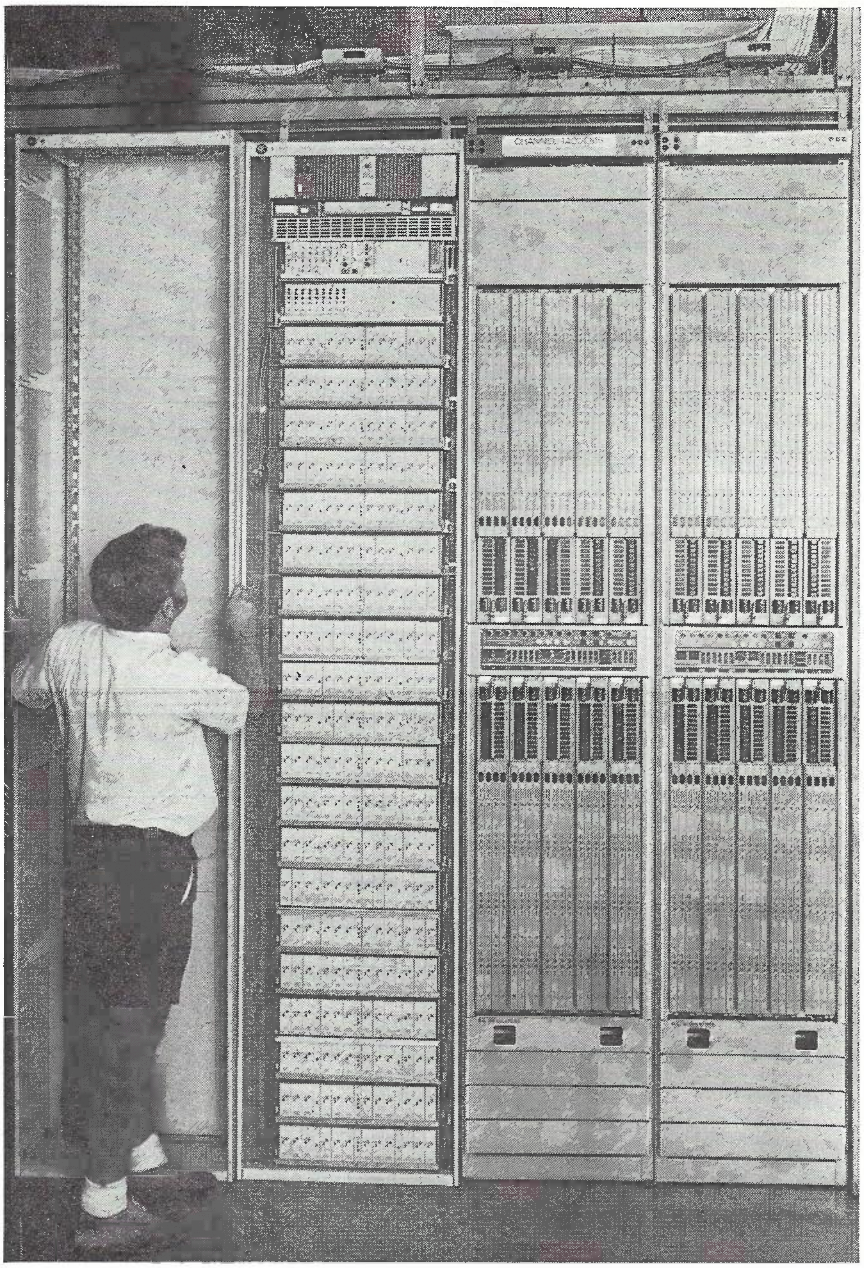


Fig. 1 — New 72-Type 240-Channel Modem Rack alongside Two Earlier 120-Channel Modem Racks. (Unequipped 72-type rack being placed in position.)

* Messrs. Spithill, van Baalen and Gregory are S.T.C. engineers engaged in the design and development of transmission equipment.

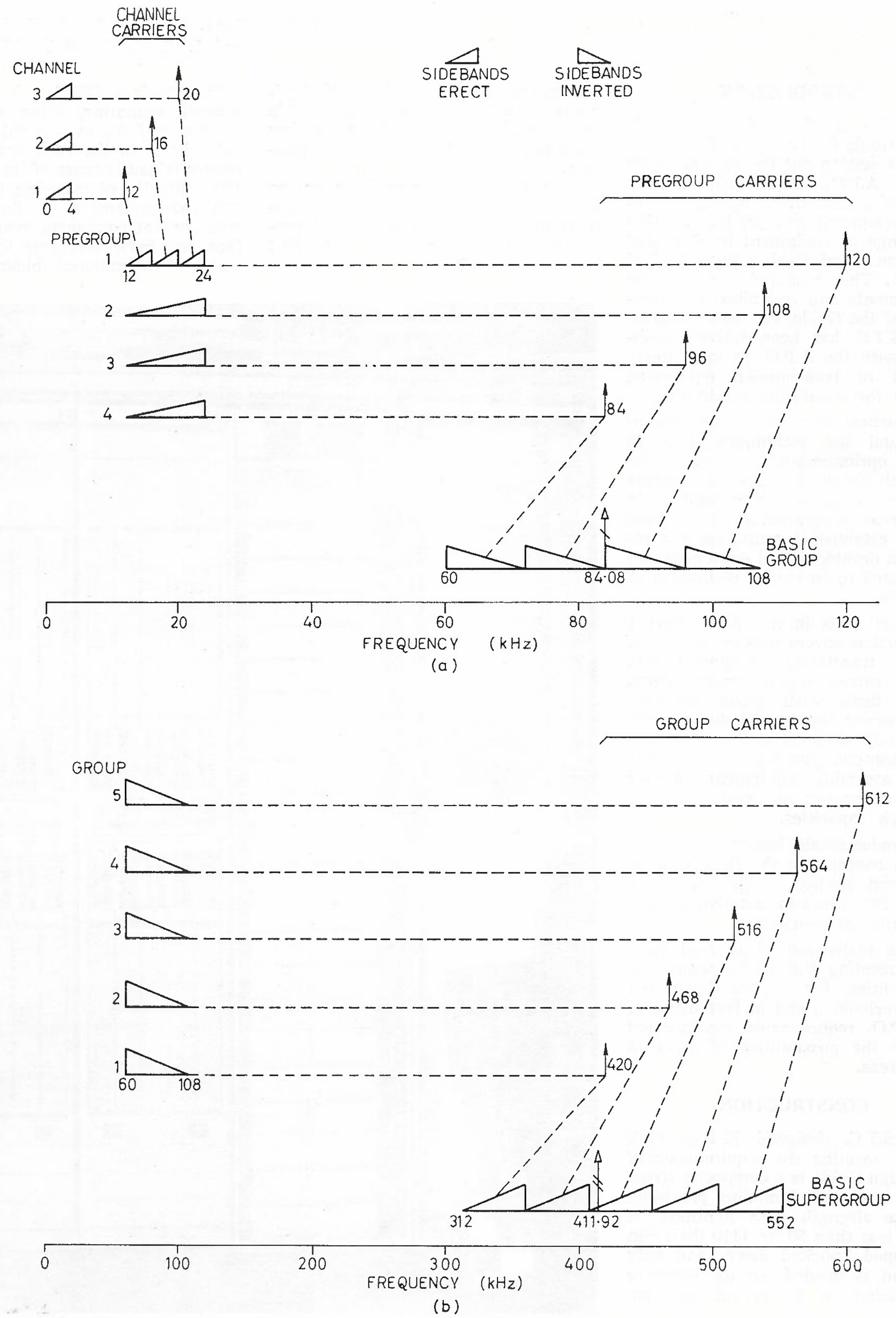
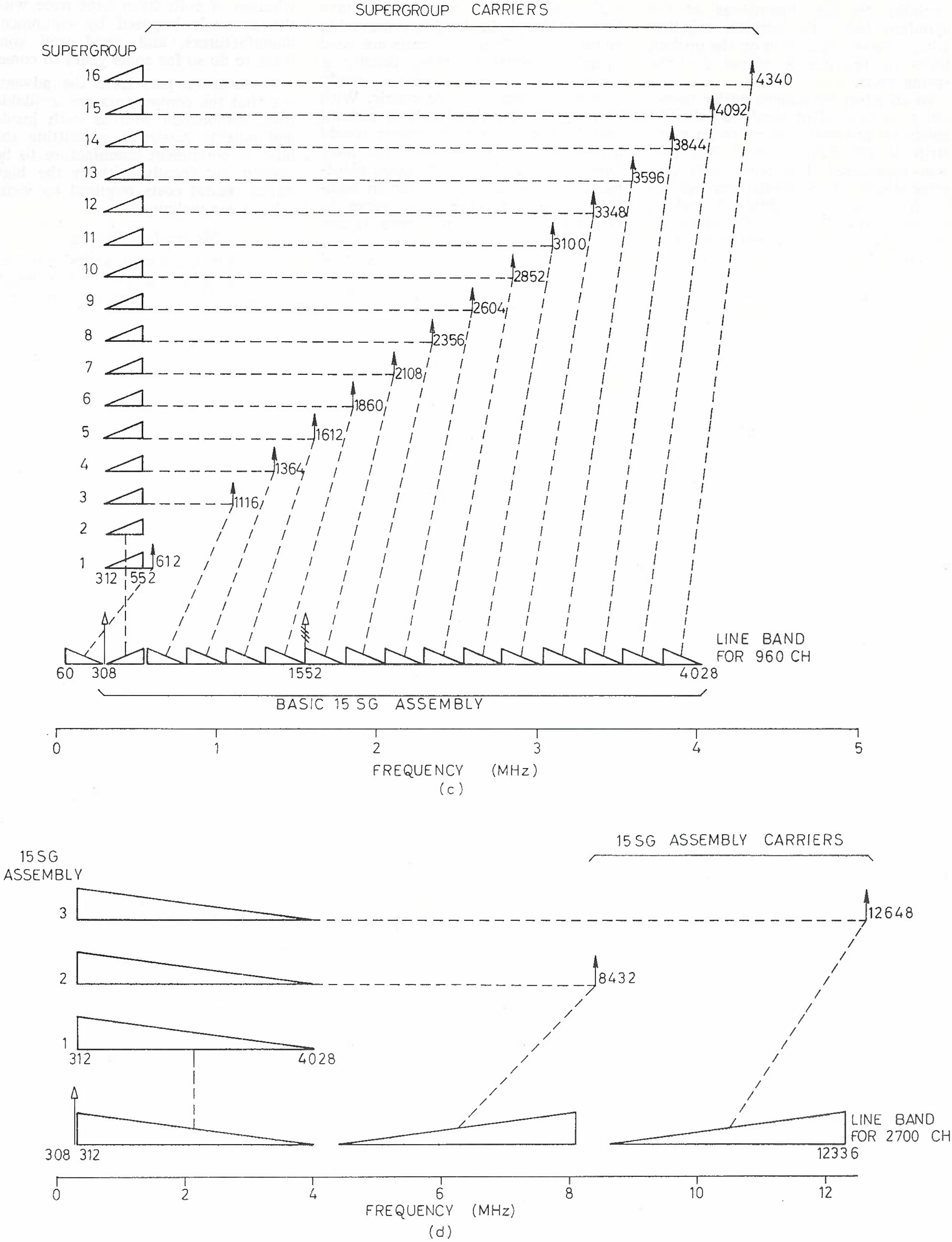


Fig. 2 — Modulation Plan for (a) Channel Modem Equipment, (b) Group Modem Equipment.



(c) Supergroup Modem Equipment, and (d) 15-SG Assembly Modem Equipment.

uprights to the dimensions of the standard Nut Grip springs, together with a tooling operation on the upright faces to produce a recess for the spring ends.

In an effort to achieve easier installation, a method of earthing subracks solely by physical contact to an earth strip at the subrack mounting face was considered. However, tests cast some doubt on the consistency of the earth connection so obtained, and on its long-term reliability. Therefore the usual practice of soldered earth connections is continued, but care has been taken to position the copper earth strips so they are readily accessible for soldering connections in the field.

These earth strips are attached along the length of the left and right-hand uprights by the rivets which hold the several components of the rack structure together at short intervals. This arrangement, being integral with the rack structure, is simpler than those used previously. The earth strips are continued without break over the top of the rack to a common rack earth bolt. A separate strip cross-connects the earth system at the base.

To exploit the wiring convenience possibilities of the side-cabled 72-type rack fully, a re-examination of the cabling techniques used with the largely back-cabled racks of the CW97 type was necessary. For some subracks, particularly those operating at the lower frequencies, the provision of a wire-wrap terminal array at the front left side of the subrack was the logical and effective answer. However, when a large number of coaxial cables needed terminating, these could not be terminated readily at the side of the subrack because of limited space. This problem has been overcome by sweeping these cables in from the side and across a terminating shelf provided on the top of the subrack to connection points conveniently arranged for front access.

Flat metal clips, taking up little cable space, have been provided in the station-cable duct on the left-hand side of the rack, to retain cables without the need for lacing.

The ease of installation and maintenance of the equipment is further assisted by the use of a service shelf which has been designed for ready attachment by quick-acting clamps at any point on the front of the rack.

Deflection tests have shown that a fully-equipped rack will support a further 136 kg (300 lb), applied at the top to simulate twice the normally allowed proportion of the weight of overhead cabling and superstructure to be borne by the rack.

Whenever necessary for electrical shielding or mechanical protection, individual printed circuit units have been enclosed in readily-removeable metal cases. When dual cards are used to achieve greater packing density, a hinged arrangement allows ready access for inspection or repair. With greater packing density it is natural that heat dissipation problems would arise. Many of these problems have been mitigated by the strategic placement of metal shields, which in addition to their nominal use, serve to conduct heat to areas where it can be safely dissipated.

ISEP* connectors, extensively used in large volumes of equipment to earlier designs supplied to the A.P.O., continue to meet economically stringent reliability requirements, and have been retained in the new equipment.

CHANNEL TRANSLATING EQUIPMENT

Design Considerations

The channel translating equipment is the basic building block of any multiplex system and constitutes the main portion of translating equipment in stations. It follows, therefore, that any economies which can be achieved in its manufacture, installation and maintenance, give rise to large savings when the total volume of this equipment is considered. The primary objective of the S.T.C. development was to incorporate in the new equipment all of the features required by the Design Guide, while still taking maximum advantage of the manufacturing cost savings now possible by the use of new techniques and components.

The ability to mount channelling equipment manufactured by different suppliers on the same rack was a fundamental requirement of the Design Guide, and from this requirement followed limits on dimensions, performance and power dissipation, each of which presented special problems to the designer.

Modulation Plan

The pregroup double-modulation scheme (Fig. 2a) with three channels and four pregroups as currently supplied by two Australian manufacturers (Ref. 2) was specified by the A.P.O. and adopted by S.T.C. for this equipment. Pregroup modulation is well proven by its use in Australia and many other countries in the world and continues to be an economical solution for channel translation using LC filters in the band 12-24 kHz. For some years now, improvements in the quality of ferrite materials and in the winding of coils have kept pace with the demands imposed by equipment manufacturers, and could well continue to do so for some years to come.

These techniques have the advantage that the components are available from established sources both inside and outside Australia, permitting the bulk of equipment manufacture to be carried out locally without the high initial capital costs required by some other filter techniques.

Mechanical Design

The A.P.O. adopted as its standard for channelling equipment a subrack height of 2½ rack units. This required a twofold increase in equipment density compared to that currently being manufactured, i.e., 240 channels per 9 ft rack instead of 120 channels. In the new S.T.C. equipment this is achieved by the use of a space-saving subrack which allows a much greater proportion of the subrack volume to be taken up by the components than in previous designs (Fig. 3). A feature of the subrack construction is the hinged rail at the lower front edge. This rail serves to lock the plug-in units in place when in its normal position, and is also used for designation of the plug-in unit positions.

The subrack is a factory-wired assembly and houses 15 plug-in units; these being 12 channel modems, 2 pregroup cards and one combining card. At the left-hand side of the subrack, a 108-pin wire-wrap terminal block is provided for termination of the V.F. and H.F. station cables which are brought down the left-hand duct of the 72-type rack. The terminal block is build up in modular fashion from interlocking 9-pin terminal straps which are moulded by S.T.C. in Sydney. The wire-wrap pin is 1.2 mm square and 19 mm long, allowing sufficient space for cable termination and also for bridging test access using a novel 6-pin socket developed by S.T.C.

Carrier distribution is by means of factory-wired plug-in links using the widely used ITT Cannon 'D' series connectors. Each channel modem and carrier supply subrack has a pair of connectors incorporated in a recessed position at the right hand side. These connectors are wired in parallel and also appropriately connected to the internal circuitry. Carrier links of fixed length are used to interconnect adjacent subracks, and one long link is used to complete the loop or ring main from the carrier supply at the top to the lowest group-end on the rack. Advantages of this arrangement are that it minimises on-site installation wiring, and permits any one modem subrack to be disconnected without

* International Standard Equipment Practice — designed and marketed by Companies of the ITT System.

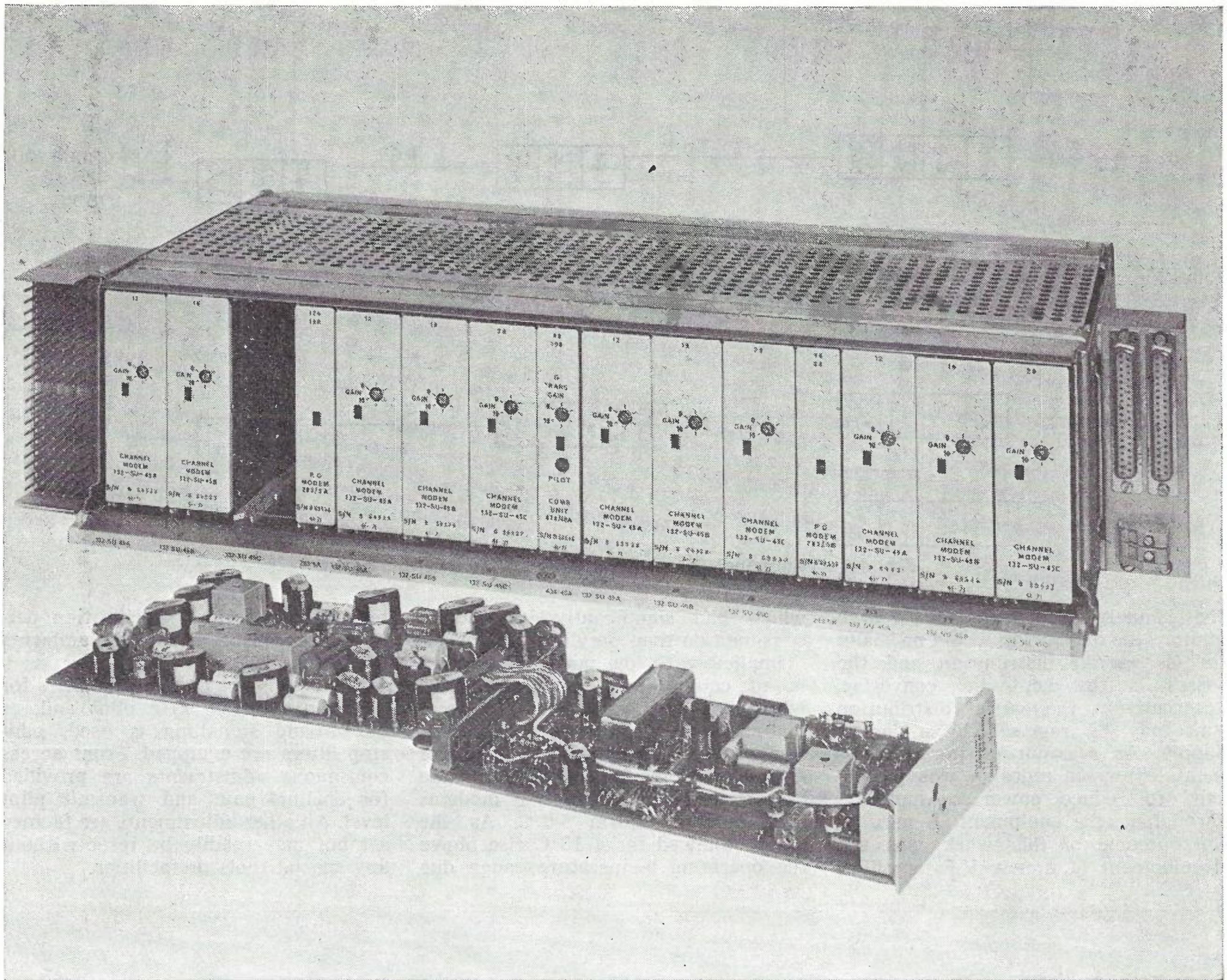


Fig. 3 — STC 72-Type Channel Modem Subrack with a Channel Modem Shown Withdrawn and Opened.

interruption to other subracks on the rack.

Power feeds to each subrack are individually fused and connect to screw-type terminals mounted below the carrier connectors at the right-hand side of the subrack.

Electrical Design

Fig. 4 shows the functional diagram of the channel modem equipment. An important concept of the Design Guide was that equipment should employ proven but up-to-date techniques and components. In addition, and of particular importance to manufacturers, multiple sources of supply should be available for all components. Accordingly, at an early stage in the development, substantial quantities of each new component were obtained from prospective suppliers and were subjected to intensive type testing prior to their inclusion in prototype units. Wherever possible components from Australian manufacturers were included in this exercise.

The channel filters use SM6 cores and high-stability sealed polystyrene capacitators. Active balanced modulators of the amplifier type are used throughout and to improve their stability, dual silicon transistors have been chosen, thus providing a high degree of matching between transistors. As only low carrier power is needed to drive modulators of this type, the carrier power has been substantially reduced compared with that required by diode modulators. A further advantage is derived from the inherent amplification, which permits a higher minimum relative level without the need for additional amplifiers. This is turn allows a lower basic noise figure to be achieved and contributes to the low power consumption of the equipment.

The Design Guide specifies that the E-lead switching device should have a minimum life of 10^8 maintenance free operations at a line current of 60mA into an inductive load. It is also required to withstand a 200V transient due to back e.m.f. and have a maximum period of contact bounce of 0.5 mS. Based on previous experience and after an examination of available devices both mechanical and solid state, it was considered that the mercury-wetted relay is still the most economical and reliable means of performing this function. It exhibits virtually zero contact bounce, has a large current interruption capacity and its use should extend the maintenance-free life of the equipment.

Conscious of the problems which can arise in large stations due to power dissipation and in small stations in remote areas due to high ambient temperatures, the A.P.O. set a target of 150 watts maximum dissipation for a fully-equipped rack. This is normally very difficult to meet in the case of

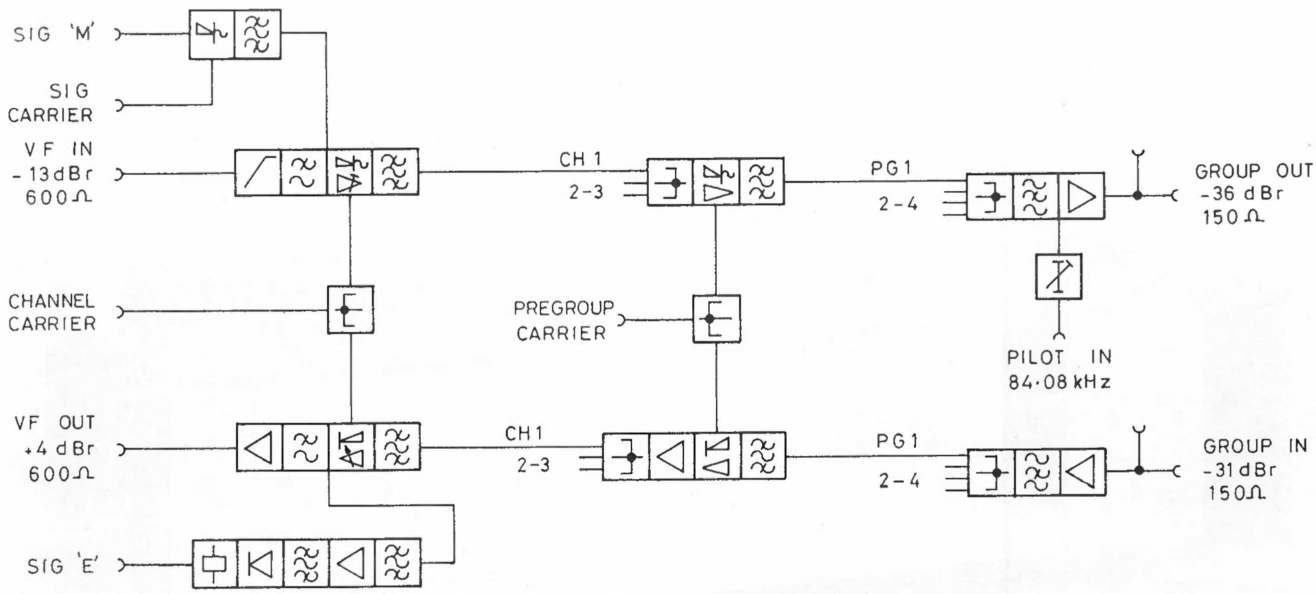


Fig. 4 — Functional Diagram of Channel Modem Equipment.

the channel modem rack, and in large stations the dissipation would normally include carrier distribution and the losses in the d.c.-to-d.c. converter. Alternatively, the carrier distribution unit may be replaced by a carrier supply. As a result of this requirement, extensive redesign was performed to reduce power consumption throughout the equipment. A particular outcome of this work was the development of a new V.F. amplifier which had significantly less power consumption than previous designs.

Implicit with low power dissipation is, of course, low temperature rise which has been established to be a feature of this equipment. Tests carried out on a fully-equipped rack of channel modems have shown that the temperature rise within the modems is a fairly uniform 5-6°C. As the design allowed for a 15°C rise above the operating temperature range due to rack dissipation, specification performance will be obtained in ambients exceeding 55°C.

The equipment includes facilities for injection of 84.08 kHz pilot and, as out-of-band signalling is used, pilot stop filters are equipped. Front access continuous adjustments are provided for channel gain and transmit pilot level. All other adjustments are factory set but may readily be reset without any special tools or facilities.

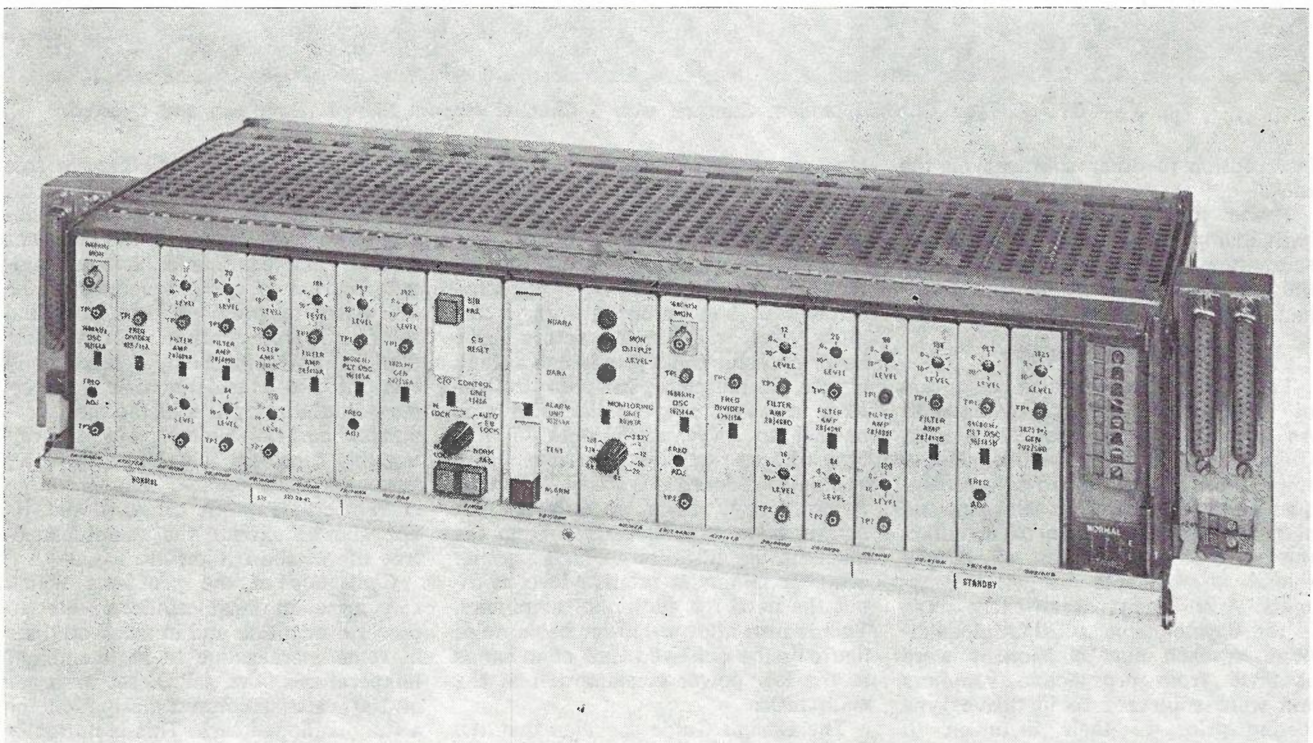


Fig. 5 — STC 72-Type Duplicated Channel Carrier Supply.

CHANNEL CARRIER SUPPLY

Design Considerations

Two types of carrier supply subrack were referred to in the Design Guide. They were:

(a) an amplifier subrack which would accept inputs of the carrier, signalling and pilot frequencies and would have sufficient capacity to drive a rack of channel modems, and

(b) a generation subrack which would generate the required frequencies and would drive either the amplifier subracks in (a) above or channel modems. Initially manufacturers were allowed a considerable degree of flexibility in deciding on the arrangement of and facilities provided in these units.

In designing equipment to meet these needs, it was noted that the requirements for carrier supplies varied widely from station to station depending on the number of channels, possible future development, availability of synchronising frequencies and security of service required. From an economic viewpoint, it is of course undesirable to provide any more facilities than are necessary in any station.

Carrier Generation Subrack

The standard subrack height adopted for the channel modems of 2½ rack units was also applied to the carrier generation subrack (Fig. 5).

Using this height, two basic subrack types were designed allowing for fully duplicated or non-duplicated supplies. These subracks are of the same mechanical construction as the channel modem subrack and differ from each other only in the number of card positions equipped. These subracks are designed for direct connection to either channel modems or distribution amplifier subracks and are fitted with ITT Cannon connectors as described for the channel modems.

A functional diagram of the equipment is shown in Fig. 6. The frequencies generated are the channel carriers 12, 16 and 20 kHz; the pregroup carriers 84, 96, 108 and 120 kHz; the signalling carrier 3825 Hz and the group reference pilot 84.08 kHz. With the exception of the group reference pilot, all frequencies are derived from a single high-frequency crystal oscillator by a process of division and modulation using integrated circuits.

By careful choice of oscillator frequency and divider chain, a minimum number of components is required in the generation and filtering circuitry, permitting a fully duplicated supply to be obtained in one half the volume previously taken for a non-duplicated supply, i.e., a four-to-one reduction in size.

The high-frequency crystal oscillator from which the carriers are derived is available in two forms as follows:

(a) As an independent crystal oscillator giving a frequency stability of one part in 10^6 per three months over the ambient temperature range of 0°C to 50°C.

(b) As a phase-locked crystal oscillator operating with the frequency stability of the master 4-kHz signal and with automatic adjustment to cater for at least 15 years of crystal ageing. On failure of the master 4-kHz signal, the supply continues to operate with an operational frequency stability of 1 part in 10^5.

Neither of these oscillators requires a crystal oven and this contributes to the low overall power consumption of this equipment. A fully duplicated supply with automatic changeover dissipates less than 20 W from a 24-V d.c. supply.

As all 72-type channel carrier supply subracks are wired for inputs of the 4-kHz synchronising frequency, the mode of operation may be changed at any time by merely changing one plug-in card.

Automatic monitoring facilities are provided which will give rise to an alarm in the event of any failure which would affect the performance of the modem equipment, and in the case of the duplicated supply, automatic changeover of all frequencies to standby working would occur.

The capacity of the supply is such that one rack of channel modems (240 channels) can be supplied directly

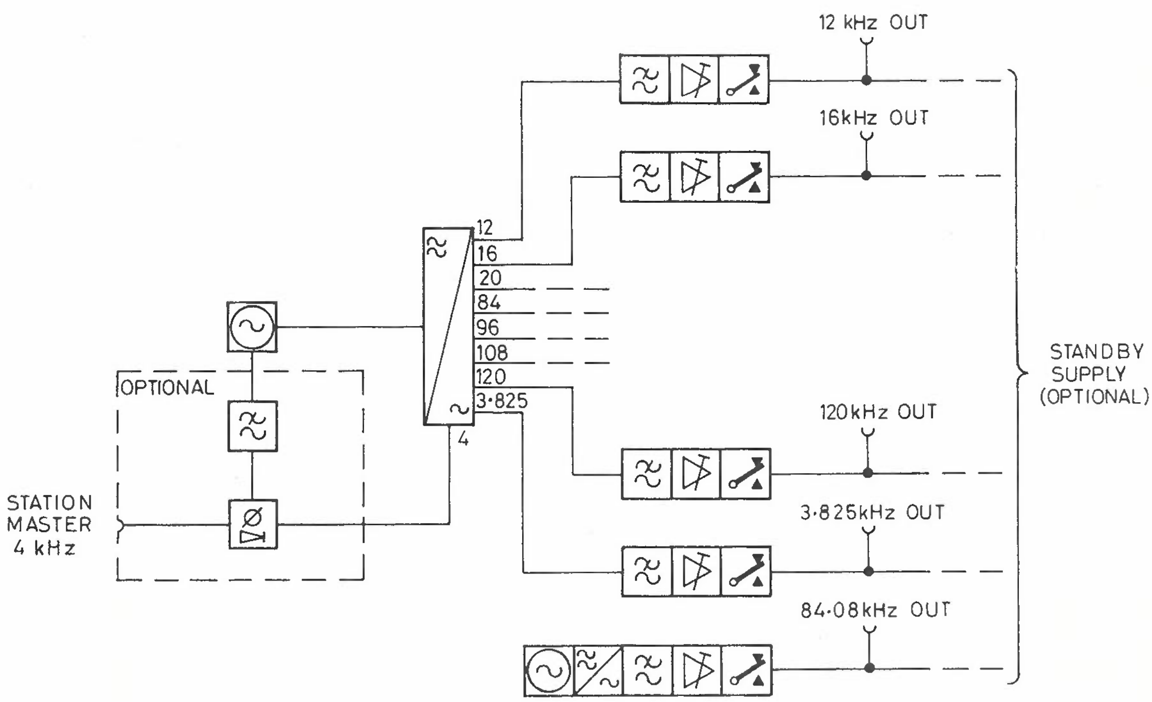


Fig. 6 — Functional Diagram of 72-Type Channel Carrier Supply.

under normal conditions or two full racks can be supplied under emergency conditions. Alternatively, by the addition of an amplifier subrack on each rack, 10 racks of channel modems (2400 channels) may be operated from a single supply. All connections between carrier supplies, amplifier subracks and modems are made with factory-wired plug-in cords thus reducing the time taken to distribute carriers in a station to a fraction of that previously required.

Therefore, as a result of the inherent flexibility of this equipment all of the varying requirements mentioned in the design considerations can be readily met. By choice of the appropriate subrack, plug-in units, and distribution arrangement, it is possible to have any combination of duplicated or non-duplicated, phase-locked or independent, centralised or decentralised operation utilizing largely the same basic set of cards.

Carrier Distribution Subrack

The carrier distribution subrack contains 9 buffer amplifiers for distribution of the 9 frequencies required by the channel modem equipment. The amplifiers are required to have a high input and a low output impedance, unity voltage gain with adjustment to take account of level variations, and should not have any significant effect on the purity of supplies to the modems. The objective of this development was to design a single amplifier which could be used for all frequencies from 3825 Hz to 120 kHz, including the 84.08 kHz pilot where a harmonic distortion limit of 35 dB is desirable. This has now been achieved and the basic design of the three-transistor amplifier has found a wide usage in other equipment.

Its output impedance is less than 1 ohm, its maximum gain deviation with frequency is 0.1 dB (3825 Hz to 120 kHz) and individual harmonics are suppressed by a minimum of 40 dB. The maximum gain variation over the temperature range 0°C to 65°C is 0.05 dB. The total power consumption of nine such amplifiers is 1.3W when supplying a full rack load of 240 channels. Under emergency conditions, 480 channels may be supplied.

When the 72-type carrier supplies and distribution amplifiers described in this article are used together, the overall level stability is such that the requirements of the modem equipment are met. However, in some locations it may be desirable to use existing carrier supplies, and to cater for this possibility, a stabilising amplifier which is interchangeable with the standard amplifier has been developed. This unit stabilises the output level to within ±0.025V for input level variations of from 0.5V to 1.5V over the ambient temperature range of 0°C to 65°C. Its performance is comparable in other respects to the linear amplifier and it can be used to stabilise supplies of the group reference pilot, signalling carrier, or if desired, all frequencies for the channel modems.

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1. A.P.O., 'Design Guide for Long Line Equipment', Issue 2, Feb. 1970.

2. C. E. Smith and N. P. Ferstat, 'New 12-Channel Multiplexing Equipment'; Telecom. Journal of Aust., February 1967. Vol. 17, No. 1, pp. 28-41.

TECHNICAL NEWS ITEM

MAJOR INTERNATIONAL AWARD TO AUSTRALIAN POST OFFICE

An entry by Arnold Holderness, MIE (Aust.), of the Australian Post Office, won $500 first prize in the international Lead Power 71 competitions judged in Hamburg, Germany. The award was presented in Melbourne on November 22 by Mr. J. B. Shackell, Chairman of Australian Lead Development Association, one of the fifteen world wide development groups which organised the Lead Power 71 programme.

The award was made for development by the Post Office of an unattended, uninterruptible power supply for remote areas, using lead batteries and wind driven generators. The power supply is used in the 1427 mile long East-West microwave link between Northam, Western Australia and Port Pirie, South Australia.

Fifty eight microwave repeater stations and two terminals make up the communications link. Forty three of the repeater stations operate automatically in remote desert areas. The unattended stations are without mains power and rely principally on wind driven generators and lead storage batteries with diesel back-up for extended windless periods. Batteries provide a 24 hour reserve.

Power requirements of the complex electronic repeater equipment demand an uninterruptible DC power supply. Due to isolated locations and unattended operation, each installation must provide extremely high reliability in maintenance of telecommunications service, with minimum attention.

The "no-break" power system based on lead batteries and wind driven generators was selected after examination of thermo-generators, solar cells and fuel cells. Installed cost of the lead battery based system is low and the design provides for future growth. Meeting these requirements over such a long link in isolated desert areas is among the most rigorous requirements yet called for in a telecommunication power plant system.

The system is suitable for all remote applications including aviation beacons, weather stations, country telephone exchanges or remote monitoring stations where uninterruptible DC power from 50 to 1500 watts is required and normal mains supply is not available. Installation and automatic operation of the link is a major electronics/engineering feat.

TECHNICAL NEWS ITEM

RADIO AUSTRALIA, N.T. — ANTENNA "PLUME" DETECTION

The present Radio Australia Booster Station installation consists of three 250 kW H.F. transmitters and five vertical log-periodic antennae. When these antennae are operated at full power, certain environmental conditions can, at times, initiate "corona" discharges from the radiating dipole elements.

These corona discharges, also referred to as "plumes" or "flares", if allowed to persist can damage the antennae by melting sections of the dipoles, and are being investigated by the A.P.O. Research Laboratories.

The quickest solution to this problem, and one that did not interfere with the scheduled operation of the station, appeared to lie in the detection and extinction of such discharges until means could be found to eliminate their occurrence. Prior to the installation of the corona detection system to be described, the station staff relied on a discharge indicating system (disabling of squelch in a 160 MHz mobile receiver by radiation from the discharges) which did not always respond to the discharges and could not be adapted to indicate from which particular antenna they were taking place.

Thus even when the station staff was aware that a discharge was taking place, the discharge could not be extinguished until its location was visually determined. Owing to the relative locations of the transmitter control room and the antennae, a considerable time elapsed before this could be done. Furthermore, the plumes were not always readily visible in the day time, and consequently at times they persisted for long enough to damage the antennae.

Previous experience with short range detection of indoor radio frequency arcs with ultra-violet radiation of the plumes could be accomtion of the plumes could be accomplished with similar devices.

At the same time various other detection methods were investigated, some of which are still under active consideration. The ultra-violet radiation detection system however appeared to the most promising, simplest and quickest to implement, and thus to minimise the risk of antennae damage it was decided to install this system as soon as possible.

Owing to the time delays involved in importing the required components, finalising the design and constructing the proposed system, it was decided to install a temporary detection system using the available ultraviolet sensors. The sensors used have a spectral response in the 190 nm to 290 nm wavelength range which renders them insensitive to natural ambient radiation. The intensity of radiation in this range from a plume however, which is mostly due to the ionised and excited electrode (copper) vapour present in the plumes, is high enough to make them extremely sensitive to such discharges. The two available detectors were found to be sensitive enough to be used at distances from which all five antennae and most of the transmission lines were in their view.

The viewing arrangement for the two detectors and the mode of antenna use at any one time enables this detection system to indicate from which particular antenna the discharge is taking place.

The detection system is combined with the transmitter urgent alarm system, and eventually will be linked up with the transmitter control computer.

The computer will then be programmed to interrupt temporarily the r.f. power fed to the discharging antenna thus extinguishing the discharge, and to record the occurrence of the discharge, the particular transmitter and antenna involved, time of occurrence and other data of interest on the transmitter fault log.

The time from the occurrence of the discharge to the r.f. power interruption will be too short (of the order of milliseconds) to allow the discharge to cause any damage and the power interruption period (under one second) too short to produce objectionable interruption to the transmitted programme.

Although the installed system achieved its purpose of relieving the station staff of the task of searching for discharge locations, thus permitting almost risk-free operation of the station at full power, the system has a number of undesirable features, and its use will be restricted to the shortest term possible. Some of these are as follows:

(i) The system is not "fail-safe".

(ii) Certain components in the detectors are not highly reliable.

(iii) Not all locations from which discharges can take place are covered by the two detectors, namely parts of some transmission lines and the antenna switching network located in a hut.

(iv) Owing to the large distances from which the discharges are detected (between 800 and 1,600 ft.) the sensitivity of the detectors could be impaired by very dense fog or heavy rain.

(v) The use of only two detectors restricts the flexibility of antenna use.

(vi) Due to the location of the sensors, precautions have to be taken when using welding equipment around the site if false triggering is to be avoided.

(vii) Occasional triggering by lightning discharges is anticipated.

None of the above problems will exist in the proposed eventual ultraviolet detection system which, however, will take some time to design, develop and construct. In the meantime, in view of (iii), (iv) and (v), nine additional sensors will be installed in the interim system before it is replaced late in 1972. A description of the eventual plume detection system will be published at a later date.

MANAGEMENT OF THE RADIO-FREQUENCY SPECTRUM IN AUSTRALIA

*H. MELLING**

INTRODUCTION

History

Before 1895, scientists had predicted, and indeed proved, the existence of electromagnetic waves. However, in that year Guglielmo Marconi, while experimenting on his father's estate at Pontecchio, Italy, discovered that the combination of an elevated aerial and an earth connection removed the limitations hitherto restricting transmission and reception of these waves over distance, thus opening up a new field of development.

The sequence of discoveries would appear to be:—

(1) Maxwell and Crookes promulgated the theory of electrical oscillations;
(2) Hertz produced these oscillations and defined their characteristics;
(3) Lodge and Popoff devised apparatus which was limited to local experiment; and
(4) Marconi discovered the means by which electric waves could be transmitted over distance, and later improved upon apparatus originated by Lodge and others.

In Russia, the claim has been made that the eminent Russian Popoff was the inventor of wireless. However, many courts of law and other qualified authorities have supported Marconi's claim.

In 1896, in order to gain official recognition of his work, Marconi travelled to England, where he found a friend in Mr. (later Sir) William Preece (Engineer-in-Chief of the British Post Office). The first official demonstration of wireless telegraphy was at Salisbury Plain, England, in 1896, over a distance of $1\frac{1}{2}$ miles. On the 20th July, 1897, Marconi founded the Wireless Telegraph and Signal Company (which was later renamed the Marconi Wireless Telegraph Company), and the history of the radio industry began.

It is interesting to note that as early as 1896 Australia was to the fore in wireless experimentation. The Chief Electrical Engineer of the Victorian Postal Department (a Mr. H. W. Jenvey) played an important role in the early developmental work. Professor W. Bragg gave a lecture (entitled 'Telegraphy without Wires'), at the Adelaide University on 21st September, 1897. During the visit of the Duke and Duchess of Cornwall and York in the vessel R.M.S. 'Ophir' in 1901, the naval escort vessels H.M. Ships 'St. George' and 'Juno' established the first marine wireless communication in Australia, with shore stations at Queenscliffe lighthouse (Victoria) in May, 1901, and at Longbeach Lightstation, Sandy Bay (Tasmania) in July 1901.

The initial step towards inaugurating wireless telegraphy as an official communication medium in Australia was taken with the passing of the Wireless Telegraphy Act in 1905. The first fixed land station was licensed by the Post Office on 7th June, 1906. Located at East Devonport, Tasmania, it was owned by the Marconi Wireless Telegraph Company, and was used to communicate with a similar station later established at Point Lonsdale, Victoria. On 12th July, 1906, when both stations were fully operational, the Governor-General of the period sent what is believed to be the first Australian official wireless telegram to the Governor of Tasmania:—

> "The Commonwealth greets Tasmania and rejoices at the establishment of new means for knitting the people of Australia more closely together—Northcote."

The Measure of Progress

In recent years, radio-communication techniques have played a vital role in man's first ventures into space.

The most sanguine of the early developers could hardly have hoped that within 73 years the new medium would advance from its first public demonstration over a distance of $1\frac{1}{2}$ miles in 1896 to voice (and also video) communication between the earth and the moon in 1969; neither could they have envisaged that the radio environment within the same span of years would encompass such activities as television, which makes extensive use of radio techniques, and radio astronomy, by means of which modern scientists are probing the uttermost secrets of space.

International Control

At the first international Wireless Conference held in Berlin in 1903, arrangements were made for the 1906 Conference (also in Berlin), at which the representatives of 29 countries initiated international management of the medium.

Controls agreed to at subsequent conferences became progressively more stringent, in order to ensure interference-free operation of the multiplicity of radio stations, systems and services which were making rapidly increasing use of the radio-frequency spectrum.

Brief comments relating to the various conferences are shown hereunder:—

Conference	Year	Comments
Berlin	1903	Preliminary Radio Conference.
Berlin	1906	The first two frequency allocations made (viz. 500 kHz and 1000 kHz) for use in the maritime service. 29 countries represented.
London	1912	The sinking of the British liner "Titanic" two months before this conference alerted participating countries and stringent "Safety-of-life-at Sea" Radio Regulations were introduced.
Washington D.C.	1927	Frequencies covering the range 10 kHz to 23 MHz were allocated catering for operations in the fixed, mobile, broadcasting and amateur radio services.
Madrid	1932	A table of transmission frequency and instability tolerances was introduced. Television bandwidths were determined having due regard to the state of technical development.
Cairo	1938	The table of frequency allocations was extended to 200 MHz.
Atlantic City	1947	This conference had to cope with the requirements of 76 countries and improved radio-communication technology brought about by the 1939-45 world war. The frequency allocation table was extended to 10.5 GHz.
Geneva	1959	The upper limit of the frequency allocation table was extended to 40 GHz.

*Mr. Melling is Superintendent, Radio Regulatory and Licensing, Regional Operations, Tasmania.

Geneva	1963	Frequency allocations, for Space radio - communication purposes, were determined.
Geneva	1966	The Aeronautical Mobile (R) Service frequency assignment plan was dealt with.
Geneva	1967	Affairs relating to the Maritime Service received attention.
Geneva	1971	Matters relating to space communication were dealt with.

In 1968, the International Radio Regulations were revised and published.

RADIO-FREQUENCY SPECTRUM ADMINISTRATION

National Control

In 1905, the Commonwealth Government passed legislation under the title of the "Wireless Telegraphy Act" which gave to the Postmaster-General (a Cabinet Minister) the exclusive right to control all manner of wireless telegraphy (and later wireless telephony) communications throughout Australia. However, the Act permitted the granting of licences for the establishment of wireless stations, subject to certain prescribed conditions. The Wireless Telegraphy Regulations made under the Act are applicable in full to all civil radiocommunication stations, and in part to those under the control of the Defence Forces.

The Postmaster-General has delegated Authority to officers of the Radio Branch (Regulatory and Licensing), Engineering Division, to enable them to administer the provisions of the Wireless Telegraphy Act, which, with its associated Regulations, is the cornerstone of the radio-communication environment in Australia.

Penal Provisions of the Wireless Telegraphy Act

Section 6 of the Act makes it a Commonwealth offence for any person to establish, erect, maintain or use radio-communication equipment without the permission of the Department. The penalty prescribed by the Act is:—

(i) a fine of $1,000; or
(ii) imprisonment with or without hard labour for a term not exceeding five years.

Section 7 of the Act provides that all appliances established in contravention of the Act shall be forfeited to the Queen for the use of the Commonwealth.

Search Warrants, obtainable from a Justice of the Peace, upon oath, may be used to assist the detection of illicit apparatus. Such warrants authorise the person to whom they are addressed to break and enter any place ship or aircraft where the appliance is supposed to be, either by day or by night—using force if necessary—to seize the apparatus.

Whilst the enforcing of the penal provisions of the Act is an unpleasant function, the Department is mindful of its obligations to the community. Inspecting officers are well rehearsed in the value of maintaining good relations with the public and their duties are performed in such a way as to protect the Department from any suggestion of injustice or harshness.

Rational use of the Radio-frequency Spectrum

A major problem confronting all radio regulatory authorities throughout the world is the rational use of the radio-frequency spectrum. Despite scientific improvements in the state of the art, certain segments of the spectrum are reaching saturation, and it is becoming increasingly difficult to accommodate additional services.

The radio-frequency spectrum is an international and national resource, and is available to all mankind. This resource, however, is different from other natural resources in that it is used and not consumed, and it is actually being wasted when its full potential is not being exploited.

Nations must co-operate with each other if maximum use is to be made of the radio-frequency spectrum. National plans can be developed only within a frame-work of international agreement, and this is one of the reasons why Australia participates in the International Telecommunications Union in general and the World Administrative Radio Conference in particular.

RADIO STATIONS, SYSTEMS AND SERVICES

The Various Categories

The types of radio stations, systems and services which are in use throughout the world are detailed in the International Radio Regulations (edition of 1968), Chapter I, Section II, page RRI-3 and include the following:—

Stations	Systems	Services
Fixed	Radio-determination	Fixed
Mobile	Radio-navigation	Land/Mobile
Radio-telemetry	Radio-location	Maritime/Mobile
Broadcasting	Radar	Aeronautical/Mobile
Base	Marker Beacon	Amateur Radio
Aircraft	Radio-altimeter	Meteorological Aid
Coast	Radio-direction finding	Standard Frequency
Ship	Radio Beacon	Time Signal
Survival Craft	Radio Astronomy	Special
Satellite Space	Radiosonde	Safety
Amateur	Instrument landing	

Increased Use of Land Mobile Services

In recent years, the land mobile service, which operates mainly in the V.H.F. segment of the spectrum, has experienced particularly rapid growth. These stations are used extensively by a diversity of undertakings, such as Government authorities, public utilities, industry, commerce, transport and mining. Some of these organisations are major contributors to the economic and social structure of the nation, and the use of radio-telephone facilities substantially increases their flexibility and efficiency.

Radiocommunication Stations Authorised in Australia

On the 18th October, 1905, the Commonwealth Parliament received Royal Assent to the Wireless Telegraphy Act.

The growth rate from that date is as follows:—

Year	No. of stations
*1906	2
*1910	30
1925	140
1935	267
1945	11,077
1955	12,714
1965	71,652
1970	135,868
1971	150,797

*Note: Records prior to 1925 are not clear.

The diversity of functions involved in radio-frequency spectrum management is exemplified in the following list:—

- Licensing
- Station Inspections
- Equipment Standards and Type-Testing
- Frequency Assignments
- Radio Monitoring
- Frequency Measuring
- Examinations for Certificates of Proficiency, Radio Television and Radiocommunication
- Interference Investigations
- Marine Radio Surveys and Inspections.

Frequency Assignments

The registration and licensing of all classes of Radio stations is an essential part of radio frequency spectrum management. Such a record requires a Master Frequency List in which certain basic data associated with each frequency assignment is compiled. Such information includes the name of the station, geographical location, the transmitter power and the nature of the service.

In Australia the Master Frequency List is compiled and published by the Australian Post Office and printed by computer process.

All frequency assignments are notified to the International Frequency Registration Board at Geneva in accordance with the requirements of Article 9 of the International Radio Regulations.

Frequency Assigning is divided into two parts, namely:—

(i) 10 kHz to 30 MHz, and
(ii) 30 MHz and above.

Frequency Assigning is a complex process, and it can take days — or even weeks — to determine a suitable frequency for a particular location. At the present time the lowest frequency in use in Australia is 10.68 kHz whilst the highest is 35.1 GHz.

Considering Assignments up to and including 30 MHz: Because of the vastness of the continent of Australia, and its isolation from other countries, a heavy demand exists for high-frequency radio-communication channels to cater for internal and international communication facilities. Indeed, the largest high-frequency radio-communication network in the world is the one maintained and operated by the Royal Flying Doctor Service, which exchanges medical, aviation, public correspondence and "School-of-the-Air" communications for people resident in remote areas.

The cardinal principle adopted by the Department on matters associated with frequency assigning is the conservation of the radio-frequency spectrum, together with the orderly development of the services.

As high-frequency radio signals cannot be contained within the borders of the country, there can exist a serious interference problem for users elsewhere in the world. For this reason, high-frequency allocations are not made in cases where communication requirements can be met by other means. Close liaison is maintained with neighbouring countries and the International Frequency Registration Board concerning the technical characteristics of the various proposed services, namely:—

Class of emission
Bandwidth
Power of transmitter
Projected signal path and propagation characteristics
Ratios of wanted to unwanted signals at the various terminals of the proposed service
Hours of operation.

Considering Assignments above 30 MHz: Again, conservation of frequencies is essential, more particularly in that part of the spectrum set aside for land and harbour mobile services, which are undoubtedly the greatest users in the V.H.F. region. Much time and effort is devoted by the frequency assigning staff to this part of the spectrum — generally single-frequency simplex networks are authorised. Base stations are restricted to a maximum power output of 50 watts, together with a ground-plane aerial gain of 2.2 decibels when compared with an isotropic radiator. This allows the user to employ a base station which is capable of radiating an effective radiated power of 83 watts.

Because of the heavy demand, it has been found necessary to share specific channels, and up to six organisations (more in certain cases) can be required to share — saturation loading is 100 mobiles per channel.

Technical considerations such as intermodulation (first, second and third order), shock excitation, blasting, harmonic radiation, etc., receive detailed attention in order to ensure interference-free operation by all stations.

RADIO MONITORING

Radio monitoring stations are located at all capital cities, and mobile stations are used to permit observations of the radio-frequency spectrum in areas remote from the main monitoring centres.

The purpose of these stations is to:—

(a) ensure compliance of all radio stations in Australia with the equipment and operating conditions which are enforced by the Commonwealth Wireless Telegraphy Act;
(b) ascertain whether any illegal use is being made of radio facilities;
(c) analyse interference to Australian radio stations from national and international sources;
(d) determine channel occupancy;
(e) observe 'off frequency' operation;
(f) give 'on-the-air' warning to licensees found to be transgressing;
(g) assist users of radio-communication facilities where problems are encountered;
(h) perform special investigations as required;
(i) conduct traffic surveillances of all categories of stations; and
(j) observe the quality of emissions from stations, having due regard to
  (i) authorised bandwidth requirements,
  (ii) freedom from spurious radiation, and
  (iii) conformity with acceptable modulation standards.

Participation in the International Monitoring Programme

As previously mentioned, high-frequency radio signals cannot be confined within the borders of a country and, because of the international uses to which they are applied, it is essential that international understanding and co-operation should exist to ensure the orderly conduct and operation of the various services. Whilst monitoring stations are designed primarily to meet the domestic needs of a particular country, they provide invaluable assistance to the International Frequency Registration Board by supplying:—

(i) special occupancy reports; and
(ii) special monitoring reports as required.

Frequency Measuring

The frequency measurement programme maintained at the various centres is designed to ensure that all radio transmitters situated within Australia comply with prescribed frequency tolerances.

Elaborate precautions are taken to ensure that Departmental frequency measuring apparatus is maintained at the prescribed accuracy. The various frequency measuring centres are connected by special lines to the Post Office Research Laboratory, Melbourne, where an Atomic Caesium Frequency Standard is employed to ensure accuracy of operation.

In order to determine the accuracy of all frequency measuring apparatus throughout the Commonwealth, and to test the skills of the operating personnel, a simultaneous measurement programme is carried out by all measuring centres each Wednesday evening at 2200 hours E.A.S.T. All centres measure pre-determined stations at a precise time and send the results to Headquarters. A typical outcome of this activity would be as shown in Table 1.

TABLE 1

Centre	VLB9 9680 kHz 1200 GMT	VLR6 6150 kHz 1205 GMT	2CR 550 kHz 1210 GMT	BBC 15070 kHz 1215 GMT	2NC 1230 kHz 1220 GMT	5CL 730 kHz 1225 GMT
Sydney	1.52L	0.86L	5.92L	0.08H	6.09H	0.93L
Melbourne	1.68L	0.94L	5.96L	0.2H	6.04H	0.98L
Brisbane	1.49L	0.69L	5.93L	0.26H	6.02H	0.97L
Adelaide	1.7L	1L	5.59L	ZERO	6H	0.95L
Perth	1.65L	0.88L	5.96L	NM QSB	5.97H	0.98L
Hobart	1.4L	1L	5.96L	0.2L	6.02H	0.98L
Maximum Difference between measurements (Hz)	0.3	0.31	0.04	0.46	0.12	0.05

Legend: L = Low, H = High, NM = No Measurement QSB = Signals varying in strength

Examinations for Certificates of Proficiency

Examinations for First, Second and Third Class Commercial, Broadcast, Amateur and Limited Amateur Radio Certificates of Proficiency are conducted to enable members of the general public to qualify and obtain these qualifications. Details of the examinations are contained in the relevant Departmental brochures, which are readily available upon application to the Superintendent, Radio Branch, Capital City.

The First, Second and Third Class certificates apply mainly to the maritime service. As an example, the First Class certificate is a pre-requisite and mandatory qualification for appointment as a Senior Radio Officer on board a passenger ship, the Second Class certificate is mandatory for Radio Officers on board cargo vessels fitted with radio telegraphy apparatus, whilst the Third Class Certificate is mandatory for Wireless Operators on board fishing, trading and pleasure vessels required to communicate with O.T.C. coast stations.

INTERFERENCE INVESTIGATIONS

One of the principal functions of the Australian Broadcasting Control Board whose responsibility it is to administer the Broadcasting and Television Act, is to detect sources of interference and to furnish advice and assistance in connection with the prevention of interference with the transmission or reception of programmes of broadcasting and television stations. This work is performed by the Post Office Radio Branch on behalf of the Board on a recoverable work basis. Interference to radio-communication stations is also investigated as a service to these licensees.

As at March 1971, there were 3,218,278 radio and television licences issued. On the basis that each licence covers one family unit (of 3.5 persons per unit), approximately 11,263,973 people expect to enjoy interference-free reception. Interference as applied to radio and television reception refers to any electrical disturbance which interrupts or interferes with the complete enjoyment of the programme. The interference problem has come to the fore to an increasing extent in recent years, owing to the sensitivity of modern radio and television receivers, together with the increasing use of household and portable appliances.

An analysis of sources of interference has revealed that the following are the main causes:—

- Low-tension services.
- High-tension services.
- Domestic apparatus.
- Television or radio equipment.
- Industrial equipment.
- Scientific and medical equipment.
- Traction services.
- Ignition sources.
- Propagation peculiarities.
- Radio-communication equipment:—
  - (a) *Receiving*
    - (i) Intermodulation.
    - (ii) Inadequate selectivity.
    - (iii) Faulty or maladjusted.
  - (b) *Transmitting*
    - (i) Excessive deviation.
    - (ii) Over modulation.
    - (iii) Faulty or maladjusted.
    - (iv) Spurious radiation.

Complaints

The number of complaints received throughout the Commonwealth during 1970/71 is listed below:—

Radio-Broadcast	4330
Television	12327
Radio-communication	1952
TOTAL	18609

In some instances, more than one source of interference affected single complaints, whilst in others a number of complaints were due to a common source.

Over the years, the state-of-the-art in interference location techniques has greatly improved, with a result that an ultra-sonic detector is now considered to be a necessity in an interference investigator's kit. As an example, in heavy traffic density areas the sonic detector, by virtue of its principle of operation, isolates the various noise sources speedily and accurately, whereas other apparatus is readily subject to extraneous interference, such as that produced by car ignitions. This device is considered to be ideal for detecting at close range defective transformers, insulators, loose ties and perforated p.v.c. sleeves on electric supply lines, conventional medium, high and very high-frequency receivers being used to determine the approximate location of the defective apparatus. Use of the sonic detector has resulted in an improved service to listeners and viewers.

In all States of the Commonwealth, interference investigation officers maintain close liaison with electric supply authorities, so that interference problems arising from electric supply plant are speedily rectified with minimum inconvenience to listeners, viewers, consumers, line crew and Post Office staff.

It can be expected that, with the introduction of colour television into Australia in the near future, Radio Branch interference investigation officers will become involved in the complex interference problems which are known to be associated with this medium.

Pollution is a much used word today; it is considered that pollution of the radio frequency spectrum by man-made devices is already a major problem confronting as it does, all radio regulatory authorities throughout the world.

MARINE RADIO SURVEYS AND INSPECTIONS

Australia, as a member-nation of the International Safety-of-Life-at-Sea organisation, provides an inspection service, in accordance with Article 21 of the International Radio Regulations, for all merchant vessels, irrespective of nationality and category, visiting Australian ports. By arrangement the Australian Post Office plays an important role in these 'Safety-of-Life-at-Sea' activities.

Responsibilities of the Department of Shipping and Transport and Australian Post Office

The Commonwealth Department of Shipping and Transport is responsible for providing the inspection service, which covers the three areas of shipboard activity — that is, deck, engine and radio. It is in the area of radio that the Australian Post Office plays its part. By arrangement, and on a recoverable works basis, the Radio Branch provides Marine Radio Surveyors to perform work involving the assessment of the efficiency of all radio-communication, radio direction-finding, automatic-alarm and survival craft apparatus. Post Office Marine Radio Surveyors are provided at all State capital cities and at some principal ports.

Surveys are conducted in accordance with the following provisions:—

Ships Registered In	Authority
1. Australia	Commonwealth Navigation (Radio) Regulations
2. United Kingdom	British Merchant Shipping (Radio) Rules
3. Other Countries	Safety - of - Life - at - Sea Conference Radio-communication Regulations.

It is pertinent to mention that the requirements of (3) above are embodied in (1) and (2) above, which are more stringent in their application.

Australian State Marine Radio Surveys

In Tasmania, Western Australia and Victoria Departmental officers act also as State Marine Radio Surveyors on a recoverable works basis on behalf of the respective State Governments. Just as the 'Titanic' disaster was responsible for the establishment of a world-wide Safety-of-Life-at-Sea Organisation for large ships, so too were the sinking of the fishing vessel 'Cathy-Jo' in Western Australian waters and the trading vessel "Will-watch" in Tasmanian waters finally responsible, after many similar tragedies, for the various State Marine (Radio) Regulations, which provide for the compulsory fitting of radio-telephone apparatus on board fishing and intrastate vessels not subject to Commonwealth survey.

Origin of the Safety-of-Life-at-Sea Organisation

In order to enable the significance of this work to be more readily grasped, it is perhaps pertinent to recall how and why the inspection service came into being. The Safety-of-Life-at-Sea Organisation was established following the sinking of the British Liner 'Titanic' in 1912, after collision with an iceberg in the murky North Atlantic icefields. 'Titanic' was the latest product of British shipbuilding and was, at that time, the largest ship in the world. On this, her maiden voyage, she was carrying 1,348 passengers and a crew of 860. Of these, a total of 1,503 was lost, only 504 passengers and 201 of the crew survived. One tragic feature of the disaster was that possibly many hundreds of other lives might have been saved had it occurred an hour or so earlier; for it was established, during the subsequent inquiry, that another ship, fitted with the then newly invented wireless transmitting and receiving installation, was only twenty miles away. Her Radio Officer, however, had gone off duty after a long day's work, and so did not receive the 'Titanic's' distress message.

An editorial which appeared in 'The Times' (of London) expressed the thoughts of many people at the time:—

'We owe it to patient research in a delicate and difficult branch of science that the "Titanic" was able with wonderful promptitude to make known her distress and to summon assistance. But for wireless telegraphy the disaster might have assumed proportions which at present we cannot measure, and should have known nothing of its occurrence for an indefinite period. Many a well-found ship has in fact disappeared in those berg-haunted waters without leaving a sign to indicate her fate. Thanks to Marconi's apparatus it is hardly possible for any vessel equipped with even moderately powerful instruments to be lost on any frequented route without being able to communicate information and to summon help. The advantages conferred by this abridgement of space are enormous. No vessel need be alone, none need vanish without sign from human ken and in none but crushing and instant disasters need any despair of help. This is surely one of the greatest of many boons conferred upon humanity by patient, persistent and often very discouraging inquiry into natural laws, carried on, at all events in its initial stages, by students animated only by love of knowledge'.

Following the 'Titanic' disaster the Governments of the principal maritime nations joined in establishing the International Service of Ice Observation and Ice Patrol, which subsequently formed part of the world-wide Safety-of-Life-at-Sea Organisation. The resultant regulations issued by this body, together with suitable amendments in the light of technological progress, have made it possible for everyone to participate in the pleasures of a sea voyage with the full knowledge that those responsible for the conduct of affairs are fully versed in the need for safety precautions. It is an international requirement that all vessels, whilst at sea, maintain a continuous radio listening watch by human or electronic means on the international distress frequency of 500 kHz or 2182 kHz. In recent years, the frequency of 156.8 MHz has been selected as the International very high-frequency Radio-telephone Safety channel.

OTHER AUSTRALIAN RADIO AUTHORITIES

No treatise concerning the use of management of the radio-frequency spectrum would be complete without reference to the aeronautical and broadcasting and television services.

Department of Civil Aviation

In Australia, the control of aeronautical radio stations, systems and services is the responsibility of the Department of Civil Aviation. However, administrative action ensures that the Radio Branch of the Post Office co-ordinates and controls such matters as frequency assigning and ensuring the observance by all aeronautical stations of the provisions of the International Radio Regulations.

Whereas the Australian Post Office is charged with the responsibility of performing marine radio surveys (to ensure compliance with international, national and State 'Safety-of-Life-at-Sea' Regulations), the Department of Civil Aviation performs similar surveys in the aeronautical sphere. The standards achieved by this body are extremely high, and no doubt have contributed immeasurably to aerial safety.

Australian Broadcasting Control Board

The broadcasting and television services of the Commonwealth operate under the provisions of the Broadcasting and Television Act 1942-1969.

The principal functions of the Board are briefly as follows:—

1. to ensure the provision of services by broadcasting and television stations in accordance with Government policy;
2. to ensure that the technical equipment and programme material is of a high standard;
3. to detect sources of interference; and
4. to hold public inquiries into applications for licences for commercial broadcasting and television stations.

LOOKING AHEAD

The rapidity of progress in the radio sphere during the past 73 years sounds a warning note for the years to come. We must keep abreast of developments as they arise, and prepare as far as practicable a sound groundwork for future expansion.

It is interesting to note that during the years 1965-1970 there was a steep increase in the number of all classes of radio stations. If the experience of the more populous countries is a reliable indicator, it appears that this expansion will not only continue, but, indeed, accelerate in the years ahead. The important — in fact, often controlling — international aspects of spectrum utilisation relating to frequency allocations, radio regulations systems standards, operating procedures and associated national problems must therefore become more complex with the passage of time.

The role played by radio-communication and television facilities in outer space exploration has caused a tremendous acceleration of creative effort in these two industries. New techniques can be expected to benefit the general public in a diversity of ways as the frontiers of knowledge are gradually pushed back. Thoughts of Alfred Tennyson, expressed with confidence about a century ago, are still descriptive of the human thirst for knowledge:—

'Men my brothers, men the workers,
Ever reaping something new;
That which they have done but earnest
of the things they yet shall do.'

FURTHER READING

Commonwealth of Australia

(a) Wireless Telegraphy Act and Regulations.
(b) Navigation Act and Regulations.
(c) Broadcasting and Television Act, and Regulations.
(d) Air Navigation Act and Regulations.
(e) Australian Post Office—current and archival records.

International Telecommunications Union

(a) Radio Regulations
(b) Publications

Maritime Historical Records
Press Material

Mr. R. T. O'Donnell.

NEW DIRECTOR, NEW SOUTH WALES

Mr. R. T. O'Donnell, M.I.E. (Aust.), has been appointed as Director, New South Wales to replace Mr. E. F. Lane. (See Vol. 22 No. 1 Page 83.)

Mr. O'Donnell joined the Australian Post Office as a Temporary Junior Mechanic in 1924. His whole career has been spent in N.S.W.; the early part progressing through the ranks of Mechanic and Senior Mechanic until 1941 when he qualified as an Engineer. From 1941 until 1958, Mr. O'Donnell occupied a number of positions as Engineer and Divisional Engineer, predominantly in the field of Country Installation. During 1957 he was seconded as a full time member of the Training of Technicians-in-Training Committee which recommended vast changes in this scheme. In 1958 he was transferred to the Planning Branch as Supervising Engineer, Internal Plant Planning and four years later was promoted as Superintending Engineer Planning Branch, a position he occupied for six years until transferring to the position of Superintending Engineer, Metropolitan Branch in 1968. In 1970, Mr. O'Donnell was promoted to Assistant Director, Engineering, where he remained until his present promotion to Chief Officer, N.S.W.

In all his positions Mr. O'Donnell has assisted the N.S.W. Committee of the Telecommunications Society with the benefit of his long experience and he has contributed to the journal.

On behalf of all readers, the Board of Editors congratulates Mr. O'Donnell on his appointment and looks forward to his continued co-operation in New South Wales.

CABLE PROTECTION AND MAINTENANCE TESTING TECHNIQUES: (PART 1)

*B. M. BYRNE, B.E.E., C.Engr., M.I.E.E.**

INTRODUCTION

Cable Protection is that branch of Telecommunications Engineering devoted to the prevention of cable failures, and the optimisation of cable plant life.

This article describes techniques in this area and associated activities in Queensland where the writer has been closely associated with these for some two decades. As the extent of these operations are rather diversified, it is presented in two parts. Part One details the more traditional Cable Protection fields of (i) corrosion mitigation, particularly in the general, or non-traction current corrosion, area, and (ii) the gas pressure protection systems. Part Two covers the associated fields of Cable Testing and several minor activities applicable to the Queensland Cable Protection Organisation.

Early cable protection history dates back over half a century and was concerned with the efforts, largely successful, to obviate the hundreds of corrosion failures from direct current traction system (tram, trains) stray current electrolysis, in the capital cities. This early organisation provided a nucleus for the formation, after World War 2, of the Cable Protection Divisions in the various States to undertake the pressurisation protection programme.

The rapid growth of telephone cable networks including the development of cable sizes up to 3,000 pairs, and of coaxial and other special cables, has required tremendous effort in the cable protection area. Most major telephone administrations have established a specific organisational unit to cope with this, as has the Australian Post Office. The precise organisational functions vary between States, according to workload, density and disposition of plant and weather conditions. In Queensland, this area and those others described in the two parts of this article are the responsibility of the Cable Protection Section (recently, Cable Protection Division).

In the early 1950's the broad charter of this Division comprised:—

(i) Reduction of wet weather fault incidence.
(ii) Prevention of corrosion from any cause (as opposed earlier to only traction current), especially in large sized cables.
(iii) Co-ordination and speed-up of fault locations and reduction of outage time.
(iv) Anticipating preventable faults generally.

Objective (i) has been fully achieved in Trunks, Junction and Main Subscribers cables. Objectives (ii), (iii) and (iv) are continuing, as the cable network expands, doubling itself each decade.

Most of the problems of 10 years ago have been solved, but a whole new series of problems, requiring different solutions, have replaced them. It is against this background that the following description of present day cable protection techniques is presented. The several current phases of this work are:—

(i) Corrosion prevention.
(ii) Cable pressurisation.
(iii) Cable testing and fault localisation.
(iv) Production and evaluation of cable maintenance test equipment.
(v) Fault recording and analysis.
(vi) Incipient cable fault location.
(vii) Preventive maintenance inspection of major cable routes, especially coaxial cables.

This article is concerned principally with (i) to (iv) above.

CORROSION PREVENTION

Traction current corrosion is now a problem in only the largest two capital cities and their environs, Sydney and Melbourne. A very minor traction network survives also in Adelaide. Electrical drainage bonds employing modern semi-conductor techniques control up to several kilowatts in drainage power to a predetermined pattern, from each of gas, water and telephone construction, from a sensed condition of only a few millivolts.

The design of traction current corrosion mitigation is, however, covered by a number of papers and articles, and it is not proposed to proceed into further detail here. Rather, the accent in corrosion prevention over the last 25 years has swung to control in non-traction areas by cathodic protection. Although negotiations and liaison with other authorities often limits the extent to which cathodic protection can be applied, it is a most powerful tool to combat corrosion of telecommunications metal sheathed plant. Several cathodic protection installations were in use to suppress traction current corrosion along with the many traction bonds, in Brisbane, prior to the closure of the tramway system.

It would be appropriate at this stage to consider, very briefly, the types of corrosion and their relationship to the application of cathodic protection.

Types of Corrosion

The C.C.I.T.T. 'Recommendations for the Protection of Underground Cables Against Corrosion' lists three groupings of corrosion:—

(a) Chemical (caused by non-electrolytes)
(b) Intercrystalline
(c) Electro-Chemical (electrolytic and non-electrolytic).

However, from these groupings, it is desirable to extract and rearrange corrosion types in accordance with the feasibility of field control, and also to relate the names of the corrosion types to the field condition which cause them. Intercrystalline corrosion (but not Intercrystalline disaggregation) is relatively rare, except under the influence of high density traction current discharge or the like.

Thus, in the control field it is pertinent to consider the following corrosion groupings:—

(i) Galvanic — from proximate metal; especially iron conduit.
(ii) Electrolytic — from 'stray' currents (not necessarily traction current).
(iii) Chemical — in its several forms (acetic, bacterial, etc.). Also electrochemical, related to soil environment.

There is no ready cure for galvanic corrosion, particularly as it applies to telecommunications cable with lead sheaths. If iron pipe is used to house unprotected lead, it will cause galvanic corrosion of the lead (and, often indirectly, the iron) sooner or later. Therefore, iron pipe must not be used in this application. Similarly, copper pipes and electrodes must never be connected to lead sheaths or the results will be disastrous. Actual field experience has, in fact, demonstrated this forcibly in a number of cases where copper earth electrodes have been so fitted.

Cathodic Protection

Electrolytic corrosion can be eliminated where it is economic to preserve the existing cable at the not inconsiderable cost of a cathodic protection installation.

Most forms of chemical corrosion can likewise be reduced to negligible proportions by cathodic protection. Some care must be exercised in the design of this equipment, following the

* Mr. Byrne is Supervising Engineer, Cable Protection, Queensland.

recognition of chemical failure of cable plant. A chemically caused fault produces current, and is not caused by it, as in electrolysis. Thus, from superficial examination, corrosion potentials appear to be reversed to the more familiar electrolysis conditions. The application of cathodic protection serves rather to keep the corrosion cell inoperative, merely by keeping it 'charged'. Removal of the protection will usually allow even more rapid corrosion than was taking place before, due to the solution of lead by accumulated hydroxides and other conditions produced by operation of cathodic systems.

The design of cathodic protection must take account of the following factors:—

(i) Extent of cable network — determined by an electrical corrosion survey, in which cable potentials to ground and to a copper/copper sulphate half cell are taken, backed up by ground resistivity measurements. Chemical tests are made on soils from the area if there have been faults and on cable laid earlier, to determine soil aggressiveness to lead. A decision on economic and engineering grounds as to the feasibility of one or more installation/s to cover the area is usually necessary.

(ii) Accessibility of a.c. power.

(iii) Availability of suitably isolated and low resistance earth electrode sites — necessarily considered in relation to (i) above.

(iv) Current required to depress the potential of the cable by a sufficient amount (negative) over the area in (i) above, without exceeding about 1 volt at any point (depending on corrosion types involved). The test current may be applied simultaneously at up to about four points on the network at about quarter mile intervals.

(v) Determination of anode materials type — both from the surface area/resistance viewpoint at the groundbed site and from the electro-chemical weight/equivalent to provide 15-20 years' life. This design is something of an art, as not only may soil resistivities range from 20 ohm/cm. to 10,000 ohm/cm. (over the 'usable' range) but also, the resistance of almost any site chosen can and does vary by a considerable factor after installation. For example, a 0.5 ohm anode (e.g. 100 lb. of silicon iron alloy) in 20 ohm/cm. salt river mud may rise from 0.5 ohm to 10 ohms, or higher for some weeks following heavy rain. At the same time an anode of much larger surface area (e.g. 2,000 lb. steel) in the upper reaches of the catchment area of the same river (but installed in dry ground of say 10,000 ohm/cm.) may have had its resistance dropped from 10 ohms to 3 ohms by the same rain.

The choice of anode materials at present used with a broad rule of thumb application are:—

Silicon Molybdenum Iron Silicon Chromium Iron	Low consumption (1-4 lb. amp/yr) in high chloride salt areas.
Silicon Iron Graphite	Low consumption (1-4 lb. amp/yr) in high salt, non-chloride areas.
Platinised Titanium Silver Lead Alloy	Low consumption rate in open sea water (the silver-lead alloys being restricted to actual suspension in clear salt water, not buried in mud).
Cast Iron	Medium consumption (2-7 lb. amp/year). Medium surface area; long life.
Steel (In any convenient form)	20-25 lb. per year (for high surface area). This is normally the most economic material in amp/years per dollar.

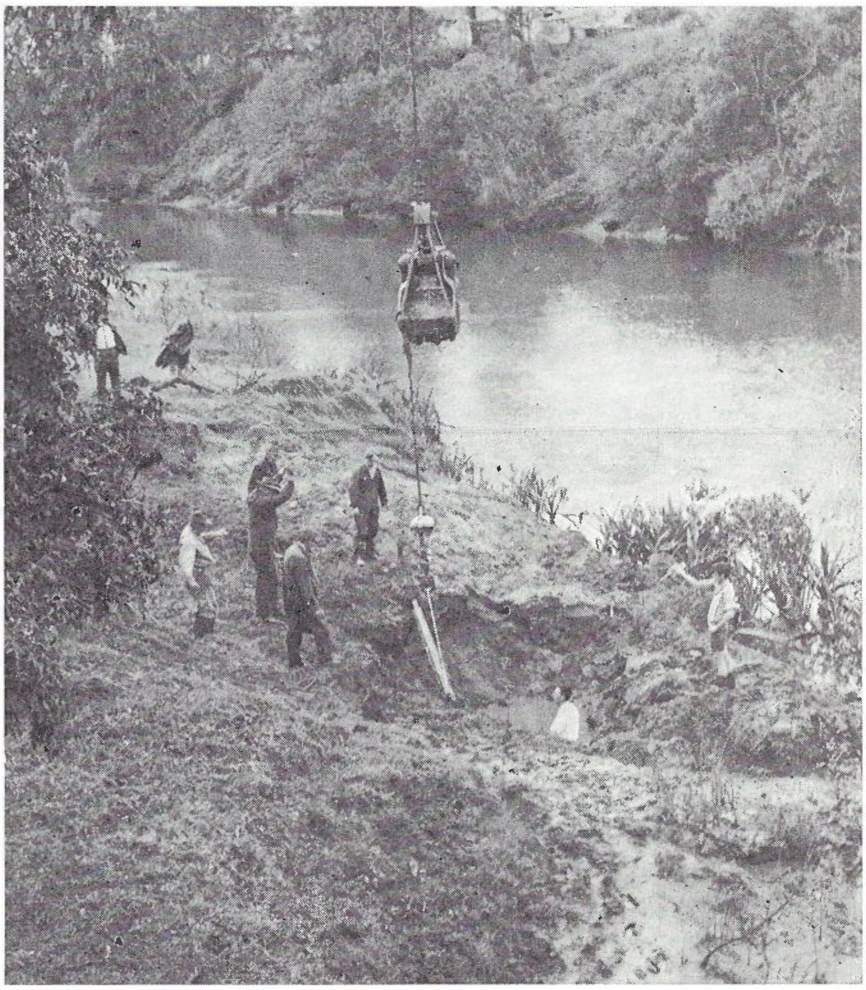

Fig. 1 — Installation of 20 x 300 lb. Steel Anode Rails for a 15 Amp. Cathodic Protection System (Caboolture River).

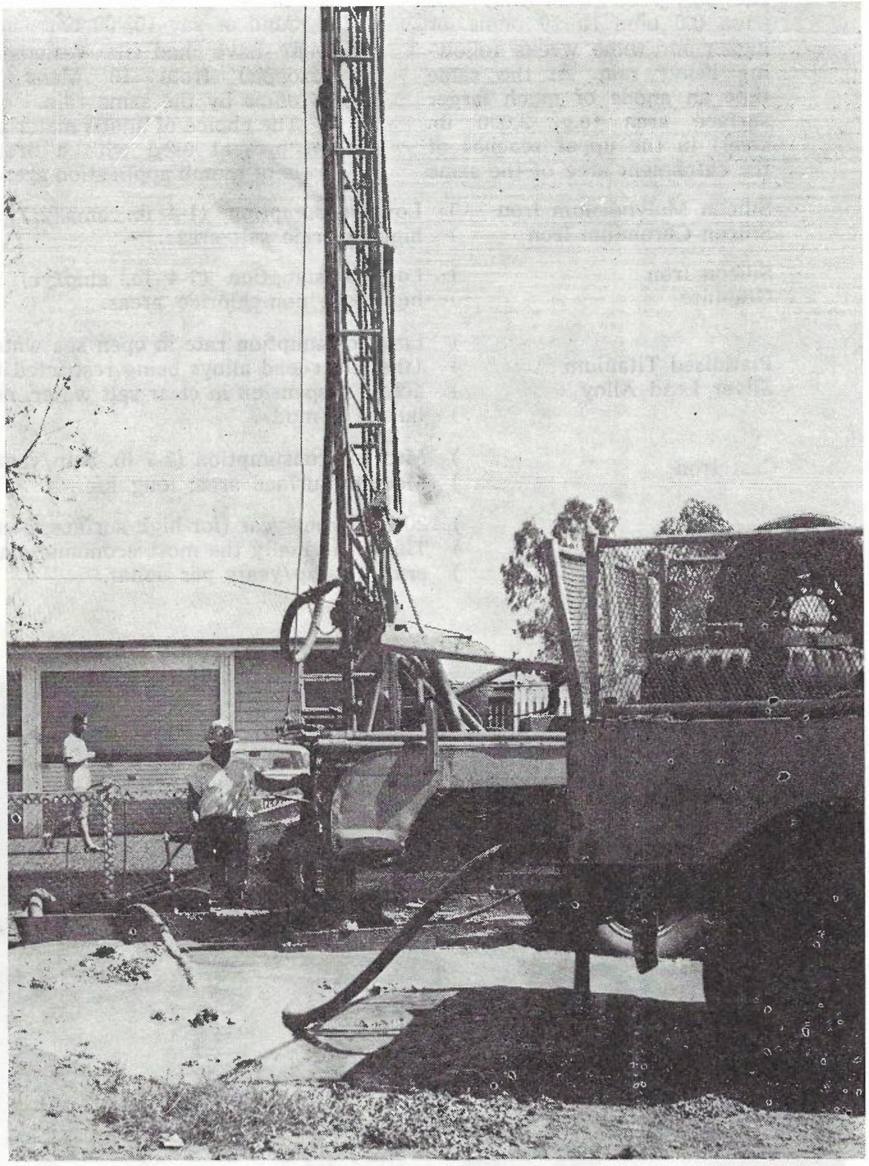

Fig. 2 — Geophysical Rig, Drilling a 10 in. x 200 ft. Hole for Three Silicon/Chromium/Iron Alloy Anodes.

(vi) Calculation of electrical requirements — cable size, rectifier voltage, range, likely resistance variations between seasons of the anode, and total current having regard to the intended 'overlap' of adjacent installations. The maximum voltage used for safety reasons is 50v. There are about 20 standard rectifier types for this application, following extensive experience and redesign to accommodate lightning surges and other encountered field problems.

(vii) Measurement and calculation of the effect on other underground plant, structures, etc. (in particular, metallic water pipes). Design of appropriate resistive electrical interconnections with these services to restore status quo potentials. Negotiation with other authorities accordingly.

(viii) Negotiation with power supply and council authorities (sometimes private persons or companies) regarding siting, energisation and tariffs for individual units. The range of different conditions in this context is remarkable.

(ix) Last but not least, the paperwork — recording of location of everything on permanent record plans — advising co-ordinating authorities — instructing maintenance staff; recording data to assist in future design or variations.

TABLE I

Period	Corrosion Failures in Main Cable (other than galvanic in old iron conduit)	Installation of Cathodic Protection	
		Date	No. of Units
1955 to 1960	17	—	—
1961 to 1965	6	1961 1962 1965	9 1 1
1965 to 1970	5	1968	1

Records of corrosion fault incidence, and, of course, of installed cathodic protection equipment have been kept, in ledger form, for the last two decades. The perusal of any page of these records yields proof of the effectiveness of this corrosion control; a typical summary prepared from these records is shown below.

For example, the city of Townsville, with two large exchanges (as provincial cities go) and several smaller peripheral ones, with a total of some 12,000 subscribers, and a cable network of about 50 sheath miles of coaxial, trunk, junction and subscribers main cable has a corrosion fault record as in Table I. (It is to be remembered that this, as with most other networks, has been doubling at about eight year intervals, both in capacity and area.)

The introduction of plastic jacketted lead cable and then, more recently, moisture barrier cable has eased the corrosion problem to some extent. The former has the effect of extending the influence of cathodic systems, by virtue of its high resistance to ground. In the more tropical zones particularly, the need to apply cathodic protection is paramount however, on even jacketted cable types, due to the voracity of the several types of small brown and black ant, which perforate the polythene jacket. This concentrates any stray electrolysis current discharge to the perforated areas. On the other hand, as most of the cable is effectively insulated, chemical (i.e. non-stray current type) corrosion is largely eliminated.

In moisture barrier cable, the barrier is aluminium foil bonded to the inside of the polythene sheath. Cathodic protection of the foil in the event of plastic perforation is possible, although the pH/potential diagram for aluminium is much more restrictive than that for lead. Damage by ants is minimised by the use of moisture barrier cable in conduit construction. Cable laid direct in the ground in the tropics is still largely plastic jacketted lead. Feasibility studies of cathodic protection on aluminium foil in M.B. cable are still in progress in Queensland.

Other problems under current investigation in the corrosion area are:—

Failure of lead sheathed cable buried direct in the ground adjacent to the cathode connection of a few (3% of total) cathodic protection installations several of which have been in the Bundaberg area.

Continued study of anode economy

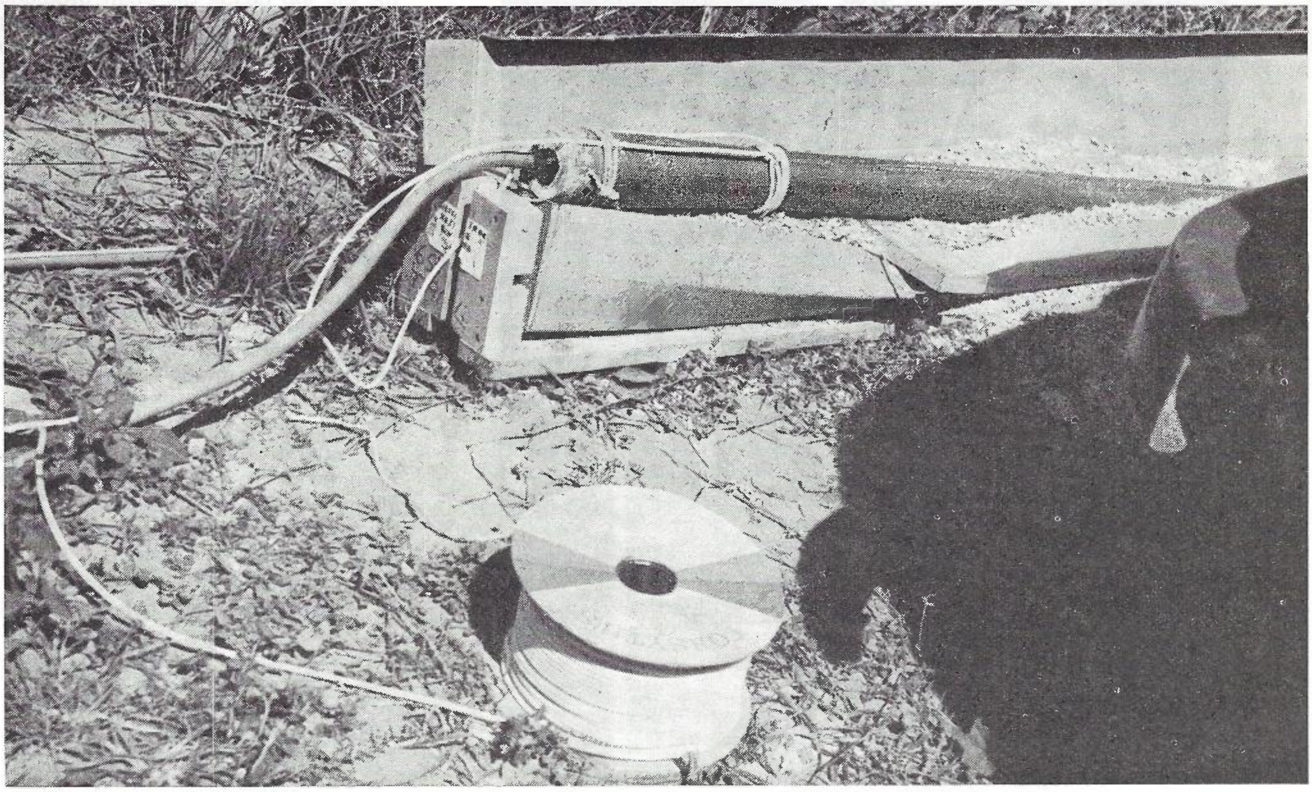

Fig. 3 — Silicon/Chromium/Iron Alloy Anode Prepared for Lowering down a Deep Well Anode. (A chlorine resistant tubing is fitted over the cable tail, and the anode weight is taken by a 600 lb. x ¾ in terylene or polypropylene rope.)

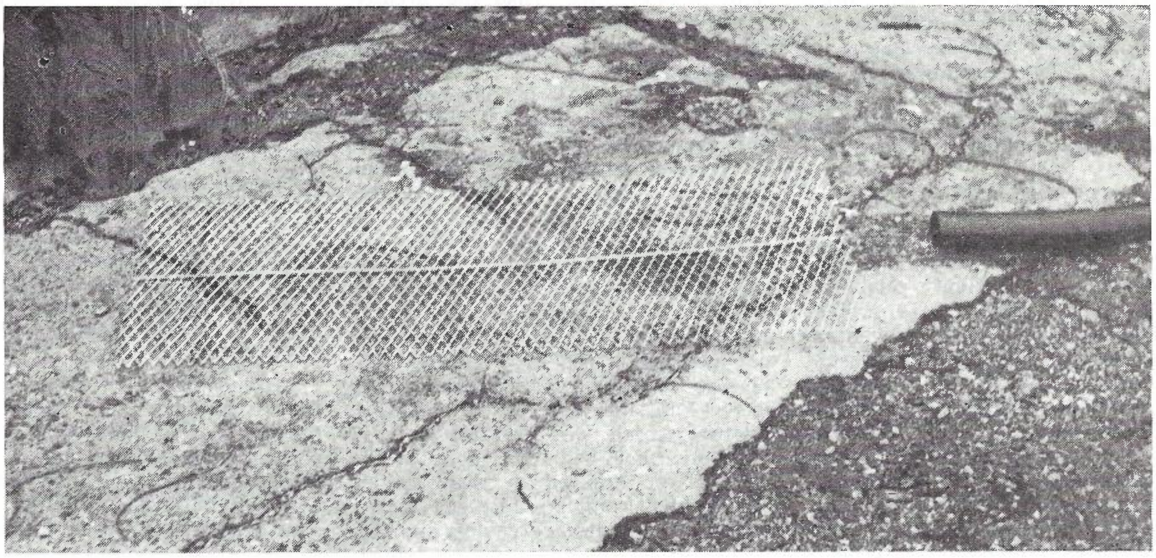

Fig. 4 — Platinised (0.5×10^{-3} In) Titanium Mesh Anode. (Laid out prior to installation in a saltwater site adjacent in the Brisbane River.)

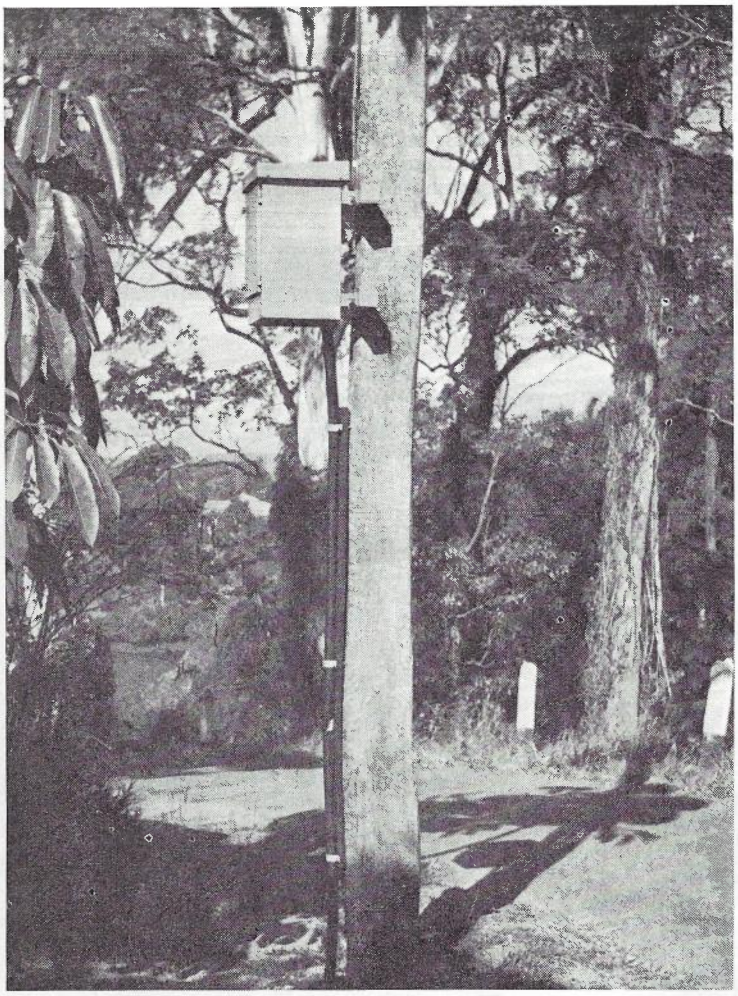

Fig. 5 — Pole Mounted 0.5 kW Cathodic Protection Rectifier.

for the several alloys and forms in various environments.

Relationship of chemical nature of various field environments to observed corrosion rates.

Free lime corrosion in F.A.C. and rigid P.V.C. conduits.

CABLE PRESSURISATION

Cable Pressurisation is a major preventive maintenance technique employed on underground telephone cables. Superficially there might appear to be little gain in preventing cable failures, if repairs are necessary in any case, except in the removal of restoration effort at penalty rates for after-hours faults. However, the loss of service revenue from inoperative main cables is quite substantial, and makes preventive maintenance a worthwhile proposition. A further gain is the avoidance of disruption of normal work by emergency demand on normal effort for breakdowns at any unpredictable time. Also the greatly improved grade of service attained is attractive from the customer commercial viewpoint.

Gas Pressure Alarm Systems rely on the elementary fact that if gas pressure (typically 10 p.s.i.g., but may be from 3 to 25 p.s.i.g. in special cases) in a cable is greater than the water pressure outside, water will not enter, and the cable will not fail.

In Brisbane, virtually the whole main cable network has been under pressure for some six or seven years. It took some 14 years to achieve this, commencing in the early 1950's. Witness to the effectiveness of the system is the fault incidence under the most intense rainfall ever recorded in Brisbane, i.e. in June, 1967. Four faults only were recorded in main cable, three being complete physical wash-aways of conduits and cables, and the fourth a cable pothead failure under an exchange M.D.F. because of the inability of the two exchange cable tunnel pumps to control the tremendous water flow. Thus under these extreme conditions no gassed main cable (some 1,500 miles) in Brisbane failed other than those physically destroyed cables mentioned.

It is quite apparent that the pressurisation philosophy has changed markedly in the last decade. Where earlier the big job facing the plant protection engineer was the massive backlog of thousands of miles of cable with literally thousands of sheath perforations, waiting to be gassed, this is no longer so.

The picture now is of a very large pressurised network of lead sheathed cables, with a rapidly increasing proportion of moisture barrier cable being added, and being pressurised as it is installed. Thus the service engineer is now concerned with alarm supervision and alarm data transfer problems plus the need to rapidly evaluate pressurisation methods developed to cope with new sheaths and new jointing and repair methods.

Electrically powered air driers have been fitted at most Queensland telephone exchanges over 400 lines. These machines have been produced principally for three purposes:—

(i) To drive some air into otherwise ungassed cable systems, to achieve some measure of pressurisation. (With the general upgrading of cables this need is now of little consequence.)

(ii) To avoid the high manhour component experienced in early gas pressure work in finding small leaks; and

(iii) To provide a dry air supply where isolation or quantity usage make it uneconomic to use compressed gas in cylinders.

The economics of purpose (ii) is debatable. On one hand the security of a no-leak system without a machine drier is very high, but can have also relatively high cost penalty. On the other hand, the mechanical or electrical failure of a machine (usually once or twice per annum) poses very urgent maintenance attention needs, if it is carrying substantial air flows to a number of cables, especially during wet weather.

Also, it must be remembered that the visual flowmeters do not tell the full story of the leak numbers or disposition. A given reading, of say one standard cubic foot per hour might be a serious (from the point of imminent failure) leak in a medium sized cable a mile from the exchange, or one or more irrelevant small leaks in a section of cable right at the ex-

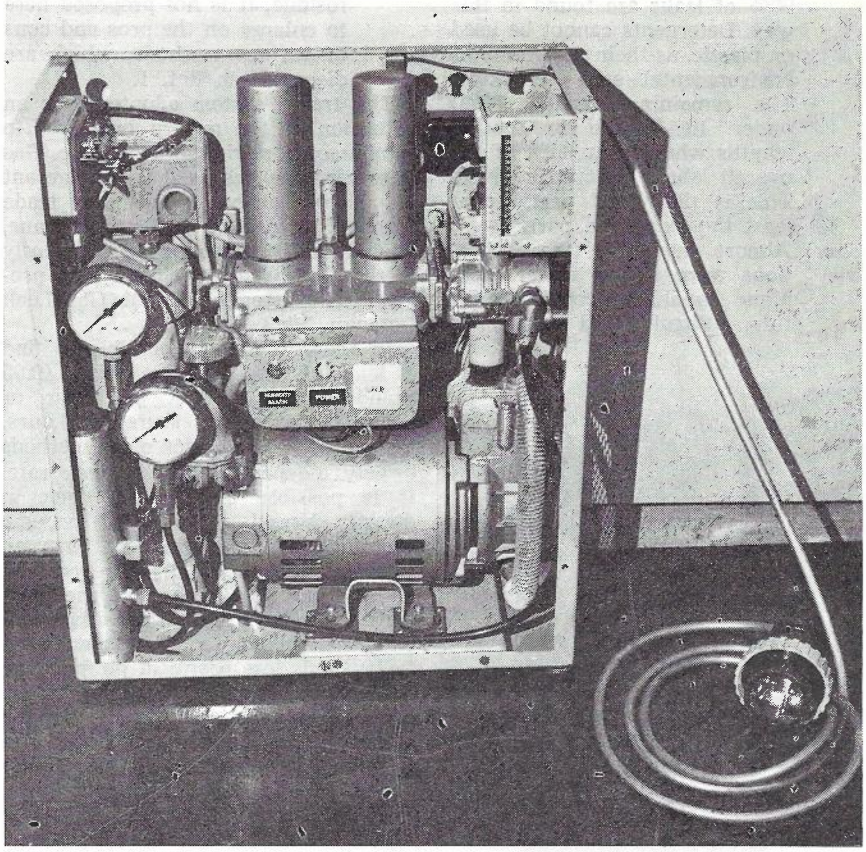

Fig. 6 — Standard 200 Cubic Ft./Day (Minimum Size) Cable Air Dryer. (Can be mounted on a wall or on equipment rack.)

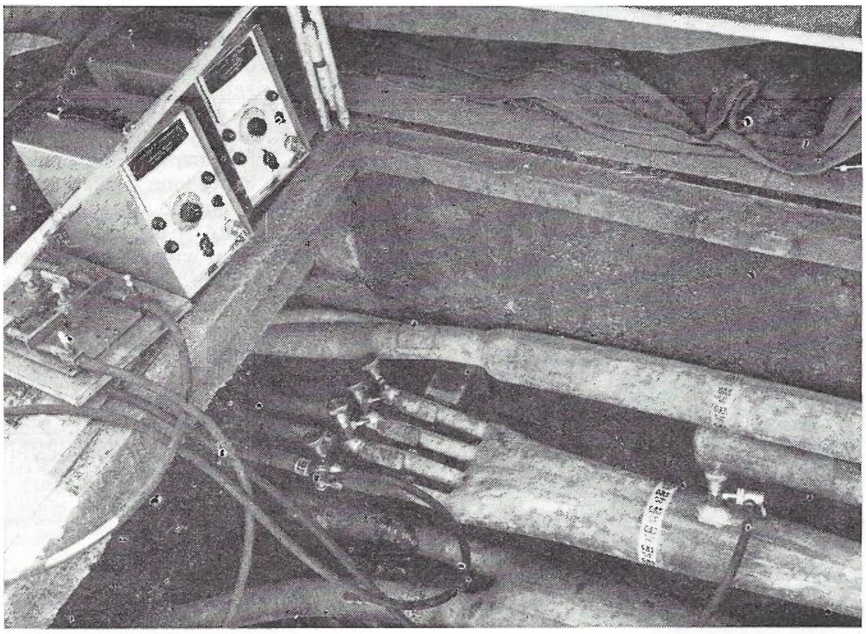

Fig. 7 — Electronic Manometer in Use to Determine which of Four Cabinet Cable Tails is Leaking. (Note the 'instant' test points on the cable; these allow access to the cable gas stream, without loss of gas during fitting, at locations where no regular test point has been fitted.)

change, where more than adequate air pressure access exists.

The ideal condition of operating at 100% pressurisation can be attained if a reasonably low cost method of small leak elimination can be achieved. The installation of machines would then provide a relatively inexhaustible supply of dry air, but still at a small enough loss rate to be held by manually applied air cylinders if a machine fails. The economies of being able to defer leak location by use of the machine, until it is convenient to do so, without incurring penalty rates, quite easily amortise the machine cost in about 12 months on a large exchange network, and in a proportionally longer time on lesser networks. In isolated country networks, of course, it is essential to be independent of air supplies by rail. It is not permissible to forward pressurised air cylinders by commercial airlines.

As it was realised some nine years ago that the pre-requisite for this low leak condition was a low cost leak location system, all existing methods of leak location were exhaustively re-examined. Needless to say, methods of leak location were under review all over the world, because of the costs involved. In the United States of America the high labour costs forced the use of large and costly machines which produce up to 15,000 cubic feet of dry air per day. Normally, for security, these are installed in at least pairs.

For the networks in Queensland, this was considered both uneconomic and of lower security than a no (or minimal) leak system. The reasoning on such problems followed these lines:—

(i) Leak location by pressure gradients can be extended just so far. Using bulky manometers, or preferably, precision jewelled bearing gauges, the limit is reached where barometric and thermal differences cause confusion. Likewise, flow sensitive devices such as ammonia indicators, pithballs, iodine indicators, etc., all have a limit of useful sensitivity, which may still represent an annoying leak in a large or coaxial cable of low pneumatic resistance per unit length. Electronic differential manometers are now available in a near ultimate sensitivity range, but require a long time to achieve stabilised flow conditions in the cable, and are essentially only a 'this way' or 'that way' indication.

(ii) Acoustic methods involving listening devices, with or without amplifiers, are too specific in that they are applicable in some cases only. Ultrasonic leak detectors are likewise a one in a hundred chance, although occasionally they have valuable application, e.g. on coaxial potheads, or on cable suspended on a bridge side.

(iii) The use of soaps or, more commonly, foaming type detergents is restricted to manholes, pits and accessible points. They are still of prime importance, of course, combined with preliminary pressure readings, as over 90% of leaks are found in this way. Detergents cannot be used on plastic, as their use promotes environmental stress cracking. The remaining portion (well under 10%), are in section lengths where over 80% of the overall labour cost is involved. This is the 'hard' part, or at least the expensive part.

(iv) Almost inevitably the indications were that a tracer technique should be employed for this difficult and expensive residue. It is not proposed here to enlarge on the pros and cons of various methods, which are discussed in Ref. 1.

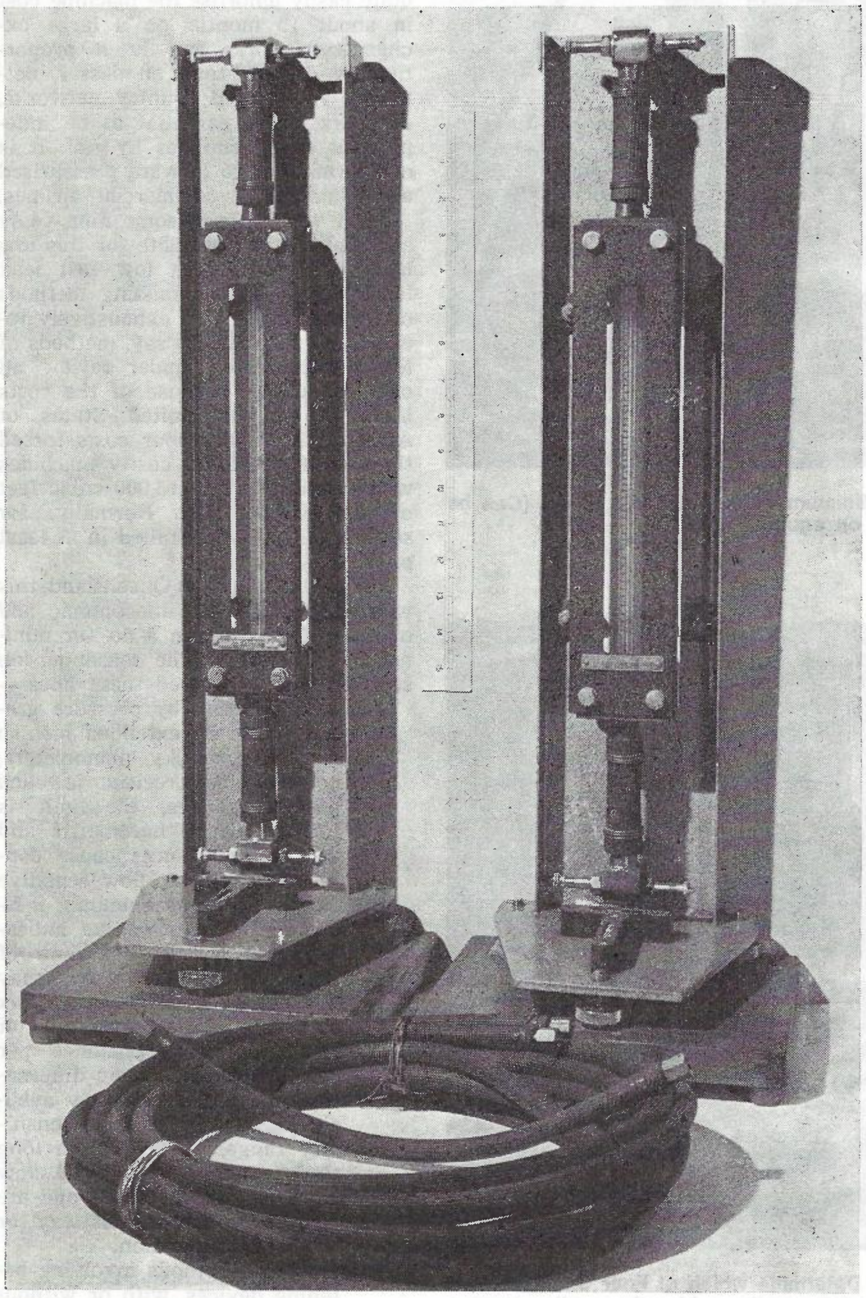

Fig. 8 — Ten Inch Scale Precision Air Flowmeters (Used for measurement of cable pneumatic properties, and for flow/gradient fault location under rivers etc.).

The tracer system adopted was an extension of the proven but hitherto cumbersome refrigeration Halide Gas Detector. The gas used is Refrigerant 12, also known by the brand or trade names, F12, Arcton 12, Freon, Forane, Icieon, etc. The detector used currently is the Queensland designed and produced transistorised Halide Gas Leak Detector Mk.3 (Ref. 1).

In short, it is now possible to find a leak of any practical size (0.05 Standard Cubic Feet per hour or larger) in a time measured in hours, instead of weeks under older methods largely independent of the leak rate. It is possible to locate a leak in directly buried cable with extreme accuracy — better in fact than an average D.C. electrical bridge reading on faulty pairs. In conduit, the principle will yield a fast and positive indication of which conduit section is faulty. It is less useful in pin-pointing the precise point of the leak in the conduit. It is, and always has been, a general policy of cable protection gas pressure work not to dig for faulty conduit sections as it is uneconomic. The cable section, if corroded, is better replaced, and if not corroded and repairable, is better repaired with little loss of cable after withdrawal, having been cutover under good conditions in the manholes. The consideration here is not speed of restoration of service, as ordinarily there is no loss of service under gas leakage circumstances. The change in conduit occupancy is, however, a disadvantage.

The pressurisation concept includes the need to be able to effect cable cutovers of faulty sections in wet ducts. For this purpose, air driers operated from a propane fuelled internal combustion engine are used, to maintain adequate pressure in the faulty section, even with its ends open, against some hydrostatic pressure. Mechanical air restructions are normally applied to the ends of the section being cutover.

A mathematical study has been made of the complex conditions of gas flow in many sizes of cables. Field measurements and verification of this study, and the incorporation of the latter results have provided design data to allow more economic use of air driers.

Previously, a flow rate of some nominal figure — say one standard cubic foot per hour (S.C.F.H.) — was an arbitrary measure of an acceptable loss in a large cable drawing air from an air drier. The intensive study of this problem now allows a reasonably accurate flow figure to be determined for any cable network, such that a safe pressure must exist in the peripheral parts of the network. One disconcerting aspect of this analysis has been that this maximum safe flow is very much smaller than the arbitrary figures adopted earlier. Figures of the order of 0.1, 0.2, etc. S.C.F.H. are not uncommon for a subscribers cable, leaving the exchange commencing as a 2,400 pairs 4 lb., and terminating perhaps 4,000 yards away as say 100/6½. Higher flows are acceptable if smaller peripheral cables are ignored.

The need is thus stronger to develop and install a reliable, economic, and convenient volume flow alarm on each cable at the exchange end. While pressure contactors provide the most convenient distributed form of alarm on long cables, they cannot, except at prohibitive cost, accurately monitor the many branches of a subscriber's cable with many laterals of various lengths and pneumatic resistance. Types of flow alarms tried in various States and localities include photo transistor and inductance variation systems to sense the height of a float in a flowmeter. One promising type, (except that it is a mass flow and not a volume flow system) uses a positive temperature co-efficient resistor in the air stream with electronic monitoring of the rate of cooling and indicates flow on a monitored thermal comparator basis. Trials and evaluation of this system are well advanced.

Development has commenced on a means of multiplexing flow alarms and on a data transmission system to operate compatibly. This is necessary to obviate inordinate use of junction cable pairs for this purpose.

Continuing development is being carried out on the performance, maintenance, methods and costs, capacity, failure modes, desiccation process, alarm mechanisms, acceptable humidity cycling, noise suppression and other phases of machine air driers. Long term performance of the various cable pressure networks is available for study, and examination of costs and methods of pressurisation is receiving attention as engineering effort becomes available.

Present practice is tending away from non-ferrous metals to plastics — nylon in particular in the manipulation of dry air feeds. Field trials of a completely non-metallic (including valves, test points, unions, ferrules) distribution are in hand. Substantial labour savings in this area are possible, but trials to date have indicated leak problems in this type of gas handling plant.

Newer cable types and practices, e.g. Moisture Barrier, plastic insulated cable, for direct termination on the M.D.F. continually require updated pressurisation practice. High pressure injection of epoxy gas seals in large size (2400, 3000 pr.) P.E.I.U.T., using thermo-shrinkable materials to retain the seal and injection flanges, has been developed. A seal of this type takes little over an hour to complete, and is 100% reliable.

The longer routes and lighter conductor gauges used in trunk cables has required redesign of alarm relay sets, with more convenient facilities than were previously acceptable. A Queensland type modern crossbar G.P.A. relay set is sensitive to shorts, opens, or earths (the latter at least on one leg) up to 6,500 ohms line loop. Electronic and electromechanical delays are incorporated to prevent lightning and power switching surges tripping the alarm. Ring, speak, receive attention, and other regular facilities are available. Equalised portable amplifiers have been provided for line staff to speak to control stations over such alarm pairs, with neither loading nor repeater amplifiers on up to 75 mile sections of a 20 lb. pair.

Gas pressurisation technology now envisages a complete overall gas supply, alarm, centralised supervision and test facility, with the time of alarm operation being engineered to the relative importance of the cable system, and the back-up air feeds elaborated to provide a very high grade of security via a constant pressure system, when necessary with alarms on the distant air feed points.

Several photographs illustrating equipment described are shown, with details in the captions.

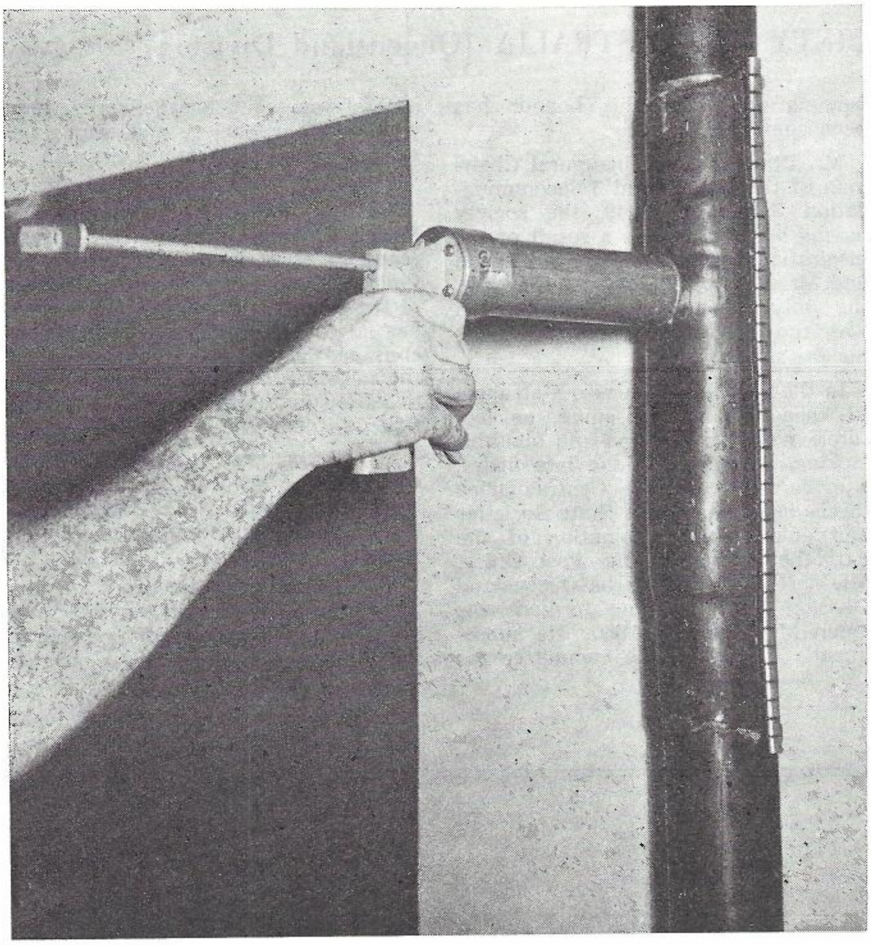

Fig. 9 — Injection of Epoxy Resin Seal into 2,400 Pair 4 lb. Polythene Insulated and Sheathed Moisture Barrier Cable.

REFERENCES

1. B. M. Byrne, 'A Transistorised Halide Gas Leak Detector for Cable Gas Pressure Alarm Systems'; Telecom. Journal of Aust., Vol. 17, No. 2, page 152.

Mr. N. M. MacDONALD, B.Sc., M.I.E.Aust.

Mr. Neil Macdonald, B.Sc., M.I.E. (Aust.) has been appointed First Assistant Director-General (Engineering Works) Headquarters, and took up this duty in November 1971, having completed a term of 2½ years in the newly created position of First Assistant Director-General (Industrial Relations).

Mr. Macdonald is very well known to Engineering staff throughout the Department, having served in various high level positions at Headquarters in recent years. He was the first Editor-in-Chief of this Journal; the position being created in 1960. He is currently chairman of the Council of Control of the Telecommunication Society.

The Society congratulates Mr. Macdonald, and offers him our co-operation and assistance in his new appointment.

TELECOMMUNICATION SOCIETY OF AUSTRALIA (Queensland Division)

Mr. G. E. K. DIXON — LIFE MEMBER

Mr. Dixon was appointed life member of the Society at a Council meeting held on the 2nd February, 1972. He joins Mr. C. R. Anderson and Mr. C. Faragher, who are the only other persons on whom this honour has been conferred.

Mr. Dixon was the inaugural Chairman of the Queensland Telecommunication Society in 1949, the society having been formed as a result of the inspiration and activities of Mr. Dixon and Mr. Brian Crutcher. At the time, the only other similar organization was the Postal Electrical Engineers Society in Victoria.

In the early years, it was a struggle to keep the Society going, as lecturers were hard to find and facilities lacking. However, in the late fifties, a move was started in Central Office to combine the various State Societies and give official recognition of the part they played in the Post Office. The first Chairman of the Queensland Division as it is now formed was again Mr. Dixon in 1960. He subsequently served on the committee for several years and has delivered three papers to the Society and also given an illustrated address on his trip to Nigeria.

He has retained his interest in the Society's activities and is always ready to assist in suggesting suitable topics for lectures or for the 'Gadget of the Month'. Whenever possible, he has attended our meetings and encouraged a better understanding of the subjects discussed through his participation in the questioning after the talk was delivered.

Mr. Dixon was presented with a certificate of his Life Membership of the Telecommunication Society of Australia, by the Director, at the Annual General Meeting held on 29.2.72.

Mr. Dixon is a member of the Institution of Engineers, Australia, and is presently a Supervising Engineer in the Construction Branch, Queensland.

THE THEORY OF MOISTURE BARRIER PAPER INSULATED CABLES

*R. A. O'CALLAGHAN; A.I.T. (W.A.), Com.Eng.**

INTRODUCTION

Ever since the introduction of plastic sheathed cables in Telecommunications it has been recognised that there are advantages in having plastic sheathed paper insulted cables but until recently the permeability of plastic to moisture vapour has restricted their development.

The British Post Office developed a moisture barrier cable which overcomes this problem of moisture permeation by bonding an aluminium foil wrapping to the inside of the cable sheath. This aluminium foil barrier greatly reduces the rate of permeation, virtually eliminating moisture vapour permeation through the sheath as a factor affecting the cable service life.

Following its successful introduction in the British Post Office and trials of both overseas and locally manufactured cables in Australia, the moisture barrier, polythene sheath is becoming the standard sheath for paper insulated cables in the Australian Post Office cable network.

This paper covers the theory of moisture permeation and its application to moisture barrier sheathed paper insulated cables.

PERMEATION RATE

The rate at which moisture vapour permeates through a plastic is dependent upon (Refs. 1, 2, 3, 5):—

(a) Permeability constant of the particular plastic.
(b) Temperature.
(c) Physical dimensions of the plastic material.
(d) Moisture vapour pressure differential.

The permeability constant (P_0) of a plastic is mainly determined by its molecular structure. The larger the holes in the molecular lattice the larger the permeability constant. Hence the alteration of the density, addition of colouring compounds etc., can have a marked effect upon the permeability constant. Polythene, like all polymers, is permeable to gases and vapours and its permeability constant for water vapour is one of the lowest.

The permeability constant is temperature dependent and follows the Arrhenious equations (Ref. 5)

$$P_T = P_0 \exp(-E_p/RT) \qquad \ldots (1)$$

Where P_T = Permeability constant of the material at T°K (cm³/sec for a gradient of 1 mm Hg/cm per cm²)
P_0 = Permeability constant of the material at 0°K (cm³/sec for a gradient of 1 mm Hg/cm per cm²)
E_p = Actuation energy of permeation (cal/mole)
R = Gas constant (1.987 cal./°C mole)
T = Temperature of operation (°K)

For an item of given physical dimensions, a constant temperature and a given vapour pressure differential, the rate of permeation of vapour through the item is given by (Ref. 1, 2, 3, 5):—

$$P = (P_T . A/s)(p_1 - p_2) \qquad \ldots (2)$$

Where P = Rate of Permeation through the item @ T°K (cm³/sec)
P_T = Permeability Constant of the material @ T°K (cm³/sec for a gradient of 1 mm Hg/cm per cm²)
A = Area of permeation (cm²)
s = Thickness (cm)
$(p_1 - p_2)$ = Vapour pressure differential (mm Hg)

Permeation of Unbarriered Polythene Sheath Cables

The rate of moisture vapour permeation in an unbarriered polythene sheath cable is determined by equation (2). Converting this equation to use the dimensions commonly specified for cables, i.e. sheath diameter and thickness (Ref. 2), we have:—

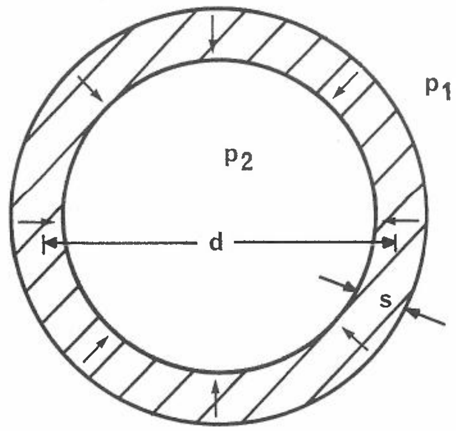

Fig. 1—Unbarriered Polythene Sheath.

$$P_1 = (P_T \pi d/s)(p_1 - p_2) \text{ per unit length} \qquad \ldots (3)$$

Where P_1 = Permeation rate of unbarriered sheath @ T°K (cm³/sec per unit length)
P_T = Permeability constant of moisture vapour through the sheath polythene at T°K
d = Mean sheath diameter (cm)
s = Sheath thickness (cm)
p_1 = Moisture vapour pressure outside the sheath (mm Hg)
p_2 = Moisture vapour pressure inside the sheath (mm Hg)

MOISTURE BARRIER

The moisture barrier used in Australian Post Office cable sheaths is an aluminium foil wrapping on the inside of the polythene sheath. The permeability constant of aluminium is negligible compared to that of polythene so that permeation is effectively limited to the area of the foil overlap.

The foil wrapping is applied longitudinally to give a minimum length of overlap for a given length of cable. Some early types of moisture barrier were wrapped helically but this resulted in a much longer overlap, reducing the effectiveness of the barrier (Ref. 6).

The reduction in permeation, or improvement of the sheath's properties as a barrier to moisture permeation, due to the addition of the moisture barrier is commonly expressed as a Barrier Factor (BF) (Ref. 2).

$$\text{Barrier Factor (BF)} = \frac{\text{Permeation Rate of Unbarriered Sheath}}{\text{Permeation Rate of Barriered Sheath}}$$

Depending upon the type of barrier sheath construction, a perfectly manufactured sheath will theoretically have a barrier factor in the range of from 20 to approximately 10,000 (See Appendix 1), but in practice, in production cables, barrier factors of 100–200 only are commonly achieved (Ref. 2, 6).

TYPES OF BARRIER CONSTRUCTION

The aluminium foil barrier can be applied to the cable sheath in several ways with various degrees of effectiveness (Ref. 2, 4) i.e. with:—

(a) *Fully bonded* to the polythene sheath but *not sealed* at the overlap (Fig. 2).
(b) *Not bonded* to the polythene sheath but *sealed* at the overlap (Fig. 3).
(c) *Fully bonded* to the sheath and *sealed* at the overlap (Fig. 4).

To achieve the bonding of the aluminium foil to the polythene sheath and to seal the overlap of the foil, a 0.0015 in layer of polythene is adhered to one side of the foil, prior to its use in the manufacturing of the barriered sheath.

Bonded, Unsealed Barrier

If the barrier foil is fully bonded to the polythene sheath but the overlap not sealed, the permeation is restricted to the area of the overlap. The major factors affecting the permeation rate, apart from the sheath material, are the physical dimensions of the overlap; however, the relative thickness of the sheath at the overlap also has a significant effect on the permeation (Ref. 4).

* Mr. O'Callaghan Engineer Class 2, Industrial Engineering Group, Western Australia.

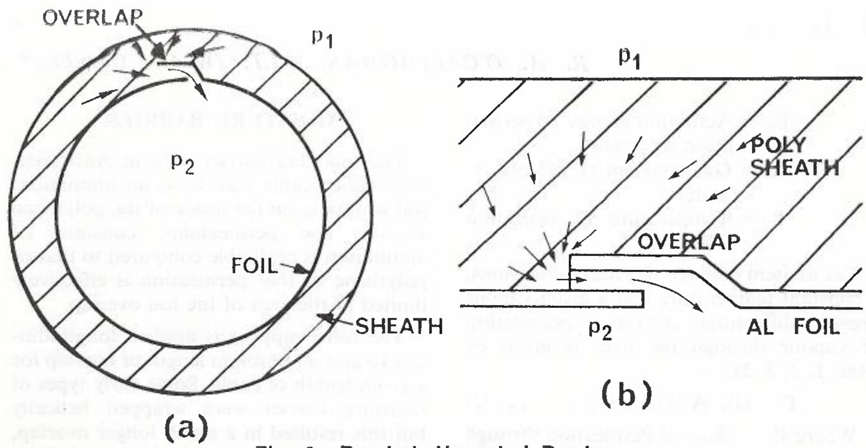

Fig. 2—Bonded, Unsealed Barrier.

The permeation rate for the bonded, unsealed barrier (P_2) in the practical case (Ref. 4) is,

$$P_2 = (P_T \pi \lambda^{0.17}/2.53)(p_1 - p_2) \text{ per unit length} \quad \ldots (4)$$

Where $\lambda = t/s$ ($\ll 1$ for the practical case)
t = (width of foil overlap)/2
P_T, p_1, p_2, s are as previously defined.

The barrier factor for this barrier construction is,

$$(BF)_1 = P_1/P_2 = 2.53d/s\lambda^{0.17} \quad \ldots (5)$$

This theoretical barrier factor varies from 26.3 for the smallest cable (10/4) to 164 for the largest cable (2400/4) in the Australian Post Office range of moisture barrier cables.

Unbonded, Sealed Barrier

In the construction where the foil barrier is not bonded to the polythene sheath but is sealed with polythene at its overlap, the resistance of the sealed overlap becomes the significant factor, not the sheath thickness. The moisture permeates through the polythene sheath resulting in approximately the same vapour pressure across the overlap seal as we originally had between the core and the external surface of the sheath. The permeation across the seal is then determined by the seal material (polythene) and its dimensions.

$$P_3 = P_T(2t/L)(p_1 - p_2) \text{ per unit length} \quad \ldots (6)$$

Where P_3 = Permeation rate of an unbonded sealed barrier @ T°K (cm^3/sec per unit length)
2t = Width of material sealing overlap
L = Length of material sealing overlap

The barrier factor for this construction is

$$(BF)_2 = P_1/P_3 = \pi dL/2ts \quad \ldots (7)$$

The theoretical barrier factors for this type of construction are approximately 2,500 to 14,300 for the Australian Post Office range of moisture barrier cables.

Bonded, Sealed Barrier

The bonded sealed construction combines the effects of the bonded, unsealed and the unbonded, sealed constructions. The bonded foil restricts the area of permeation through the sheath to that adjacent to the overlap but the permeation rate is still greatly in excess of the permeation rate through the overlap seal, i.e. barrier factors of approximately 100 compared to 10,000 and therefore the permeation through the overlap seal is the significant factor.

The permeation rate for this construction is virtually the same as for the unbonded sealed construction.

$$P_4 = P_3 = (P_T 2t/L)(p_1 - p_2) \text{ per unit length}$$

The barrier factor is:—

$$(BF)_3 = (BF)_2 = \pi dL/2ts$$

The barrier factor varies from approximately 2,500 to 14,300 for the Australian Post Office range of moisture barrier cables.

MANUFACTURING DEFECTS

In the preceding analysis of the various types of moisture barrier sheath construction, the bond of the foil to the polythene sheath and the sealing of the foil overlap are assumed to be perfect. However, in production cables this is seldom, if ever, true. Australian manufactured moisture barrier cables have the foil bonded to the sheath and the overlap sealed, which theoretically would give barrier factors of the order of 10,000 but overseas manufactured moisture barrier cables of the same type of construction have only given barrier factors of the order of 100 (Ref. 6). This reduction in barrier factor is due to manufacturing defects, both in the bonding and in the sealing of the overlap.

It might be inferred from the preceding theoretical analysis that the overlap seal is all important, however, if the analysis is extended to include the effects of manufacturing defects on the efficiency of the barrier, this is shown not to be so (Ref. 2).

Fig. 5 shows in general terms the effects of defects on the permeation rate relative to an unbarriered sheath based on average values falling within the ranges $(BF)_1 = 50$ and $(BF)_3 = 8{,}000$. These curves give the order of the effects and it is necessary to define more closely the nature of the defects, i.e. their dimensions and disposition, to estimate accurately their influence on permeation rate. To illustrate this point, consider the situation wherein one half of the foil was not bonded to the sheath but the whole of this unbonded area was well removed from the overlap. The effect on the permeation rate would be negligible; however, this case is not very probable. Important points to note on these curves are:—

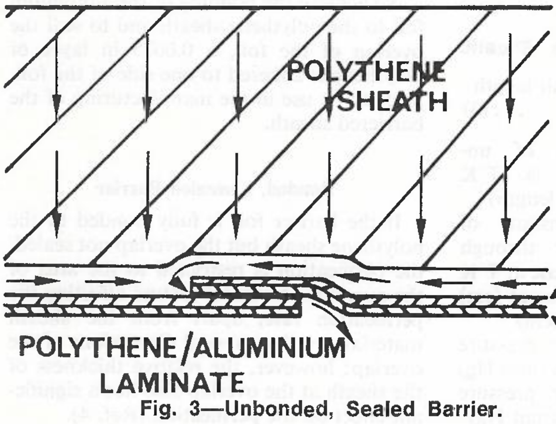

Fig. 3—Unbonded, Sealed Barrier.

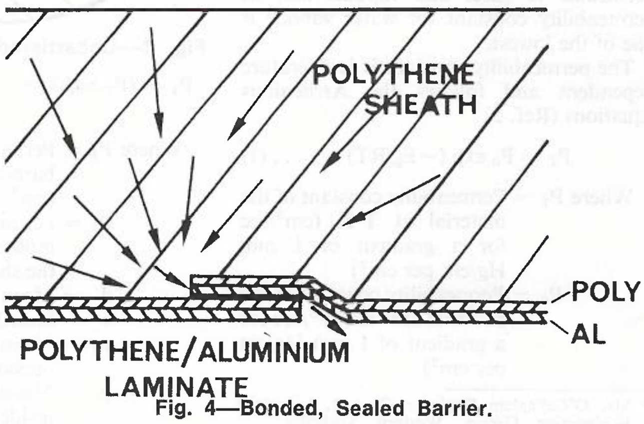

Fig. 4—Bonded, Sealed Barrier.

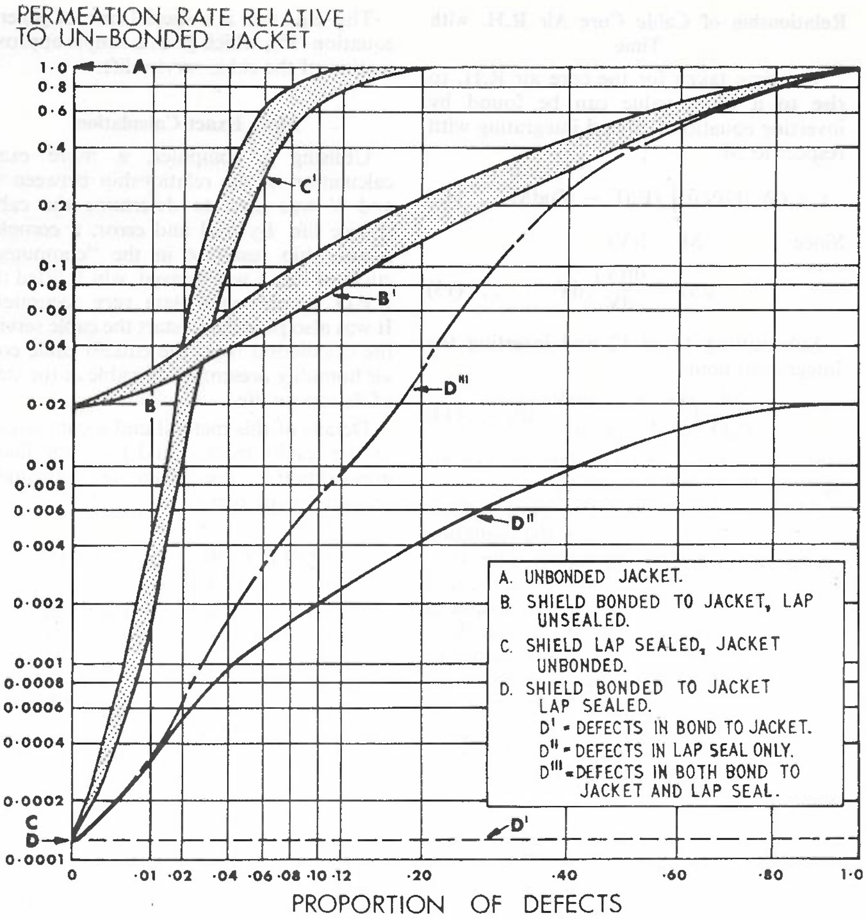

Fig. 5—Effect of Defects on Barrier Factor.

(a) The point B indicates the perfectly bonded jacket with the foil overlap unsealed. The broadband covered by B′ indicates how the barrier factor is decreased by increasing the proportions of defects in the bonding.

(b) Point C represents the unbonded jacket with the overlap sealed. C′ represents the influence of defects in the overlap and it can be seen that the effects can be quite catastrophic for quite a small proportion of defects. A large area of sheath is available to feed each individual defect in the overlap seal.

(c) Point D refers to a perfectly bonded foil with a perfect overlap seal. The permeation rate is virtually the same as for the unbonded, sealed case but the influence of defects is far less drastic. Defects in the bond only (D′) hardly affect the permeation rate at all. Curve D″ shows the effects of flaws in the overlap seal only, and the permeation rate never exceeds that of curve B (bonded, unsealed). Where defects occur in both the bond and the seal (D‴) the initial deterioration is similar to curve D″ because the defects will not generally overlap, but with an increased proportion of defects the deterioration will proceed much more rapidly and approach curve B′.

From this discussion of manufacturing defects it is apparent that the bonding of the foil to the polythene sheath and the sealing of the foil overlap are complementary and both are highly desirable in production cables.

OVERLAP SEALING MATERIAL

In the analysis of the types of moisture barrier sheath construction, the plastic used for sealing the overlap is assumed to be polythene with the same permeation coefficients as the sheath, but in practice this is often not the case. The permeation rate of a cable with a perfectly sealed overlap is due almost solely to the permeation through the overlap sealing material, therefore in this theoretical case the equation for barrier factor should contain the correction factor to allow for differing materials in the sheath and the seal, i.e. equation (7) becomes:—

$$(BF)_2 = (\pi dL/2ts)(P_{T1}/P_{T2})$$

Where P_{T1} = Permeability constant for the sheath polythene

P_{T2} = Permeability constant for the overlap sealing material

At the temperatures the cable will be subjected to in the field, the variation in the permeability constant of the two types of polythene will be relatively small but as the temperature increases the different temperature response of the two polythenes may make this factor considerably more significant (Ref. 1, 3). In order to reduce the time required to measure the permeation rate of the moisture barriered cable, the tests are conducted at a higher temperature (60°C), than that experienced in the field, so in theory, the polythene in the seal could have a significant effect on these measurements.

However, it is the defects in the bond between the foil and the polythene sheath and the seal of the foil overlap, rather than the polythene material of the seal, which determine the barrier achieved in production cables. Hence differences in the permeability constants of the seal material and the sheath polythene are ignored in the determination of the actual barrier factor, of production cables.

BARRIER FACTORS OF PRODUCTION CABLES

The barrier factor of a cable sheath has been defined as the ratio of its permeation rate when unbarriered, to its permeation rate when barriered. The permeability constant of polythene at a given temperature varies considerably with change in density and type and quantity of additive, e.g. polyisobutylene. The activating energy also changes with density and is affected by type and quantity of additives. Therefore it is virtually impossible to determine the permeation rate of one sample of polythene at one temperature from the permeation rate of another sample of polythene at another temperature, even though both meet the same specification for general physical and electrical properties as permeation rates are not, and probably could not be included in general specifications, such as Australian Standard 1049, used for cable sheath polythene. The maximum acceptable rate of permeation for a moisture barriered cable is based upon its unbarriered permeation rate at the mean cable temperature experienced in the field (15°C is an acceptable value in Australia). To reduce the time taken, permeation tests are usually conducted at 60°C and the data from these must be adjusted to apply at 15°C.

However the barrier factor for a given sample of polythene sheath varies very little with temperature, so the barrier factor can be determined accurately and quickly by identical tests at identical temperatures, on unbarriered and barriered sheaths with the unbarriered sample having been prepared by chemically removing the barrier from otherwise identical sheath samples.

The British Post Office data (Ref. 2) indicated that cables with barrier factors with less than 50 are rejected and that over 95% of all cables accepted have barrier factors in excess of 100 (their specification actually calls for a direct measurement of the rate of entry of moisture into the cable core).

Equipment suitable for barrier factor tests has not yet been widely used in Australia but there is good reason to be confident that our production is of similar quality to that of British factories. Later sections of this paper study the variation in insulation resistance characteristics with time for cable with a barrier factor of 100.

MOISTURE PERMEATION INTO PAPER INSULATED CABLE

Formulae (3), (4) and (6) express the moisture permeation rate into cables. They are of the general form:—

$$P = (P_T\,D/BF)\,(p_1 - p_2)$$

where P_T, BF, p_1 and p_2 are defined as before, P is the permeation rate into the cable and D is the ratio of the mean circumference to the thickness of the polythene of the sheath.

In this formula and the earlier equations, the permeation rate (P) is in units of volume per second per unit length of cable. It is more convenient for the remainder of this paper to express the permeation rate in units of mass (in lieu of volume) per year per 100 m of cable and to use relative humidity rather than pressure to express the water vapour pressures. With these changes the general formula becomes:—

$$P = (P_R D/BF)\,((E - V)/E) \quad \ldots (9)$$

where P_R is the permeability constant at 15°C with a 100% relative humidity (R.H.) difference and E and V are the percentage R.H. of the air outside the sheath and inside the cable core respectively. With the equation in this form, the units of P_R are gm cm per year per 100 m per cm.

Moisture Absorption in Paper

In a paper insulated cable, the weight of paper is much greater than the weight of the cable core air and hence only the moisture absorbed by the paper insulant and wrappings need be considered, except in so far as the actual proportion of moisture in the paper is a function of the proportion of moisture in the cable core air. Therefore the permeation rate, when divided by the weight of paper in the cable core (W), becomes the rate of increase of the moisture content of the paper. Thus, if M is the moisture content of the paper:—

$$\frac{dM}{dT} = (P_R\,D/W)\,((E - V)/E) \quad \ldots (10)$$

The relationship between the moisture content of the paper and the core air R.H. is shown in Fig. 6 (Ref. 6, 7) and can be expressed as:—

$$M = f(V) \quad \ldots (11)$$

Relationship of Cable Core Air R.H. with Time

The time taken for the core air R.H. to rise to a given value can be found by inverting equation (10) and integrating with respect to M

$$t = (W/(DP_R)) \int (E/(E - V))dM \quad \ldots (12)$$

Since $M = f(V)$

$$dM = \frac{df(V)}{dV}.dV \quad \ldots (13)$$

Substituting 13 in 12 and inserting the integration limits

$$t_v = \frac{W}{P_R D}\int_O^V \frac{E}{E - V}\,\frac{df(V)}{dV}.dV \quad \ldots (14)$$

where t_v is the time taken for the core air R.H. to increase from 0 to V.

Moisture in the insulating paper affects its resistivity and hence affects the insulation resistance (I.R.) of the cable. The time taken for the I.R. of the cable to be reduced from the value at installation, to the value at which the cable is no longer serviceable is the cable's service life (T_c). The values of cable core air R.H. corresponding to any required I.R. values (V_1 and V_2 respectively), can be determined and when substituted in Equation 16 give an equation for the cable service life, the time for R.H. to rise from V_1 and V_2.

$$T_c = \frac{W}{P_R D}\int_{V_1}^{V_2} \frac{E}{E - V}\,\frac{df(V)}{dV}.dV \quad \ldots (15)$$

Linear Approximation

If the relationship between paper moisture content and cable core air R.H. is approximated as a straight line (Ref. 6), equation (11) becomes:—

$$M = kV$$

Differentiating with respect to V:—

$$\frac{df(V)}{dV} = k \quad \ldots (16)$$

And if the cable service life is considered to be the time for the cable core R.H. to rise from zero to a specified value, V, then by substituting equation (16) into equation (15) and including the specific integration limits:—

$$T_c = \frac{W}{P_R D}\int_O^V \frac{E}{E - V}.k.dV$$

$$= 2.303\,C\,R\,\log_{10}(E/(E - V)) \ldots (17)$$

Where T_c = Cable service life (as determined by moisture permeation through the sheath)

C = W.k.E. = The moisture capacity of the paper when V is 100%

$R = \frac{1}{P_R D}$ = Inverse of the moisture permeation rate when V is 0%

This equation is a special case of general equation (15), which gives a simple approximation of the cable service life.

More Exact Calculation

Utilising a computer, a more exact calculation of the relationship between M and V was used to determine the cable service life. By trial and error, a complex relationship resulting in the "computed" curve of Fig. 6 was derived, which fitted the B.P.O. experimental data very accurately. It was also possible to start the cable service life calculation from the (small) cable core air humidity present in the cable at the start of its service life.

Details of this method and a comparison of the results from it and from the linear approximation are given in subsequent sections of the paper.

CABLE CORE INSULATION RESISTANCE LIMITS

In the life of a cable there are three important cable core I.R. limits. They are:—

(a) The Specified Manufacturing Limit.
(b) The Installation Acceptance Limit.
(c) The Maintainability Limit.

The I.R. limits are combined with data on paper moisture content and cable core air R.H. to derive moisture content and humidity limits.

The specified manufacturing limit for the A.P.O. paper insulated cables is at present 25,000 megohm-miles. This is a minimum acceptable value of I.R. when the cable leaves the factory. To achieve this, drying is required during the manufacturing process, so this value is the maximum likely to occur at the beginning of a cable service life with perfect installation techniques.

The installation acceptance limit is the minimum value, after installation, for which the cable will be accepted as part of the network and is 2,500 megohm-miles. This reduction from the manufacturing limit allows for the moisture which enters the cable during installation and jointing. As this moisture is generally concentrated in small areas, e.g. at the joints, with time it will migrate away from these areas to produce a relatively uniform moisture content over the whole length of the cable. This migration improves the overall I.R. of the cable substantially. The installation acceptance limit of I.R. is therefore the most pessimistic value of cable core I.R. at the beginning of a cable's life.

When the I.R. of a normal telephone subscribers' line or junction falls below 1 megohm the line is considered faulty. As subscribers lines up to 3 miles and junction lines up to 10 miles are common, this value of 1 megohm approximates a cable core I.R. of 3 to 10 megohm-miles. For isolated faults of one megohm to be locatable, the general I.R. level could not be allowed to fall to 10

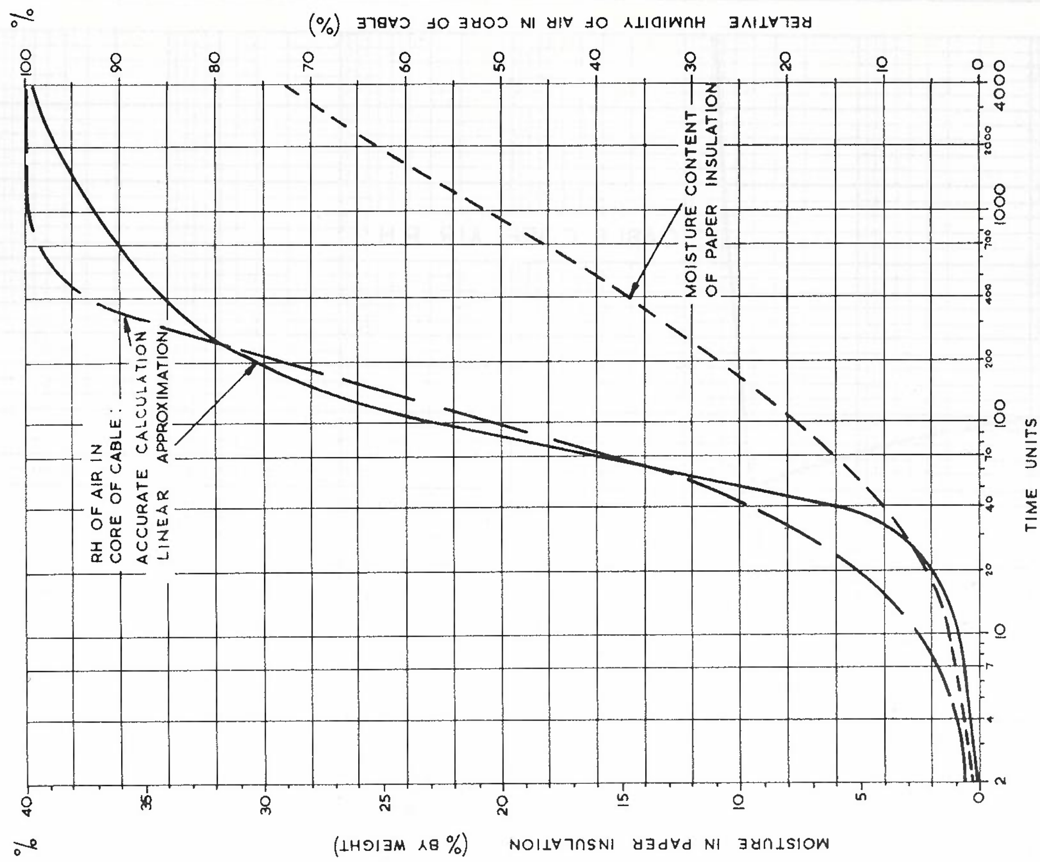

Fig. 8—Moisture Content of Paper Insulation and R.H. of Air in Core of Cable as a Function of Time.

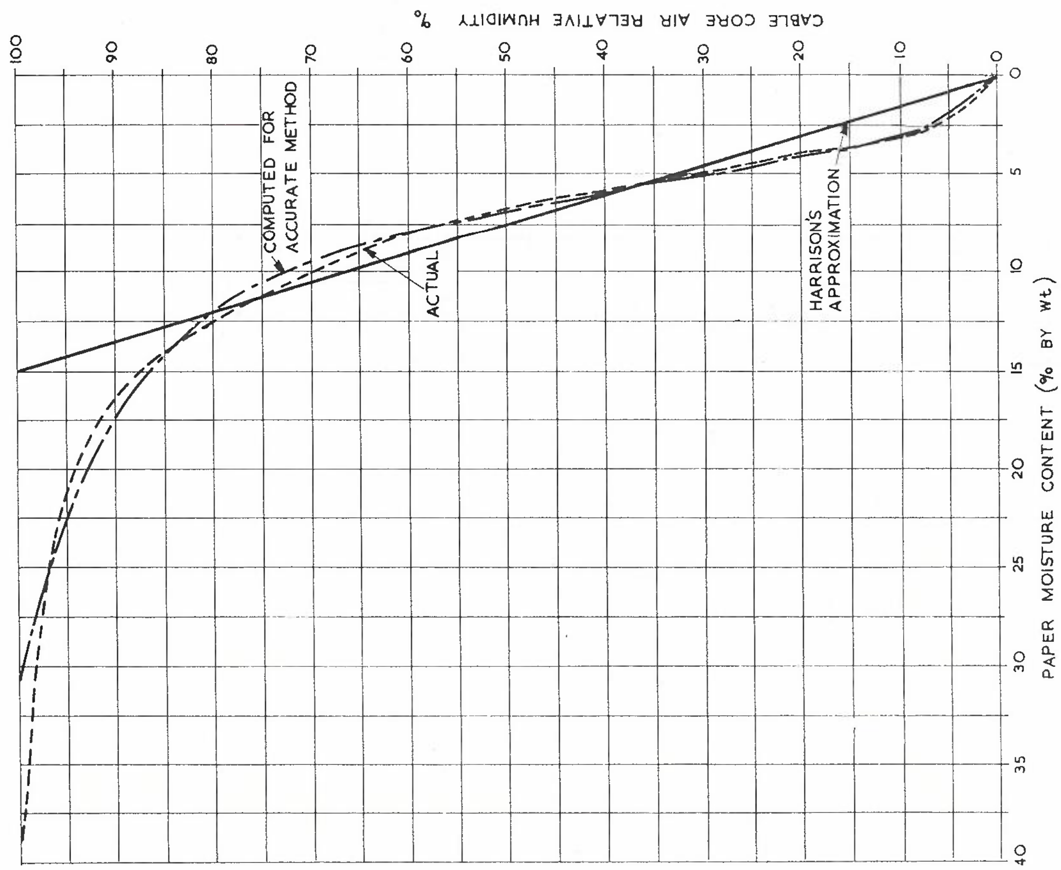

Fig. 6—Relationship Between Paper Moisture Content and Cable Core Air Relative Humidity.

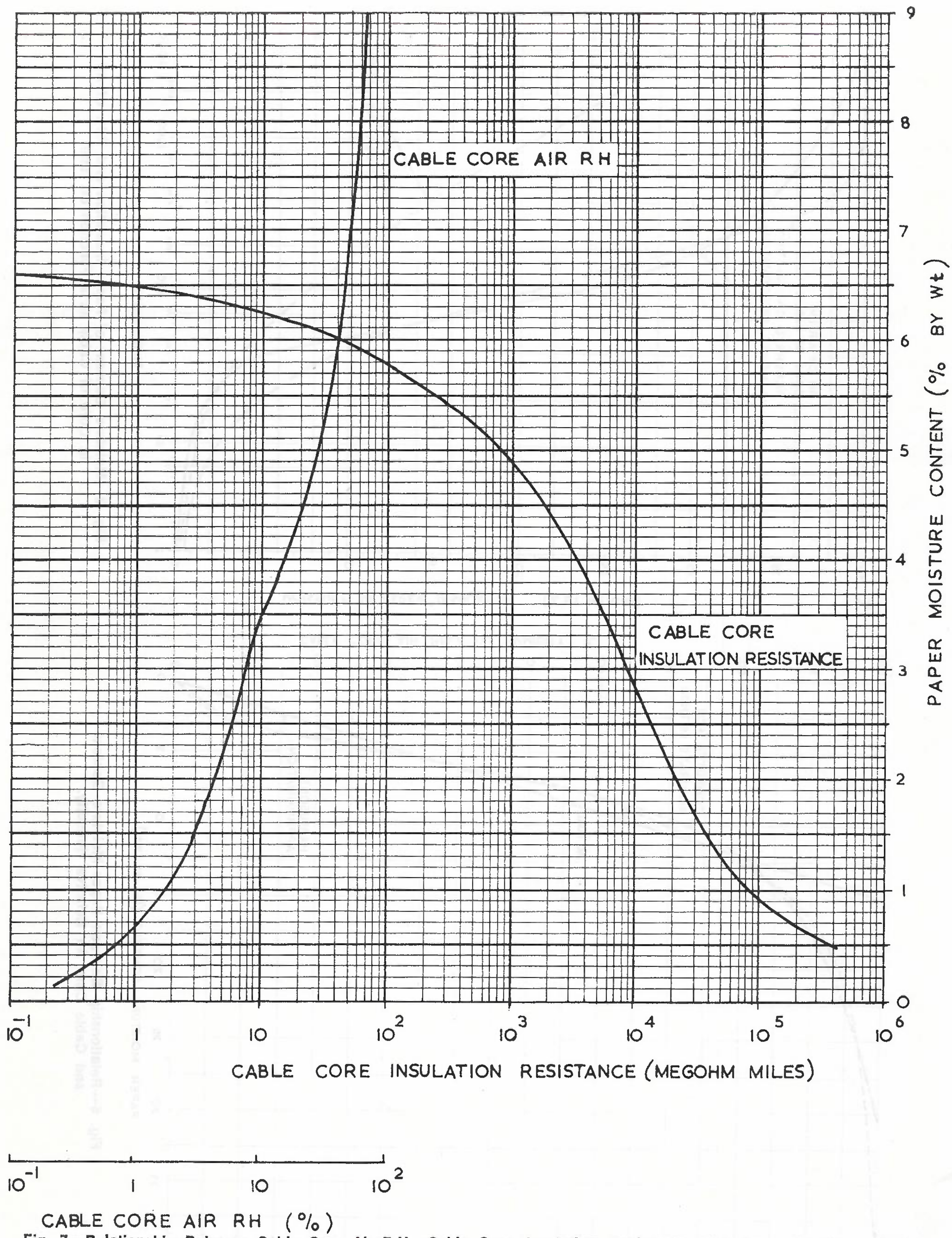

Fig. 7—Relationship Between Cable Core Air R.H., Cable Core Insulation Resistance and Paper Moisture Content.

TABLE 1: PAPER MOISTURE CONTENT AND CORE AIR R.H. VALUES AT I.R. LIMITS

Limit	Insulation Resistance (M Ω mile)	Paper Moisture Content (% by wt.)	Cable Core Air R.H. (%)
Manufacturing	25,000	1.85	4.0
Installation	2,500	4.25	19.0
Maintainability	40	6.07	40.0

TABLE 2. — CABLE SERVICE LIVES, VARIOUS CABLE SIZES, BARRIERED AND UNBARRIERED.

```
PERM. RATE=   1.530 GRAM CM PER YEAR PER 100M PER CM
PAPER WT= 2200 GRAMS PER SQ CM 100M LENGTH
MAX. R.H.= 40.00 P.C.      INITIAL R.H.= 19.00 P.C.
BARRIER FACTOR=100.00

  10/ 4 CABLE     .3800 IN OUTER DIAM      .0650 IN SHEATH
     CABLE SERVICE LIFE=     .788 YEARS UNBARRIERED            78.8 YEARS BARRIERED

 100/ 4 CABLE     .8900 IN OUTER DIAM      .0700 IN SHEATH
     CABLE SERVICE LIFE=    2.934 YEARS UNBARRIERED           293.4 YEARS BARRIERED

 600/ 4 CABLE    1.8500 IN OUTER DIAM      .0900 IN SHEATH
     CABLE SERVICE LIFE=    8.716 YEARS UNBARRIERED           871.6 YEARS BARRIERED

1800/ 4 CABLE    3.0100 IN OUTER DIAM      .1000 IN SHEATH
     CABLE SERVICE LIFE=   16.584 YEARS UNBARRIERED          1658.4 YEARS BARRIERED

  10/10 CABLE     .5500 IN OUTER DIAM      .0650 IN SHEATH
     CABLE SERVICE LIFE=    1.444 YEARS UNBARRIERED           144.4 YEARS BARRIERED

 100/10 CABLE    1.2100 IN OUTER DIAM      .0760 IN SHEATH
     CABLE SERVICE LIFE=    4.585 YEARS UNBARRIERED           458.5 YEARS BARRIERED

 600/10 CABLE    2.6100 IN OUTER DIAM      .1050 IN SHEATH
     CABLE SERVICE LIFE=   14.756 YEARS UNBARRIERED          1475.6 YEARS BARRIERED

1200/10 CABLE    3.4500 IN OUTER DIAM      .1200 IN SHEATH
     CABLE SERVICE LIFE=   22.694 YEARS UNBARRIERED          2269.4 YEARS BARRIERED

  10/10 CABLE     .7600 IN OUTER DIAM      .0650 IN SHEATH
     CABLE SERVICE LIFE=    2.268 YEARS UNBARRIERED           226.8 YEARS BARRIERED

 100/20 CABLE    1.6200 IN OUTER DIAM      .0850 IN SHEATH
     CABLE SERVICE LIFE=    7.115 YEARS UNBARRIERED           711.5 YEARS BARRIERED

 600/20 CABLE    3.4500 IN OUTER DIAM      .1200 IN SHEATH
     CABLE SERVICE LIFE=   22.694 YEARS UNBARRIERED          2269.4 YEARS BARRIERED
```

TABLE 3. — CABLE SERVICE LIVES, 100/4 CABLE, EFFECT OF INITIAL CABLE CORE R.H.

```
PERM. RATE=   1.530 GRAM CM PER YEAR PER 100M PER CM
PAPER WT= 2200 GRAMS PER SQ CM 100M LENGTH
MAX. R.H.= 40.00 P.C.      INITIAL R.H.= 11.00 P.C.
BARRIER FACTOR=100.00

 100/ 4 CABLE     .8900 IN OUTER DIAM      .0700 IN SHEATH
     CABLE SERVICE LIFE=    3.836 YEARS UNBARRIERED           383.6 YEARS BARRIERED

PERM. RATE=   1.530 GRAM CM PER YEAR PER 100M PER CM
PAPER WT= 2200 GRAMS PER SQ CM 100M LENGTH
MAX. R.H.= 40.00 P.C.      INITIAL R.H.=  7.25 P.C.
BARRIER FACTOR=100.00

 100/ 4 CABLE     .8900 IN OUTER DIAM      .0700 IN SHEATH
     CABLE SERVICE LIFE=    4.759 YEARS UNBARRIERED           475.9 YEARS BARRIERED

PERM. RATE=   1.530 GRAM CM PER YEAR PER 100M PER CM
PAPER WT= 2200 GRAMS PER SQ CM 100M LENGTH
MAX. R.H.= 40.00 P.C.      INITIAL R.H.= 5.50 P.C.
BARRIER FACTOR=100.00
 100/ 4 CABLE     .8900 IN OUTER DIAM      .0700 IN SHEATH
     CABLE SERVICE LIFE=    5.335 YEARS UNBARRIERED           533.5 YEARS BARRIERED

PERM. RATE=   1.530 GRAM CM PER YEAR PER 100M PER CM
PAPER WT= 2200 GRAMS PER SQ CM 100M LENGTH
MAX. R.H.= 40.00 P.C.      INITIAL R.H.=  4.00 P.C.
BARRIER FACTOR=100.00

 100/ 4 CABLE     .8900 IN OUTER DIAM      .0700 IN SHEATH
     CABLE SERVICE LIFE=    5.886 YEARS UNBARRIERED           588.6 YEARS BARRIERED
```

megohm-miles and a value of 40 megohm-miles has been adopted, somewhat arbitrarily, as the maintainability limit, i.e. as the end of the cable's service life.

From Fig. 7, the values of paper moisture content and cable core air R.H. corresponding to the above I.R. limits can be found, and are summarised in Table 1.

COMPUTER CALCULATION

A computer program was written (Ref. 8) to calculate:—

(a) The variation of the cable core air R.H. and paper moisture content with time.

(b) The cable service life of various dimensioned polythene sheathed cables, both with and without a moisture barrier, for various limiting values of cable core air R.H.

The fundamental data values used in the calculations were:—

(a) Permeability Constant (P_R) is the rate of permeation of moisture through polythene with a 100% R.H. difference at 15°C and is considered to be 1.53 gm cm/year/100 m/cm. This figure has been derived from the average of the values given in Appendix I of Ref. 6.

(b) Weight of Paper (W) is 2,200 g per cm^2 of cross-sectional area of 100 m of cable length and is an approximately average figure for various sizes of cable supplied to the A.P.O.

(c) Cable Core Air R.H. (V). The values developed from the I.R. limits are used. The effect of using other values was also studied.

(d) Barrier Factor (BF) of 100 is selected as the mean minimum value likely to be achieved with a good manufacturing process for an aluminium/polythene laminate moisture barrier sheath as supplied to the A.P.O.

(e) Cable Dimensions taken from the A.P.O. Specification 912, Table 9.

The results of the computer calculations are given in Figs. 8 and 9 and Tables 2 and 3. Figs. 8 and 9 provide plots of paper moisture content, cable core R.H. and cable core I.R. against generalised time bases. The relation between the general time bases and actual time varies for different cables and is affected by cable diameter, sheath thickness and sheath barrier factor.

Tables 2 and 3 are computer-generated data for particular cables. In Table 2 the cable service lives are the time for the cable core R.H. to rise from 19% to 40%, i.e. for the cable I.R. to fall from 2500 megohm-miles to 40 megohm-miles. In Table 3 the cable service lives for one cable (100/4) is given for initial cable core air R.H's ranging from 19% down to 4% for a final R.H. of 40%.

DISCUSSION OF RESULTS

Non-Barriered Cables Service Life

For a minimum service life of 30 years, polythene sheathed, paper insulated cables, without some form of moisture barrier, need to have an external sheath diameter of 3.45" or greater. This excludes all but the largest sizes of cables. The smaller diameter cables could have service lives lower than one year. Although the conditions used for these calculations may be slightly pessimistic, the order of these results makes it clear that this type of cable construction could not be tolerated in the telephone cable network.

Moisture Barrier Sheathed Cables Service Life

All sizes of moisture barrier sheath paper insulated cables with a sheath barrier factor of 100 or greater have a calculated service life in excess of 75 years (Table 2). The larger sizes have lives in the hundreds of years. The permeation of moisture through the sheath can therefore be neglected as a practicable consideration in the actual service life of this type of cable construction.

Comparison of Accurate Calculation and Linear Approximation

While the linear approximation is satisfactory for the purpose described in reference 6, when used for other purposes it can produce large errors. A graph of the variation with time of the core air R.H. for both the more accurate relationship and the linear approximation is given in Fig. 8.

Middle Values of R.H.: Over the range of cable core air R.H. from 25 to 80% the time taken for the core air R.H. to rise from 0 to a given value is approximately the same whichever relationship is used.

Low Values of R.H.: Over the range of values of core air R.H. from 0 to 25% large errors can result from the linear approximation. If the cable service life is considered to be from 4 to 40% R.H. instead of 0 to 40% R.H., the accurate calculation indicates that the cable service life is reduced by 25.4%, whereas, the linear approximation indicates a reduction by 8.0%. If it is considered, as in this paper, that the service life is from 19 to 40% R.H., the accurate calculation indicates a reduction in the service life of 61% whereas the approximation indicates a reduction of 47%. The inaccuracies in the results obtained by the linear approximation could lead to inaccurate decisions when determining manufacturing specification and installation I.R. limits.

High Levels of R.H.: Over the R.H. range 80–100% large errors also result from using the approximation. When considering the use of paper wrapping in a polythene insulated cable to delay the onset of internal moisture condensation, the accurate calculation indicates that for a given quantity of paper the time taken for the core air R.H. to rise from 0 to 95% is three times as great as the time indicated by the approximate calculation.

Insulation Resistance Limit

The variation of the cable's I.R. with time due to moisture permeation through the sheath is shown in Fig. 9, and the calculated service life of a 100/4 cable for various initial values of cable core air R.H. are shown in Table 3. From the examination of these, and other computed data, the following comments are made:—

Specified Manufacturing Limits: The present A.P.O. Specification sets a manufacturing I.R. limit of 25,000 megohm-miles (5.5% R.H.) which reduces the moisture that can be absorbed before the I.R. falls from infinity to the installation acceptance limit by 19.6%. This result assumes that the moisture absorbed during installation is absorbed uniformly throughout the cable. It is however, considered more likely that most moisture enters and remains initially near joints and if so, the effect of reducing the manufacturing limit is greatly reduced, probably decreasing the allowable moisture absorption during installation by less than 5%.

Installation Acceptance Limit: The installation acceptance limit of 2,500 megohm-miles corresponds to 19% core air R.H. The effect of increasing this limit from 2,500 to 5,000 megohm-miles was studied. It increased the amount of moisture that the cable can absorb during its service life by 36%.

Again this result assumes even distribution of moisture at the time of installation acceptance but the effect of uneven distribution on the results has not been assessed. To change the limit would however result, in many cases, in additional costs and extra drying of cables after jointing to meet the enhanced limit and this extra expense would not seem to be warranted as the extra cable service life gained is most unlikely to be availed of (the life being already greatly in excess of practical life achieved with traditional cable designs).

Maintainability Limit: The choice of the maintainability limit used in this study has been somewhat subjective but the cable service lives derived are so greatly in excess of practical requirements that electrical requirements are unlikely to dictate reconsideration of this limit.

SOME RELATED CONSIDERATIONS

Gas Pressure Alarm Systems

The relationship between paper moisture content and core air moisture content used in this paper apply at normal pressures and at the pressures used inside gassed cables. Hence the R.H. of the air injected into gassed cable must be lower than 19% at the pressure in the cable if the I.R. of the cable is to be kept above the present installation standard. However, if the installation standard is considered to reflect the situation that, immediately after installation the R.H. of the core air varies from somewhat above 19% near joints down towards the R.H. at manufacture (4%) midway between joints, there could be some case for using gas dryer than 19% R.H. particularly if the extra cost of equipment is not high.

In the absence of a high rate of flow of low humidity air through all parts of the moisture barrier sheathed paper cable network, the cable core I.R. will be controlled by moisture permeation through the sheath and within the normally expected service life of cables (say 30–40 years), the I.R. will fall below the present 2,500 megohm-mile installation standard. It will however remain well above any maintainability level likely to be adopted. For cables with an assessed service life (due to moisture permeation) of 100 years that I.R. would be around 1000 megohm-mile after 30 years.

Moisture permeation considerations do not dictate that continuous flow gas pressure systems be an essential adjunct to moisture barrier cables.

Cable Conductor Corrosion

It is possible, particularly with aluminium conductors, that at the humidity level proposed as a maintainability limit, conductor corrosion (chemical) could occur. Such corrosion might lower the I.R. of the paper leading to faults and electrolytic corrosion. This aspect was not studied in this paper.

Temperature Effects

Many of the phenomena detailed in this paper are heavily temperature dependent. The study results are for 15°C. All effects are long term and hence the results need modification only when the mean annual temperature exceeds 15°C. Short excursions into higher temperatures are of no consequence. The major effect of a rise in mean temperature to, say 25°C, is to lower the I.R. of paper at any particular moisture content quite substantially, and to moderately increase the permeation rate. Overall, however, the effects do not lead to a conclusion that moisture barrier cables should not be used in say, tropical Queensland.

Quality of Moisture Barrier

The reduction in the permeation rate produced by even a poor quality barrier increases the service life of a cable to greater than its estimated service life due to other factors, so the main considerations in the manufactured quality of the foil barrier are these other factors, such as the possible damage it may cause to the core and the stresses borne by it which could cause its rupture in service. The causes of these other conditions also result in an increased permeation rate, e.g. transverse ripples which could cause damage to the core, increase the permeation rate by increasing the width of

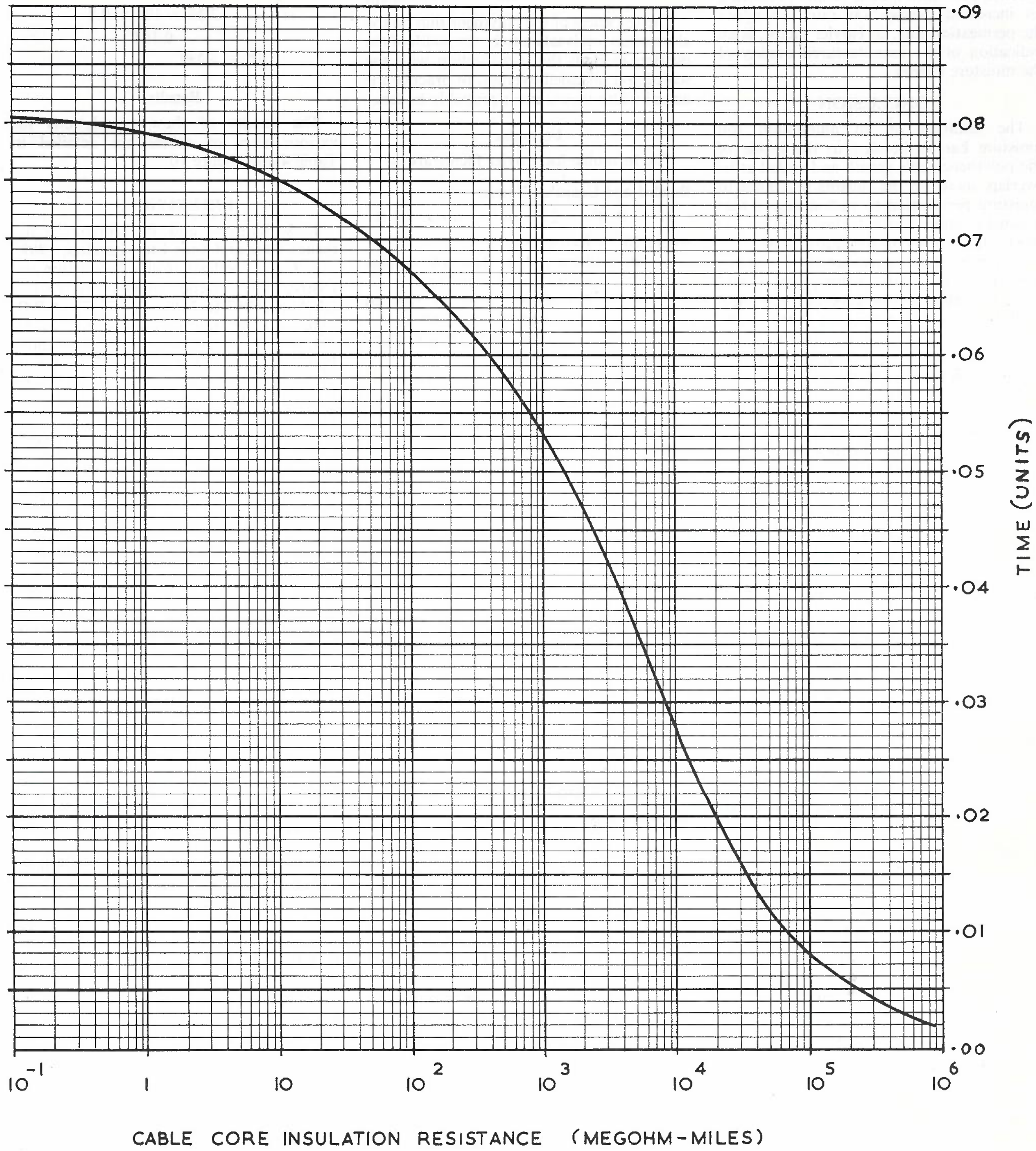

Fig. 9—Relationship Between Cable Core Insulation Resistance (From Computed Calculation) and Time.

the overlap and in areas where the foil is not bonded to the polythene sheath causing stress to be borne by the foil, an increased effective permeation area results producing an increased permeation rate. Therefore the permeation rate, or barrier factor, is an indication of the manufactured quality of the moisture barrier.

CONCLUSION

The addition of an aluminium foil moisture barrier bonded to the inside of the polythene cable sheath and sealed at its overlap, increases the sheaths resistance to moisture permeation to such a degree that it can be ignored as a factor affecting the service life a of paper insulated cable.

However, the effectiveness of the moisture barrier, i.e. barrier factor of the sheath, is an indication of the general mechanical quality of the foil barrier. It is the mechanical quality of the barrier, not moisture permeation resistance, which will have the greatest effect upon its service life.

The study of the relationship between cable core air R.H., I.R. of the insulating paper and time shows that the specified manufacturing and installation acceptance I.R. limits do not need to be tightened, or special gas pressure alarm systems installed, to cater for moisture barrier sheathed cable.

ACKNOWLEDGMENT

The Author would like to express his thanks to the members of the Lines Section, Headquarters, in particular the Plant Provision (Cable) Sub-section, the Physics and Polymer Section, P.M.G. Research Laboratories, and Austral Standard Cables Limited, who so willingly supplied information and participated in discussion of the various sections of this paper.

APPENDIX I

POLYETHYLENE/ALUMINIUM LAMINATE MOISTURE BARRIER SHEATH—THEORETICAL BARRIER FACTORS

Specification

From the Australian Post Office Specification No. 1076 Cable Sheath Composite Polythene Aluminium Barrier we have,

Minimum Length of Foil Overlap (L) = 0.25″ = 0.536 cm

Thickness of Polythene Film (2t) = 0.0015″ = 0.0038 cm

The thickness of the polythene film on the aluminium foil is taken to be the width of the overlap in both the construction with the sealed and unsealed overlap. In practice the actual width would most probably be less.

Formulae

The formulae for barrier factor are:—

Bonded and Unsealed Barrier

$$BF = P_1/P_2 = 2.53d/s\lambda^{0.17} \text{ for } \lambda \leqslant 1.0$$

where BF = Barrier Factor

P_1 = Permeation Rate of Unbarriered Sheath (cm^3/sec)

P_2 = Permeation Rate of Bonded Unsealed Sheath (cm^3/sec)

d = Mean diameter of polythene sheath (cm)

s = Thickness of sheath (cm)

λ = t/s

2t = Width of foil overlap (cm)

Bonded and Sealed Barrier

$$BF = P_1/P_4 = \pi dL/2ts$$

where P_4 = Permeation rate of bonded sealed barrier

L = Length of sealed overlap

For Specification No. 1076 sheaths, L and t are constants so this equation can be rewritten as,

$$BF = P_1/P_4 = 2.54 \times 10^2 \times \frac{d}{s}$$

Typical Calculation

10/4 Cable

Maximum External Diameter = 0.065 cm

Sheath Thickness (s) = 0.165 cm

Mean Sheath Diameter (d) = 0.800 cm

$$\lambda = \frac{t}{s} = \frac{0.0019}{0.165} = \frac{1}{87}$$

Barrier Factor BF

(a) Bonded, Unsealed Barrier

$$BF = \frac{2.53d}{s\lambda^{0.17}} = \frac{2.53 \times 0.8 \times 2.14}{0.165}$$

$$BF = 26.3$$

(b) Bonded, Sealed Barrier

$$BF = 2.54 \times 10^2 \times \frac{d}{s}$$

$$= \frac{2.54 \times 10^2 \times 0.8}{0.165}$$

$$BF = 2{,}540$$

Results

The results of these calculations for various sizes of cables are detailed in Table 4 and Figure 10.

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TABLE 4: THEORETICAL BARRIER FACTORS FOR VARIOUS A.P.O. CABLES

Cable Size	Maximum External Diameter (cm)	Sheath Thickness (s) (cm)	Mean Sheath Diameter (d) (cm)	Theoretical Barrier Factor	
				Bonded, Unsealed	Bonded, Sealed
10/4	0.965	0.165	0.800	26.3	2,540
100/4	2.26	0.178	2.084	64	6,150
600/4	4.70	0.23	4.47	111	10,200
2400/4	8.63	0.305	8.325	164	14,300
10/10	1.40	0.165	1.235	39	3,920
100/10	3.07	0.19	2.88	84	7,650
600/10	6.63	0.267	6.363	140	12,500
1200/10	8.76	0.32	8.44	159	13,800
10/20	1.70	0.165	1.535	50	4,850
100/20	4.11	0.216	3.894	109	9,450
600/20	8.76	0.52	8.44	159	13,800

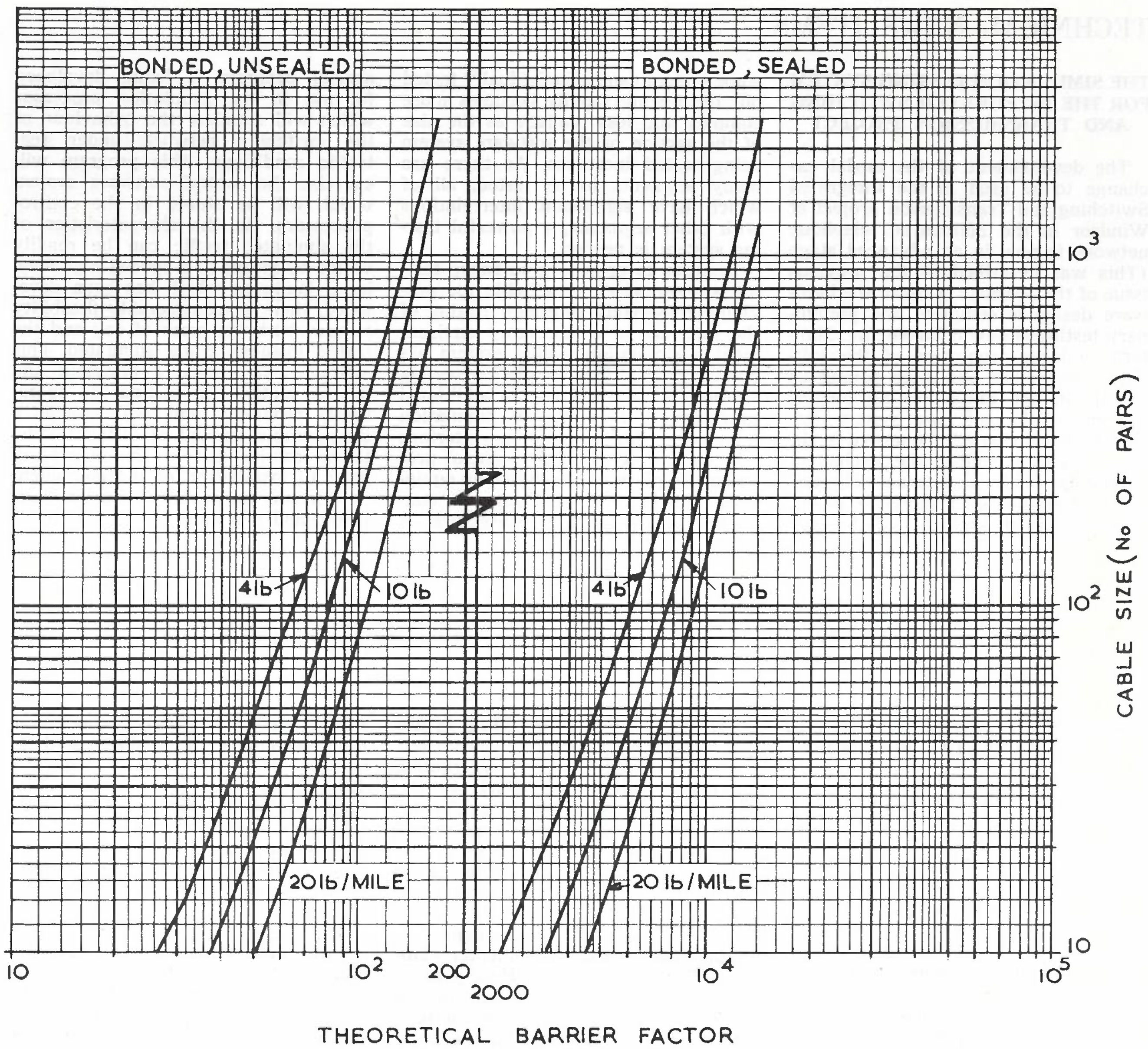

Fig. 10—Relationship Between Cable Size and Theoretical Barrier Factor for Bonded, Sealed and Bonded, Unsealed Barriers.

TECHNICAL NEWS ITEMS

THE SIMULATION TESTING SYSTEM FOR THE INTEGRATED SWITCHING AND TRANSMISSION PROJECT

The development of the model exchange to be used in the Integrated Switching and Transmission project at Windsor in the Melbourne telephone network is now in an advanced stage (This was described in the previous issue of the Journal). Most of the hardware design is complete and preliminary testing is now commencing. Similarly, a large proportion of the software system has now been completed and is in the initial testing phases. Testing of the software system (i.e. the programs that will be stored in the processors controlling the exchange) cannot be finally and completely carried out until the exchange is placed in traffic. Small segments of the software system can be individually tested but the testing rapidly becomes more complex and less realistic as the size of the section of the software system being tested increases. As there are many segments to be tested, all of which have significant interrelations with other segments, a powerful testing system is needed.

In order to provide a software testing system which is suitable for providing reasonably thorough testing of the software in a laboratory environment, a simulation testing system has been designed. This simulation testing system (S.T.S.) will use an additional processor with a special simulation interface; this simulation interface will be connected to the control processors in place of the switching equipment which would normally be connected to the control processors. A special program is being developed for use in the simulation processor which will simulate the behaviour of the switching network under real traffic conditions. This program will exercise the control software system which will be stored in the control processors. As the characteristics of the simulated traffic can be readily varied by means of a special high level input language which has been developed, there is considerable flexibility to vary both the types of call and the traffic loadings being simulated. This method will provide a powerful and flexible method for testing the operational programs and will enable a considerable amount of initial testing to be carried out in the laboratory prior to installation of the equipment in Windsor for testing using artificial traffic and test calls.

SOCIAL FORECASTING AS AN AID TO FUNDAMENTAL PLANNING

Everyone is a prophet! It seems that almost every journal has some prognostications on the future of mankind, perhaps preaching doom from over-population and pollution or the boon of Utopian automation.

The Post Office engineer who has ever considered where the paths of telecommunications will lead in the future, can conjure up devices to cater for any real or fancied telecommunication need. Every exhibition of electronic invention displays great schemes of future innovation, suggesting to the engineer that the technology to accomplish these marvels is here now, or at least just around the corner.

But what can the Post Office make of all this fanciful stuff? Our problem in operating a telecommunications network is to plot a course into the future which will give the greatest benefit from investment in telecommunications. Simply stated, we must go from 'now' to 'then'. 'Then' is not just where we happen to arrive but some future out of all the alternative futures we can predict, which we, the Post Office, think is worth aiming at. The paths between 'now' and 'then' must be planned so that we only take those steps which will allow us to approach the 'then' in the most economical and efficient manner.

In the face of this challenge to predict the future, Fundamental Planning Branch at A.P.O. Headquarters is working to throw more light on the forces that generate demands for telecommunications services in the community. In particular, the position of telecommunications in the present day social structure is being examined. Sociological and psychological research methods are being used to study the interdependence of telecommunications, the individual and the community.

However, knowledge of the present day situation offers little useful data to forecast likely future trends. We aim to predict progressive changes in the community 'life style' and to extract from this total concept the demand on telecommunications. Will the future society demand, say, a T.V.-telephone, or will the demand for personal privacy, in a world where that commodity is being steadily eroded, suppress the desire for such a service?

The forecasting of 'life styles' is new to the Post Office; it has not yet seriously been attempted in this country and has only recently been recognised overseas as a necessary tool to the prediction of technological change.

Without a sound knowledge of the forces acting upon society's communication requirements, and without some indication of how these forces may alter in the future, no telecommunications authority can predict the future demands or the facilities required with any confidence. The Fundamental Planning Branch studies aim to provide the Post Office with just that confidence.

S.T.D. PUBLIC TELEPHONE

*A. A. RENDLE, B.A.**

INTRODUCTION

Although limited facilities have been available in a few places (see Ref. 1), Australia has lacked an S.T.D. public telephone. This need will be met by a new instrument which provides full S.T.D. facilities, as well as handling operator assisted, local and emergency calls. The new telephone, Coin Telephone No. 3 (CT.3), is based on the Nippon Telegraph and Telephone Public Corporation (N.T.T.P.C.) booth type S.T.D. coin telephone. but considerable modifications, particularly in protection against vandalism, have been made to suit local needs. The telephone will be made in Japan initiallv, but local production is expected within a few years. This article describes the main features of this instrument.

* Mr Rendle is Engineer Class 2, Subscribers Equipment Section, Headquarters. See Vol. 18, No. 1, page 69.

GENERAL PRINCIPLES

The basic principles of the S.T.D. public telephone were covered in an earlier issue of this journal (Ref. 2). In brief, the accounting and coin control logic, coin tone generators, etc., are located within the instrument, which forms an almost self-contained system. No coins are needed for dialling emergency and other non-chargeable numbers, but at least one coin must be inserted before answer

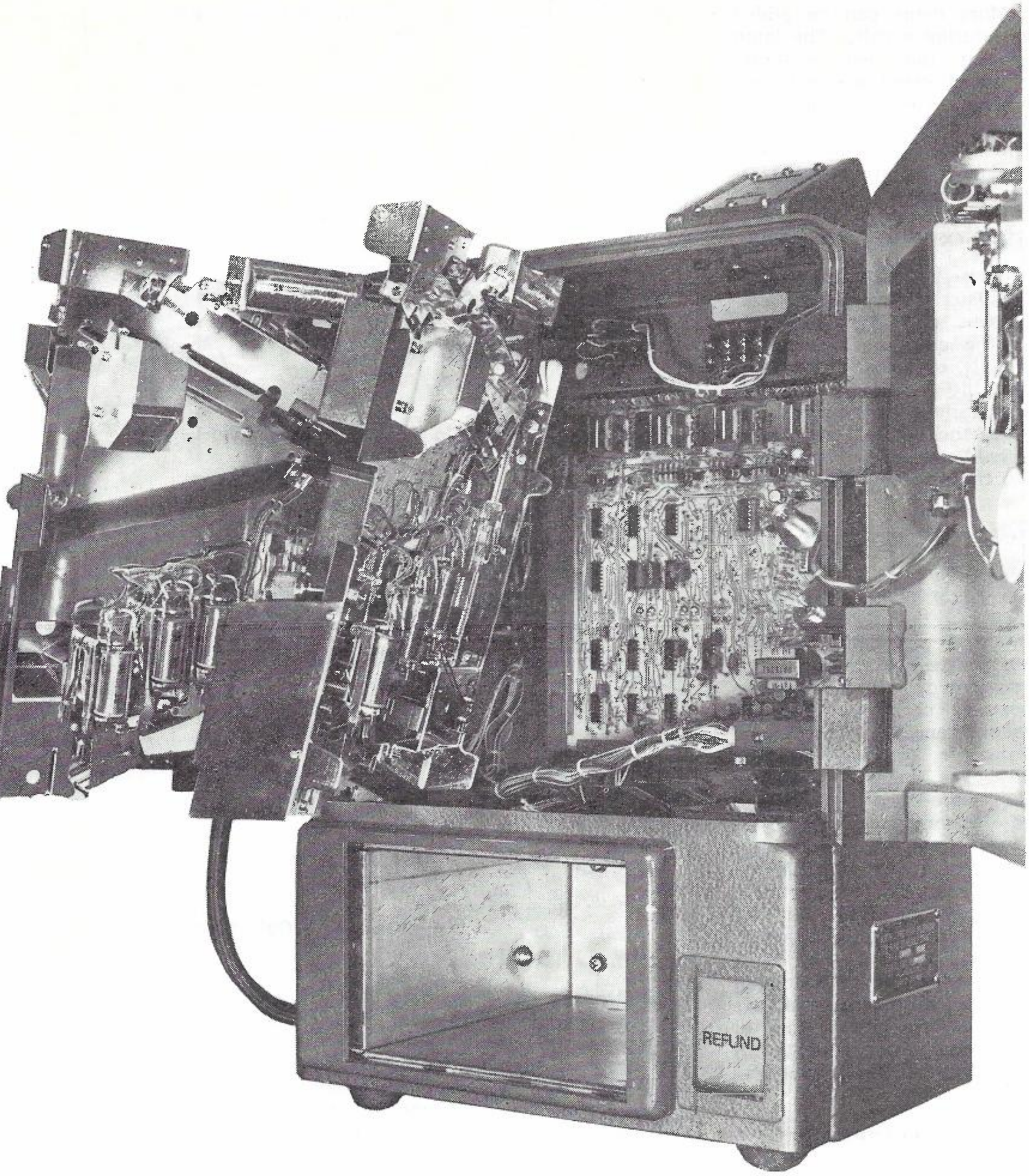

Fig. 1. — Coin Mechanisms Swung Out for Servicing. (The electrical control circuit can be seen at the rear of the instrument.)

on chargeable calls or the loop will be disconnected. The normal method of use will be to insert a coin (or several coins for S.T.D. calls) before dialling. The coins are held in suspense until a metering pulse is received on answer, when one coin is taken. On S.T.D. further coins will be taken as needed during the call. The instrument equates the cost of the call, indicated by the arrival of metering pulses, with the value of coins taken. Low value coins are taken first, to minimise loss in the case of a wrong number. When all coins in suspense have been taken, a steady red lamp glows, to warn the user that his credit is nearly exhausted. More coins can be added at any time during a call. The lamp flashes during the last metering period. Unused coins are returned on hanging up. Two coin sizes can be accommodated, initially 5 cents and 20 cents. The coin mechanisms can be replaced by other values if tariffs are changed.

PROVISION OF LOCAL POWER

A.C. power is supplied, via a double insulated transformer, to run the control equipment and provide ample power for the coin mechanism. If the power fails, emergency and other non chargeable calls can still be made, but chargeable calls are not available. If the power fails during an S.T.D. call, unused coins will be returned to the user and the call cut off.

ELECTRONIC CONTROL

The control system is based on the circuit of Ref. 2 with a number of changes to suit the present mechanism and rationalise components. High threshold logic (HTL) digital ICs were chosen, as they are now almost as cheap as standard DTL (Diode Transistor Logic) and TTL (Transistor Transistor Logic) lines and give better protection against noise produced by adjacent relays and electromagnets. The components are mounted on a single printed wiring board attached to the rear of the mechanism compartment (see Fig. 1). The trunk unit fee rate (cost of one metering period) can be adjusted to 4, 5, 6, 7, 8 or 10 cents by plugs on the circuit board. Power supply components are located in a module in the floor of the mechanism compartment. A hybrid regulator supplies 15 volts to the logic ICs.

EXCHANGE EQUIPMENT

The signals required to operate the telephone are multi-metering pulses, transmitted as 50 Hz signals, and a polarity reversal on answer. Relay sets to provide these signals have been designed for crossbar and step exchanges. The step exchange relay set also provides P.T. tone to the operator to identify the call as from a public telephone. P.T. callers from crossbar exchanges will be able to gain operator assistance on a nominated code only. Due to difficulties in signalling through the network to remove the P.T. tone, most of the initial STD public telephones will be connected to crossbar exchanges.

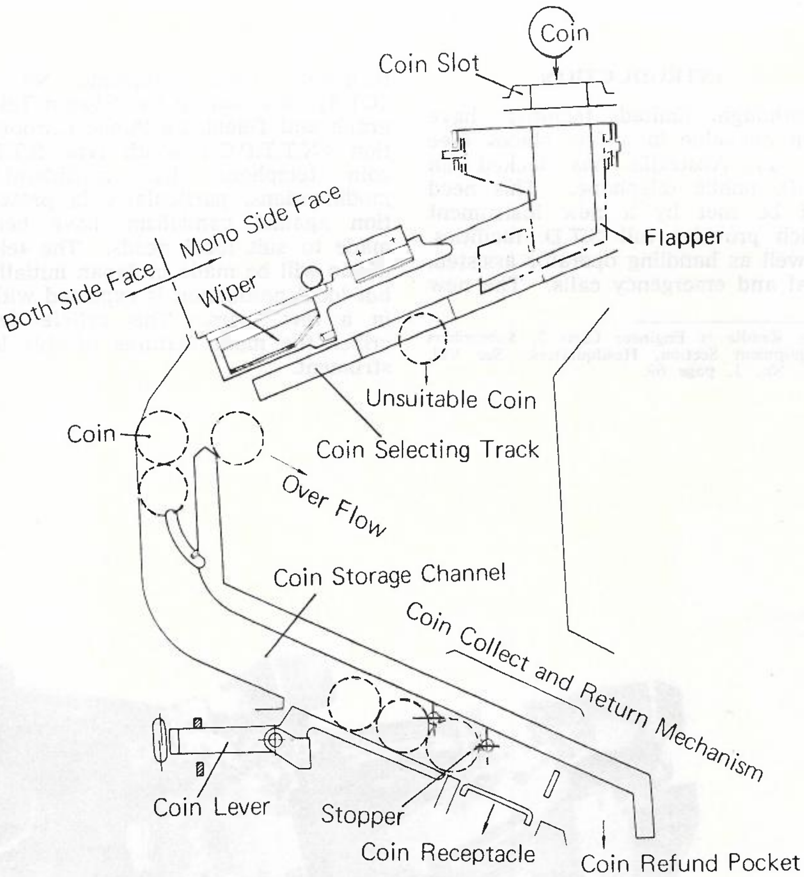

Fig. 2 — Coin Mechanism Layout.

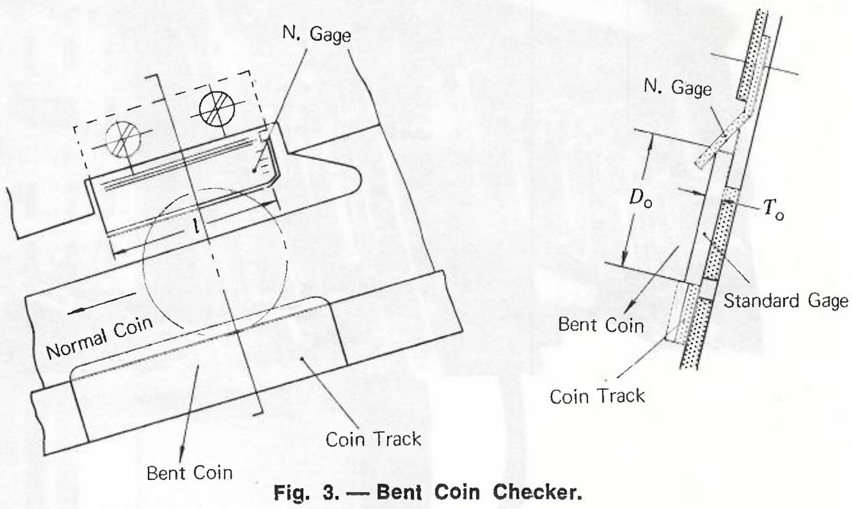

Fig. 3. — Bent Coin Checker.

COIN MECHANISM

This is similar to the N.T.T.P.C. coin mechanism, but is adapted to

Australian coin sizes. The original mechanism was the subject of a considerable theoretical and practical study by the Electrical Communications Laboratory of the N.T.T.P.C. and the manufacturers (Anritsu Electric). In the course of development, many different models were tested. A detailed study of the principles of the design is given by Yanagi in Ref. 3. The chief aim was that the mechanism be simple and trouble-free. All the parts for one coin size are built on to a single, separate plate. A single sided coin selector forms the upper part of the coin mechanism (see Fig. 2). Coins are checked for diameter, thickness and magnetic properties. The number of tests has been deliberately restricted in the interests of reliability. After being checked, coins stack up, edge on edge, in the double sided storage chute which forms the lower part of the mechanism. The titanium balance arm operates a sealed reed switch, via a small permanent magnet. Bent coins which could jam the chute are removed by the device shown in Fig. 3. Thin coins, which could also jam the chute by wedging together, are rejected by falling through a slot in the selector runway. Coin collection is controlled by three electromagnets on the rear of the mechanism (see Fig. 4). The upper two magnets operate pins in the path of the coins. On S.T.D. they work together like an escapement to release coins one at a time. For operator assistance working both pins are withdrawn to allow all the coins held in suspense to run out together. The third magnet controls a slotted section of the runway and either allows coins to fall through to the coin tin or run into refund. The flapper device (Fig. 5) is designed to release blockages (accidentally or deliberately induced) below the coin entry slots.

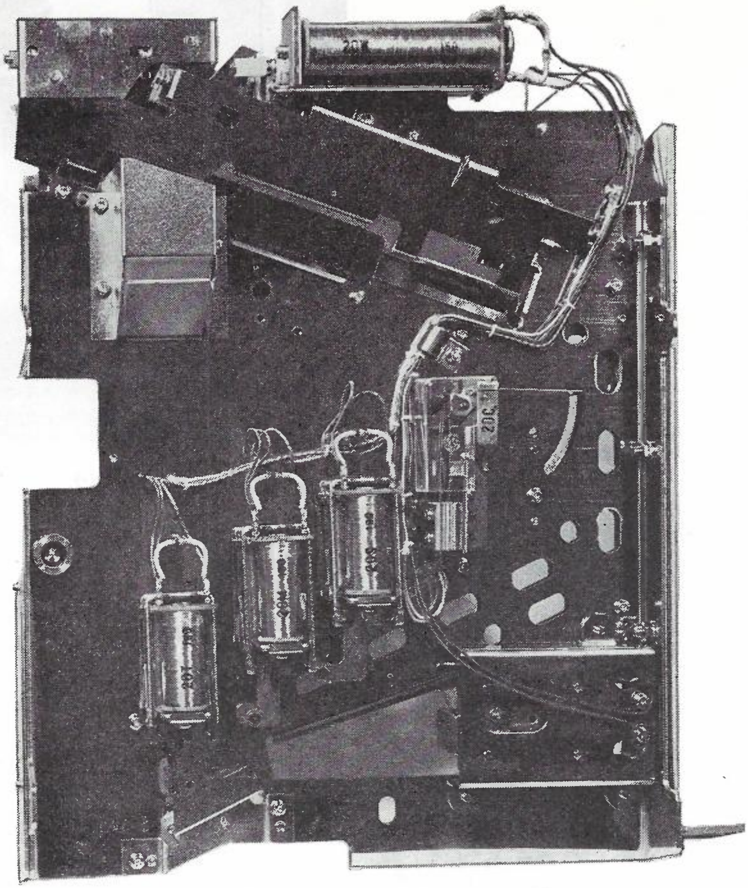

Fig. 4. — Rear View of the 20 Cent Coin Mechanism.

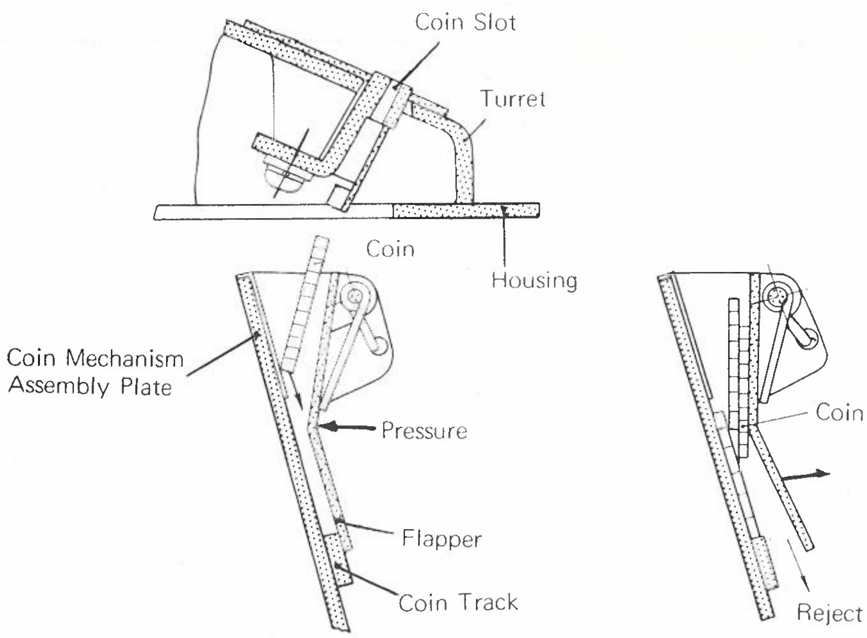

Fig. 5. — Flapper Structure.

THE CASE: PROTECTION FROM THEFT AND VANDALISM

Along with other administrations, the Australian Post Office has suffered severely in recent years from vandal and theft attacks on public telephones. The most successful weapons against this have been campaigns to detect and prosecute offenders, and to improve and strengthen the instruments in service. One of the fruits of this work is the strengthened Coin Telephone No. 1 case, designed and manufactured by Sydney Postal Worshops (see Fig. 6). Although of no beauty, this case is one of the most rugged enclosures yet devised for a coin telephone. In view of its proven performance, it was taken as a standard for the CT.3. The CT.3 case was developed by the proven method of exposing a series of steadily improved models to the attentions of a Post Office team of "professional vandals." One

Fig. 6. — Strengthened Coin Telephone No. 1 Case, Showing Coin Safe Door Arrangement.

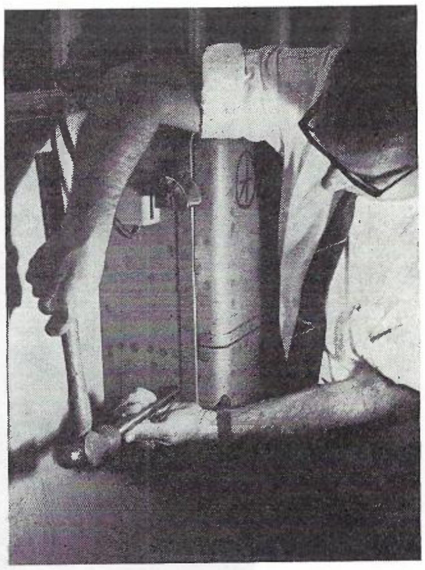

Fig. 7. — Testing an Early Model Case.

of these can be seen at work on an early model of the CT.3 case in Fig. 7. The case, which ultimately satisfied the standards of the vandal group, is shown in Fig. 8. It relies mainly on the brute strength of heavy gauge steel, mostly 3.2 mm, supported by massive hinges and locking bolts. All joints are well protected against levers and chisels. The coin safe arrangement is taken from the strengthened CT.1 case (Fig. 6). The coin safe door is, in effect, a large bolt; the lock merely moves a pin to prevent the door being slid sideways. The door is held within a hardened steel frame. A new self-sealing, deep drawn, coin tin has been developed by the manufacturers for this instrument. The handset cord is built around a steel chain and is proof against pulling. The handset caps are firmly cemented in place. In a way, it is a sad commentary on the society we live in that such extreme measures have to be taken to protect a public utility: but, from the point of view of an operating organisation, it is much cheaper in the long run to build great strength into the design of a public telephone than to have to keep on repairing vandal damage.

INSTALLATION

One disadvantage of the brute strength approach is that the total weight of the instrument has risen to just over 100 lbs. This is obviously more than one man can handle unaided, so the Sydney Postal Workshops work study group have devised a hoist system for hauling the telephone into position. The telephone is mounted on a tubular steel frame, attached in the case of the aluminium cabinet, by bolts through the rear wall. Stainless steel coach nuts are used on the outside of the wall. The frame also serves as a temporary support for the hoist.

POTENTIAL FOR FURTHER DEVELOPMENT

The massive case described above is an inelegant answer to the vandal/theft problem. Apart from poor appearance it is also much too heavy for convenient handling. Stainless steel could be exploited to make a lighter and better looking case, without reducing security. The simple lamp system to warn of impending disconnection is an unsatisfactory compromise. The user really needs a continuous credit indication to be able to control his call properly. The availability of light emitting diode arrays and complex logic ICs may soon make this economically feasible. A complex MOS chip is also likely to displace the discrete ICs used in the control circuit.

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Fig. 8. — The New S.T.D. Public Telephone.

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R. A. O'CALLAGHAN, author of the article 'The Theory of Moisture Barrier Paper Insulated Cables,' joined the P.M.G.'s Department as a Technician-in-Training in 1957 in Perth. He was appointed as an Engineer Class 1 in 1968, and in 1969 transferred temporarily to the Automotive Plant Unit of the Mechanical Aids Division, Support Services Branch in Headquarters. In 1970 he transferred to the Cable Design Division of the Headquarters Lines Section, where he was engaged on investigation of the electrical characteristics of telephone cables. He has since returned to Western Australia where he is appointed to the position of Engineer Class 2 in the Industrial Engineering Group. Mr. O'Callaghan gained an Associateship in Communication Engineering with Distinction from the West Australian Institute of Technology.

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L. R. GREGORY, co-author of the article 'Type-72 Multiplexing Equipment for the A.P.O. Network', is Senior Mechanical Design Engineer in the Line Transmission Division of Standard Telephones and Cables Pty. Limited, Sydney. He is mainly concerned with equipment practice design and related problems and represents the Company on the ITT world-wide technical committee dealing with Equipment Practice.

His long association with the design and manufacture of transmission equipment has included considerable periods in charge of all phases of factory planning and production.

In 1944 he completed a Diploma in Mechanical Engineering at the Sydney Technical College and is a Member of the Institution of Engineers, Australia.

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R. J. SPITHILL, co-author of the article 'Type-72 Multiplexing Equipment for the A.P.O. Network', is Project Engineer for Multiplex Equipment in the Line Transmission Division of Standard Telephones and Cables Pty. Limited, Sydney. He joined S.T.C. as a Cadet Engineer in 1962 and graduated from the University of N.S.W. in 1967.

Since 1965 he has been engaged on all facets of the design of multiplex equipment and now heads a team of engineers and laboratory support staff principally engaged in the local development of transmission equipment meeting the needs of the A.P.O.

He is also responsible for the performance and reliability of multiplex equipment. Technical performance standards, manufacturing processes and reliability procedures are established under his guidance.

G. van BAALEN, co-author of the article 'Type-72 Multiplexing Equipment for the A.P.O. Network', joined Standard Telephones and Cables Pty. Limited in 1962 on an engineering cadetship, graduating from the University of N.S.W. in 1969. Since 1964 he has been involved in various aspects of line transmission work, and participated in the design, installation, and commissioning of the Mt. Newman iron ore mine private communication system. At present he is engaged in the design and development of higher-order multiplexing equipment.

★

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H. MELLING

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He was born in Denmark in 1922, and received his M.Sc.E.E. Degree with Honours from the Technical University of Denmark in 1945. After five years academic and practical engineering work in Denmark, Mr. Dossing was recruited by the A.P.O., and during the period 1950 to 1964 he was attached to the Headquarters of the A.P.O. in Melbourne on the operational aspects of electrical communications. He was awarded an M.E.E. Degree by the University of Melbourne in 1959.

He was promoted to his present position in 1964. Mr. Dossing has travelled overseas on various missions for the A.P.O., and during the course of his career has written a number of papers on a variety of engineering topics.

★

H. MELLING, author of the article 'Management of the Radio Frequency Spectrum in Australia', joined the Postmaster-General's Department in 1952. He occupied inspectorial positions in the Radio Branch until appointed Superintendent, Radio Regulatory and Licensing, Regional Operations, Tasmania, for which he is also Senior Commonwealth Marine Radio Surveyor, since 1970. He served in the Wireless Branches of the Royal Navy and Royal Canadian Navy during World War II. From 1946 to 1952 he was engaged in the Telecommunications activities of the British Foreign Office and the Marconi Wireless Telegraph Company at various places throughout the world. Mr. Melling designed a unique and complex Frequency Assignment Plan, integrating the mobile radio communication networks of community services, after the disastrous fires of 1967 in Southern Tasmania.

★

B. M. BYRNE, author of the article 'Cable Protection and Maintenance Testing Techniques', was appointed Engineer in the Queensland Administration of the Postmaster-General's Department in 1952, following completion of an Electrical Engineering Degree Course at the Queensland University. His earliest Cable Protection experience was in 1952, with some time spent subsequently in District and Primary Works. Since 1959, he has controlled the activities of the Cable Protection Division (now Section) in Queensland. He has represented the Central Administration, as well as the State, at various Cable Protection conferences interstate and in New Zealand. He is president of the Queensland Branch of the Australasian Corrosion Association, and is a past Australasian President of that Association. Mr. Byrne is a member of the Institution of Electrical Engineers, and currently holds the position of Supervising Engineer, Cable Protection, Queensland.

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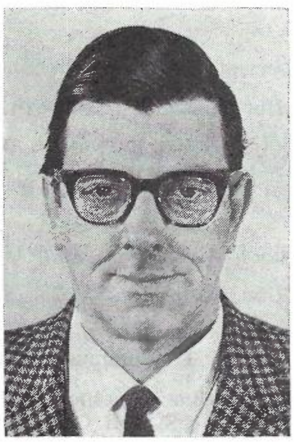

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J. M. WARNER, author of the article 'The Accuracy of Electrical Measurements Made by Electronic Techniques', was born and educated in Hobart, graduating from the University of Tasmania with a B.Sc. in Physics and Electrical Engineering. From 1948 he was employed in the A.P.O. Research Laboratories where he was responsible for instrument maintenance and calibration and the development of special instrumentation. He has been in charge of electrical standards since 1963 and is at present manager of the Electrical Standards Section of the Laboratories. He is a Member of the Institution of Electrical Engineers.

TELECOMMUNICATION JOURNAL OF AUSTRALIA
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Increasing costs have forced an upward revision of subscription rates for the above journals with effect from 1972 calendar year, which is also the volume year. **The new annual subscription rates** and the first volume affected are shown below:

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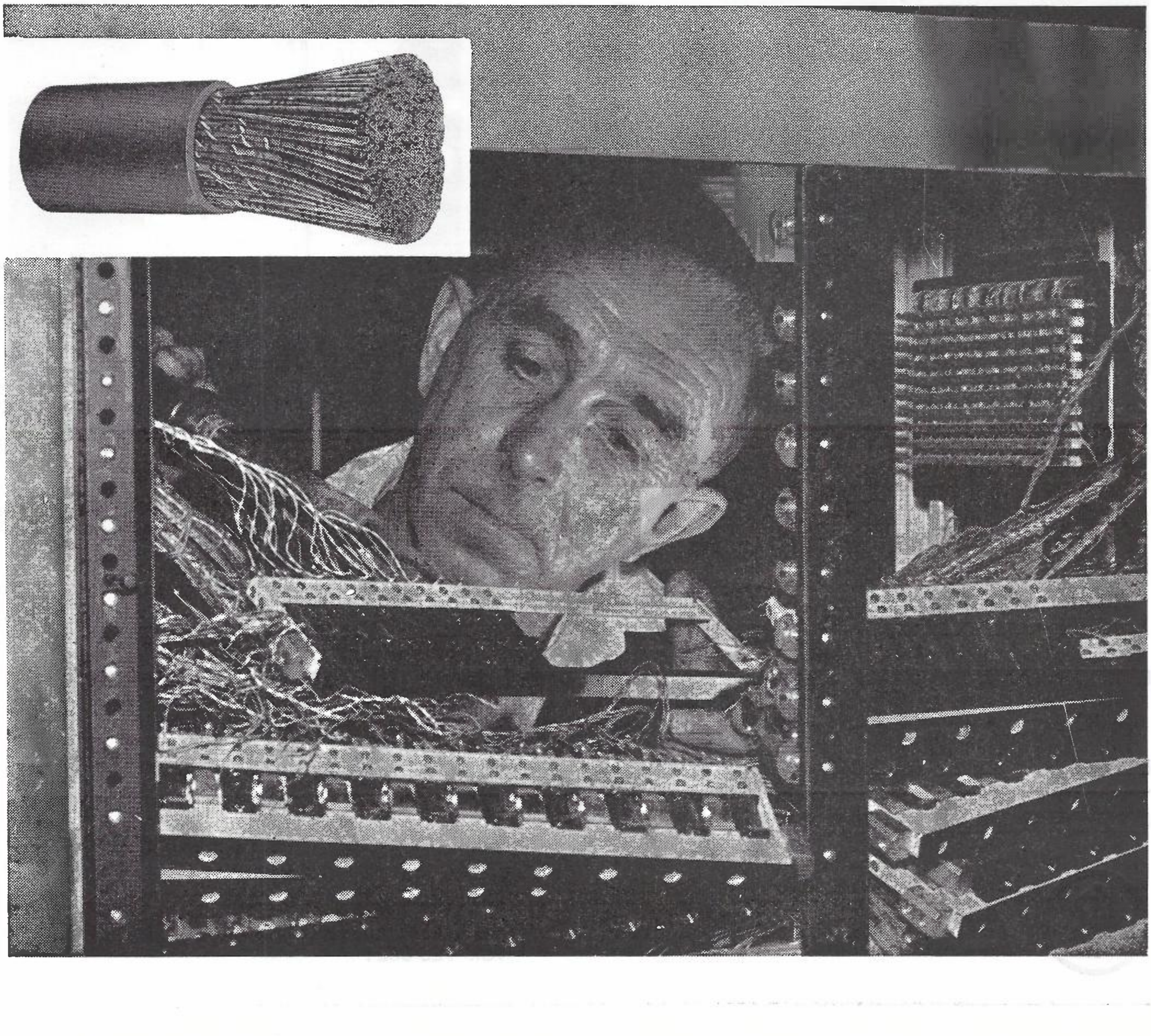

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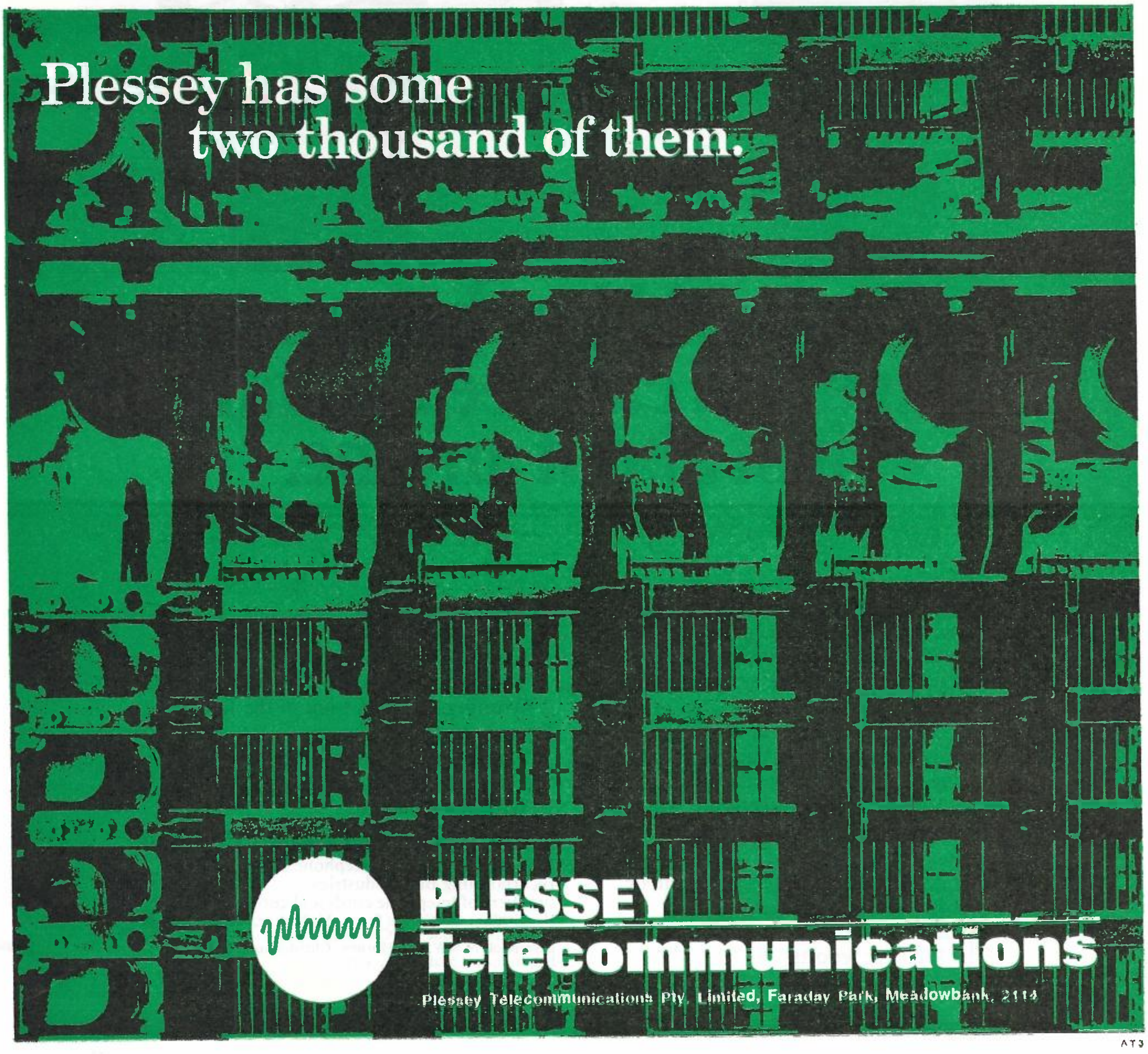

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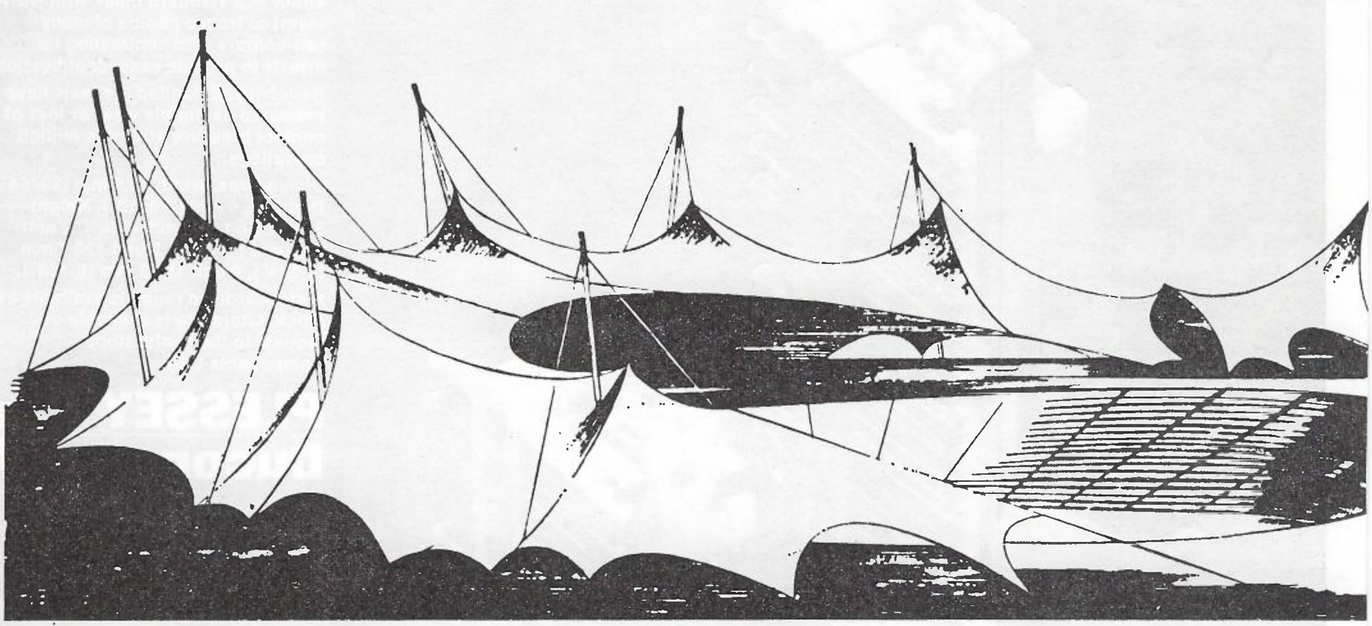

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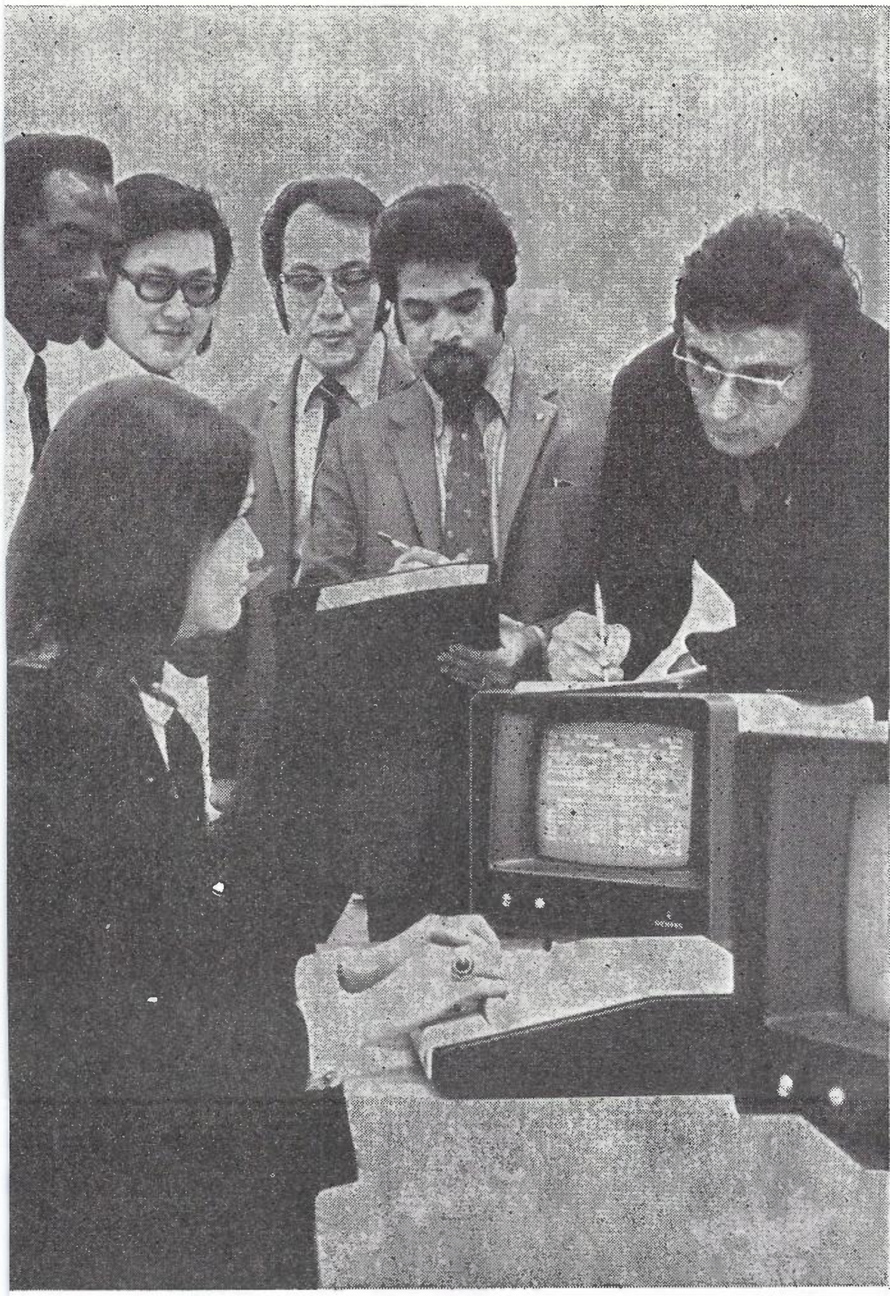

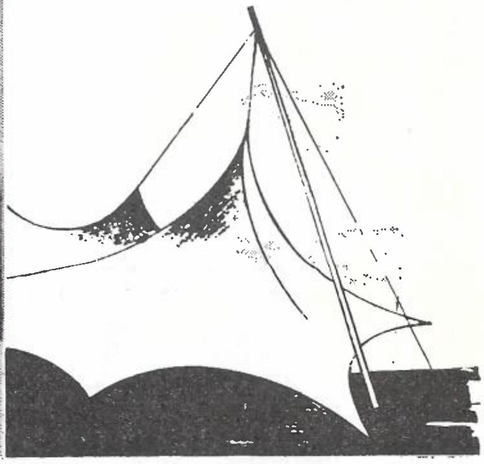

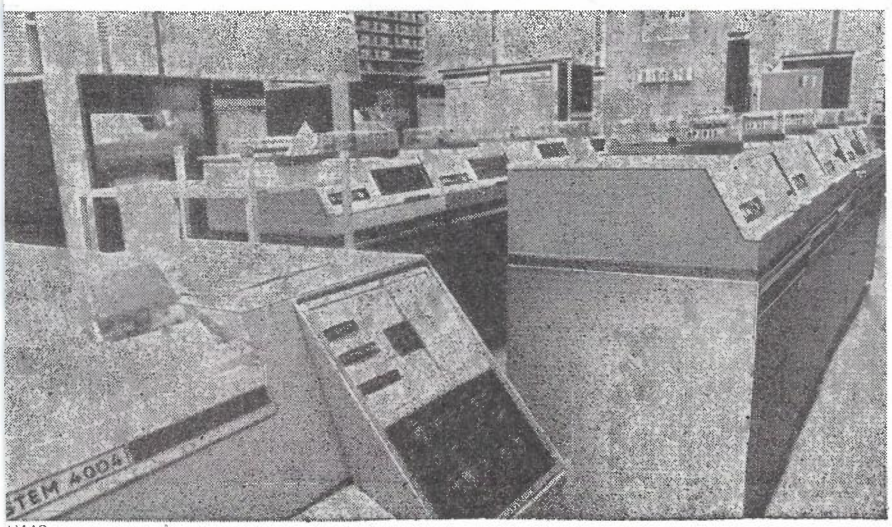
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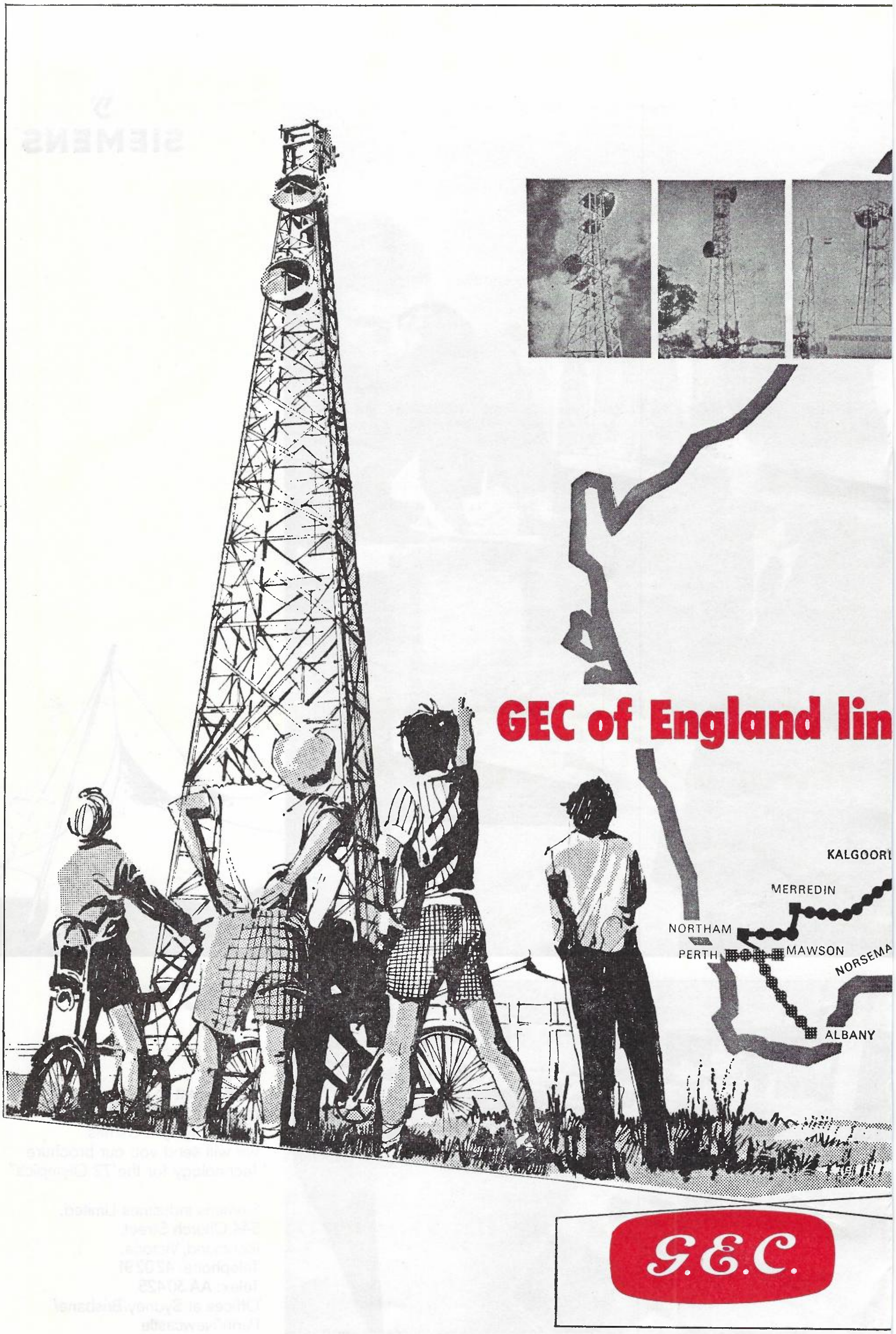
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ABSTRACTS: Vol. 22, No. 2

WARNER, J. M.: 'The Accuracy of Electrical Measurements made by Electronic Techniques'; Telecom. Journal of Aust., June 1972, page 110.

The use of electronic instruments is essential in some types of measurement. The published specifications of the more complex electronic instruments, such as digital voltmeters, are capable of misinterpretation, even by technical personnel. This paper highlights those parts of such specifications which, in the author's experience, are not unequivocal and makes particular reference to the problems of alternating current measurement.

SPITHILL, R. J., Van BAALEN, G. and GREGORY, L. R.: 'Type-72 Multiplexing Equipment for the A.P.O. Network'; Telecom. Journal of Aust., June 1972, page 123.

This article describes the development and production of the new range of channel multiplexing equipment by STC Pty. Ltd. (Australia) in accordance with the requirements of the Australian Post Office Design Guide for Long Line Equipment. The article outlines the key features of the electrical and mechanical design of the equipment, with reference to such aspects as reliability, facility of installation, and operational needs. The article is in two parts, the second part being in the next issue of the Journal, Volume 22 No. 3.

KITCHENN, R. G.: 'The 2-wire/4-wire Interexchange Telephone Circuit'; Telecom. Journal of Aust., June 1972, page 115.

The switched telephone circuit which terminates in a 2-wire switch at one end and a 4-wire switch at the other presents some interesting transmission problems. In this paper the network implications of the design of this type of circuit are examined. In particular, the paper examines the following factors:— transmission system loading, asymmetry of loss in opposite directions in a connection, data transmission implications, national semi-loop loss, noise, national sending and receiving reference equivalents.

It is shown that when the circuit is required to introduce loss into a connection, such loss (relative to a zero-loss circuit) should be provided in the 2-wire receive path only.

RENDLE, A. A.: 'S.T.D. Public Telephone'; Telecom. Journal of Aust., June 1972, page 159.

This article describes the new STD (Subscriber Trunk Dialling) public telephone. It uses electronic logic for accounting and coin control. Only simple exchange equipment is needed. The article also describes special measures taken to combat vandalism and theft.

O'CALLAGHAN, R. A.: 'The Theory of Moisture Barrier Paper Insulated Cables'; Telecom. Journal of Aust., June 1972, page 147.

This paper outlines the theory of moisture permeation through the plastic and plastic/metal laminate cable sheaths as used by the A.P.O. and investigates the variation of the cable core paper insulation resistance with time due to this moisture permeation. Included is a discussion of some practical applications of this investigation in particular the various insulation resistance limits throughout a cable's service life.

DOSSING, S.: 'Future Telephone Switching Systems'; Telecom. Journal of Aust., June 1972, page 103.

For the purpose of comparison with future telephone systems, the main features of past and present systems are discussed briefly.

The requirements of telephone switching systems of tomorrow and the more distant future are described in some detail. It appears that the requirements of the immediate future, including the requirement of reasonable cost, can be met by new types of processor controlled electronic systems at present under development. The main features of these new systems are discussed.

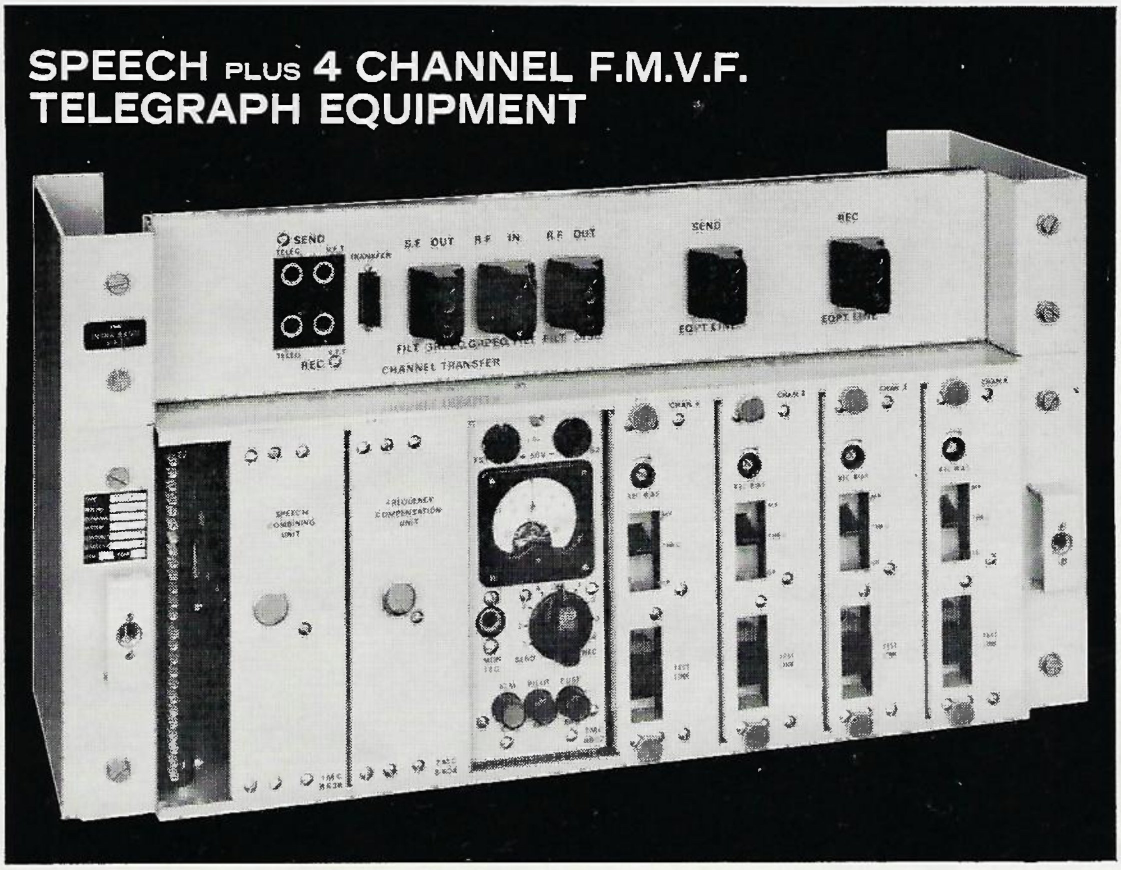
The day when even these systems will become obsolete (mainly in economical terms) is clearly seen and even more advanced systems which will integrate switching and transmission into a unified system (integrated switching and transmission) are already being developed.

BYRNE, B. M.: 'Cable Protection and Maintenance Testing Techniques'; Telecom. Journal of Aust., June 1972, page 138.

Part 1 of this article describes various Cable Protection activities, largely as applied in the Queensland Administration of the Australian Post Office. Cathodic protection in corrosion prevention is discussed briefly in design, anode materials, performance and results. Present investigations are noted. Gas pressurisation is detailed briefly in application, performance and significance. Part 2 of the article describes cable testing for faults and substandard performance; miscellaneous cable protection activities are also described.

MELLING, H.: 'Management of the Radio Frequency Spectrum in Australia'; Telecom. Journal of Aust., June 1972, page 132.

This article outlines the use and allocation of radio frequencies from Marconi's day to the present time. The administration of the Radio Frequency Spectrum in Australia is described, together with methods of monitoring radio frequencies, and investigating radio interference. The article concludes with an outline of the responsibilities of various Authorities in Australia for radio frequency allocation.



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