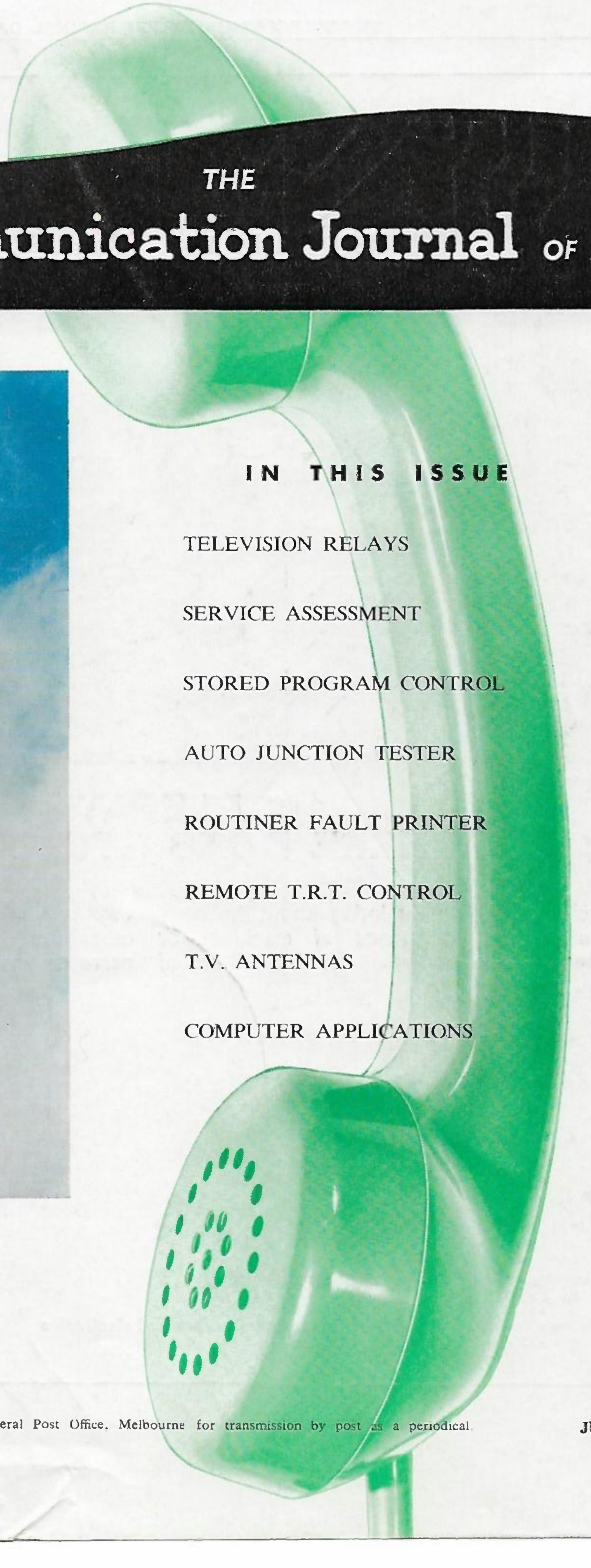
THE

Telecommunication Journal OF AUSTRALIA



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ROUTINER FAULT PRINTER

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T.V. ANTENNAS

COMPUTER APPLICATIONS

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OF AUSTRALIA

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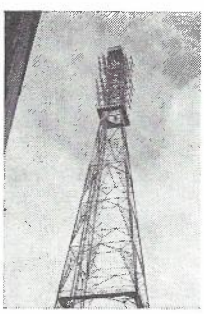

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THE RELAYING OF TELEVISION PROGRAMMES IN AUSTRALIA

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INTRODUCTION

General

The pattern for the development of public television services in Australia was set by the recommendations of a Royal Commission published in in 1954, and the first transmissions were from Sydney and Melbourne in 1956. The Australian Broadcasting Control Board (A.B.C.B.) is responsible for the overall planning, technical and programme standards, and licensing of television stations. These are either commercial (owned by private enterprises) or National (programmes and studios provided and controlled by the Australian Broadcasting Commission and transmitter and relay links provided and controlled by the Australian Post Office).

The Need for Relay Facilities

Both commercial and National services are broadcast from transmitters in the six State capital cities and in 26 major regional areas of the Commonwealth (April, 1966). Expansion of services to another seven regions is in hand; by the end of 1966, National and/or commercial television transmitters will be operating from 38 regional locations, and from the 39th (Mackay) in 1967. In some areas, commercial and National transmitters are housed in the same building and use the same tower for aerials. Programmes for National stations in a given State are generated principally at studios in the State capital city, and the Post Office provides common-programme relay facilities to the remote transmitters.

There are growing requirements for inter-capital-city programme exchanges for both National and commercial operators; at present these are regularly available only between Sydney, Canberra and Melbourne.

Finally, relay facilities are required by regional commercial stations which require occasional programme segments generated in capital-city studios. These stations may sometimes wish to transmit a programme to the capital city; if so, a second link in the reverse direction would be required, since relay links are undirectional.

The Post Office is responsible for the provision and maintenance of all television-relay facilities in Australia, with the exception of short studio-transmitter links for commercial stations.

THE RELAY NETWORK

General

A bandwidth of at least 5 Mc/s is required to accommodate a video signal to Australian standards. The same bandwidth can provide upwards of a thousand telephone channels, by frequency-division techniques. Since the Post Office also has the responsibility of providing the Australian telecommunications network, it is convenient and economical to provide television relay facilities on routes which also require large numbers of telephone circuits; the high common costs (e.g. of cable-laying, building towers, etc.,) of the basic communication system may be spread over more than one type of service. Fig. 1 shows the present and probable future long-distance routes which may be used for the relaying of television signals. Most of the links are provided by line-of-sight frequency-modulated radio-relay systems at carrier frequencies of the order of gigacycles per second, but some use underground coaxial-cable systems in which the television signal is transmitted by the vestigial sideband method (amplitude modulation)

The relay channels so far discussed terminate in Post Office buildings at the main population centres. It is necessary to provide extension links to customers' premises (e.g. studios) and means for equalizing, inter-connecting, monitoring and testing all links. The latter functions are provided at Television Operating Centres (TOC). A TOC also provides similar facilities for the associated audio signals.

The relatively short links connecting customers' premises to TOCs are mostly provided by direct video transmission over underground coaxial cable.

The television operating centre for a State is located in a Post Office building in each capital city. Fig. 2 shows typical relay link connections. Line-of-sight radio links generally require repeater stations to be located on high points along the route; in some cases such locations are also suitable as television transmitter sites serving small communities outside the range of the normal high-power regional transmitters (Ref. 1). The possibility of tapping the programme signal passing through a repeater station and re-radiating it to small communities via an inexpensive, simple, low-powered transmitter using the same site, buildings and tower as the relay-link repeater is attractive, and is being investigated in detail at present.

Similar facilities are not likely to be so easily provided on links provided by coaxial cable, since the route of the latter will generally not pass over the mountain-top locations which are desirable for the re-broadcast transmitters. However, the routes will generally pass through small towns, and in some cases, it may be possible to tap the passing television programme and feed it to to a low-power transmitter separately located in the town. Such spurs from relay links can be achieved without detriment to the quality of the through signals.

Radio Links

Since the introduction of television in Australia, the Post Office network of radio television bearers has grown from two single-path studio-to-transmitter links into a network of regional bearers which now extends throughout all States (Fig. 1). Because the design of these bearers is developing rapidly, the equipment often differs from route to route and minor differences occur even between some of the bearers of the same route. These designs can be conveniently grouped in terms of the radio-frequency band in which the equipment operates, since each frequency band has its own features which the equipment has been designed to exploit.

At the present time most of the major radio trunk systems in Australia operate in the 4-Gc/s band because it represents an optimum compromise between factors which include transmitter power, receiver noise factor, and aerial gains.

Within this band, the transmitter design has relied upon a two-klystron frequency modulator followed by an intermediate - amplifier, crystal - controlled local oscillator and travelling-wave output tube to produce the linear modulation characteristic and power output necessary. The receivers have used crystal mixers for conversion of the incoming radio-frequency energy to a lower intermediate frequency which can be easily amplified, followed by a variable-gain amplifier to ensure that a signal of substantially constant average amplitude is fed through peak-amplitude limiters to the frequency demodulator.

The Post Office has also installed systems operating in the 6-Gc/s band, which yields higher aerial gains at the expense of a propagation medium which for certain types of paths requires more attention to be paid to fading effects. The equipment reflects a later design in the modulator section where the klystrons have been replaced by a phase-shift oscillator using conventional valves. The overall receiver design is substantially the same as as the 4-Gc/s equipment.

The spur routes shown in Fig. 1 have been equipped with short-dis-

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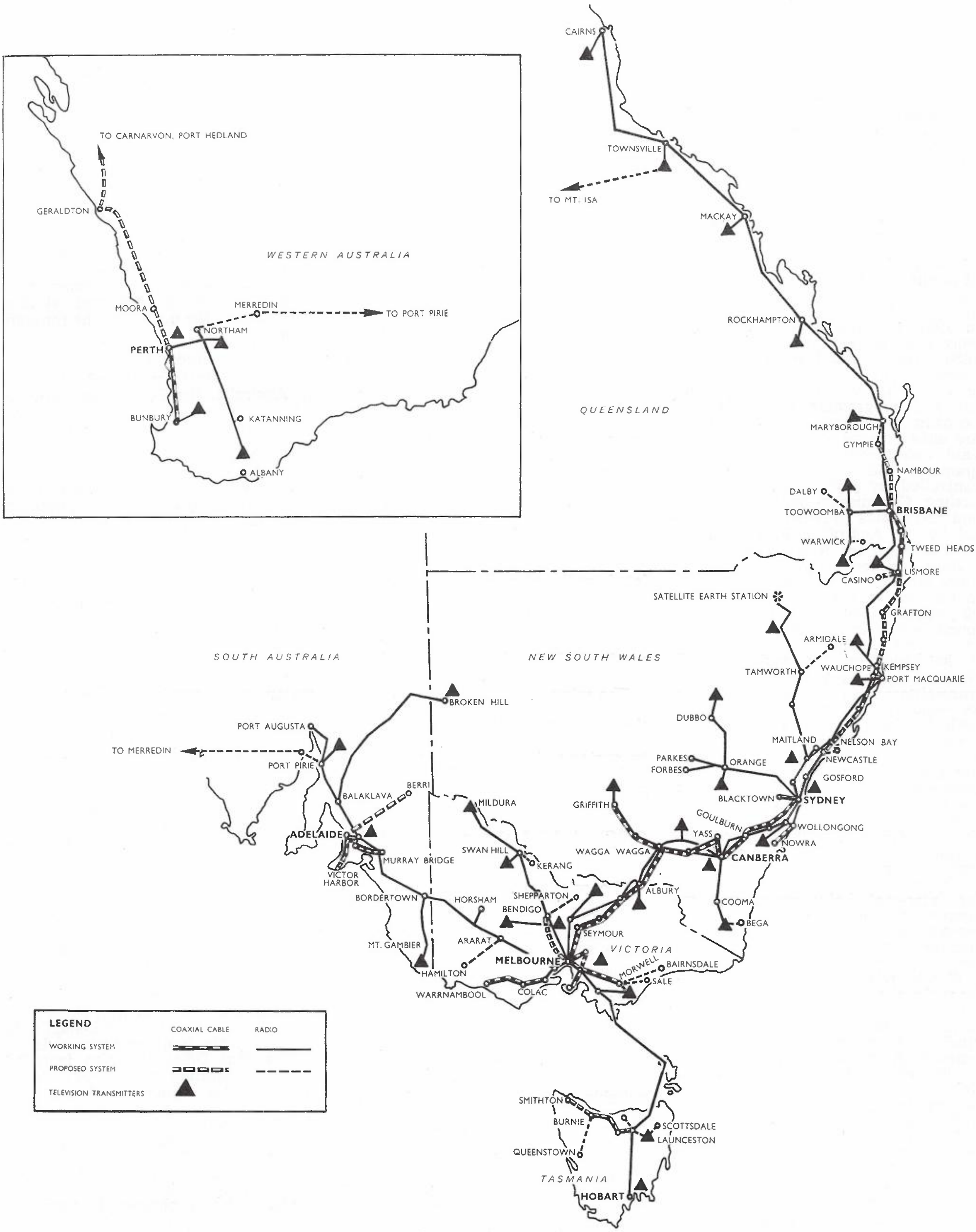


Fig. 1 — Broadband Bearer Systems.

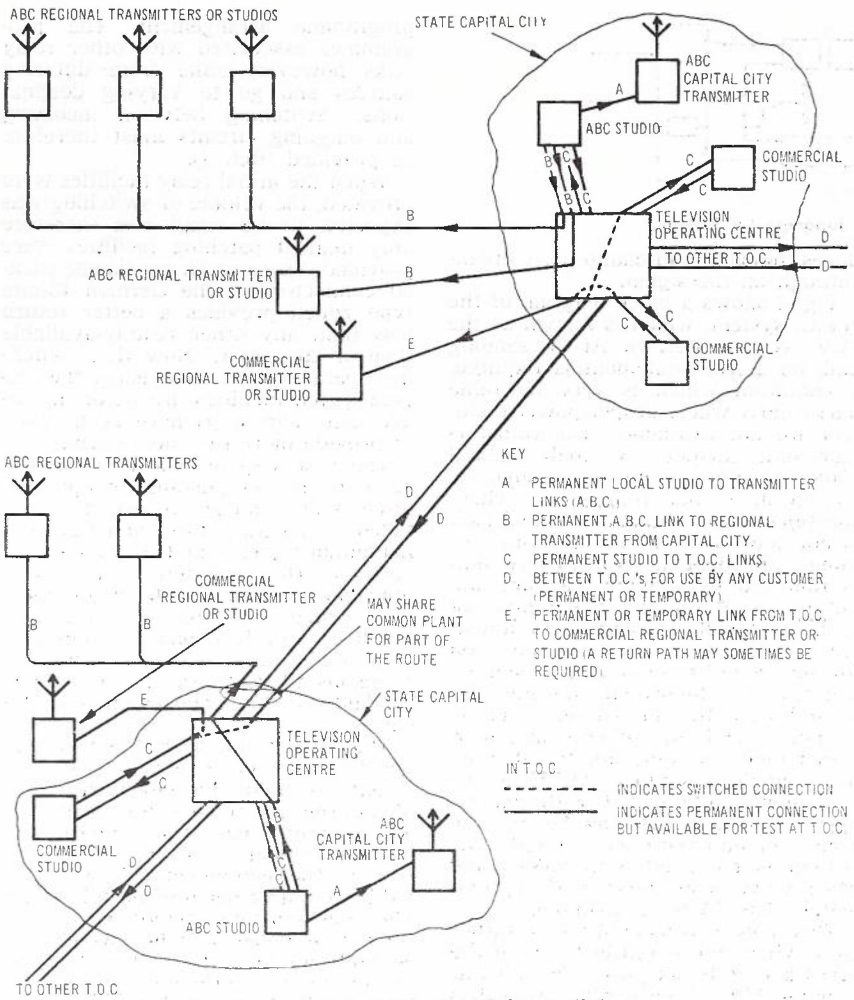


Fig. 2 — Typical Television Relay Facilities.

tance systems operating in the 7-Gc/s band. With high aerial gains and short paths, these systems provide excellent performance using a simple transmitter virtually consisting only of a video amplifier and a single directly-modulated klystron.

As yet, the 2-Gc/s band has not been used for other than minor systems, but the relatively smaller propagation losses for grazing paths in this section of the spectrum will be exploited wherever long paths are essential, e.g., those bridging the mainland and Tasmania.

In order to provide the reliability necessary in a trunk circuit, all Post Office radio television-relay systems are operated with standby protection bearers. On the routes which have also been developed for telephony, the protection bearer is shared with the telephony bearers, being automatically switched as required by commands received from a separate supervisory system. In the rare case where two bearers happen to be faulty at the same time, a system of priorities determines the bearer to receive the protection.

There are various methods of switching the protection bearer. In the simplest case, switching occurs only between the terminals of a bearer, where the input and output are switched at baseband. In other systems, the modulator can be switched independently, so that the baseband and the radio-frequency sections are separately protected. In another type using intermediate-frequency switching, the switching may occur over several repeater sections, or isolated switching may be performed at a repeater so that a spur may be fed without demodulation and still retain access to the protection bearer.

The advantage of a switching system is of course the reduction in patching time after failure of the working bearer. In general, the resulting outage is of the order of 1 ms for those cases where the bearer degradation occurs throughout a period of a second or so (as is generally the case), but could extend up to approximately 100 ms for cases where a component failure causes an abrupt break in the transmitted signal.

Cable Links

Long-distance Video Links on Cable: It is also possible to provide long-distance video relays over coaxial cable by means of vestigial sideband (VSB) transmission. Routes of this type are usually associated with long-distance telephony routes on the same coaxial cables, because the line equipment is very similar and in some cases, interchangeable. It is thus possible to use the television-bearer line equipment as a standby for the telephony bearer when not required for video transmission.

The video transmission band is similar to the telephony transmission band. The 0 to 5-Mc/s video signal is translated by a double modulation process to occupy the frequency spectrum 0.556 to 6.05 Mc/s. The signal between 0.556 and 1.556 Mc/s has the shaped vestigial characteristic, and an effective carrier of 1.056 Mc/s. The demodulation process also involves two stages of modulation, to produce the original 0 to 5-Mc/s band. The second of these demodulation processes incorporates a phase-sensing oscillator so that the correct phase relationships are maintained between the transmitting and receiving oscillators. This phasing is important in the part of the band having the vestigial characteristic, and also allows somewhat greater tolerances on the carrier-frequency generator stability.

The modulation process is not limited to 100 per cent modulation, and the system generates a maximum ratio of signal information in relation to carrier and noise amplitudes.* Pre-emphasis and de-emphasis are used to improve further the signal-to-noise ratio and the spectral energy response of the transmitted signal. Fig 3 shows a typical line-frequency signal.

* For a fuller explanation see Rieke, J. W. and Graham, R. S. — The L3 Coaxial System: Television Terminals, Bell System Tech. Jour., Vol. 32, No. 4, July 1953, pp. 915-42.

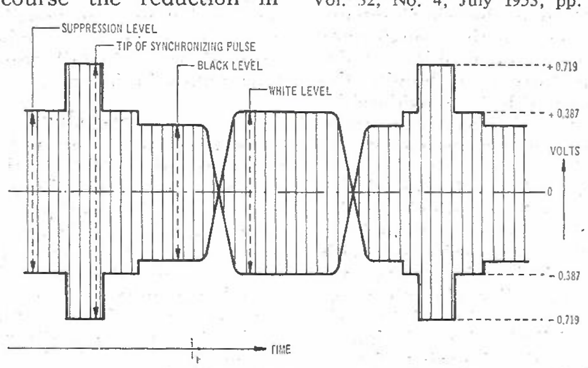


Fig. 3 — Vestigial-Sideband Television Signal on Coaxial Cable.

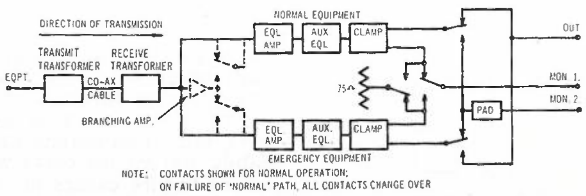


Fig. 4 — Block Diagram of Japanese CV System.

The normal line equalization used for telephony transmission is not adequate for television signals. While the frequency-response limits are not very different, the television bearer must be more accurately equalized for group delay (phase response). A maximum group delay distortion of less than 0.1 microsec is required. In the case of the Sydney-Melbourne bearer, having approximately 100 repeaters, group-delay distortion exceeding 5 microsec occurs on the overall line transmission path. Special phase equalizers are required, one containing equalizer sections of the cosine type, the other being an echo equalizer. The difficulties of achieving adequate equalization are very great, and currently an investigation is in process to adapt pulse techniques for the adjustment of the echo equalizers (Ref. 2).

Short-distance Links: Apart from the long-distance links provided by radio bearers or vestigial-sideband bearers, connections must be provided between the long-distance terminal equipment and the TOC and between the TOC and the various programme sources and destinations which may require connection. The Post Office uses direct video transmission on coaxial cables for this purpose.

By using direct transmission, the cost of modulation and demodulation processes is avoided, together with the non-linearities inescapably associated with such processes. As a penalty however, the interfering voltages produced on coaxial cables at low frequencies must be eliminated. The coaxial cable sheath provides little shielding at frequencies below 10 kc/s, and power-frequency interference is a particular source of trouble on direct video circuits. There are three main methods of eliminating low-frequency longitudinal voltages, viz. coaxial chokes, hum-cancelling amplifiers, and transformer coupling. The systems used in Australia, which are manufactured by the Nippon Electric Company (N.E.C.) of Japan, use the transformer isolation method. The problem of designing a transformer to handle the full video bandwidth is considerable, and some compromise has been made in the low-frequency response of the transformer. To restore the low-frequency transmission characteristics satisfactorily, each terminal equipment uses a line clamp. Action is in hand to provide a transformer with sufficiently good low-frequency response to eliminate line clamping, except perhaps at strategic points such as the TOCs. Elimination of clamps greatly improves the linearity of synchronizing-pulse transmission, and reduces the danger of clamp pulse breakthrough on the signal.

Fig. 4 shows a block diagram of the N.E.C. system, which is known as the "CV" system (Ref. 3). At the sending end, no active equipment is required, a condition which is very desirable particularly where proper power facilities are not available. The transformer unit includes a small coaxial choke to improve the longitudinal rejection at higher frequencies where the rejection of the transformer itself is not adequate. At the receiving terminal, an identical transformer unit is followed by a line-equalizing amplifier which consists of a number of variable sloped-gain amplifiers adjustable in steps to provide compensation for line lengths up to approximately 6 miles. The line-equalizing amplifier is followed by an auxiliary phase equalizer and the clamp amplifier, which includes some additional mop-up equalizing facilities. All the active equipment is duplicated, with changeover facilities which can be manual, remote or automatic as required. The system is equipped with valves and has a power consumption of approximately 650 VA for a terminal.

This power consumption is rather large when considered in terms of the necessary no-break power facilities at a major TOC. Considerable work has been done overseas to produce transistorized video transmission equipment, but so far it has not been possible to obtain equipment which meets the Australian requirements fully. For this reason, the prospects of developing systems designed and built in Australia, and equipped with transistors are at present being investigated. The target of this investigation is a system which will occupy no more than 7½ in. of standard rack space, with a power consumption of approximately 300 mA from 24-V or 48-V (nominal) battery supplies. The cost of such a system should be much less than that of the larger valve system, and it may be possible to mount repeaters in cable pits where it is not convenient to install equipment in a Post Office building.

Switching

As previously outlined, one of the functions of a TOC is the switching of the programme between various sources and destinations. Many of the relay links in the Australian network are permanently connected, such as those associated with the National regional transmitters. These are usually fed via an exclusive path from the studio to the transmitter. Switching at the TOC is required only in case of emergency operation or some unusual programme arrangement. The programmes associated with other relay links however, come from differing sources and go to varying destinations. Switching between incoming and outgoing circuits must therefore be provided (Ref. 4).

When the initial relay facilities were provided, the volume of switching was expected to be small and therefore only manual patching facilities were provided. These patch panels use coaxial connectors of the German 13-mm type which provides a better return loss than any other readily-available type of connector. Now that switching operations are increasing, the original patch facilities are becoming inadequate, and steps have been taken to provide more flexible switching.

The first step in this direction has been the use of push-button-operated direct video and audio switches, provided in a matrix form and having a maximum capacity of 11 inputs and 14 outputs. The switching is at a low-impedance point, with high-impedance bridging of the bus so that a number of outlets may be connected to a single input. These switches are being installed at Brisbane, Canberra, Adelaide, Perth, Launceston and Hobart.

The capacity of these direct switching devices is not expected to be sufficient to hold the development in Melbourne and Sydney for more than a very limited period, and more complex equipment is planned for these places. This equipment will be operated by a matrix panel of push-buttons. The push-buttons remotely control solid-state video switches which can be built up in units of 1 x 4 crosspoints to an ultimate capacity of 24 x 24. Each one of these is associated with a relay for switching the corresponding audio circuits. The necessary control signals and interlocks are provided electronically. The type of control is such that when the demand justifies the change, the switcher can be completely controlled by either perforated tape or punched cards. By using uniselectors in the control path, it is possible to pre-set each pattern of switching operations.

Switching operations at present are carried out at a scheduled fixed time with a tolerance of 15 seconds for a single switching operation. Where more complicated switching operations are required, this switching time tolerance must be increased, and it can be seen that if a large amount of switching is required in the future, the provision of partial or complete automation of switching will be essential. It would appear unlikely that these facilities will be required in Melbourne and Sydney before 1970, and will probably not be required in other centres (except possibly, Canberra) until several years later.

When the requirements at Melbourne and Sydney extend beyond the 24 x 24 capacity of the initial system, it will probably be desirable to provide secondary switching equipment, which acts as a line concentrator where a relatively large number of circuits, used occasionally, can be connected when required to the main switcher through a few inlets.

PHILOSOPHY OF TELEVISION SYSTEM ASSESSMENT

General

The television system exists to transmit pictures in conformity with the Australian television standards from the programme source to the viewer. The criterion which finally decides how good or bad a television picture is, must be the subjective effect experienced by the viewer. Hence, for any overall television-transmission system, the final consideration is how much subjective degradation has been caused in the picture signal as it is presented to the viewing audience. From an engineering point of view a subjective statement of picture quality is of very little practical use. It is therefore necessary to test the performance of a television system in some objective way, thereby obtaining results which can be meaningfully interpreted in terms of subjective degradation.

Apart from picture geometry (which is determined by the scanning arrangements of the two electro-optical transducing processes at the input and output respectively of the electrical part of the system), the two main factors which affect the subjective quality of the viewed picture are:

(a) grey-scale fidelity (non-linearity distortion);

(b) the accuracy with which the distribution of light values in two-dimensional space is reproduced by the system (linear distortion).

This latter factor can be broken down further into resolution of fine detail and the accuracy with which a particular signal level can be maintained over line and field intervals.

The picture signal may be considered as a series of impulse functions and step functions convolved with the characteristic transfer function of the electro-optical transducer — the television camera (Refs. 5, 6). Because of this, any test signals for the evaluation of the system performance should be similarly constructed. For this reason, waveform testing has been adopted by the Post Office as the accepted method of television-system assessment.

Linear and Non-Linear Distortions

In general terms, any characteristic which, when plotted on a linear graph, does not produce a straight-line characteristic has in the past been termed non-linear. However, in television systems these terms are used in a more precise network sense, in that they describe rather the type of equivalent network which represents the system under test. Thus where the term 'linear' is used in connection with a system characteristic, it should be interpreted as meaning that, in regard to the characteristic concerned, the system under test behaves as a linear equivalent network*. The term 'non-linear' is likewise used to denote that this requirement is not met†.

Hence when we speak of linear waveform distortion, we mean that the equivalent circuit of the system under test is that of a linear network in which the waveform passing through the network is in some way altered other than by a constant time delay or amplitude variation. A typical example of such distortion is that introduced when a test wave form with frequency components up to 5 Mc/s (say) is passed through a filter with a cut-off frequency of less than this value.

In making all tests other than those associated with the grey-scale fidelity of the system, a linear equivalent network is always assumed. Provided any non-linear effects are relatively small, as will be required to ensure that the grey-scale fidelity of the system is adequate, the above assumption will have very little effect on the interpretation of any measurements which are made, as long as no attempt is made to convert the response data obtained from the time domain to the frequency domain.

From this discussion it will be seen that tests for non-linear distortion should be undertaken before tests for linear waveform distortion, since the latter relies for its validity on the former. It has been tacitly assumed in the above that dynamic non-linearity does not exist to any degree in the system under test (Ref. 7). The discussion of this type of problem which can exist in certain v.s.b. and f.m. transmission systems is outside the scope of this paper. The usual way of overcoming such problems in practice is to specify the linear waveform testing levels in such a way that only a linear part of the system transfer characteristic is used during the tests. While this approach is not entirely satisfactory, improvement in the testing method can be obtained only at the expense of considerable increase in complexity.

System Assessment

It is therefore necessary when measuring non-linearity distortion and linear waveform distortion to specify the performance of a video system fully. Noise is the most significant other factor which should be measured. The insertion gain and insertion-gain variations with time are also specified for Australian systems. For measurement and interpretation reasons, it is convenient to measure various aspects of each of the above factors largely independently. Hence the following should be measured:

(a) *Noise.*
- Continuous random noise;
- Periodic noise;
- Impulsive noise.

(b) *Non-linearity Distortion.*
- Field-time non-linearity distortion of picture signal;
- Line-time non-linearity distortion of picture signal;
- Short-time non-linearity distortion of picture signal;
- Non-linearity distortion of synchronising signal.

(c) *Linear Waveform Distortion.*
- Field-time waveform distortion (including frequencies approaching zero);
- Line-time waveform distortion;
- Short-time waveform distortion.

Continuous random noise is always present in any television signal from the time it is generated. The objective in specifying a limit to the continuous random noise generated within a video system is to ensure that transmission equipment does not materially degrade the signal-to-noise ratio already existing on the television signal before transmission. **Noise due to periodic and impulsive sources** on the other hand, is more generally introduced within the system alone; the objective is to ensure that the level of these two noise components is such as to have no subjective effect upon the viewer. **Impulsive noise** is generally not objectionable unless it occurs in large bursts so that many points on the screen are affected over a long period; hence large amplitudes of short duration can be tolerated for this type of noise. **Periodic noise,** on the other hand, can produce objectionable stroboscopic patterns on the television screen. For this reason it is a far more objectionable form of interference and must be closely controlled or eliminated from the transmission system.

Field-time non-linearity distortion of the picture signal corresponds to a change in the grey scale of the picture in a vertical direction. In other words, the peak white video level corresponding to the top of the picture may be represented by a light intensity different from that which represents peak white at some lower point in the picture. This type of effect may also extend over a number of fields with the result that the gain of the system apparently changes with time. **Line-time non-linearity distortion** of the picture signal does not represent the same effect in the horizontal direction of the displayed picture. The subjective effect of this type of non-linearity is to create a picture which seems either harsher or softer in tonal rendition than the original picture, leading in extreme cases to some combination of black and white "crushing" of the picture signal. **Short-time non-linearity distortion** represents the situation where transitions of different amplitudes within the overall picture signal are reproduced with varying degrees of resolution depending upon the part of the system transfer characteristic which they use. This type of non-linearity is not generally specified at the present time, although tests are often made to determine whether or

*Linear-network: A network in which the impedances of the elements are independent of the magnitude of the current or voltage. (32005 : BS204 : 1960).

†Non-linear network: A network containing at least one element with an impedance dependent on the magnitude of current or voltage. (32006 : BS204 : 1960).

not it is present. **Non-linearity distortion** of the synchronizing signal is generally represented by a tolerance on the delivered synchronizing signal amplitude under varying conditions. Whilst this type of distortion has little effect on the signal, it is necessary to set limits to it to ensure that equipment operating from the synchronizing waveform will remain locked under all conditions of picture signal.

As a result of the work performed by Lewis *et al.* it has been found possible to apply a unified rating system to linear waveform distortion based on a K-rating, such that systems exhibiting a similar K-rating are subjectively equivalent in performance. This does not mean that systems with the same K-rating will exhibit the same form of distortion, but that the subjective degradation is equivalent in the two cases. **Field-time (linear) waveform distortion** tests are made to ensure that the system under test is equivalent to a number of monotonic responses in tandem as far as the low-frequency response of the system is concerned. Such a response is necessary to ensure that if clamping is finally applied to the television signal, the resultant response of the system will be acceptable. The difference between field-time and line-time distortion lies mainly in the fact that with the former, improvement can usually be achieved by the application of clamping at some part of the transmission system. **Line-time waveform distortion** however, cannot be corrected in this way but depends entirely on the adequacy of the response of the system from a few hundred cycles per second up to about 1 Mc/s. Short-time waveform measurements are intended to provide information of the system's performance from about 1 Mc/s up to the cut-off frequency of the adequacy of the response of the system from a few hundred cycles per second up to about 1 Mc/s. **Short-time waveform** measurements are intended to provide information of the system's performance from about 1 Mc/s up to the cut-off frequency of the system. The main system distortions which can occur in this area would be either a loss in general resolution or the introduction of spurious picture responses due to echoes, ringing, etc. Provided the degree of non-linearity distortion is quite small (of the order of G = 2 per cent) it is possible to correlate the results of linear waveform distortion measurements with the alternative specification of the response of the system in terms of steady-state attenuation versus frequency, and steady-state phase delay versus frequency. Whilst these latter forms of specification are of little value to the user of television equipment, it is sometimes necessary to understand the shortcomings of television systems in these terms, since most of the network design which is carried out for the equalization of television systems is still performed in the frequency domain.

The m-rating evaluation of the system also depends on the non-linearity distortion of the system being relatively insignificant, although it is not as restricted as is the case when the above transformation is used.

RELAY PERFORMANCE OBJECTIVES

General

Since the degradation of transmission performance increases with distance and with the number of interconnected links, it is necessary to define the various links which can make up a connection and to set performance objectives for each type of link so that satisfactory transmission can be provided over any combination of links which may be required to set up a television relay connection.

Basis of Performance Objectives

The C.M.T.T. (Joint C.C.I.R./C.C.I.T.T. Committee for television transmission) has defined a long-distance international television circuit as a 1600-mile (2500-km) circuit with two intermediate video points. No requirements have been laid down for the National local lines at each end of the circuit. The adequacy of this hypothetical reference circuit (HRC) to ensure satisfactory results on circuits longer than 1600 miles is at present under study by C.M.T.T. Television-transmission equipment design, throughout the world, is based on the HRC, and if a more rigorous specification than C.M.T.T. were attempted for Australia, it would require special equipment design, at greater expense. Therefore the Australian performance objectives are based on the C.M.T.T. HRC, and no objectives are set at present for links longer than 1600 miles.

The Australian National Reference Video Connection (NRVC) corresponds to the HRC of the C.M.T.T. and comprises three main video links, plus two local video links (see Fig. 5 and Appendix I).

This definition results in four intermediate video points compared with the two of the HRC, but the HRC relates to international television connections and permits the connection of local links at each end of the circuits, without substantially degrading the overall performance of the connection.

National television connections in excess of 1600 miles may be degraded compared with the HRC standards. Each video link comprising NRVC is assumed to be correctly aligned before inter-connection. Further, it is assumed no overall waveform correction or adjustment is required subsequent to interconnection. However, where necessary, additional waveform correction will be applied to meet the overall standard.

Quantitive Performance Objectives

Table I gives the transmission objectives for television relay links provided by the Australian Post Office. Conditions of measurement were described previously.

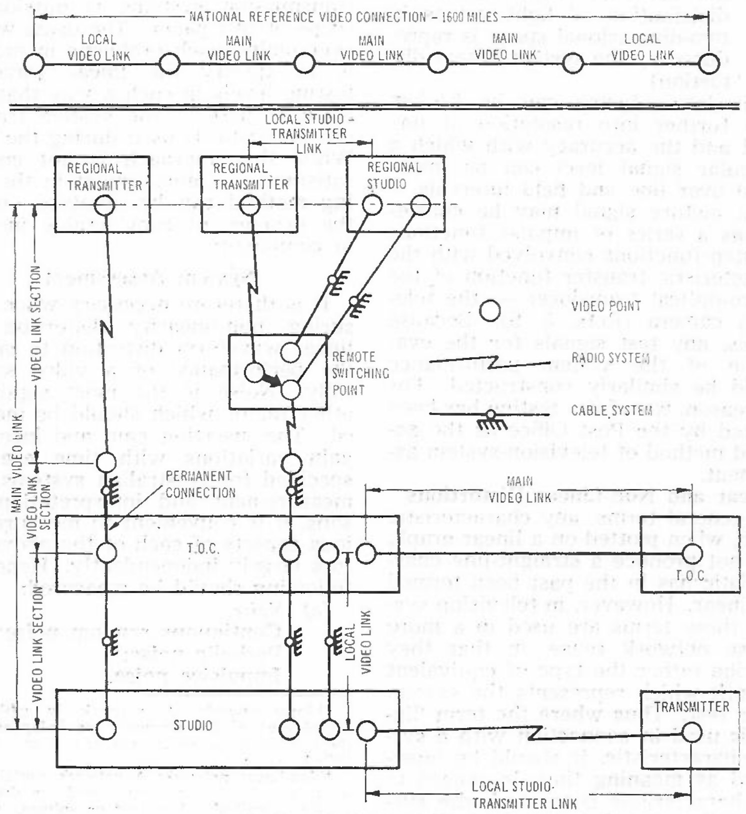


Fig. 5 — Link Definitions.

TABLE I: PERFORMANCE OBJECTIVES FOR TELEVISION RELAY

Characteristic	NRVC	Main Link	Local Link
Input and output impedance	75 ohm unbalanced	75 ohm unbalanced	75 ohm unbalanced
Return loss (input and output) (30 c/s-5 Mc/s)	24 db	24 db	24 db
Insertion gain	0 db ± 1 db	0 db ± 0.4 db	0 db ± 0.2 db
Insertion gain variations:			
Short-period (minutes)	±0.3 db	±0.1 db	±0.1 db
Medium-period (hours)	±1.0 db	±0.4 db	±0.2 db
Noise:			
Continuous random noise (S/N ratio)	52 db	58 db	62 db
Periodic noise:			
Power supply hum (including harmonics)	30 db	36 db	40 db
1 kc/s-1 Mc/s	50 db	57 db	57 db
1 Mc/s-5 Mc/s, decreasing linearly	50 db-30 db	57 db-36 db	57 db-40 db
Impulsive noise	25 db	25 db	25 db
Non-linearity distortion:			
Synchronizing signal	30-45 I.R.E.*	36-42 I.R.E.*	38-42 I.R.E.*
Line-time	G = 20%	G = 10%	G = 2%
Field-time	Limits not yet defined		
Short-time			
Linear waveform distortion:			
Field-time			
Line-time	K = 5%	K = 2%	K = 0.5%†
Short-time			
Reliability:			
Outage time summed over 12 months not to exceed:		250 minutes = 0.05%	250 minutes = 0.05%

*See Glossary—Appendix 1.
†The measurement of such a small limit may be difficult with present field measuring apparatus.

TESTING TECHNIQUES

Noise

Continuous Random Noise: The signal-to-weighted-noise ratio for continuous random noise is defined as the ratio expressed in decibels of the peak-to-peak amplitude of the picture signal to the r.m.s. amplitude of the weighted noise within the range 10 kc/s to 5 Mc/s. The purpose of the lower frequency limit is to ensure that hum and microphonic noise is excluded from the measurement. The upper frequency limit is imposed to normalize the pass band of the equipment under test to that which will materially affect the subjective performance of the picture when viewed by the final audience. To take into account the relative visibility of low-frequency and high-frequency components of noise, a weighting network is also used in this measurement. The general test arrangement is shown in Fig. 6. As can be seen from Fig. 6, two different methods of measuring the noise are possible. The first of these requires the elimination of any signal from the equipment under test; a power measurement is made using an instrument with an effective time constant of one second, the actual value of the noise signal being read directly from the meter. This method is extremely simple and satisfactory for use on those circuits which do not contain keyed clamps, such as radio links. However, when keyed clamps exist in the equipment under test, it is necessary that synchronizing signals be present to ensure the correct operation of the equipment during the period of the measurements. Under these conditions the following method is more convenient at present.

Using an oscilloscope, the quasi-peak-to-peak noise amplitude is obtained. This value is the apparent peak-to-peak amplitude of the noise component of the signal measured from the oscilloscope with a sweep rate locked to line frequency. Using this peak-to-peak noise value a quasi-peak-to-peak signal-to-noise ratio is calculated. To obtain the signal-to-weighted-noise ratio as originally defined, 17 db is added to the calculated value. The 17 db factor is an empirically-determined value which converts the quasi-peak-to-peak noise measurement to an r.m.s. value, and is sufficiently accurate when "white noise" or "weighted white noise" is being measured. Some inaccuracy may be expected when noise with high-frequency boost is being considered (the effect of the weighting network on the noise is 8.5 db for white noise, but 16.3 db for triangular spectrum noise).

Periodic Noise: The signal-to-noise ratio for periodic noise is defined as the ratio, expressed in decibels, of the peak-to-peak amplitude of the picture signal to the peak-to-peak amplitude of the noise. Periodic noise is specified in three separate frequency bands. These bands are:

(a) power supply hum including its lower order harmonics;
(b) periodic noise in the band 1 kc/s to 1 Mc/s;
(c) periodic noise in the band 1 Mc/s to 5 Mc/s.

The measurement of periodic noise in the frequency range from 10 kc/s to 5 Mc/s is carried out directly using an oscilloscope. In Fig. 6 the output of the high-pass section of the branching filter is fed via the 5-Mc/s low-pass filter directly to the oscilloscope, and the peak-to-peak amplitude of the periodic noise obtained. By measuring the frequency of the periodic noise the band to which it belongs is ascertained and the resulting signal-to-noise ratio checked against the requirements of the particular band concerned.

Power supply hum is measured from the output of the low-pass section of the branching filter as shown in Fig. 6. This measurement is most conveniently performed on a meter, but in this case the clamping system of the video link under test must be disabled. When a meter is used, it should be a true peak-to-peak measuring device to obtain a correct assessment of the signal-to-noise ratio. Periodic noise in the region 1 kc/s to 10 kc/s is also tested for in the above manner by switching in a 1 kc/s high-pass filter before the meter. If a significant periodic component is detected using this test, this component must be allowed for in determining the actual power-supply hum components.

In general, the clamping system cannot be disabled (owing to the clamps being at an unattended repeater site, for instance) and it is therefore necessary to make the measurement using an oscilloscope.

The sweep rate should be set to display a number of periods of the 50-c/s waveform across the screen. The interpretation of the waveforms obtained by this means in terms of the actual signal-to-noise ratio is tedious. However, an oscilloscope is generally used at present because of equipment and other limitations.

Impulsive Noise: In general only severe impulsive noise can be adequately measured because of its random nature. In such cases the oscilloscope test is the most general method available, with the time base running

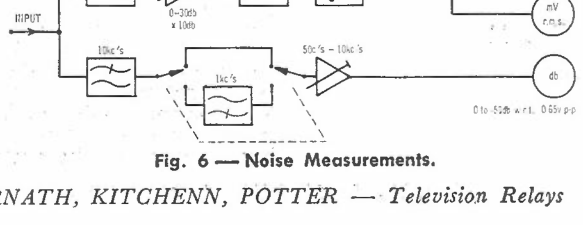


Fig. 6 — Noise Measurements.

at approximately line frequency. Where only light impulsive noise is present, it can generally be detected only in the picture itself or with the use of special equipment which cannot be used outside the laboratory. Hence this type of measurement is made only in severe impulsive noise conditions.

Non-linearity Distortion

At present, only line-time non-linearity of the picture signal and non-linearity of the synchronizing signal are defined by distortion limits. Under many circumstances these are the two most important forms of non-linearity. However, in some cases short-time non-linearity distortion of the picture signal is of great importance, as too is the field-time non-linearity distortion of the signal. Hence, although limits for these latter two distortions are as yet undefined, the measuring techniques used at present are included here for completeness.

Field-time non-linearity in the system under test is detected by the use of a video signal which resembles Test Signal No. 1 shown in Fig. 7 except

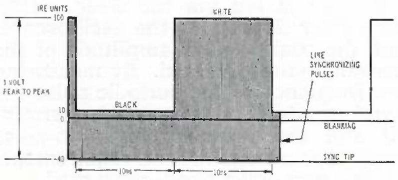


Fig. 7 — Test Signal No. 1.

that the period of the superimposed square wave is variable over the range 0.5 to 5 seconds (a "bounce" test). Non-linear distortion is detected with this signal by measuring the synchronizing signal amplitude and the amplitude of the black-white transition after the black level of the signal has been stabilized to a constant value. Under these conditions, picture signal non-linearity appears as an apparent variation in the system gain over the white period of the signal whilst non-linearity of the synchronizing signal is indicated by a variation over the period of the square wave of the synchronizing signal. These measurements can conveniently be made only if black-level stabilization of the output of the system under test has been achieved prior to measurement. A special clamp unit built to Australian Post Office design is generally used for this purpose.

Line-time non-linearity of the picture signal and non-linearity of the synchronizing signal is measured using the test signal shown in Fig. 8. This consists of one line sawtooth and three lines at either black or white level. The sawtooth has superimposed upon it a 0.1-volt peak-to-peak sine wave of 1 Mc/s. Synchronizing signal non-linearity is determined by measuring the synchronizing signal amplitude for the two possible conditions of the test signal; that is, firstly with the three lines at white level and then with the three lines at black level. The synchronizing signal is required to remain within the amplitude limits given under both of these conditions. Line-time non-linearity distortion is measured in terms of a rating factor G. This is also measured under the two possible conditions of the intermediate lines and the G-value obtained is the greater of the two measurements. The measurement of the G-factor is made by passing the test signal through a high-pass filter. shown in Fig. 9 (a), to remove the line sawtooth component from the waveform displayed on the oscilloscope. This results in a display as shown in Fig 9. (b) and the rating factor G is defined as G = 100 (1 — m/M) where m and M are as defined in Fig. 9 (b).

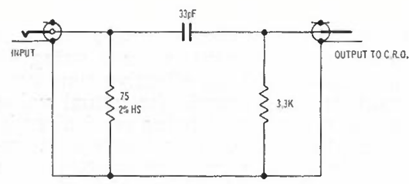


Fig. 9(a) — High-Pass Filter.

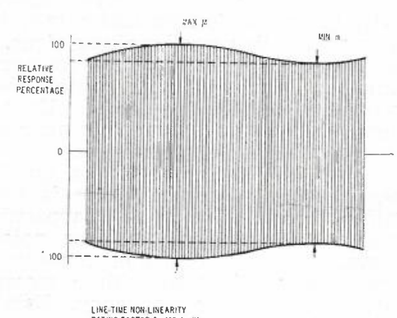


Fig. 9(b) — Response to Test Signal No. 3

Using the same technique, some indication of short-time non-linearity can be obtained by using the sawtooth test signal with the modulation frequency varied in steps between 1 Mc/s and 6 Mc/s. Variation in the line-rate envelope display between frequencies indicates the presence of dynamic or short-time non-linearity.

It is normal practice to perform the above measurements at a 3-db higher input level than normal, under which conditions the G-factor is allowed to be no more than double the value obtained with normal input. In noisy situations the sawtooth of the test signal in Fig. 8 may be replaced by a 10-step staircase. Under these conditions the G-factor is measured in the same way, using instead of a sine-wave envelope the height of the staircase steps after these have been effectively differentiated in a special shaping filter which gives considerable noise protection.

Linear Waveform Distortion

Field-time waveform distortion is measured using the test signal of Fig. 7, both as a 50-c/s square wave and as a bounce test signal as described above. The purpose of the bounce-test measurement is to inspect the form of the resulting waveform to ensure that the shape is consistent with that to be expected by the passage of such a signal through a number of monotonic responses in tandem. Once this has been done, the 50-c/s square-wave test can be made and a K-value obtained for it in accordance with the overall K-rating system used to specify the linear waveform performance of television systems.

The background of the K-rating system has been dealt with in many previous papers (Refs. 4, 8, 9). Apart from the 50-c/s square wave mentioned above, the K-rating system assesses the performance of the system in terms of a bar signal to specify the line-period distortions of the system, and a pulse signal to specify the short-term distortions of the system. The pulse-and-bar signal used in Post Office practice is shown in Fig. 10. The shape of the pulse is defined by a Thompson sine-squared filter (Ref. 10) which has a characteristic period of 2T, where T = 100 ns and is the period of one picture element in the Australian system. The bar transitions are also shaped by passage through the same filter. This results in a test signal which has no frequency components beyond the 5-Mc/s cut-off of the Australian television system. The pulse-and-bar waveform may also be used with a T instead of 2T filter as the shaping element. This T pulse is used to determine the cut-off frequency (ring-frequency) of the system under test and also in specific cases to determine the acceptance-test K-rating of a system (Ref. 11). The response limits for 50-c/s square-wave response and the 2T pulse-and-bar response of the system is shown

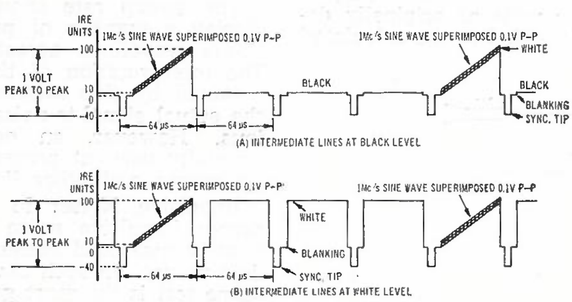


Fig. 8 — Test Signal No. 3.

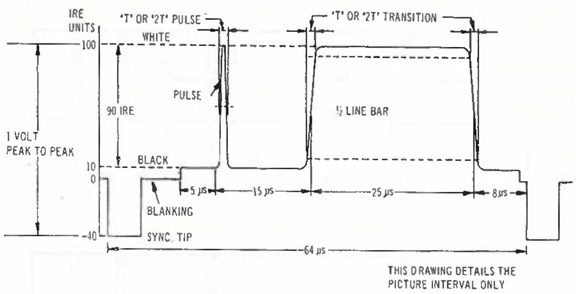


Fig. 10 — Test Signal No. 2.

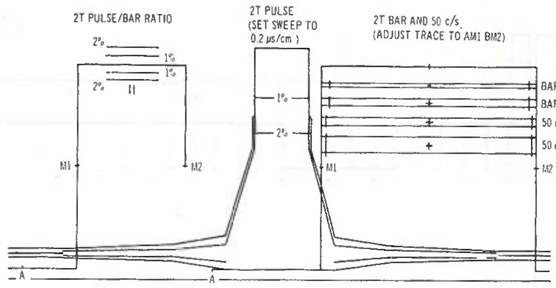


Fig. 12 — Television Radio Bearer Graticule.

in Fig. 11. The largest K-value of all those measured determines the K-rating of the system.

In general, routine K-rating measurements are made with the aid of special graticules, a typical example of which is the radio TV-bearer graticule shown in Fig. 12. The use of such graticules can of course only result in the system performance being rated as e.g., better than 1 per cent K-rating, but this is a satisfactory method of measurement, particularly for K-ratings over 2 per cent. For the determination of smaller K-ratings of a more exact determination of the actual K-value of any system it is necessary to make detailed measurements on the waveforms themselves. By the use of a special trigger unit (Ref. 12), a folded pulse and bar can be produced on the oscilloscope screen, thereby assisting in the measurement of the smaller K-values with the pulse and bar waveform. The different weights given to various types of distortion in these tests follow from limits determined subjectively.

Vertical-Interval Test Signals

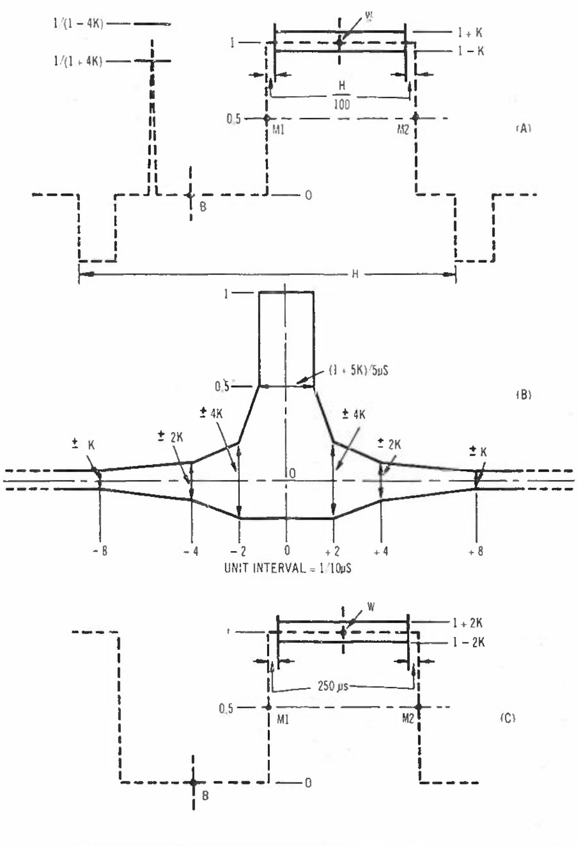
As the number of relay routes for television in Australia increases and the complexity of the combinations of picture sources and destinations becomes more formidable, the need for more than routine testing of relay facilities is becoming more apparent. Generally, the above tests are made daily for most video circuits as a whole, whilst individual link sections may be tested much less frequently. In many cases, individual sections will be tested only when the overall response of a system becomes marginal. The difficulty of performing adequate tests is increasing with the increasing number of hours for which relay circuits carry live programmes. In a main television operating centre with as many as 10 to 20 incoming and outgoing channels, most of which will be required for service at about the same time, it becomes impossible to make adequate daily performance tests on all systems.

A technique which inserts a Vertical Interval Test Signal (generally reduced to the acronym VITS) is therefore being introduced into the Post Office television relay network. The basic principle is similar to that used in carrier telephony where pilot frequencies are constantly transmitted through the system and their received levels monitored to determine the system performance while it carries traffic.

In the VITS method of system monitoring, the video performance is continuously determined using a number of test signals (such as the pulse-and-bar and line sawtooth waveforms) which have been inserted into the vertical blanking interval following the vertical synchronizing block.

To perform the above tests with accuracy, the oscilloscope must be of the highest quality. Some of the requirements of this important piece of test equipment are as follows:

(a) direct-coupled with a capability of backing-off the unwanted d.c. component;
(b) an accurately-calibrated time-base range of between 0.2 s/cm and 20 ns/cm;
(c) high-impedance (relative to 75 ohms) input;
(d) accurately-calibrated vertical expansion to allow portion of a test waveform to be examined without amplitude errors or frequency-dependent distortion degrading the measurement accuracy;
(e) an a.c. input with coupling time constant of the order of one second;
(f) an indicated rise-time to a step function of the order of 25 ns, the shape of the rising flank to be similar to that of the bar of the pulse-and-bar test signal without overshoot or preshoot.



(A) 2T - BAR RESPONSE AND 2T - PULSE/BAR RATIO.
(B) 2T - PULSE RESPONSE.
(C) 50 c/s SQUARE WAVE RESPONSE

Fig. 11 — Response Limits for Test Signals 1 and No. 2.

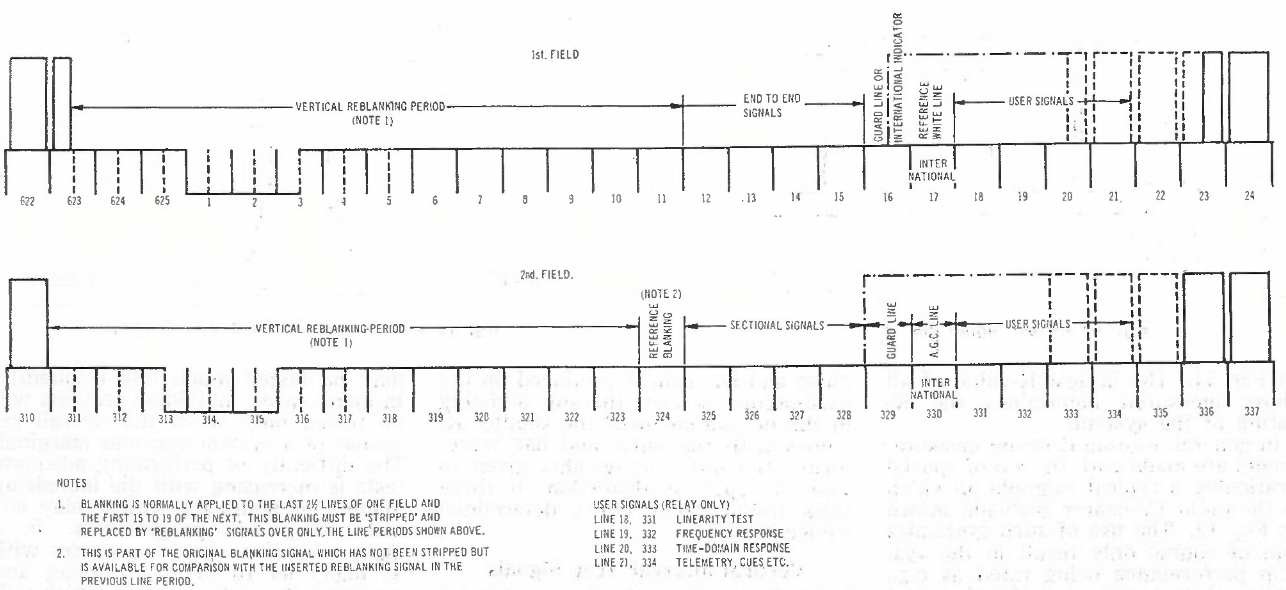


Fig. 13 — Test Signals Inserted in Vertical Blanking Period (VITS).

The positions in which the test signals are inserted into the vertical blanking period are illustrated in Fig. 13. Lines 12 to 15 and 325 to 328 are for the exclusive use of the Post Office, the former group being for signals sent from one end to the other of the relay and the latter for signals introduced to test various sections of the relay. The allocation of lines within the vertical-blanking period for test signal insertion has been co-ordinated by a committee representing television stations, P.M.G.'s Department, A.B.C. and A.B.C.B. interests (Ref. 13). Lines 18 to 21 and 331 to 334 have been reserved for the use of television stations and line 17 is designated to contain a reference-white-level signal to ensure that all authorities maintain the original character of the signal as it is produced by the originating station. Provision is also made on line 330 for an automatic gain-control reference signal. The reference signal of this line is used by the Post Office to maintain the overall gain of each section of its relay system at 0 db.

Using these inserted test signals it is possible to perform all the line-time and short-time measurements described above, while the relay link is transmitting a programme. The accuracy of these measurements is to some extent impaired by the presence of noise on the signal and this is not as easily "integrated out" by the eye since the waveform is presented only once every 40 milliseconds. However, the method is entirely adequate to determine the suitability or otherwise of the relay system for the continued transmission of programme material. These matters and details of the insertion unit used by the Post Office have been described elsewhere (Refs. 14, 15). Fig. 14 is a photograph of the vertical block period of a television waveform before and after insertion of VITS.

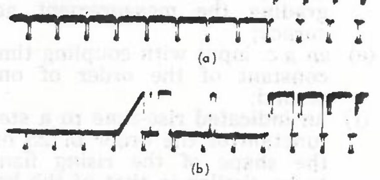


Fig. 14 — Oscilloscope Trace of Signal in Vertical Blanking Interval (a) Normal, (b) With VITS Inserted.

MEASURED RELAY PERFORMANCE

General

The transmission of vision and sound signals from a studio to a regional television station requires the co-ordination of a complex system which, in general, consists of two or three coaxial cable short-distance systems operating in tandem with one or two radio bearers.

In order to ensure that all the sections are fully operational, sound and vision test signals are transmitted from the studio master-control each morning just prior to the commencement of the normal programme. These daily tests use 400 c/s for audio gain adjustment, and line sawtooth signals for video loss measurements followed by a vision grey scale (staircase) which is used to set the contrast of all monitors along the route.

Once each week the studio master-control also originates a series of tests including random noise, audio-frequency response, modulated sawtooth, 50-c/s square-wave and pulse-and-bar signals which allow the performance of the entire route to be assessed in detail.

Radio Links

In the Post Office, the performance of radio television bearers is assessed mainly by means of 2T pulse-and-bar, 50-c/s squarewave and the low-frequency transient tests. Experience has shown that action is rarely necessary as a result of the non-linearity distortion (C.C.I.R. differential gain) tests, since in most cases, the television modulators are installed alongside telephony modulators and so are linearised to their more stringent requirements using the telephony test set.

The service limits for performance beyond which maintenance action is taken are K-factors of 1 per cent for the pulse-and-bar and 2 per cent for the 50-c/s tests. Because of lack of correlation between the various sec-

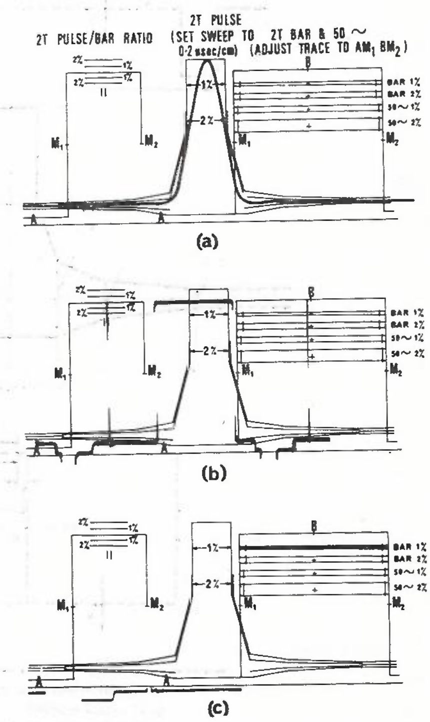


Fig. 15 — Oscilloscope Traces — Radio Link Performance, Surrey Hills to Lookout Hill.

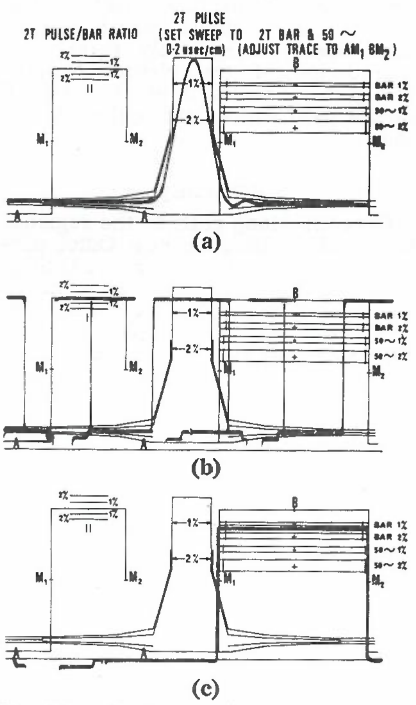


Fig. 16 — Oscilloscope Traces — Radio Link Performance, Redfern to West Orange.

tions of an overall studio-to-transmitter link, individual bearers may exceed this value for a short time without affecting the overall performance objectives given above. Photographs of typical performance of radio bearers are given in Figs. 15, 16 and 17, with (a) (b) and (c) showing their

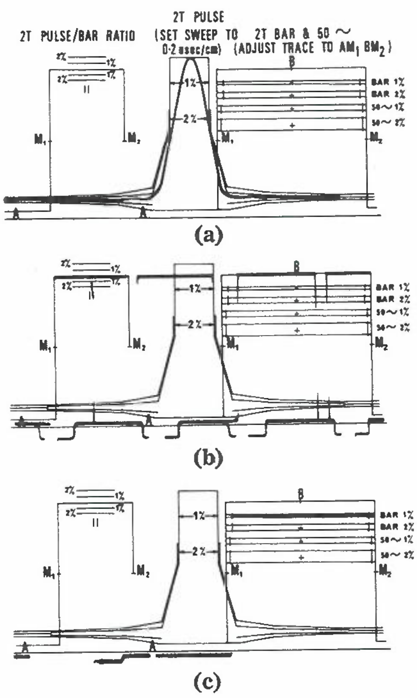


Fig. 17 — Oscilloscope Traces — Radio Link Performance, Adelaide to The Bluff.

response to a 2T pulse, the 2T pulse-and-bar ratio, and the ½-line bar respectively.

Measurements on an interstate relay link from the TOC in Melbourne to the National television transmitter at Mt. Sugarloaf, N.S.W., are grouped in Fig. 18 to show the contributions arising from the individual cable and radio sections along the route. The radio section consists of two tandem bearers, Redfern-Heaton and Heaton-Mt. Sugarloaf. The photographs are arranged so that each column shows the performance at a demodulation station. The tests vary with each row in the following order: (a) 2T-pulse and bar, (b) T-pulse, (c) 50-c/s, (d), (e) linearity (2 rows) and (f) l.f. transient.

As the low-frequency transient performance is a function of the equipment design, this characteristic is generally measured only during the acceptance stages or whenever new routes are operated for the first time. The peak values of this transient must be limited to prevent overloading in any section of the route and, in particular, to prevent an interruption to the output of the stabilizing amplifier at the television transmitter. In addition, there is a need to eliminate the minor operational effect whereby fluctuations due to changes in programme brightness can make the monitoring process rather trying.

Because the effect of this phenomenon on cascaded bearers is difficult to predict, it is desirable to limit the peak-to-peak value of the transient produced by a single bearer to that of a single monotonic circuit. This means, of course, that the equipment design must ensure that only one time-constant is effective in producing the transient and that all other time constants are either of second-order magnitude or are completely absent.

The low-frequency transient performance of single bearers is shown in Fig. 19, where the top and centre photographs indicate a satisfactory monotonic response, while the lowest photograph shows an unsatisfactory response.

In each case, the traces represent the white (or black) blanking and synchronizing levels of the composite waveform, the fine structure of which has been lost because of the relatively low speed of the time-base.

Cable Links

Long-distance Links: Since the long-distance cable links using vestigial-sideband transmission perform a similar function to radio bearers of equivalent lengths, the overall transmission requirements are also similar. However, because of the nature of both the bearer and terminal equipment, the problems of obtaining satisfactory transmission are quite different. Slow changes in the line characteristics affecting the overall transmission do occur, and it has been found that while it is possible to line-up a bearer such as the Sydney-Melbourne link to produce a K-rating of approximately 1 per cent, it is unlikely that this will be maintained for a period measured in months. It is therefore necessary to carry out major re-alignment at intervals indicated by performance changes. This is one of the reasons why the development of methods for adjusting the echo equalizer using pulse techniques is so important. The non-linearity of the v.s.b. system can be held readily to less than 3 per cent, provided that the signal is in fact restricted to the nominal 1.0 volt peak-to-peak. If this figure is exceeded by more than 10 per cent, severe non-linearity results, and these systems are being equipped with peak-white limiters to overcome this problem.

Noise in v.s.b. systems, while generally meeting the requirements for a main link, also suffers some variation, and its level must be watched closely. As stated previously, the receiver demodulator must be synchronized with the transmitted carrier. Some difficulties have been encountered in maintaining the phase of the synchronization to the limits required.

Taking an overall view of v.s.b. circuits, it appears that the maintenance effort required is greater than that of radio systems of a similar length. The results obtained under typical conditions between Melbourne and Sydney are shown in the first and second columns of photographs in Fig. 18.

Short-distance Links: The direct video-transmission equipment used for short links is required to have performance of a very high order, so that the possibly large number of such links in an overall circuit causes minimum degradation. Some difficulties have been encountered in obtaining equalization of the cable losses to meet these strict requirements. In fact, the specified performance for the local link of K = 0.5 per cent represents almost the limit of field measurement of K-ratings. It is therefore difficult both to install this equipment, and maintain it to the required K-rating. Because of this, maintenance action is taken to correct performance only when the K-rating exceeds 1 per cent. The linearity of these systems is usually adequate to meet a 2 per cent G-factor, but some trouble has been experienced with maintaining the synchronizing pulse amplitude to the limits set down. This is because the system uses a clamp of the d.c. restorer type which operates on synchronizing pulse tips; these are therefore subjected to some distortion. As was stated previously, it is hoped to eliminate clamps in future systems.

In both long-distance and short-distance cable systems, the low-frequency transient performance also has to be watched. The low-frequency test signal has been

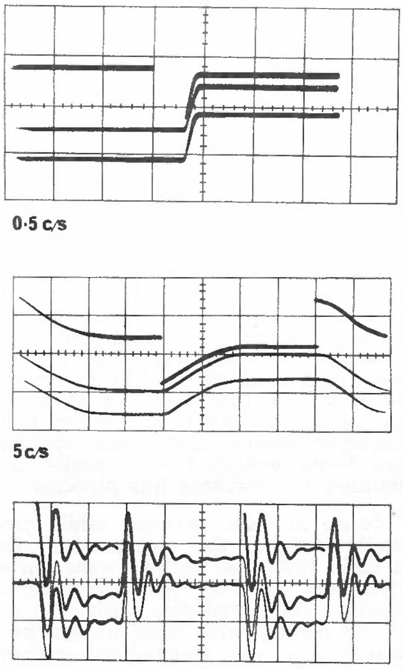


Fig. 19 — Oscilloscope Traces — Radio Link Performance. Low-frequency Transient Response.

found valuable in detecting incipient failures of components such as electrolytic capacitors before serious reduction in picture quality occurs. The third column of photographs in Fig 18 shows the combination of the long-distance VSB system plus the short-distance direct video system between the TOC in Sydney (City South) and the radio terminal (Redfern). Although at the time of test the K-rating of the short system was of the order of 1 per cent, it can be seen that there is very little difference between the waveforms received at Redfern and those received at City South.

Overall Performance

The interconnection of main and local links to provide a long-distance relay provides further specialized problems. Where the overall path has a large number of individual components, it is found that while some of the variations and deficiencies tend to be additive, others tend to produce cancellation effects, so that the combination of a number of individual paths having stated performance characteristics does not necessarily produce a satisfactory overall connection, although the statistical probability is very high. It is therefore considered desirable to provide some form of auxiliary equalization at the termination of very long links. Experimental work has shown that improvement of K-ratings can be achieved by this means, but the equipment cost is very high, and the amount of equipment provided must therefore be restricted. This whole question is being examined in order to see whether an economic solution can be found.

Noise is probably the characteristic of long systems which will prove most difficult to overcome. Insertion-gain variations and amplitude changes of the synchronizing pulses are also likely to occur. A previous section dealt with the use of VITS as a method of assessing both sectional and overall performance, and mentioned that reference white and automatic gain-control (AGC) reference signals would be provided. The reference white signal ensures that the signal delivered to the Post Office equipment can be accurately determined, so that system overloading is minimized while signal-to-noise ratio is maintained at a maximum. The AGC signal will be used to control the gain of the transmission paths, so that any variations due to changes in gain of each link section will be minimized. At the same time, the VITS equipment regenerates the synchronizing pulses. The use of VITS for assessing the performance of sections of, and the whole video link, is limited to manned stations at present. It may prove economical to provide additional regulating equipment, or at least telemetry facilities so that the VITS signals at unattended stations can be used for correcting the link performance. Information fed back from these stations to the controlling TOC could provide indications to the TOC operators of incipient troubles in a link section or sections.

Long-distance relays are checked daily for linear and non-linear waveform distortions, and unless in continuous operation, are also checked for noise when each through connection is made.

Relays longer than the national reference video circuit cannot be produced with existing facilities. The completion of the Melbourne-Adelaide and Sydney-Brisbane bearers will enable a connection to be made between Adelaide and Cairns to a total distance of about 2,500 miles. The performance of such a long-distance link will necessarily be degraded beyond the present NRVC limits, which are in turn, based on a barely perceptible degradation of the picture quality. The picture received at the end of such a path will be still quite acceptable.

Reliability

General: Along each of the regional routes, the Australian Post Office performance objective for reliability places a limit of just over 4 hours on the loss of programme in any one year. To meet this objective, it is necessary that each system be designed as a complete entity giving due weight to the vital factors of equipment design, system and route design, and maintenance organization. Only the reliability aspects of the equipment itself are discussed in this paper.

Radio Routes: An analysis of all the broadband bearer routes in New South Wales through the year 1964 shows that on a 24-hour basis, the radio equipment was responsible for an average traffic outage per route of approximately 6 hours per annum. Although the outages due to power failure and installation action are not included in this figure, they undoubtedly contributed to the equipment performance which is expected to improve significantly after completion of the no-break power installations along the routes. As indicated below, the introduction of solid-state equipment is also expected to further reduce this figure.

The equipment factors which contributed to the bearer outages are given in Appendix III, which shows the average number of occurrences in one year for the various types of fault. The figures are given separately for a bearer-terminal and a bearer-repeater (a bearer-terminal consists of either a single transmitter or a single receiver whilst the bearer-repeater consists of a single RF receiver/transmitter combination). The figures arranged in order of normalized frequency of occurrence, with respect to valve failures, are given in Table 2.

TABLE 2

Fault cause	Normalized frequency
Valves	1.0
Adjustments	0.48
Fuses	0.062
Resistors	0.044
Capacitors	0.036
Relays	0.035
Diodes	0.030
Pilot lamps	0.015
Circuit-breakers, sockets	0.009 (each)
Potentiometers	0.008
Meters	0.006
Plugs	0.005
Transistors, switches, transformers	0.004 (each)
Crystals, connectors, blowers	0.003 (each)
Thermostats, U-links, cavities	0.002 (each)
Regulators, thermistors, attenuators	0.001 (each)

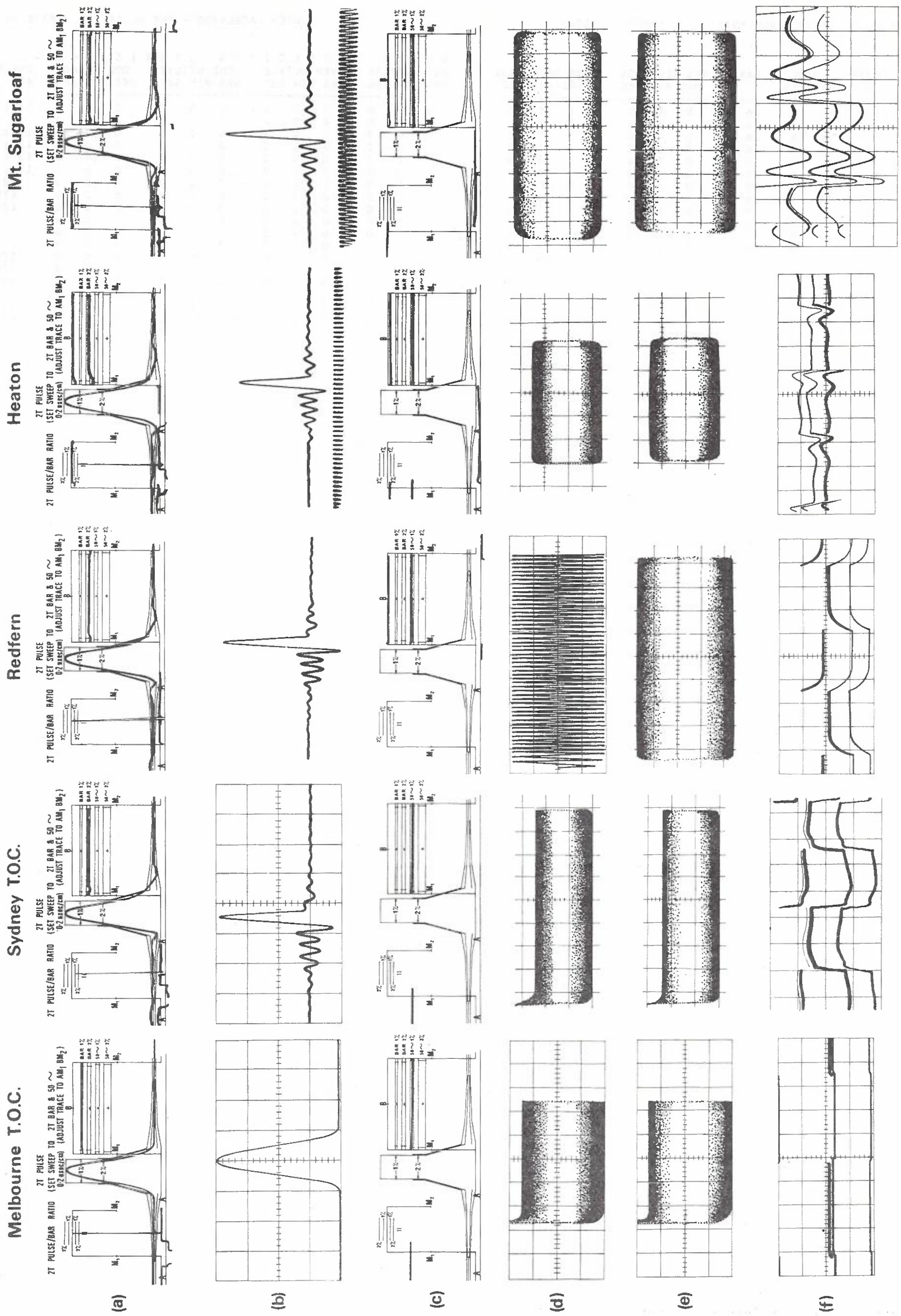


Fig. 18 — Oscilloscope Traces — Link Performance, Melbourne to Mt. Sugarloaf.

S.A. RADIOCOMM SERVICE ANALYSIS MARCH 1965 ROUTE- ADELAIDE - THE BLUFF TV PAGE NC. 9

BEARER NUMBER	SITE NR	TIME		DAY	NET TFC LOSS			MAIN BR OUTAGE			ROUTE PROTECTION STATISTICS EVEN UTILIZ			EVEN OUTAGE			ODD UTILIZ			ODD OUTAGE			CMFCCFPL EQ AC
		HRS	MIN		HRS	MIN	SEC	HRS	MIN	SEC	HRS	MIN	SEC	HRS	MIN	SEC	HRS	MIN	SEC	HRS.	MIN.	SEC	
009	510	8	0	26	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	13 1
001	510	14	24	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	99
001	501	16	15	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	13 1
009	501	16	15	26	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	13 1
001	501	8	0	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	13 1
009	501	8	0	28	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	13 1
001	510	23	25	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	0	38
001	510	8	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	1742
001	510	8	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1742
001	510	13	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
011	510	13	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
019	510	13	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
009	500	9	25	31	0	0	0	0	30	0	0	0	0	0	0	0	0	30	0	0	0	0	1742
009	5C0	9	25	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1742
021	513	14	50	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45
021	512	14	50	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	47
029	513	14	50	31	0	0	0	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45
029	512	14	50	31	0	0	10	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	47
021	513	15	8	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	47
029	513	15	8	31	0	0	10	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	47
021	513	15	12	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	47
029	513	15	12	31	0	0	10	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	47
021	513	15	14	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	47
029	513	15	14	31	0	0	10	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	47
021	513	15	36	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	9
029	513	15	36	31	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	9
001	501	20	0	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	13 1
009	501	20	0	31	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	13 1
TFC INTERRUPTIONS- 7				TOTALS	0	13	40	5	0	40	0	0	0	0	0	0	0	30	0	16	58	40	

Fig. 20 — Radio Route Performance, Computer Print-Out.

The probability of the items appearing in the above order is of course weighted by the population of each item. Even so, the list does indicate the state of affairs which exists in systems which are almost totally equipped with valves. By eliminating valve failures from Appendix III, the expected performance from solid-state equipment has been predicted and is shown in Appendix IV.

It may be of interest to describe briefly the type of analysis which is used to calculate route performance and to predict the availability of the protection bearers for second-programme use. Such an analysis is given in Fig. 20, which is a copy of the computer print-out for a television route. These analyses are produced from data which are essentially compiled in the field. The computer programme takes account of times and outages on both the main and protection bearers, and correlates traffic time lost, main bearer outages and protection bearer utilizations as they occur. In addition, coded details of the fault are given in the table on the right-hand side of the analysis.

Long-distance Cable Routes: Statistical information is not available on the fault incidence on v.s.b. routes. However, the outage time appears to be of the order of 10 hours per annum, neglecting special maintenance procedures performed when the system is not required for programme transmission.

Short-distance Cable Routes: Again neglecting maintenance periods during out-of-service hours, the programme loss on the direct video links is of the order of 3 hours per annum. Most of these failures are due principally to valves and (to a lesser extent) relays, both of which will be eliminated when transistorized video line equipment is available.

Future Reliability: Whether the overall target of 99.95 per cent reliability can be achieved economically for both local and main links, depends on the types of new equipment coming into service and changes in the organization of service activities.

It will not be possible to state the results of these changes for some years, as the introduction of new equipment will be gradual and any overall path almost certainly will contain both new and old equipment. The grade of service provided, however, compares favourably with that obtained in other countries for video transmission paths of similar length and complexity.

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APPENDIX I.

Glossary

Bearer: A unidirectional transmission path between adjacent traffic access points and designed for the effective transmission of signals of specified bandwidth regardless of the nature of the signals or the type of equipment used. Thus a bearer of bandwidth 300-3400 c/s may carry one speech channel or up to 24 telegraph channels; a bearer of about 1.2 Mc/s bandwidth could accommodate 300 speech channels, and a bearer of 5-Mc/s bandwidth might alternatively accommodate about 1000 telephone channels or one television signal channel.

I.R.E. Unit: A unit of a linear voltage scale provided on the y-axis of an oscilloscope for measuring composite video waveforms. There is no absolute voltage calibration.

The scale is calibrated from 0 to 100 and from 0 to —50; 0 corresponds to the blanking level of a composite video signal and 100 corresponds to peak white in the video signal. The synchronizing signal level is read in the range 0 to —50 (Ref. 16).

Local Studio-transmitter Link: Any video link which is a permanently-installed facility provided for the connection of a television studio to its associated transmitter, the studio being situated within the main service area of the transmitter. Examples of such links are those between capital city studios and transmitters, operated for the A.B.C.

Studio-transmitter links will be provided to local video link standards which will ensure compatibility with the A.B.C.B. specification for such links.

Local Video Link: A short link connecting video facilities in the same town or area by means of video transmission on coaxial cable or single-hop short-distance radio link or a combination of both.

TABLE A

From	To
(a) TOC	TOC (adjacent State)
(b) Capital city studio	Regional transmitter } (generally the same State)
(c) Capital city studio	Regional studio } (generally the same State)
(d) Regional programme source	TOC (generally same State)

The following types of connection will be provided to the local video link standards:—

(a) Studio to TOC and TOC to Studio.
(b) Studio to local transmitter.
(c) Studio to Studio. (Regarded as two local video links if routed via TOC.)
(d) Permanent outside - broadcast points to TOC.

Main Video Link: As the name implies, this comprises a connection over longer distances than the local video link, and it is generally provided over most of the distance by a main-line radio system or vestigial-sideband transmission on coaxial cable.

Main video link objectives will apply to Table A connections.

On a main video link greater than 500 miles, performance may tend proportionally towards NRVC performance.

Remote Switching Point: A remotely-controlled switching facility provided, for example, at a radio terminal to connect either a local studio or a capital city programme to a regional transmitter. The remote switching point will not be the end of a video link; the relevant video link performance objectives will include the performance of the remote switching point.

Television Operating Centre (TOC): An office (generally in a capital city) equipped for monitoring, testing, equalizing and interconnecting video and associated sound programmes.

Video Connection: Any tandem arrangement of video links provided as a relay facility for video signals between a studio source and a studio or transmitter destination.

Video Link: A one-way transmission channel between video points which are provided primarily for operational use.

Video Link Section: A one-way transmission channel between video points which are provided primarily for engineering use. A video link may be provided between video points at a studio (A) and a destination (D) via coaxial cable (A-B), a radio link (B-C), and another coaxial cable (C-D). There are video points at B and C for engineering purposes and for interconnection between the different media. Then A-B, B-C and C-D are video link sections, since the video points at B and C are not provided primarily for operational use.

The performance of a video link section is not specified separately from that of the video link.

Video Point or Video Interconnection Point: A point in a video link or link section at which a standard composite video signal may be inserted, extracted or monitored. Video points may be provided for operational or engineering purposes.

APPENDIX II.

Requirements at Video Points

Impedance: Input and output impedance shall be nominally 75 ohms unbalanced to earth. The return loss of such impedances relative to 75 ohms resistive shall not be less than 24 db (measured using pulse techniques).

Polarity and D.C. Component: The polarity of the signal shall be "positive", i.e., such that black-to-white transitions are positive-going.

The useful d.c. component, which is related to the average luminance of the picture, may or may not be contained in the video signal.

Any unwanted d.c. component which is present shall be such that not more than 0.5 watt is dissipated in the 75-ohm load impedance. If the load impedance is disconnected, the voltage of this component shall not exceed 60 volts.

Signal Amplitude: The amplitude of composite video signals containing reference white and with synchronizing signals shall have a peak-to-peak amplitude of 1.0 volt ± 5 per cent. The signal levels shall be measured by the I.R.E. scale.

Amplitudes of the signal components (with the blanking level taken as the reference level and equal to 0) shall conform to the following nominal values and tolerances:—

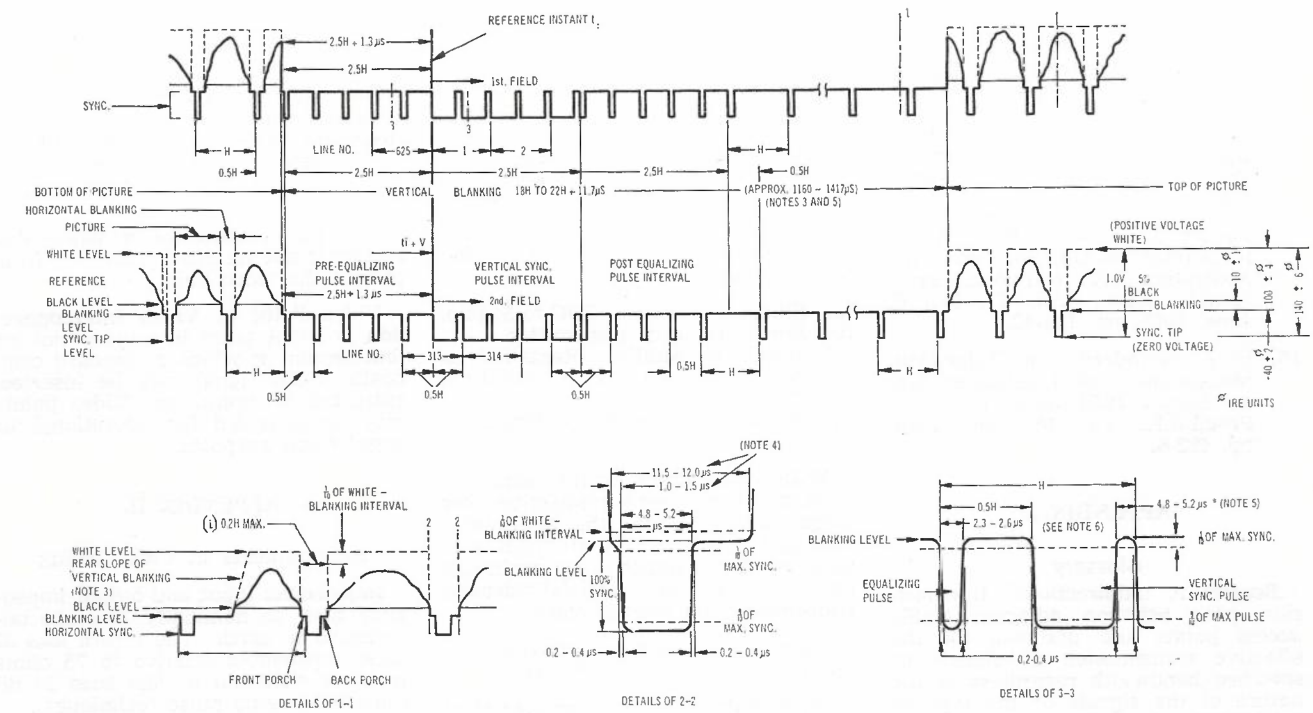
Blanking to white level (picture signal) = 100 ± 4 I.R.E. units

Blanking to black level = 10 ± 1 I.R.E. units

Blanking to sync. tip (sync. signal) = —40 ± 2 I.R.E. units

Fig. 21 shows the standard video waveform for 625 lines/picture.

Provided that the signal supplied at the input to the system meets the above requirements, the signal level delivered at the output shall also be within the above level tolerances.



NOTES:

1. H = TIME FROM START OF ONE LINE TO START OF NEXT LINE (= 64μs).
2. V = TIME FROM START OF ONE FIELD TO START OF NEXT FIELD (20μs).
3. LEADING AND TRAILING EDGES OF VERTICAL BLANKING SHOULD BE COMPLETE IN LESS THAN 0.1H (10% – 90% OF BLANKING – WHITE INTERVAL).
4. TIME OF RISE FOR LEADING AND TRAILING EDGES OF HORIZONTAL BLANKING PULSES 0.2 – 0.4uS (10% – 90% OF BLANKING – WHITE INTERVAL).
5. DIMENSIONS MARKED WITH AN ASTERISK INDICATE THAT TOLERANCES GIVEN ARE PERMITTED ONLY FOR LONG-TIME VARIATIONS, AND NOT FOR SUCCESSIVE CYCLES.
6. EQUALIZING PULSE AREA SHALL BE BETWEEN 0.45 AND 0.5 OF THE AREA OF A HORIZONTAL SYNC. PULSE.
7. THE VALUES OF H AND V SHOULD VARY BY NOT MORE THAN 0.1% FROM THE ASSIGNED VALUES.

Fig. 21 — Australian Standard Television Waveform, 625 lines per Picture.

APPENDIX III.

All Broadband Radio Bearers — New South Wales, 1964
Average No. of Occurrences per Bearer-Terminal and Bearer-Repeater

Component	Terminal	Repeater	Component	Terminal	Repeater
Valve	13.4	13.3	Meter	0.11	0.053
Adjust Attenuator	1.94	0.95	Socket	0.14	0.098
Adjust Potentiometer	1.41	0.66	Circuit Breaker	0.18	0.049
Adjust Other	1.26	0.52	Terminal	0.012	—
Adjust Transformer	0.12	0.97	Cord	0.012	—
Adjust Filter	0.015	—	Attenuator	0.015	0.019
Adjust Relay	0.027	0.94	Cavity	0.015	0.040
Adjust Inductor	0.051	—	Thermostatistor	0.024	0.011
Tuning Adj.	0.83	1.17	Connector	0.027	0.034
Tuning Adj. Cavity	0.59	1.40	Filter	0.027	—
Fuse	0.90	0.75	U-Link	0.031	0.019
Resistor	0.66	0.51	Thermostat	0.046	0.019
Capacitor	0.65	0.32	Blower	0.055	0.011
Relay	0.45	0.48	Switch	0.660	0.042
Diode	0.43	0.38	Transformer	0.074	0.049
Pilot Lamp	0.34	0.057	Potentiometer	0.082	0.12
Other	0.33	0.97	Motor	0.092	—
Wiring	0.29	0.14	Invertor	—	0.019
Transistor	0.10	—	Regulator	—	0.034
Plug	0.11	0.023	Vibrator	—	0.038
			Crystal	—	0.083

APPENDIX IV.

Predicted Fault Rate of Solid-State Radio Equipment

Equipment faults — Average yearly occurrences

Present Equipment		Predicted for Solid State Equipment	
Bearer Terminal	Bearer Repeater	Bearer Terminal	Bearer Repeater
25	25	12	12

SERVICE ASSESSMENT FACILITIES

*M. D. ZILKO, Dip.E.E., M.I.E.E., C.Eng.**

INTRODUCTION

Irrespective of whether we are concerned with a machine making screws, or a telephone exchange establishing connections, it is necessary for the quality of the product to be controlled. In a telephone service the quality of the product is not controlled continuously but by random sampling, using two methods:

(a) A percentage of the real telephone calls are sampled and their quality appraised.

(b) Test calls are made in the telephone network either by dialling or by machine.

The method currently employed by the Australian Post Office to assess the quality of the service given to the public for both local and S.T.D. traffic is by manual sampling of live telephone traffic. Test calling (method (b)) is used primarily for supervision of traffic routes.

This article is the first of a series of four on recent developments in service assessment facilities for both local and S.T.D. traffic in Australia. In this article the general procedures and facilities for local and S.T.D. service assessment are reviewed. Future articles will outline the facilities and circuit operation for the sampling of local and S.T.D. traffic and assessment facilities for unattended exchanges.

GENERAL

The quality of the telephone service as seen by the subscriber is dependent on a number of factors including the time taken to establish an effective call at the first attempt, the number of repeat attempts in establishing a connection, and the transmission quality of the connection. Therefore the method employed to assess the quality of service and the presentation of this statistical information should be such as to clearly indicate factors leading to service deterioration, and should point to appropriate remedial action. It should be noted that corrective action must be practical, economically justified and may extend beyond exchange maintenance operations. For example, deficiencies due to human factors may indicate a need for subscriber education or provision of additional facilities.

SAMPLING METHODS

Sampling Scheme

An important feature of a service assessment scheme is the development of an economic sampling plan, based on precise definitions of the aspects of service which are to be checked. This subject will be discussed in a subsequent article in this Journal.

Step Exchanges

For step exchanges, observation access will be provided to first selectors or equivalents, chosen so that calls originating from any subscriber have an equal chance of being sampled. Access to a minimum of 40 and a maximum of 60 selectors, will be provided to supply a steady flow of traffic to the service assessment centre.

Crossbar Exchanges

For ARF exchanges, access will be provided to a sample of SR relay sets. The extent of SR access will vary according to the installed capacity of the exchange as shown in Table 1.

TABLE 1: EXTENT OF SR ACCESS

Size of Exchange (Lines)	No. of SR Relay Sets Sampled
1,000	20
2,000	40
3,000	45
4,000	60
5,000	50
6,000	60
7,000	35
8,000	40
9,000	45
10,000	50

In country exchanges provide a minimum of 40 and a maximum of 60 SRs to ensure adequate call loading.

S.T.D. Traffic

For S.T.D. traffic it is desirable that wherever practicable access should be provided to exclusively S.T.D. traffic, preferably immediately after it is segregated from local traffic. The method of providing this access will depend on the trunking arrangements employed, but the object is to provide maximum coverage to S.T.D. traffic with the minimum of assessment junctions.

The S.T.D. network is designed to route trunk traffic from its source to the required destination as economically as possible, and this will be achieved by trunking S.T.D. traffic via an ARM exchange, or an ARF exchange equipped with REG-ELP, or by trunking S.T.D. traffic on a point to point basis using step equipment.

Where the trunking arrangement is such that S.T.D. traffic is concentrated on 'O' level selectors it will be possible to use the same access circuit which is used for the assessment of local traffic. Where S.T.D. traffic is trunked directly to the ARM or ARF exchanges equipped with REG-ELP it will be necessary to provide access to a sample of FIR's. This will be a special access in which the incoming junctions are bridged with a high impedance input amplifier, the output of which will be connected to multifrequency code (M.F.C.) receiving equipment capable of detecting all the forward and backward M.F.C. signals.

OUTLINE OF THE SYSTEM

Local Service Assessment

Fig. 1 shows in block schematic form the arrangement of the new ser-

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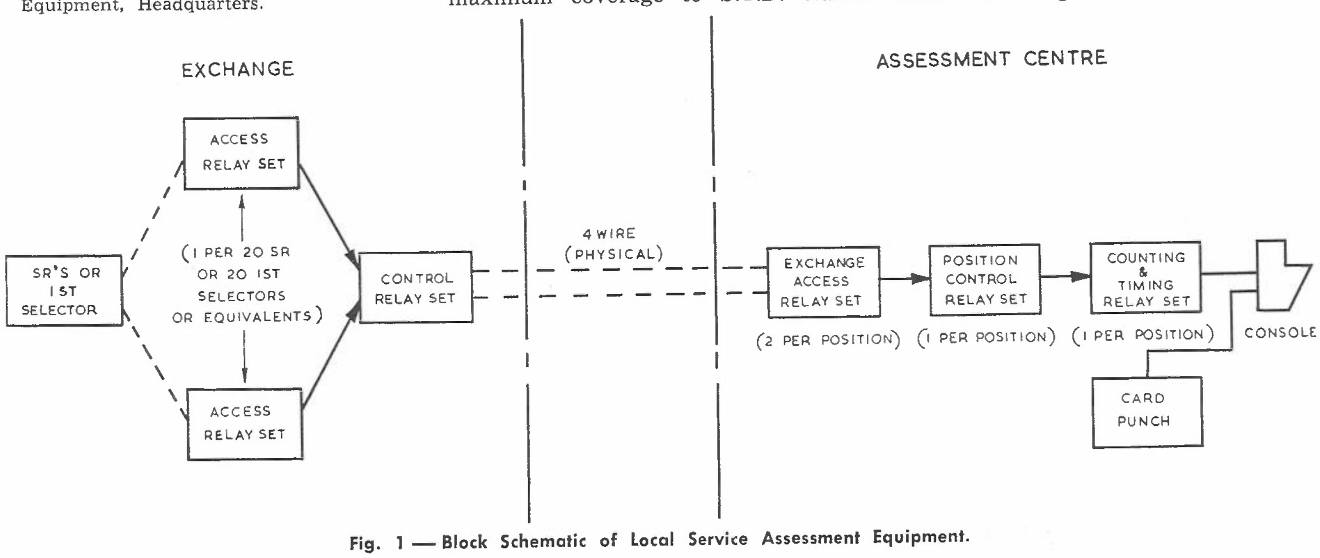

Fig. 1 — Block Schematic of Local Service Assessment Equipment.

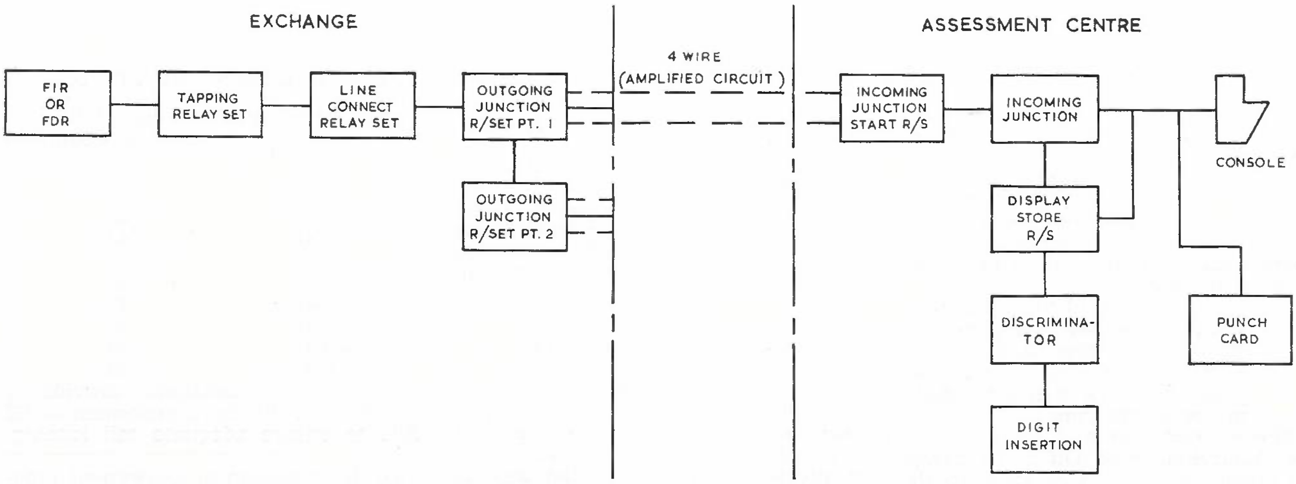

Fig. 2 — Block Schematic of S.T.D. Service Assessment Equipment.

vice assessment equipment to Drawing CE-20011-17. This circuit is designed to permit service assessment and special subscriber observations for a network of exchanges to be carried out from a centralised assessment centre consisting of a number of positions staffed by operators. Up to 100 exchanges can be accommodated with full multipling between positions; more than 100 exchanges can be connected by using partial multipling between positions. Special subscriber observation facilities are also provided at all exchanges but only one subscriber may be connected in each exchange and the total number of subscribers observations cannot be greater than the number of positions provided at the assessment centres. Each operator's position has four exchange access uniselectors on which appear the lines from the exchanges. These access switches are positioned by the operator on the desired lines, all four being in use simultaneously if required.

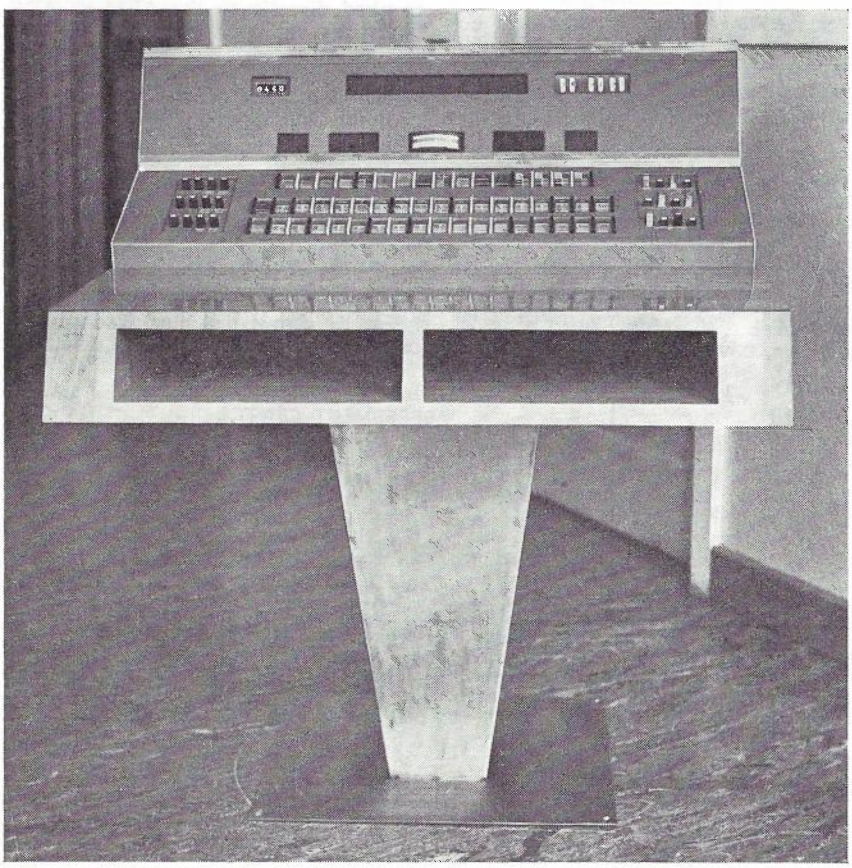

Fig. 3 — Service Assessment Position.

The information obtained from each assessment is presented to the operator by lamp display units and pilot lamps. The entire display is under the control of the operator and may be retained at the conclusion of a call or cancelled when desired by operation of a single key.

The information derived from each call assessed consists of:—

(a) Digits dialled.
(b) Meter pulses received.
(c) Duration of the assessment in seconds.
(d) Exchange from which the call is assessed.
(e) Whether the call is from crossbar or step equipment.

Facilities Provided

It is not intended to enumerate all the facilities that have been provided, but mention of some of the salient points may be of interest.

The service assessment operator may check all calls but cannot speak to the subscriber. The equipment position may be strapped so that operators may check calls either for 15-20 seconds after answer or for an unlimited period.

Provision has been made to allot a quota of calls, from 0-49 to each exchange or each part of a hybrid exchange. The quota is automatically sensed by the equipment, which accepts the required number of calls and then indicates to the operator that the quota is complete. The operator may ascertain the quota for an exchange or the number of calls received at any stage.

A facility is provided to permit the assessment of only those calls with first digit '0'. For any other first digit, the call is released and the display reset automatically.

ZILKO — Service Assessment

The equipment has been designed to operate under the following conditions

(a) Battery voltages 46V to 52V at both the exchanges and service assessment centre.

(b) Maximum single wire DC resistance of 1500 ohms.

(c) Insulation resistance not less than 50,000 ohms to earth or between wires of the pair.

(d) Loss not greater than 13dB. These loss and loop figures correspond to approximately 17 miles of 10lb. loaded cable.

Provision has been made for extracting information from the position into equipment which will punch a card for computer analysis.

S.T.D. Service Assessment

As mentioned earlier access to a sample of FIR's at the ARM exchanges or ARF exchanges equipped with REG-ELP will be provided for the assessment of S.T.D. traffic.

Fig. 2 shows in block schematic form the arrangement of the S.T.D. service assessment equipment. This facility is still being developed and it is expected that the prototype will be manufactured and tested towards the end of the year. In the meantime arrangements have been made for a programme of manual test calls to assess the quality of service via the ARM grid.

The information obtained from each assessment will be presented to the operator in a manner similar to that used for local service assessment and will consist of:—

(a) Zone of origin.

(b) Digit dialled including national code.

(c) Meter pulses received.

(d) Duration of the call from the time the FIR is seized.

(e) Indication of FIR under observation.

The following are some of the facilities that will be provided:—

(f) One position will be capable of observing up to 4 ARM exchanges individually.

(g) The operator will have the facility of observing M.F.C. calls, only, decadic calls only, or both.

(h) Access will be available up to 100 FIR's.

(i) For M.F.C. calls lamp indication of plant congestion and non-metering.

(j) Facility to discriminate up to 4 digits so that assessment on individual routes may be obtained if desired.

Operator's Positions

A new assessment position has been designed as shown in Fig. 3 whilst Fig. 4 shows the layout of the lamps display and keys. The working conditions at the console are comfortable and attractive. The console was de-

Fig. 4 — Face Layout of Service Assessment Position.

ANALYSIS OF CALL ATTEMPTS OBSERVED .... EXCHANGE/S DURING MONTH OF ....

EXCHANGE	CALLS OBSERVED (EXCL DND)	EFFECTIVE CALLS	CUSTOMER LOSS						CONGESTION LOSS			SWITCHING LOSS					INDET	OTHER TECHNICAL DEFECTS			POST DIAL DELAYS 4 SEC	D.N.D. (NOT INC. COL.2)	REMARKS
			WDA	CA	WN	CN OR VA	OTH'S	TOTAL	WBY	NET CON	TOTAL	WN	NP	TC	OTH'S	TOTAL		MET. IRREG	OTH'S	TOTAL			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
No.																							
%	100																						

Fig. 5 — Service Sampling Results Tabulation

signed with the operator in mind, and included consideration of human engineering practices, operator, circuit and maintenance aspects.

The eye can scan a limited horizontal space at a glance and still retain the image. The digital indicating tubes at the top occupy only 9.5 ins. enabling the operator to see a ten digit number easily upon display.

The initial requirements for push-button keys and associated lamps resulted in the development of keys which are illuminated or nonilluminated as needed. The inclusion of the lamps inside the key is intended to focus the operator's attention on a fewer number of objects. The same hardware will be used for the S.T.D. assessment positions but with a slightly different face layout to accommodate the additional facilities required.

PRESENTATION OF STATISTICS

At present a sample of 200 calls is observed monthly from each exchange in the metropolitan areas and the results are compiled manually and tabulated as shown in Fig. 5. The information obtained from these statistics shows only the average performance throughout the day and no attempt has been made to extract busy hour statistics; mainly because of the amount of time and effort that would be required to obtain these figures. With the new equipment facilities will be provided so that information received on the position, e.g., exchange under observation, number dialled, etc., will be automatically extracted on a punch card. The operator will have to ascertain the condition of the call and transmit this information on the punch card by pressing the appropriate keys shown on the bottom two rows of the face layout (Fig. 4). Initially the information on the punch card will be processed by the use of a mechanical sorter and this will reduce considerably the time required for the compilation of the monthly statistics. With this system it will be possible to obtain in future two sets of statistics, busy hour performance and total average performance. The results will be weighted according to the originating traffic from each exchange. A better spread of the sample throughout the month will be possible as facilities have been provided for the operator to set automatically a quota of calls for each exchange under observation.

As computers become more readily available throughout the Department the compilation of these statistics will be done by computer process, but in the meantime valuable information can be obtained using a punch card and mechanical sorter.

FUTURE TRENDS

With the new service assessment equipment an attempt has been made to introduce semi-automatic facilities for the sampling of live telephone traffic which offer a number of advantages in comparison to the current manual system. The next step tends towards full automation for the sampling of telephone service and although this appears very attractive in so far as cost savings, it has a number of disadvantages.

The advantages and disadvantages of a fully automatic system may be briefly summarised as follows:—

Advantages:

(a) It is possible to sample calls optionally at anytime or all day.

(b) It will result in considerable operator cost savings.

(c) It eliminates differences due to subjective judgements between individual observers.

Disadvantages:

(a) Wrong number dialled by the caller cannot be detected. With the manual system the operator checks all calls which receive voice announcement or N.U. Tone to ascertain whether this condition was due to either customer's error or due to wrong switching.

(b) Wrong switching due to plant faults cannot be detected.

(c) Difficulty in positively identifying the various service tones.

Completely automatic service assessment equipment is used extensively by the B.P.O. and the Swedish Administration, whilst the Nippon Telegraph and Telephone Corporation is planning to replace the existing manual system in the next five years. The A.P.O. has purchased two units from the B.P.O. for extensive field trials in Sydney and Melbourne.

The author's opinion is that fully automatic service assessment equipment can be a very useful adjunct but not a substitute to manual sampling for the appraisal of the quality of the service as seen by our customers.

ELECTRONIC EXCHANGES WITH STORED PROGRAM CONTROL

F. W. WION, B.E.E., M.Eng.Sc., M.I.E.E.*

INTRODUCTION

It is becoming apparent that the coming generation of electronic telephone exchanges will make extensive use of some form of Stored Program Control (SPC) to control their switching stages. A number of advanced developments have already been reported (Refs. 1, 3, 4, 7, 8, 9, 10) and others are known to be in progress. The form which the SPC takes in these developments varies greatly, both in extent of application and the methods employed. These variations will be discussed below but it is apparent that SPC is a very general term covering any situation where the logical behaviour of a control unit is governed by information stored in something which can be recognised as a memory unit. Alterations to the stored contents of the memory unit will result in an alteration to the behaviour of the control. Thus, for example, modifications to exchange register functions could be effected much more readily by altering the contents of a program store than by adding relays and springs, and modifying the wiring in a large number of registers. The most advanced form of SPC uses equipment very closely related to commercial computers to perform control functions. This type of control is commonly called processor control, as the computers are being used to process data rather than for computational work. Processor control of real time processes is already well accepted for large-scale industrial and chemical engineering applications. The differences between processors and computers are important but not very obvious, and stem mainly from the very stringent reliability requirements for processors. Other differences result from the different work to be executed.

Although processor control seems to be favoured for large exchange applications, some designers feel that not all control operations are most economically handled by the processor. Thus there is a tendency to have some exchange control functions performed by autonomous "boxes", which the processor calls into service as required. The processor is the chief administrator, while the autonomous boxes perform some executive functions, for which reason they are sometimes called executive units. In some exchange systems, executive units are provided for all control functions, and the SPC only administers or directs the sequence of operation of these executive units (Refs. 8, 10). In such a case the SPC unit becomes relatively small and cheap, and much of the potential flexibility in exchange facilities is lost. On the other hand, the control comes in much smaller increments and could be better suited to a wide range of exchange sizes. Although it is possible to consider the simpler SPC units as "processors", it is proposed to reserve that term for the computer type machines which control most or all of the activities of some exchanges. This paper will concentrate on this processor control; readers requiring further information about the simpler form of SPC should consult Ref. 11.

PROCESSOR CONTROL CONCEPT

Although some use may be made of executive units in conjunction with processor control, this possibility will be discussed only in a later section, and a fully processor-controlled exchange will be considered at this stage. The exchange is primarily a switching network to which a number of lines (subscribers, junctions, trunks) and signalling devices are connected. A control is provided to detect and process requests for service. Thus from the point of view of the control, the rest of the exchange is first of all a source of data derived from line and information signals. The control must accept all of this input data, interpret it, and then issue operating instructions to the switching equipment. For any single call, of course, a number of interleaved input and output actions are required during setting up and clearing down. What has been said is true of any type of control but it suggests how a single box, which can accept input data, process it and then issue results, could perform exchange control functions. The box, or processor, must also obtain information about the instantaneous state of the exchange (for example, which lines and switches are busy) before it can complete the processing tasks. This type of data could be obtained by the processor examining the exchange whenever information is required, but this is a relatively slow process, and it is generally preferable to store an image of the state of all variable devices in a data store associated with the processor. The processor can interrogate this data store much more rapidly than it could interrogate the exchange proper. The processor also requires yet another type of data before the processing can be completed. This is the translation and other semi-permanent data for the exchange, including, for example, the equipment/directory number translations, the routing and charge translations, classes of service and abbreviated dialling codes. Finally, the program instructions, held in the processor program store, direct the processing activities using the incoming and stored data as raw material. The processor, and its associated stores, are shown in Fig. 1. The different stores shown could be separate

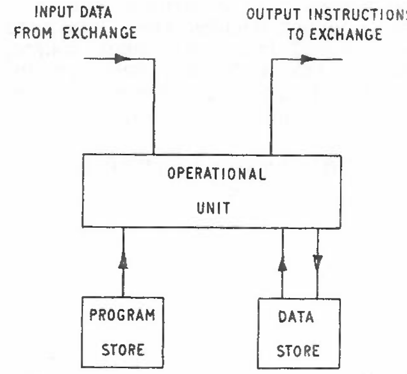

Fig. 1. — Processor and Associated Stores

from each other, or could share a common store.

The processor, like a commercial digital computer, can execute only one program instruction at a time. The rate at which instructions can be executed is largely governed by the read-write cycle time of the stores (ferrite core stores are commonly used, and these destroy the stored information on reading, so the information must be rewritten). A good modern ferrite store has a cycle time of about 1 microsecond, and instructions average about 2-3 cycles to execute. Thus a processor could execute about 500,000 instructions per second. On the average, some thousands of instructions will be required for controlling each call through the exchange, so some limit can be seen to the number of calls which can be processed each second. Even to approach this limit requires careful organisation of the program to ensure that time is not wasted on unimportant activities while urgent work remains to be done, and the means of achieving this are described later. Apart from the need to organize carefully the processor's activities, there is a clear advantage in minimizing the number of instructions required for each call.

The word length used in the processor is limited, ranging from about 16 to 32 bits in most cases. Only this number of bits in parallel can be accepted as input data or transferred to or from the data store at one time, and each step in the processing is concerned with manipulations of words of this length. Pathfinding through a switching network having many thousands of crosspoints, or performing large translations, does not impress as a simple task when the limitation of processor word length is considered. However, quite efficient methods of performing such tasks have been devised, and the short word length is not a serious limitation in performing any processing tasks.

It is not possible to permit originating data to arrive at the processor in

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an uncontrolled fashion, one reason being that the processor only has, say, 16 input leads and there are thousands of separate sources of data. In fact, all input flow is under the control of the processor (or strictly, the program), which decides when data is to be accepted from any input source, that is, the processor issues an instruction to an input source as a prelude to an input operation.

PROCESSOR/NETWORK INTERFACE

Interface equipment is required between the switching network and the processor. The switching network will usually contain electromechanical devices such as reed relays, conventional relays or even crossbar switches, and a power interface is required between the low-level electronics of the processor and the electromechanical devices. The interface much also cope with a great speed difference. If a relay takes 20 milliseconds to operate, the processor could lose 10^4 possible program steps if it maintained an output instruction for that length of time. Thus, the processor output instruction must be held on an electronic flip-flop, or similar device, in the interface equipment. This will immediately free the processor to execute further program instructions.

If the electromechanical devices are self-latching, the interface equipment can also be freed after operation. Separate arrangements must then be made for releasing the devices.

Finally, the interface equipment must enable the, say, 16 input and 16 output wires of the processor to be coupled to whichever of many thousands of input and output points is to be operated on at any time. This involves decoding equipment. If each input or output point (or small group of points) in the switching network is given a discrete binary address, then the processor can issue the appropriate address to a decoder in the interface equipment which selects the particular device, or group of devices, required. If an input device is addressed, the interface transfers the appropriate input data to the processor input leads. The addressing of a relay, say, causes it to operate or release.

In a processor with a sixteen bit word-length, up to 2^{16} (65,556) different addresses could be generated with a single processor output word. A 10,000 line subscribers' exchange using crossbar switches would have something like 30,000 switch magnets and 15,000 relays (in line, junction, m.f. signalling and cord circuit relay sets) to operate, and each of these would require an address. (Remember, there would be no logic-performing relays required.) In addition there would be at least 16,000 input points (lines, junctions, m.f. and decadic digit receivers) which, when grouped into 16's, would require 1,000 addresses. This rough calculation indicates that the 16-bit output word is of the right order to address the necessary points in the switching network. In some cases, two successive output words might be required to address fully the switching network.

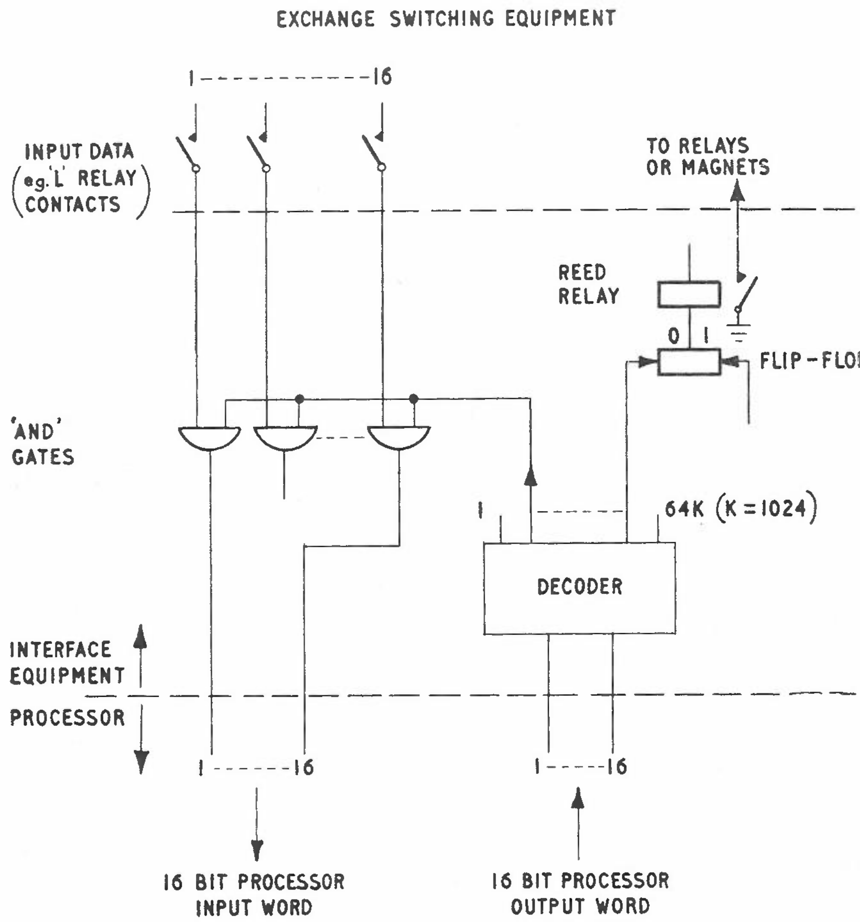

Fig. 2. — Interface Equipment (Diagrammatic)

Fig. 2 gives a very diagrammatic representation of an interface equipment, illustrating the main requirements of the interface, as discussed above. In practice, the address decoding would be carried out in two or more stages, with the holding flip-flops between the decoding stages. This lowers the cost of the interface equipment, as a flip-flop would not be required for each electromechanical device to be operated. Nevertheless, it should be clear that the interface circuits between the processor and the switching network are fairly complex and account for a significant part of the exchange cost.

PROCESSOR OPERATION

The processor has to carry out functions appropriate to the processing of telephone calls and the program instructions are the means of doing this. The instructions are thus selected to be appropriate to the processing task and some may be very specialized for exchange control. The program instruction list should be as short as possible without seriously lengthening the total number of instructions required for the whole program. In general, a list of less than 100 different instructions is sufficient. Each instruction to be executed is brought from the program store and is held in a register in the processor while the instruction is executed. A register is usually a set of electronic flip-flops which can hold information in the processor. Numbers of registers are provided for different purposes, including holding the data which is being manipulated as a result of the instruction. This latter type of register may have the ability to shift the data word it is holding, bit by bit, if ordered to do so by a program instruction. The relationship between the main registers and the rest of the processor is shown in Fig. 3.

The more complex the operation which can be carried out by each instruction, the fewer the instructions required in the whole program, and the shorter the time required to write and check the program. To exemplify this principle, the multiplication process in a conventional computer could be considered. Multiplication can be effected by repeated additions, and many cycles of computer time would be required to do a multiplication this way. Alternatively, a single-shot multiplication could be carried out in one cycle time, at the cost of a wired

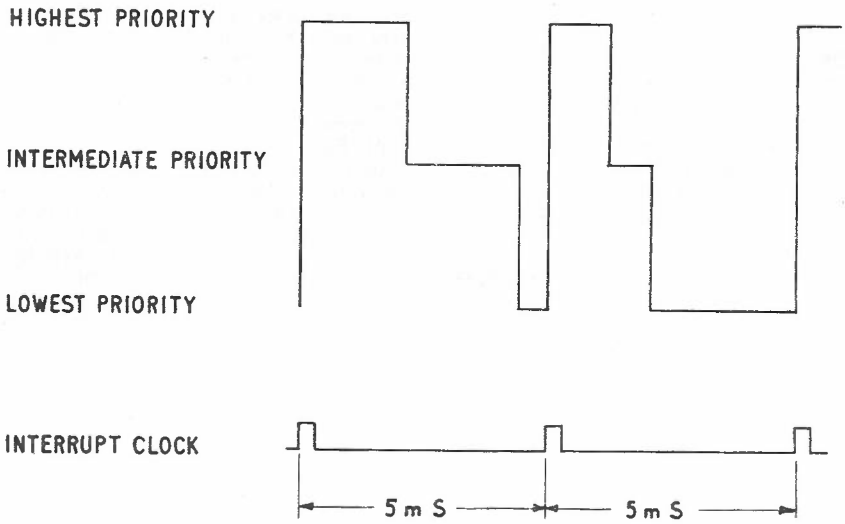

Fig. 3. — Simple Processor Organisation

hardware multiplier unit. The main limit to this sort of trading between computer cycles and additional hardware is that no additional data can be extracted from, or returned to, the data store while a complex instruction is being executed. This limitation may be offset to some extent by providing a number of very high speed registers in the processor, and these can be used as a scratch-pad memory. The processor then carries out complex instructions at a much higher speed than the normal store cycle time, using the registers as temporary stores.

PROGRAM INSTRUCTIONS

The program instruction list will be peculiar to each manufacturer, but most of the instructions are concerned with simple manipulations of data such as reading from store, data inputs and outputs, shifting and Boolean processes (logical AND and OR). Other instructions are involved in selecting the next program instruction to be executed. This is because the program is not executed in a strictly fixed order, and many conditional jumps are required, depending on what happens in the exchange (for example, is the wanted subscriber free or busy?), and the pressures of urgent work (for example, attending to an incoming call from a step-by-step exchange). In Table 1, some typical operations performed by single program instructions are listed. The first five examples are data manipulation instructions and the last two are program jump instructions. In the processor each instruction is stored, and recognized, as a binary code (machine language). It would be unnecessarily laborious for the programmer to write the programs in machine language, and the programming is usually done in so-called assembly language, using mnemonic codes. Examples of possible mnemonics for the instructions of Table 1 are included in the Table.

TABLE 1: TYPICAL PROGRAM INSTRUCTIONS

No.	Instruction	Possible Assembly Language Code
1	Load word from the data store, address x, into Register A	LDA, x
2	Load word from the data store (address in Register B) into Register A	LIA, B
3	Load word from the store data, address x, into Register B, and shift n bit positions	LSB, x, n
4	Perform logical AND function between word in Register C and word in data store, address x, and place result in Register C	LAC, x
5	Perform logical inclusive OR function between word in Register B and word in data store, address x, and place result in Register B	LOB, x
6	Jump n positions in program store	JPD, n
7	Jump the number of positions in the program store indicated by the contents of Register B	JIB

A computer, or the exchange processor, is used to translate from the assembly language (in the form of a punched paper tape, say) to machine language. The second instruction in Table 1 is an example of indirect addressing. Here, rather than specify the address where wanted data is to be found, a location has been specified in which the address can be found. This manoeuvre is very commonly applied in programming, both as a means of reducing the numbers of address bits required in an instruction and as a programming tactic. Indirect addresses may be used for many instructions and the last instruction in Table 1 is another example.

A complete program might consist of 20,000 to 100,000 separate instructions, depending on the exchange facilities and the amount of programmed fault location. The program is subdivided into recognizable processing tasks, each defined by a set of instructions. Typical exchange processing tasks would be the examination of digits for route analysis, or the selection of a path through the switching matrix. The set of instructions defining a particular task is not repeated many times in the program, but is stored only once and referred to whenever required. Such a referable set of instructions is called a subroutine.

PROGRAM ORGANIZATION

As mentioned earlier, the program must be organized to ensure that time is not spent on non-urgent tasks when more urgent work is waiting. This is achieved by giving each processing task a priority classification, and then devising some way of ensuring that the higher priority tasks are given some precedence over lower priority tasks (Refs. 1, 2, 5, 6). As many tasks have such a high priority that they must be attended to in some tens of milliseconds (for example, scanning a dial pulse) it is necessary to give the processor some sense of elapsed time. This is done with an interruption clock external to the processor, generating pulses about once each 5 milliseconds. These pulses interrupt the processor in whatever it is doing, and cause the program to jump to more urgent work which may be waiting. Typically, call processing tasks are assigned to three priority levels. Fig. 4 shows how, at each clock interruption, the program jumps to the highest priority and performs all tasks of this priority which are waiting. When all top priority tasks are completed, the second priority tasks are executed and the remainder of the interruption period is spent on low priority work such as routine exchange maintenance tasks. It will take a relatively long time to complete all the low priority work but all waiting higher priority work normally would be executed in each 5 millisecond clock interruption period.

The American Bell ESS No. 1 System uses a different method from that

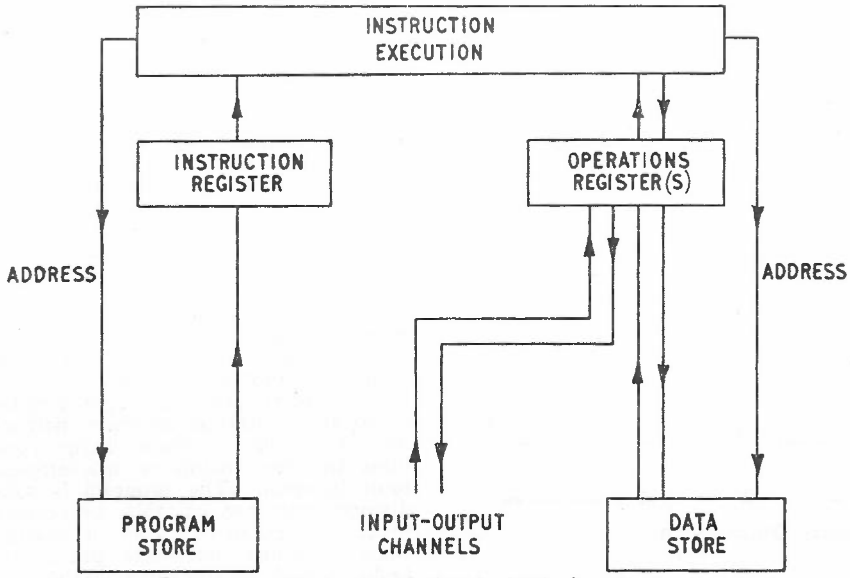

Fig. 4. — Program Priority and Clock Interrupts

just described for attending to waiting tasks (Refs. 1, 12). All tasks other than the highest priority ones are allocated to one of five classifications A to E, depending on the time delay tolerable for each task. The classes of task are executed in a cyclic order which ensures that Class A tasks are executed twice as often as Class B tasks, which are executed twice as often as Class C tasks, and so on. Each clock interruption will cause a transfer to the highest priority tasks but the program then reverts to the point in the A to E class cycle reached when the interruption occurred. This approach has the effect of maintaining the ratios of time delay for the execution of different tasks at roughly constant values, irrespective of the call processing load on the processor. This contrasts with the priority level system, which tends to introduce very long delays for low priority work as the call processing load increases. At this stage it is not clear which method of task allocation is preferable for exchange control, but most manufacturers appear to favour the priority level system.

There are signals other than the external clock which can produce program interruptions. The most notable of these signals is a fault interruption from external fault-detecting equipment. When such an interruption is received, the processor control is transferred to a special, high priority level where fault location programs are executed. While a high priority interruption is activated, lower priority interruptions are ignored.

SECURITY CONSIDERATIONS

When the control of an exchange is concentrated into a single processor, the reliability and repair times of the processor become extremely important. Electronic circuit reliability and repair times are not adequate at present to provide the necessary degree of security, unless standby equipment is used. A duplicate processor is therefore required, and usually this twin duplicates the work of the first processor. The two processors operate in synchronism and their outputs are compared at each step of processing by a checking unit. Whenever a discrepancy occurs, each processor checks the other to determine which is faulty. The faulty processor is removed from service and the good processor carries out fault-finding analysis, as well as continuing with the processing work. An exchange failure will only occur if the remaining processor fails before the first fault can be repaired. With existing component failure rates, and allowing about 2 hours for repair (with the assistance of the working processor) a mean time between failures (MTBF) of a processor pair of the order of 100 years could be expected. Assuming an exponential distribution of failures, some implications of an MTBF of 100 years are that there is a 63% probability of a total failure occurring within the 100 years, a 1% probability of a total failure within the first year of operation, and intermediate probabilities of failure within periods of between 1 and 100 years.

Another method of providing processor security is by means of load sharing (Ref. 7). Once again there are two processors involved but rather than have one processor idling, the two processors share the processing load. If one processor fails, the remaining processor can still continue operation alone, although the peak processing capacity is reduced by the loss of one processor. If this occasional loss of peak processing capacity can be tolerated, there is a clear advantage in avoiding the cost of a processor which never shares in the processing load but is only provided for security reasons. However, an Administration may well be unwilling to have the peak processing capacity reduced on the few occasions each year when one processor has failed. If so, the exchange would be dimensioned so that a single processor could carry the peak traffic, and the added capacity of the second processor would be redundant. Fault detection in a load-sharing system is performed by each processor checking the other for correct operation. This checking is carried out periodically and instantaneous fault detection, such as is achieved by synchronous processors, is not possible. It is not clear at this stage whether the small delays in detecting a fault condition would ever prove an embarrassment.

The stores used for program and data storage are also duplicated, for security. However, the stores are usually not permanently assigned to a particular processor, so that a store failure will not also remove a processor from operation. If there are four items of equipment, two processors and two stores, and a working system can be obtained with any one processor-store pair, the overall reliability is higher than if the processors and stores were permanently associated in pairs.

It is quite possible that the interface equipment could also suffer faults which would affect a large portion of the exchange. If this is the case, then duplication of critical sections of the interface equipment would be necessary, and provision would have to be made for rapid changeover in the event of faults occurring.

MULTI-PROCESSOR OPERATION

To this stage, the discussion has been limited to the provision of a single, duplicated processor to control an exchange and alternatively, a load sharing pair of processors, either one of which is capable of carrying the load. However, many Administrations can foresee network requirements for exchanges so large that their control would be beyond the capacity of a single modern processor. The control of such an exchange would require a number of processors (for example, four) interworking to share the total processing load (Refs. 13, 14). If the philosophy of synchronous working for security was followed, each working processor would have its synchronous, standby twin. On the other hand, an extension of the purely load-sharing philosophy would see, say, five processors sharing the load. Any single processor could fail and the remainder would continue to carry the load. At first sight this is a comparison between four processors with four standbys, and four processors with one standby, and a choice would be simple. However, there are many other related factors to be considered simultaneously, and more studies are required in this area before any firm conclusions can be drawn.

In any multi-processor arrangement for exchange control, there must be some reduction in processing capacity below the total of the capacities of the separate processors. This loss results from the need for the processors to spend some time intercommunicating with each other. There are many possible ways of dividing the control load between a number of processors but, to take a very simple case, consider an exchange which is divided completely into a number of sub-exchanges. Each processor would control all processes within a sub-exchange. This appears satisfactory, so long as calls are set up completely within a sub-exchange, but a percentage of calls would involve setting-up through two sub-exchanges. These calls would require intercommunication between the two processors. The actual method of load sharing used is likely to be much more refined than this, but any other load-sharing system will also be found on examination to require intercommunication between processors. The amount of processor capacity lost in a multi-processor organisation will vary with the way the load sharing is done, and also with the number of processors involved. With some arrangements, a situation could be visualized where the addition of an additional processor to a load-sharing group would not increase the processing capacity sufficiently to be economically justified. It is not expected that this situation will arise in practical exchange situations, but a load-sharing system which minimized the loss in processing capacity would be desirable.

MAINTENANCE ASPECTS

The question of security of the most centralised equipment has been discussed above, without mention of the means by which faults, when detected, are localised and repaired. To find a fault in electronic switching circuitry, using only an oscilloscope and other basic test instruments, is a very lengthy procedure, often requiring days to repair a simple fault. It is also easy to produce other faults while localising the first one. For these reasons, the fault localising processes should be as automatic as possible, and fault localising in the processors would usually be completely automatic, carried out by working processors. The aim would be to specify automatically a plug-in unit for replacement. Even this degree of automatic fault localisation would require a considerable amount of permanently-stored program for its execution, perhaps as much again as would be required for the basic telephony processes. As far as possible, manually-loaded programs would be used to back-up the work of the automatic programs. These manually-loaded programs might be required for fault localisation in the interface equipment, and for routine testing, fault detection and localisation in the switching network and its peripherals. The tendency is to permit longer time and more human intervention for fault detection and repair in the less centralised equipment. In some cases special routiners would be used for fault work, but the use of the processor is the more attractive concept.

In some cases it may be possible to replace faulty components in the exchange, but generally this work would be most efficiently handled at centralised depots. This comment is true, of course, of other types of electronic exchange not using processor control.

PROGRAMMING REQUIREMENTS

The facilities of an exchange, which are defined by wired circuits in more conventional exchanges, are defined by stored program instructions in a processor-controlled exchange. Thus the frequently-required alterations to the facilities will be achieved by altering the programs. Also, new facilities will only require program alterations. Modified programs could be inserted in a large number of exchanges almost simultaneously, thus effecting wholesale changes very rapidly. However, with these benefits of stored program come some potential problems. It is very easy for even experienced programmers to produce errors, and a faulty program inserted in a working exchange could mutilate a great deal of traffic and important stored data before the program faults could be corrected. This would not be tolerable, and means must be found to test programs without any danger to the operations of a working exchange. As a preliminary, simulation tests could be carried out on a computer, or using a laboratory model of a processor with artificial traffic. These tests, particularly the latter, would eliminate most faults. Some protection would still be necessary when the new program was tested in a real exchange. The protection required would have to safeguard the existing programs and data, permit the exchange to continue operation, and yet enable dynamic fault localisation to progress. In the rare event of program or other faults affecting the stored information in the processors, the processors must be able to untangle the situation automatically.

The work of writing and testing programs is not a rapid process, and only of the order of 1000 instructions per man year is the common experience for programming teams. A programming team must include members with a detailed knowledge of the requirements of the exchange and of the interface between the exchange and the rest of the network, members with a knowledge of the existing programs, and members able to write the actual instructions. In addition, computers and processors will be required for program assembly (the translation to machine language) and testing. For the sake of efficiency and economy, the programming teams required to maintain and update processor-controlled exchanges will have to be fairly centralised. This will have the side effect of rationalising the programming of numbers of exchanges.

EXECUTIVE UNITS

As mentioned in an earlier section, there is still disagreement on whether a processor should control all processes in an exchange, or whether some processes, and if so which, should be delegated to executive units. The disagreement suggests that the economic balance between the choices is fairly fine. As an example of the use of executive units, the marking process for crossbar switches could be considered. The processor could select and operate a horizontal, check that operation had occurred, then select, operate and check a vertical, and finally select and release the horizontal. Alternatively, a marking unit could be provided which responded to a processor order 'operate crosspoint x in switch y', and supplied all the necessary timing, operating and checking functions. Obviously this would save the processor a number of program steps and would allow the processor more time for other operations, thus increasing the overall call-handling capacity. This would allow a larger exchange to be controlled without resorting to multi-processors, and would require fewer multi-processors for a very large exchange. On the other hand, the executive unit must be paid for.

One type of largely unproductive work which would be required in an all-processor-controlled trunk exchange would be the detection of 600 and 150 millisecond line-signalling pulses. To detect and discriminate such pulses would require each line to be examined at periods not exceeding about 20 milliseconds. This process would have to continue at all times, as a pulse can occur at any time. However, pulses very seldom do occur, and most of the scanning does not produce any signalling information. The entire scan process for 16 lines, say, might take something like 10 microseconds of processor time, and if each line must be scanned each 20 milliseconds, a maximum of $20{,}000/10 \times 16 = 32{,}000$ lines could be scanned by one processor. This is a big price to pay for line-signal scanning. An alternative is to place hardware in each line relay set, to detect pulses and measure their duration. Much less processor time would now be occupied with the line signalling, but the cost of the hardware in each line relay set would be about the same as the saving in processor cost.

A similar situation exists in subscribers' exchanges where some lines must be scanned about once each 5 milliseconds to detect dialled impulses. This is not so severe as it seems, as lines only have dialling present at fairly predictable times, shortly after the lines are seized. However, there is still a case for using dial pulse receivers consisting of hardware circuits which count the impulses in each train, and transfer the count to the processor. Once again, there is no clear preference at this stage.

The advantages of transferring some functions from the processors to executive units are the reduced processor and programming requirement, and possible economic benefits. The disadvantages are that additional hardware must be designed, less standardisation is possible in line relay sets, and some flexibility may be lost.

CONCLUSION

The coming generation of telephone exchanges will probably include some use of stored-program control techniques; in particular, processor control for large exchanges. The concepts involved in processor control are a large jump from present-day control techniques although probably not so large as the jump from step-by-step to common-control techniques. However, processor-controlled exchanges will present a new set of challenges to the Department and new talents will have to be developed and existing organisation examined critically if the challenges are to be met effectively.

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MR. A. H. KAYE, M.V.O., B.Sc., F.I.E.E., M.I.E. Aust., S.M.I.R.E.E. (Aust.)

MR. A. H. KAYE, M.V.O.

The appointment of Mr. A H Kaye as Assistant Director (Engineering), South Australia, culminates a distinguished engineering career which began in 1929 with an appointment as cadet engineer in Victoria. After graduation as Bachelor of Science and an initial appointment as engineer in the Radio Section at Headquarters, Mr. Kaye was attached to the Queensland Administration for a period in which he supervised the installation of new radio stations in Papua and New Guinea. On return to Headquarters in 1940 he coordinated radio construction works throughout Australia, including those required by the Armed Services.

Mr. Kaye was promoted Divisional Engineer in 1944 and Assistant Supervising Engineer in 1949 in the Headquarters Radio Section where he became responsible for all aspects of 'new works'. In 1955 he was promoted Supervising Engineer, Radio in the Victorian Administration where as head of the Radio Section he directed all radio activities in the State. He returned to Headquarters in 1957 to take responsibility for the co-ordination of all aspects of the Sydney-Melbourne Co-axial Cable Project.

In 1962, Mr. Kaye was appointed to the special post of Commonwealth Communications Officer for the visit to Australia of Her Majesty the Queen. His task was to co-ordinate mails, telephone services, telegraphs, broadcasting, and television relays for the Royal Party, officials and the Press. In recognition of this work, the Queen bestowed on Mr. Kaye the award of Member of the Royal Victorian Order.

After a period as head of the Headquarters Subscribers Equipment, Telegraphs and Power Section, Mr. Kaye proceeded to London for a 3-year term as the Australian Post Office Representative at Australia House. On return to Australia, he took up an appointment as Engineer Class 5, Radio Section and shortly afterwards was promoted to his present position.

Mr. Kaye has been a prominent member of the Professional Officers Association for many years. He was a member of the Executive Council from 1955 to 1964, President of the Victorian P.M.G. Engineers Group in 1958-59, and was the Association's General President from 1959 until his departure for London in 1964.

A DECADE OF PLASTIC CABLING

*R. A. READ, C.Eng., F.I.E.E.**

INTRODUCTION

Polyethylene was first synthesized in 1933 in England but it was not until some 6 years later that production of this invaluable plastic was undertaken on a commercial scale. Throughout World War II its remarkable electrical properties were exploited in radar and other high frequency cables and by the early 1950's its place in the coaxial cable industry had become firmly established. In particular it gained prominence in the submarine cable field where its properties were exploited in the first transatlantic submarine telephone systems and the many subsequent lightweight communication cables now traversing the globe.

Its introduction to the local network was inhibited by cost considerations until the early 1950's when improved manufacturing techniques made possible the production of fully colour coded polythene insulated conductors with extruded sheaths up to approximately 1 in. in external diameter at prices considerably lower than their lead paper equivalents.

Here now was the apparent fulfilment of many a distribution engineer's dream. A cable of excellent physical and electrical properties and of great versatility. The light, flexible and chemically inert sheath would eliminate the traditional problems of vibration fatigue and corrosion. The conductor insulation would not unravel or fray and would not be subject to low I.R. in the presence of moisture. The potential of such a cable was indeed enormous. It could be handled in great lengths, laid in the ground by plough or in trench, drawn into pipes or suspended from poles. It could be bent around sharp corners and coiled in tight loops and its moisture insensitive conductor insulation would permit direct termination on tags or terminals in unsealed enclosures.

Plastic cable for the distribution network was in fact a 'must' and by the late 1950's production in Australia was adequate to meet the requirements of the A.P.O. for large scale introduction of a suitable range of sizes and gauges and fully colour coded, plastic insulated and sheathed cables for use in distribution areas.

During the past decade their usage has increased progressively and at the time of writing more than 40,000 sheath miles of plastic insulated and sheathed cables are in service in the distribution areas. Whilst this large scale change to plastic networks has eliminated many of the traditional problems associated with lead paper systems, it has introduced an entirely new set of problems which has taxed the ingenuity of engineers, physicists and chemists throughout the world and which remain in many cases only partially solved. It has opened up new concepts in network design and layout and has necessitated sweeping changes in installation practices and jointing techniques. It has altered dramatically the pattern of service performance and has necessitated radical changes in maintenance methods and procedures. It has in fact demanded an entirely new technology which throughout the years has of necessity been subject to change and which is as yet far from stabilized.

This paper examines the more progressive developments in this technology over the past decade; it discusses the experience gained by the A.P.O. and its effect on future trends in our development.

CABLE DESIGN AND SPECIFICATION

The early plastic distribution cables were laid up with 6½ lb., 10 lb. and 20 lb. per mile cores in twin formation insulated with low density polyethylene with full colour coding and a core wrapping of plastic tape. P.V.C. containing carbon black for ultra violet protection was chosen as the sheathing material as, at that stage, the available grades of polyethylene had comparatively poor mechanical strength and inferior weathering properties. A range of cable sizes up to 75 pairs was provided to meet the requirements of the distribution areas.

In succeeding years the quality of insulant was improved and advantage was taken of the advancement in plastics technology to effect the change of sheathing material to a grade of polyethylene containing carbon black and polyisobutylene or butyl rubber having satisfactory weathering and mechanical properties and good resistance to stress cracking. At the same time the plastic tape core wrapping was superseded by paper which serves to prevent the condensation of moisture within the sheath which is slightly water permeable.

In about 1962/63 the range of conductor sizes was extended to include 4 lb. per mile gauge and at the same time advantage was taken of the improvement in manufacturing techniques, to reduce insulation thickness. The twin layer formation was changed to unit quad, each basic unit containing 5 quads fully colour coded and with distinctive unit binders, the cable sizes ranging from 2 to 100 pairs.

In the current cables Grade 03 polyethylene to British Specification 3234 of 1960 is used for both insulant and sheathing material. The specification calls for not more than one insulation defect or 'pinhole' in 40,000 conductor yards in the smallest gauge conductor insulation the thickness of which is required to limit the mutual capacitance to 0.080 microfarads/mile in each factory length. Manufacturers generally are able to meet this specification without difficulty and the average pinhole level normally is in excess of 1 per 50,000 conductor yards.

Whilst carbon and butyl rubbers are no longer included in the latest issue of BS 3234 they are retained in Australian cables to reduce the possibility of degradation or environmental stress cracking which could occur under the wide range of temperatures and high ultra violet light content to which the cables may be exposed.

In underground cables the paper wrapping is still retained for absorption of moisture and no metallic screen is provided as experience has shown that the necessity for electrostatic screening rarely arises in cables laid in the ground and the screen can increase the hazard of breakdown to lightning surges.

In areas where termites and certain voracious species of ant prevail unprotected plastic cables have suffered severe attack by these creatures and efforts have therefore been made towards the development of a suitably protected sheath (See Ref. 1). Recently a range of small size cables protected by a thin oversheath of nylon which, because of its hardness and smoothness appears to resist such insect attack, has been introduced.

Aerial Cable

In recent years, increasing application for plastic distribution cable erected aerially on Joint Use poles has arisen. Whilst the early aerial cables were of conventional underground type and were suspended from bare catenary wires, to meet more fully the requirements for Joint Use a range of screened plastic cables with fully insulated integral bearer wire was developed. These cables were first introduced in the early 1960's and are now used extensively. Distribution requirements can normally be satisfied by a range of sizes up to 50 pair in 4 lb. conductor gauge with a solid bearer wire, though larger sizes are provided with a 7 strand 18 gauge bearer. In these cables the bearer wire consists of high tensile steel, galvanized for corrosion protection, and insulated with polythene, the bearer wire and cable being joined continuously by a polythene web giving the familiar 'Figure 8' formation. The screen consists of aluminium foil which is applied as a helical wrapping over the conventional plastic core (Fig. 1).

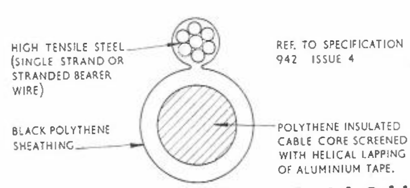

Fig. 1. — Integral Bearer Aerial Cable

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Drop Wire

For aerial lead-ins a flat twin plastic insulated drop wire with integral steel bearer was developed in a succession of experimental designs. Flat triple, trefoil in 10 and 20 lb. conductors, insulated with P.V.C. or high density polythene showed the 'delta' lay up in 20 lb. gauge with steel bearer fully insulated with high density polythene to best meet the needs for toughness, corrosion resistance and strength consistent with flexibility and appearance and this is now the current design (See Fig. 2). A multipair form

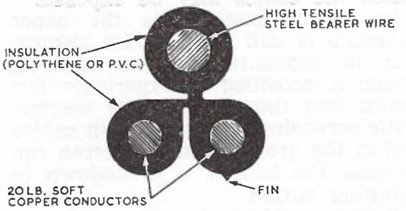


Fig. 2. — 'Trefoil' Type Drop Wire

of drop wire consisting of 5 or 10 twisted pairs formed around a centrally located single strand insulated bearer wire was also introduced experimentally in the early years but was later discontinued on account of its unsatisfactory performance.

UTILIZATION AND NETWORK DESIGN

Prior to the introduction of plastic cables almost all cables in the A.P.O. network were of the lead sheath paper insulated type. There was therefore one class of cable technology for the entire network which had remained basically unchanged since the turn of the century. In the distribution networks urban reticulation had been based on the traditional pillar system since the 1930's the discrete pillar distribution areas serving generally from 60-150 ultimate subscribers. The small size lead paper distribution cables were normally buried directly in the ground and protected where necessary by G.I. pipe. Fully underground distribution was widely favoured, the lead paper single pair leads being buried in 'solid' or drawn into pipes for protection where required.

In the rural areas the need for subdivision of the smaller exchange areas into pillar distribution areas did not normally arise and reticulation was based generally on directly buried cable feeds with open wire subscribers leads serving the scattered subscribers from pole mounted terminal boxes.

Aerial cable though used to a certain extent had fallen into disfavour both for urban and rural reticulation because of its poor performance and general unsuitability and because of its higher costs compared with underground cables.

With the introduction of plastic cables, both for street cabling and for leading-in it soon became apparent that these long established principles no longer were applicable and as experience with the new cables highlighted their potential and revealed their limitations new concepts in network design began to emerge.

Joint Use of Poles

Mechanical damage and the problems associated with jointing, fault localization and repair tended to favour aerial distribution rather than fully underground systems and the lightness and flexibility of the cables soon revived interest in the advantages of aerial cabling. Moreover with the development of integral bearer aerial cables and drop wires the prospect of a fully insulated aerial distribution system removed many of the traditional obstacles to the negotiation of Joint Use with the power authorities and by 1962 local arrangements for the sharing of poles had become well established in Victoria, N.S.W. and Queensland.

The economic and engineering advantages of these arrangements both to the Department and to the Power Authorities led to the negotiation in 1965 of a Commonwealth Arrangement for Joint Use between the P.M.G. Dept. and the Electricity Supply Association of Australia which aimed to facilitate the extension of such practices throughout Australia (See Ref. 2). Currently, drop wire distribution from aerial street cables suspended from the power authorities L.V. distribution poles has become widely accepted as the preferred system of distribution for the newly developing residential areas surrounding the larger towns.

Where Joint Use cannot be engineered, as is frequently the case in established areas where power poles have not been provided with adequate height, aerial distribution from departmental 'Island' Terminal Poles is practised extensively, both the power authorities and the Department sharing each others poles to facilitate the crossing of each others lines.

Fully Underground Distribution

However, mainly for aesthetic reasons, fully underground distribution systems have retained much of their traditional popularity in spite of their generally low standard of performance and economic penalty when compared with plastic aerial distribution. Consequently, the attention of network designers has been directed towards the development of fully underground layouts more consistent with the limitations of the plastic underground cables and the techniques used for jointing them. The liberal provisioning of distribution pairs, the multipling of spares, the 'tailing on' of 'reserve' pairs to selected access joints are typical design manoeuvres which have been introduced to compensate for the loss of flexibility and the high incidence of unserviceable pairs, imposed by the sealed jointing systems to be described later.

To reduce the complexity of the distribution joints with their inherent fault potential, systems using multiple small size cables have been adopted in preference to the more conventional tapering street cable layouts associated with lead paper networks while in some areas in an endeavour to provide fuller flexibility and to reduce the hazards of underground jointing, systems employing above ground access joints have been provided.

Conduit Systems

In recent years the increasing incidence of mechanical damage in urban areas has focussed attention on the need for protection of both street cables and lead-ins and the availability of relatively inexpensive rigid P.V.C. small size pipes has reduced the cost of such protection. The difficulties of localizing such damage, and the cost of repairing it, which often necessitates the replacement of considerable lengths, tends to favour such protection. Moreover, the uncertainty of telephone demand, particularly in established residential areas where flats and home units are tending to replace the older single residences provides a strong argument in favour of the early installation of conduit systems rather than direct burial of cable. In many areas 'pit and pipe' systems have now become the generally accepted standard layout principle in spite of their considerably greater installation cost compared with burial in 'solid'.

Rural Application

In the rural areas underground plastic cabling has found extensive application as a less costly alternative to lead paper cable for replacement of aerial distribution routes, though its greater susceptibility to insect attack has placed severe limitations on its usage in areas where termites and various species of ants are known to prevail.

Used aerially on established pole routes, it has provided an attractive and economic alternative to underground cabling, particularly where insect attack is prevalent or soil conditions preclude installation by mole plough. Where, however, aerial cable has necessitated the retention of pole routes which would otherwise have been recovered, pole maintenance and inspection costs have generally tended to more than absorb the savings on installation.

A comparatively recent measure to extend the range of plastic cable in rural networks and, to a certain extent, to economize in conductor gauge, is the introduction of inductive loading. Hitherto, the variable transmission characteristics of plastic cables, due mainly to the ingress of moisture into the cores, had been considered inconsistent with the standard of stability required for successful loading. However, more recent consideration in the light of the improved characteristics of modern cables has led to the conclusion that, worthwhile advantages can be gained by the insertion of loading coils though capacity balancing within quad is generally necessary in order to maintain satisfactory crosstalk levels.

INSTALLATION PRACTICES

Compared with lead paper cables, plastic distribution cables have provided considerable economies and appreciable engineering advantages in laying. Their decreased weight, clean surface and great flexibility have facilitated transport and handling enabling them to be laid in great lengths, bent around obstacles, threaded through small bore pipes and coiled in tight loops without the risk of sheath cracking. To exploit fully these advantages burial in solid was originally preferred in most urban situations and in the early 1960's a range of cheap narrow surface type footway jointing pits was introduced to accommodate the joints and the slack left for jointing. These pits, illustrated in Fig. 3, were prefabricated by moulding

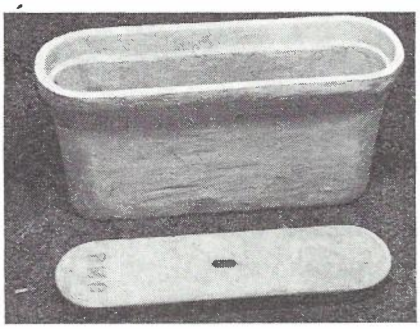


Fig 3. — Jointing Pit for Plastic Cable

from ⅜ in. asbestos cement sheet and were designed for installation in the narrow trenches cut by light ditching machines, with an open slot in the base to enable them to be installed over the loop of cable subsequent to the laying operations. Whilst these pits are still the current standard for directly buried cable, for which they were designed, they are not suitable for 'pit and pipe' construction which is now so widely used in urban areas and pits of local design which are deeper and wider and provide for entry of pipes via the ends and sides have been adopted in many areas. To cater for such conduit systems a selected range of rigid P.V.C. pipes has now been standardized. Besides protection by pipe, which is mandatory for all lead in cables and for road crossings, the depth of placement of plastic cable has been proved to have an important bearing on the incidence of mechanical damage, and laying instructions now specify a depth of cover of at least 1 ft. 6 in. for street cables and 1 ft. for lead-ins while in rural areas depths of at least 2 ft. of cover are aimed at.

End Sealing

Cables are supplied from the factory with their ends sealed in neoprene caps compressed by hose clips to prevent the ingress of moisture to the cable core. Until comparatively recent years little attention was paid to the importance of end sealing in field operations and cables were commonly laid without end seals and the open ends left coiled in jointing pits prior to jointing. Consequently many of the cables became moisture laden so impairing their performance and aggravating the problems of jointing.

Recently, after suitable trial a range of simple polythene push on end caps has been developed and these when secured by means of P.V.C. tape provide an effective temporary end seal to protect the cables (See Fig. 4).

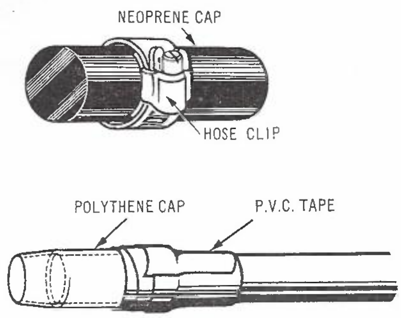


Fig. 4. — End Caps for Plastic Cable

Erecting Aerial Cable

Because of their lightness and flexibility plastic cables are easy to erect aerially and, on existing routes, they cost little to install. Normally they require only a light bearer and 'the low' tensions impose little load on the poles. In the earlier techniques conventional underground type cables were lashed to tensioned bearer wires by means of cable spinning machines or were supplied prelashed to the bearers for erection in one operation. Subsequently integral bearer type cabling has largely superseded separate bearer type cable particularly on Joint Use poles where it has its major application. Installation techniques are simple, though to gain the necessary slack cable for access at the distribution points it is necessary to sever the bearer wire and terminate it from both sides. Moreover special practices designed mainly for the protection of the staff of both authorities have had to be developed and a range of pole fittings has been devised to satisfy the requirements of the Department and of the Power Authorities both as regards their performance and their appearance.

Fig. 5 depicts a typical distribution arrangement on a Joint Use L.V. power pole. Of particular interest is the pole mounted Distribution Box which was developed specially to facilitate Drop Wire distribution from cable heads on either Joint Use or the Department's poles (See Fig. 6).

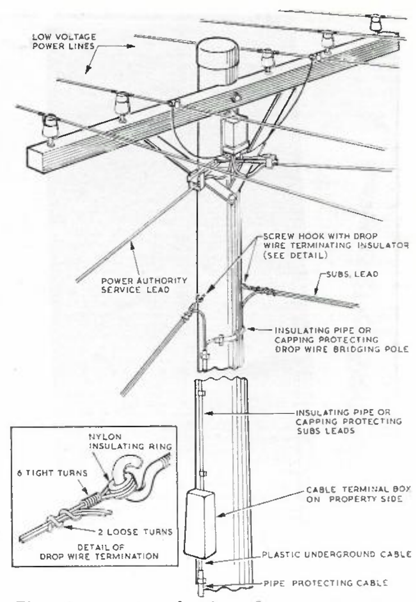


Fig. 5 — Distribution from Joint Use Pole

The box consists essentially of a light, cast aluminium framework with demountable terminal strips to which are connected the cable pairs and the drop wires. The framework is secured to the pole by coach screws and is enclosed in a polythene cover. It admits looped cable for extraction of up to twelve pairs for distribution. Behind the framework, accommodation is available for conductor joints, if required, the box therefore serving as a combined distribution terminal and aboveground jointing enclosure which is equally suitable for underground or aerial cable and which meets fully the requirements for insulation on Joint Use poles of a power authority.

JOINTING

The A.P.O. entered the field of plastic cabling somewhat late when already considerable experience of jointing practices had been gained in overseas administrations. Unfortunately this experience served only to highlight the problems inherent in plastic cable jointing rather than to provide a satisfactory solution. Paradoxically it was those very features of plastic cable which appeared as its most attractive attributes which defied early attempts to joint it satisfactorily.

The chemical inertness of the sheath resisted all known adhesives and although injection moulding methods proved effective for sheath sealing the techniques were far too complex and costly for field application. The best that could be achieved, therefore, was a pressure type bond, which, because of the inherent 'compressibility' of the comparatively loosely packed cables and the tendency of the sheath material to cold flow, could not be expected to provide an effec-

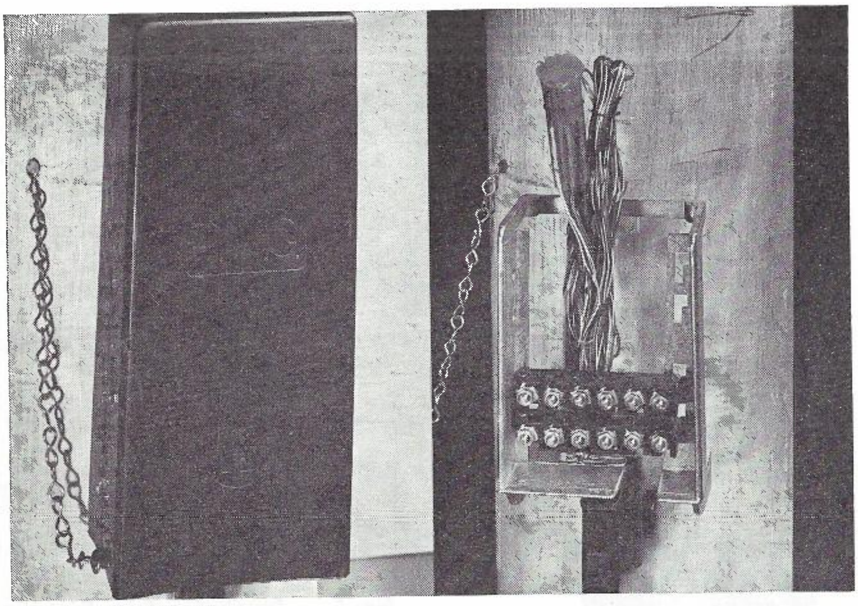


Fig. 6. — Untailed Terminal Box

tive and enduring sheath seal. A wide variety of mechanical sheath enclosures was developed, none of which proved completely effective.

Apart from the problems of effecting a satisfactory sheath seal, it was quickly learned that if joint enclosures were to be protected against the ingress of moisture it was necessary also to develop an effective means of preventing its entry via the core of the cable; a phenomenon which had not arisen with paper insulated cables. Paper quickly absorbs moisture and gives early indication of its presence by a fall in insulation resistance which can be readily detected and located. Moreover, paper rapidly swells and so confines water to the area around which it has entered. Plastic insulation, however, is unaffected by water which can remain undetected in the cable cores and can migrate freely via the air space so producing in time a waterlogged cable. Unless therefore cables entering the joint enclosures are effectively 'blocked' water can fill the joint area and thence penetrate the cores of other cables so, in the course of time, permeating the entire network. Once in the cables, it cannot be removed economically and where discontinuities in conductor insulation occur, as at 'pinholes' or unsealed conductor joints fault conditions will arise.

Various measures for effecting water barriers were therefore devised using mastic compounds injected into the cable cores outside the joints while in some administrations advantage was taken of the development of epoxy resins to develop jointing techniques using liquid resin for full encapsulation of the joint enclosure so affecting a sheath seal and water barrier and preserving the insulation over the jointed conductors.

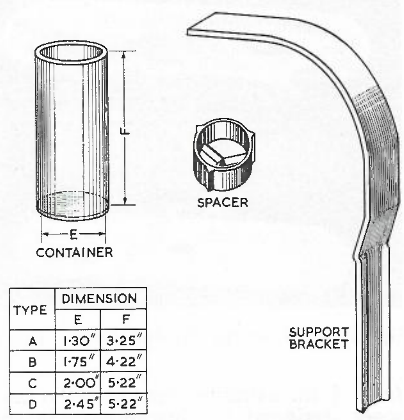
Hot Twist Joint

In a desire to preserve an accessible system and to avoid the complications of joint encapsulation a technique was developed in the A.P.O. which aimed to seal completely the insulation over each individual conductor joint. In this process, which was known as hot twisting, the unstripped conductors to be jointed were heated and the ends twisted tightly together so that the bare wires were twisted into electrical contact through the semi-molten polythene insulation which was then formed into a 'knob' over the wire ends by further heating. The 'hot twist' joint provided the advantage of simplicity, it required no piece parts, it gave ready access to the full range of conductors and by providing continuity of insulation over the conductor joints it appeared to be consistent with a wet cable network. The technique was introduced as the standard jointing method in the early 1960's and was practised generally without the installation of water barriers and often with inadequate sheath seals.

Experience, however, revealed a progressive deterioration of 'hot twist' joints, in part through low insulation due to cracking of the insulation caused by overheating of the polythene and in part through the high resistances which developed with relaxation of the twisted conductors. Moreover the technique could not be applied to the thin walled insulation which it was desired to introduce, coincident with the change to poly-quad layup and the development of 4 lb. conductor cables, and an alternative technique had to be found.

Epoxy Resin Encapsulation

For some time experiments had been proceeding with epoxy resin encapsulation and in the light of past experience it appeared that the principle of full encapsulation would offer good reliability and moreover it could be readily introduced. Full encapsulation, it was appreciated, would preclude subsequent access to the cable conductors via the joint enclosure with consequent loss of flexibility and complication of fault localization and repair facilities. These penalties, it was considered, however, could be more than compensated for by liberal provision of cable pairs on the distribution side of the pillar and by the high standard of performance that was confidently expected of a system fully sealed with such joints. Full encapsulation was therefore introduced as standard in 1962-63 using double ended moulds shaped from sheet lead and a two part formulation of epoxy resin. At the same time trials were commenced with a single ended version using a cylindrical plastic pot to contain the resin. Evaluation of the two joint types resulted in adoption of the single ended version as the preferred type and this joint has now been the current standard since 1965. Fig. 7 shows the standard components for this joint.



TYPE	DIMENSION	
	E	F
A	1·30"	3·25"
B	1·75"	4·22"
C	2·00"	5·22"
D	2·45"	5·22"

Fig. 7. — Components of Single Ended Fully Encapsulated Joint

The joint container is of polystyrene and is supplied in 4 sizes to accommodate all required ranges of joint size. A small plastic spacing ring encloses the sleeve bank to separate the conductor joints from contact with the container. A galvanized mild steel joint support bracket is used to position the cable ends correctly in the container and to hold the cables in a right angled bend so that the pot is vertical in the pit during curing.

To make the joint, a short length of sheath is removed from the cable ends to be jointed and the cables are bunched so that the sheath ends coincide. 'Through' cable is looped and the sheathing removed from the bight of the loop. The wire joints are made on the short exposed conductors by stripping only sufficient insulation from the wire ends to enable them to be 'finger' twisted. They are then tip soldered and the joints enclosed in plastic sleeves.

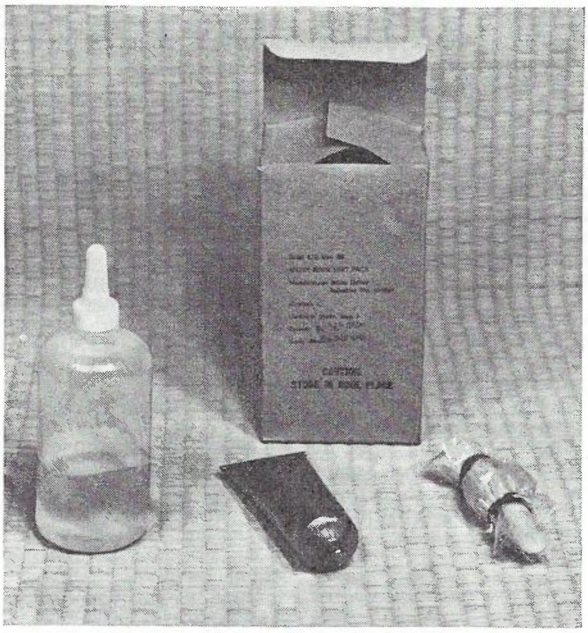


Fig. 8. — Epoxy Resin Field Pack

The sleeve bank is fitted into the plastic spacing ring and the completed joint is inserted into the mould which is taped to the end of the support bracket so that the cable ends are correctly positioned in the centre of the mould, the cable being securely bound to the bracket.

The encapsulant is provided in a convenient field pack (See Fig. 8) which contains a polythene bottle of resin and an aluminium tube of hardener in the correct proportions for mixing. Plastic gloves supplied in the pack are worn to protect the operator during mixing and pouring the encapsulant. Mixing is carried out in the polythene bottle and the mixture is then poured into the polystyrene pot so that the wire joints, the unsheathed insulated conductors and the cable sheath ends are fully immersed in the resin (See Fig. 9).

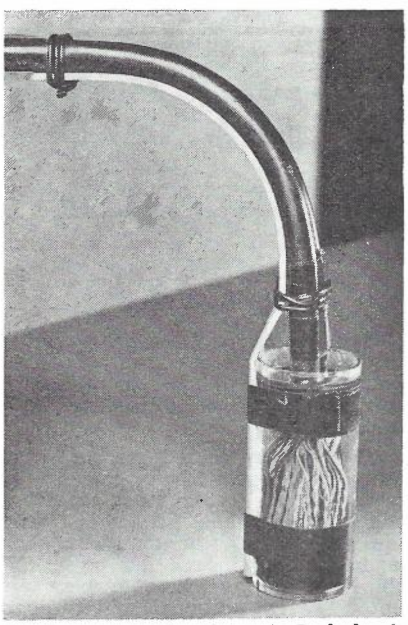


Fig. 9. — Completed Single Ended Joint

Experience of the method, which is used for all sizes of plastic cable joint and for joints between plastic and paper insulated cables, has not realised the hopes of high reliability expected of it.

Faults in the joints arise through a number of causes. Faulty workmanship, due largely to the high standard of manual skill required to make the conductor joints on the very short lengths of conductor, difficulties in correctly positioning the jointed conductors in the mould and imperfect mixing of the resin, account for many faulty joints. In the larger joints, the large bulk of resin necessary, in relation to the heat conducting surfaces which can dissipate the heat of exotherm, can result in excessive temperatures during encapsulation which can melt the polythene insulation on the conductors and contact faults have arisen through this cause. Moreover, in such large bulk the differential rates of cooling can set up stresses which result in cracks after curing which subsequently give rise to low insulation within the joint. A common cause of failure is the entrapment of moisture within the joint during encapsulation. Many of the cables contain water and the short conductor ends are difficult to dry prior to jointing. In very wet cables water tends to flow from the cable ends into the sleeves during encapsulation with resulting low insulation and corrosion of the conductor joints. Epoxy resin provides only a pressure bond with polythene and with lead and the ingress of moisture via this imperfect seal is doubtless responsible for many failures and in particular for the very high fault incidence in plastic to paper insulated cable joints.

The penalty which loss of access imposes in a system which is fault prone is indeed severe. Faults within the joints can be repaired only by complete replacement of the joints and access for fault localization can be gained only by opening the cables. Moreover the loss of flexibility significantly reduces the efficiency of the network and increases operating costs.

Openable Joints

Whilst the merits of completely reliable fully sealed systems in areas where growth forecasts can be relied upon, cannot be overlooked, within the limits of our present technology it appears that the needs of fully underground urban networks can best be served by a reliable form of openable joint which will provide ready access for fault localization and repair and for subsequent pair rearrangement and addition of new or replacement cables. Such a joint is particularly desirable at the distribution points where the subscribers lead in cables are connected with the street cable and in many areas openable joints of local design have been introduced.

One such joint, developed in Queensland has for long given good service. It consists essentially of a simple type of joint enclosure using cellulose acetate butyrate tubing. The cables are sealed into a short length of tube using epoxy resin both to affect a sheath seal and water barrier. The conductor joints are made by conventional crank twists and enclosed in silicone grease filled sleeves. The cylindrical cover is sealed to the base using butyl rubber putty bound with P.V.C. tape. Many thousands of these joints are in service and the experience gained with them has led to the development of a standardized design which is based on similar principles but which provides extended facilities and incorporates features of design which promise to overcome many of the limitations of previous types of joint. The new joint, which is now in course of production as a simple moulding is expected to be available for large scale field trial during 1968. Prototypes have already been in field service for nearly 2 years and their standard of performance has proved to be highly satisfactory.

The prototype components are illustrated in Fig. 10. They consist essen-

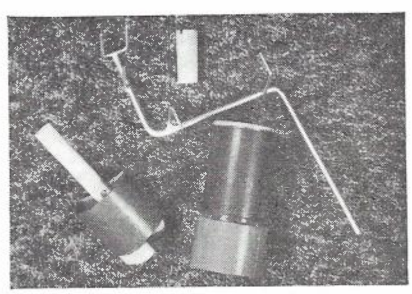


Fig. 10. — Components of Openable Joint (Prototype Models)

tially of a small cylindrical plastic container, a hood and a support bracket. The container is closed at one end and is divided into four compartments by plastic partitions.

An oval shaped open nozzle gives access to the largest compartment which serves to admit the cables to be jointed initially, while a small cylindrical closed nozzle provides access to a smaller compartment used for entry of a subsequent cable. Each of the two remaining compartments provides accommodation for the conductor joints on a complete 10 pair unit. The entry compartments are designed to hold epoxy resin to form water barriers over the sheath ends and to seal the sheaths into the mould. The jointing compartments are designed to accommodate the jointed conductors which may be conventional twisted and soldered joints enclosed in silicone grease filled sleeves bunched in convenient groups for insertion into the compartment. Alternatively, the jointed conductors may be sleeved in standard open ended sleeves and encapsulated in groups in small cylindrical phenoxy pots which fit the joint compartments.

A plastic cylindrical hood fits on to the base and encloses the length of plastic insulated conductors between the sheath ends and the conductor joints thus giving access to the complete range of pairs in the joint.

Butyl rubber putty is used to seal the cable ends in the entry nozzles to prevent escape of the resin during curing and also to seal the cover on to the base so providing a readily openable enclosure.

A simple support bracket engages with the main entry nozzle and serves to bend the cables through a right angle and to centre the unsheathed ends in the entry nozzle. The support bracket is also used to hold the joint vertically above the pit during the jointing and encapsulation process and to position it in the pit after completion. (See Fig. 11).

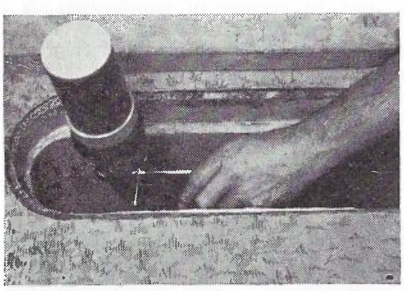


Fig. 11. — Completed Openable Joint. (Prototype Model)

Subsequent rearrangements and repairs may be made within the joint by removing it from the pit, opening the hood by cutting the sealing compound and rejointing either by the use of silicone grease filled sleeves or by discarding the original potted joint and remaking the joint in a new pot.

Additional cable may be added subsequently by cutting the cylindrical entry nozzle to admit the new cable into the spare compartment and forming an epoxy resin water barrier over the cable end. The new cable can then be jointed into the existing cable pairs using the spare jointing compartment to accommodate the jointed conductors which may be in silicone grease filled sleeves or encapsulated in a phenoxy pot for insertion into the joint compartment.

A larger version of the joint has been developed for accommodating up to 5 jointed units initially, each in a separate compartment, and with facilities for subsequent cable entry and the jointing of an additional unit. Two such joints can be coupled together by a simple plastic coupling piece which engages with the main entrance nozzles to provide facilities for jointing up to 10 complete units, i.e., a complete 100 pair joint.

To make the technique suitable for jointing plastic cables to lead paper cable a lead sheathed, plastic insulated 'tail' cable has been developed. The short 'tail' cable is jointed into the lead paper cable by conventional paper insulated cable techniques and the sheaths are plumbed. The 'tail' cable is equipped with a thick paper wrapping to protect the P.V.C. insulation from overheating during the plumbing operation. The plastic insulated conductors are jointed to the plastic cables in the new type joint the water barrier, formed over the lead sheathed tail cable end, protecting the paper insulated cable from moisture via the plastic cable cores.

The new technique, besides providing ready access facilities and a means of adding and jointing cable subsequently, overcomes many of the difficulties associated with previous designs of joint and is expected to improve considerably the performance of distribution networks.

The long tail of unsheathed conductors greatly simplifies conductor jointing and enables the conductors to be separated and dried prior to jointing and the simple centering device enables them to be positioned accurately in the pot for encapsulation. Exclusion of the conductor joints from the water barrier compartment ensures that moisture which may ooze from the cable ends during encapsulation of wet cables cannot affect the joints.

The design of the water barrier compartments and the small jointing pots precludes the use of an excessive quantity of encapsulant so avoiding overheating of the conductor insulation and possible cracking of the encapsulant due to excessive exotherm which can arise where a large bulk of resin is used.

The jointing compartments allow versatility in the means of protecting the conductor joints and the proposed field trials, it is hoped, will enable the relative merits of individual joint protection by silicone grease filled sleeves and bulk encapsulation in epoxy resin to be assessed.

The cover provides added protection for the jointed conductors and for the unsheathed insulated wires. It also provides the jointer with a measure of protection from the resin fumes which are generated while the resin is curing.

The bracket, besides holding the joint and enabling it to be positioned prevents movement of the cables during curing of the resin a requirement essential for satisfactory encapsulation.

Above Ground Joints

Many of the problems associated with underground plastic cable jointing can be eliminated if the jointing enclosure is located above ground. By enclosing the conductor joints in silicone grease filled sleeves to protect them from atmospheric moisture, the joints have been found to perform satisfactorily in a protected enclosure without necessarily providing sheath seals or water barriers.

Where aerial distribution is practised from pole mounted terminal boxes the untailed box provides accommodation for street cable joints in either underground or aerial cables and joints made in this way have given very little trouble. In fully underground systems in urban areas difficulty is normally experienced in satisfactorily locating above ground jointing enclosures and consequently they have been little used. In rural areas however, where such posts can serve both as cable markers and to house the joints they have been widely used.

Whilst above ground joints have not normally been sealed there is undoubtedly advantage in the provision of water barriers over the cable ends to confine moisture within the cables and to prevent its ingress via the open ends. In this connection the new openable joint lends itself readily to above ground mounting and has the advantage that it provides a sealed enclosure with water barriers over the cable ends.

A typical above ground jointing post used in rural areas is illustrated in Fig. 12.

TERMINATION

Plastic distribution cables require termination of conductors at street pillars, terminal boxes and, in small rural exchanges, on the main distribution frame.

Street pillars have been provided with plastic insulated tail cables with factory made terminations on tags solidly encapsulated in epoxy resin (see Fig. 13) for mounting on the standard pillar base. To these tail cables the plastic street cables are jointed by conventional underground joints.

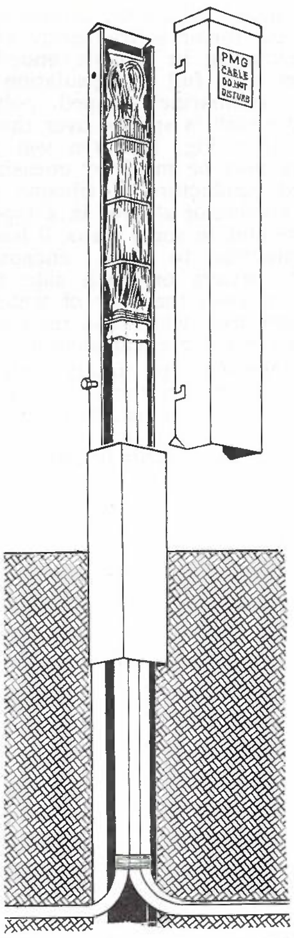


Fig. 12. — Above Ground Jointing Post

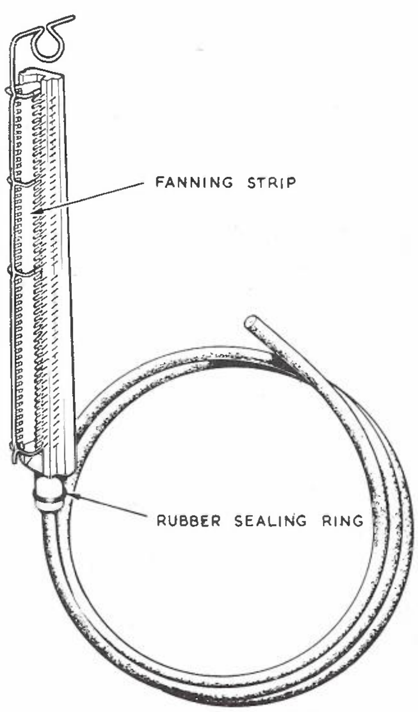


Fig. 13. — Pillar Tail

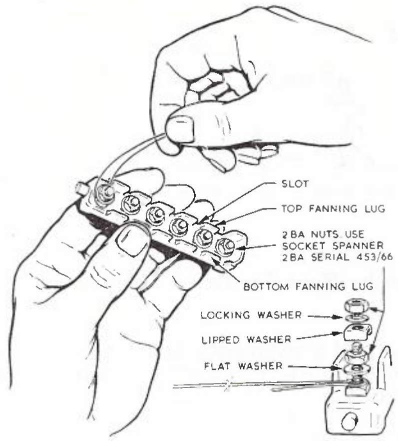


Fig. 14. — Cable Termination in Untailed Box

In the untailed terminal box the unstripped conductors are looped around the terminals on the demountable terminal blocks and by tightening the terminals the insulation is crushed and sound electrical contact established. (See Fig. 14.) Recently the flat washer has been replaced by a lipped washer to improve the certainty of good contact which was not always achieved on the heavier gauge conductors.

On distribution frames plastic insulated conductors may be soldered directly to the tags or jointed to P.V.C. insulated tail terminating cables. Some administrations do not permit the direct termination of polythene insulated conductors because of the possible fire hazard and this principle was followed originally in the A.P.O. However, the risk has since been discounted and external type plastic cables are now terminated on internal frames without necessarily using tail cables. Similarly lead in cables and drop wires are now terminated inside subscribers premises on the telephone socket or other suitable terminal block.

MAINTENANCE PRACTICES

In contrast to the economic and engineering advantages which plastic cable has bestowed on the installation engineer, to those responsible for its maintenance it has not been so kind. When used above the ground it has performed admirably but, in its major role as an underground cable its fault incidence has far exceeded that of lead paper cables of equivalent size and the types of faults have proved both difficult and expensive to locate and to repair.

Fault Localization

Unlike lead paper cables, which fail rapidly and positively at the point of sheath puncture enabling faults to be pinpointed by simple testing methods, plastic cable faults are generally insidious and elusive. Man-made mechanical damage, faulty sheath seals and the ravages of termites and a wide variety of ants have presented the maintenance engineer with a system of partially waterloged cables. Discontinuities in conductor insulation through manufacturers 'pinholes', insects, unsealed conductor joints, and a variety of other causes have confronted him with varying and incipient fault conditions, partial low insulation, conductor corrosion, high joint resistances, unbalances and crosstalk and general degradation in transmission. d.c. bridge techniques, the traditional tools of fault localization are no longer effective and the non-conducting sheath deprives him of a readily available return path. Consequently he has been forced to rely largely on deduction methods involving range testing of pairs and testing between joints, a process which, in recent years, has been severely restricted by the adoption of full encapsulation of joints.

Test Equipment

Though it had long been apparent that the comparatively simple testing and measuring equipments provided for fault detection and localization in the lead paper network had very limited application in plastic cable networks, it was not until comparatively recently that positive action was taken to develop specialized alternative methods and equipment. Whilst simple d.c. testing meters have been made available for the detection of fault conditions in plastic cables and in joints, more sophisticated techniques are necessary for precision measurements where the fault conditions are unstable and are complicated by such phenomena as 'foreign battery' or polarization (See Ref. 3). Various principles have been adopted to meet these exacting conditions and a number of instruments are available commercially throughout the world.

For the localization of low insulation faults, where the fault coincides with the point of sheath failure — a common result of mechanical damage — the "tone search" method has met with considerable success. In this method a tone is injected into the faulty wires and the ground potential is explored by the operator by means of a ground probe and amplifier carried along the cable route. Where the tone leaks to earth via the fault a potential gradient is set up in the surrounding earth so producing a rise in intensity in the tone as the gradient is bridged by the probe. Fig. 15 illustrates the principle which is used in a variety of commercially available instruments a number of which are currently in use in trial areas throughout Australia.

Another device designed to overcome the effects of foreign battery and polarization is the high impedance low frequency bridge. The instrument uses reversal of battery at the rate of 3.5 cycles per second and is capable of precision measurements and Varley type locations of low insulation resistance up to about 2 megohms. Trials of these instruments are also proceeding in the field.

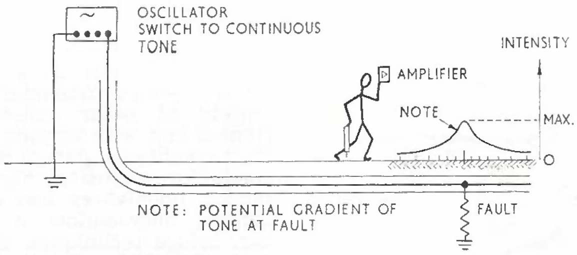


Fig. 15. — Fault Location by 'Tone Search'

The location of impedance irregularities by the pulse echo reflection principle has also met with some success and suitable instruments are on experimental trial. The potential of these instruments for field use has however, yet to be evaluated.

For the identification of pairs in plastic cables there has long been need for a method which does not necessitate puncturing the conductor insulation and recently a convenient test set has been developed which promises to fulfil this requirement. The method involves injection of a balanced supersonic frequency into the wanted pair which can then be traced rapidly, at the point where identification is required, by means of a small search probe and heterodyne detector which produces a distinctive audio tone when 'homed' onto the wanted pair. The use of a supersonic tone enables the device to be used in working cables without causing interference with working circuits. A less sophisticated version employing an audio tone is now being produced to meet the requirement which arises spasmodically in distribution area work for identification of isolated plastic cable pairs and for the tracing of jumpers. (See Fig. 16). The miniature transistorized audio oscillator can be mounted readily in a pillar enclosure and the small search unit comprising capacity probe and amplifier with hearing aid earpiece can be carried conveniently in the pocket. The device, which greatly facilitates the tracing of cable pairs and jumpers in plastic cable networks, has similar application in the main cable network where rapid identification by random search is of particular importance and widespread demand is anticipated.

Service Restoration and Repair

Because of the difficulty in localizing faults in plastic cables and, particularly where only isolated services are affected, the normal approach to restoration is to transfer the affected service to a good pair. In due course, the occurrence of further faults enables the location of faulty joints or lengths to be deduced by range testing of pairs or by localization measurements. Repair action may involve replacement of faulty lengths, the insertion of repair joints or the complete replacement of faulty joints.

Insect attack can necessitate the renewal of considerable lengths of cable as the effect on cables is often widespread and in such case replacement by insect resistant plastic cable, lead sheathed or even armoured cable may be essential to prevent the recurrence of the trouble.

Repair joints are often complicated by the presence of water in the cables at the fault location and by the absence of slack cable to enable the conventional type encapsulated joints to be made. Where the conductors can be dried, repair is frequently effected by rejointing in 'double ended' formation and full encapsulation in a small 'submarine' shaped polythene mould which is sprung over the cable ends. (See Fig. 17). On wet cables repairs may be made by encasing the jointed conductors in silicone grease filled conductor sleeves in a taped enclosure and, in some areas, it has been the practice to form encapsulated water barriers on each side of the fault, to stem the flow of water into the joint area, which can then be kept suitably dry for encapsulation.

Replacement of faulty joints in above ground systems generally involves only the remaking of individual conductor joints using silicone grease filled sleeves. Repair of faults in fully encapsulated joints, however, necessitates the complete rejointing of all conductors and re-encapsulation in a new mould so involving considerable interruption to working circuits. Moreover replacement by encapsulation is often made difficult by the presence of moisture in the cables and by lack of slack cable.

Preventive Maintenance

To prevent damage by insects, considerable success has been achieved with soil treatment methods, particularly in Western Australia, where impregnation of the soil with dieldrin solution during laying operations has prolonged the life of cables in situations where previously early failures had been experienced. While undoubtedly effective, the practice is costly and its lasting potency has yet to be proved. It has, however, provided an interim relief measure pending the development of suitable insect protected cable which only very recently has become available and as yet only in small sizes.

Gas pressurization of plastic cables has been little favoured in the A.P.O. both for economic and engineering

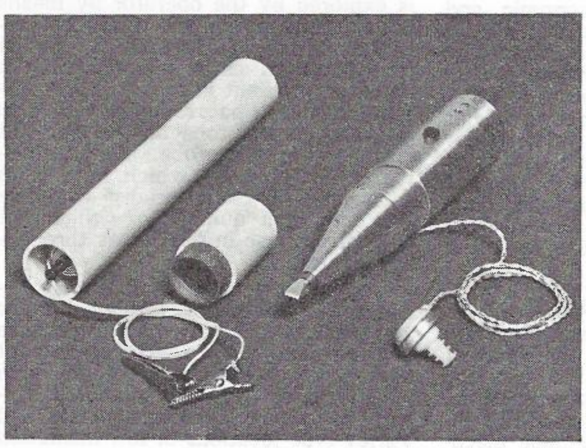


Fig. 16. — Pocket-size Prickerless Identification Kit

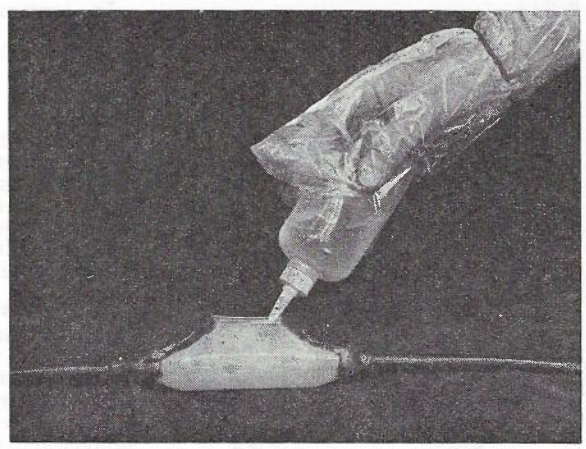


Fig. 17. — Repair Joint in 'Submarine Mould'

reasons. Plastic cables are normally confined to the 'extremities' of the network, they are inherently 'leaky' and the maintenance of positive pressure would almost certainly involve continuous flow from compressor type units. Gas supplies would therefore have to be piped to the pillar areas or supplied from separate local compressors at considerable cost. Moreover, such systems are not consistent with the standard jointing arrangements which, in above ground systems are unsealed and, below ground, incorporate resin water barriers. However, in some areas trial installations are in operation using specially designed joints, fully sealed, but with resin barriers only where gas blocks are required and their effectiveness has yet to be evaluated. In a newly installed network the use of gas certainly ensures that the system is dry and free from leaks initially and would doubtless provide protection against the ingress of moisture via minor sheath punctures. However, in the event of a severe sheath fracture in a wet situation, the loss of pressure could result in cables taking in water and the restoration of pressure could conceivably force this water into the joints with disastrous results. An essential adjunct to a gassed system would therefore seem to be a practical and economical method of removing water from cables and as yet no such method is available.

SERVICE PERFORMANCE

Since its inception into the distribution networks plastic cable has followed a varying pattern of performance. The Commonwealth average fault incidence throughout the years has never compared favourably with lead paper cable yet selectively, statistics have diverged so widely from the mean as to be almost meaningless. Environment, method of usage, climate and technique, each in themselves decisive factors in influencing the behaviour of plastic cable when suitably combined, can give rise to a range of performance statistics from the unbelievably good to the unacceptably bad.

Sufficiently detailed and reliable statistics have always been difficult to compile and with the successive changes in technique and wide variation in the other influencing factors the true significance of the early broad statistical records was extremely hard to interpret.

However, in recent years the A.L.F.A. (Automatic Line Fault Analysis) system of external plant fault recording, aided by computerized analysis has enabled the major causes of service failure to be revealed and this information, backed up by field experience, has resulted in some fairly firm conclusions regarding the performance of plastic cable.

Fault Incidence

The overall incidence of recorded faults, i.e., faults affecting service, per 100 sheath miles of plastic cable is given in Table 1.

TABLE 1.

ANNUAL INCIDENCE OF FAULTS

Year	Recorded faults per 100 sheath miles of plastic cable
1958/59	280
1959/60	400
1960/61	580
1961/62	550
1962/63	630
1963/64	670
1964/65	510
1965/66	400
1966/67	300

The alarming increase in fault rate up to 1964/65 was doubtless due to the preponderence of fully underground urban distribution in the early years and the legacy of highly fault prone joints installed in early construction. The subsequent improvement in fault incidence up to the present day is doubtless weighted by the increased mileage of rural cabling and by the growth in aerial cable usage. However, the growing preference for above ground distribution, the introduction of encapsulated jointing and the more effective control of mechanical damage have certainly been contributory.

Aerial Faults

Breakdown of these overall statistics has confirmed the relatively fault free performance of aerial cables which currently represent about 10% of the total sheath mileage of plastic distribution cable in service. Their current fault incidence is less than one-tenth of the figure for underground cable and the relatively few faults that arise present little difficulty in localization and repair. The majority of aerial cable faults occur in the joints or terminal connections which, being accessible, are easy to detect and repair without disturbance to other services. Some faults have arisen through breakage of the bearers through corrosion or wind vibration, but these have generally been traced to damaged insulation through careless handling or over tensioning and the use of non-standard fittings. The use of standardized techniques and tools, specified tension limits and the damping of vibration by insertion of twists in the cable during installation, it is hoped, will largely eliminate such faults in the future.

Aerial drop wires, however, have shown themselves to be far from fault free, largely on account of low insulation and corrosion of the conductors. In particular, the 10 lb. conductors in the early designs of drop wire proved to be insufficiently robust and the thin insulation was easily damaged by abrasion or careless handling. The current design of "trefoil" drop wire with its 20 lb. conductors and high density polythene insulating covering, when used in accordance with the prescribed techniques, is giving a more reliable service and is easy to repair or replace.

Underground Faults

Underground plastic street cables, compared with their lead paper counterparts, have, however, given a sorry performance. Whilst they have eliminated the traditional hazards of sheath corrosion and vibration fatigue and reduced the incidence of lightning damage, these compensations have been heavily outweighted by the many other problems they have introduced.

In rural areas insect damage, though relatively insignificant in terms of service interruptions, has proved so far-reaching in its effect that on examination long lengths of cable have often been found to be beyond repair and have had to be completely replaced. In many country areas the further use of undergound plastic cable has had to be abandoned in preference for lead paper cables and at present in the whole of North Queensland and the Northern Territory underground plastic cable is not used, while in the rural areas of Western Australia it survives only by virtue of the protection provided by the soil treatment process which has been adopted generally throughout that State. Only recently the introduction of a limited range of nylon protected cables has provided a partial solution to this problem and as yet the effect of this innovation has not had time to make itself felt.

In urban areas both street cables and lead-ins have suffered severely from mechanical damage and whilst, in this respect, they are perhaps little more susceptible than lead paper cables laid in the same environment, the inherent difficulties they present in localization and repair of the damage has greatly increased the cost of restoration and the duration of service interruptions. Moreover, water admitted to the cable as a result of such damage has remained in the length as a potential source of subsequent faults at pinholes in the conductor insulation or at inadequately sealed joints. Whilst publicity campaigns, better liaison with other authorities, laying at increased depth and protection by pipe has done much to reduce mechanical damage, it is still a major factor in the poor performance of fully underground distribution systems.

Faults in joints have, however, always proved to be the predominating cause of service failure in such networks and this is not surprising in view of the large number of joints in the average pillar area and their high fault potential. Whilst much has been done to replace the early taped enclosures, expanded plugs and hot twist joints, the failure rate of the fully encapsulated replacement joints is still too high to be regarded as satisfactory. Moreover, the difficulty of service restoration, fault localization and repair is proving a severe penalty to pay for the dubious advantages of full encapsulation and the current high costs of maintenance is undoubtedly a reflection of these maintenance difficulties. Where above ground joints have been used in underground networks, performance has been vastly improved and maintenance costs have been substantially reduced.

Overall, the incidence of service failures due to faults in joints which had risen to almost 400 faults per 100 sheath miles in 1963/64 has been reduced by approximately 50% according to the latest returns. Whilst this is certainly due in large part to the greater use of above ground distribution systems, there is little doubt that current underground jointing methods are an improvement on the older techniques. It is, however, an unfortunate limitation of our current statistical system that the failure incidence of the various joint types cannot be computed, and at the time of writing no reliable statistics are available which would reveal the true performance of the current joint types.

FUTURE DEVELOPMENT

After 10 years of experience with plastic cabling, perhaps the most important lesson we have learnt is the deleterious effects of water within the sheath. Our early efforts aimed at learning how to live with wet cables rather than how to prevent them from becoming wet. In more recent years we have aimed at restricting the ingress of moisture and at confining it, and, above all, at keeping it out of the joints. We have not succeeded in preventing it from entering the cables, neither have we found how to remove it.

Some overseas administrations have attacked the problem by resorting to gas pressurization of their distribution networks to maintain their cables dry and various somewhat complicated and expensive practices have been adopted for the prompt removal of moisture and the drying of the length into which it has entered. A more recent approach developed in Britain is to manufacture the cables with discrete water blocks at every 20 yards along the cable. This principle has since given rise to the development of continuously blocked cables, and in the British Post Office system all plastic cables up to 100 pairs now being installed are manufactured with a filling of petroleum jelly, which renders the cores completely waterproof. To maintain the desired low mutual capacitance between wires, a foamed polythene insulant is used.

The B.P.O. claim this development as a major break through in plastic cable technology and their experience with it is being followed with interest. Some doubt is felt that petroleum jelly is the most suitable filler and its long term effect on the polythene remains to be proved by experience. The concept of a filled cable, however, certainly has much to offer and sample lengths of the British Post Office cables are currently on order to enable trials to be conducted in Australia.

To extend the application of underground plastic cables in the rural areas, the need for a suitable range of insect protected cables has long been apparent. The development of nylon protected cables in small sizes (up to about ½ in. external diameter) is already well established and there are now good indications that the difficulties of extruding nylon over larger diameter sheaths can be overcome. It is therefore expected that in the near future a full range of plastic cables protected with a nylon oversheath will become available at economic prices for use in areas where termites and ants would normally preclude the use of unprotected cables.

In the field of underground jointing, a change to an openable system seems inevitable and the new design of openable joint is expected to overcome many of the disabilities of full encapsulation. The development of waterproof connector joints is well advanced in the U.S.A. and double ended press type connectors which require no conductor stripping, twisting and soldering, and which it is claimed provide a reliable moisture proof joint are already available commercially. Single-ended connectors, however, appear to be more suitable for small sized plastic cable jointing and Australian firms are currently investigating supply of the American 'B' type connector suitably filled with silicone grease to provide a moisture proof conductor joint. The advantages of connector jointing compared with the present methods of stripping, finger twisting and soldering are highly attractive, and if the connectors can be made to provide suitable moisture proofing, it seems likely that they will supersede silicone grease filled sleeves and bulk encapsulation. With this possibility in mind, the new openable joint has been designed to accommodate, if required, bunches of connector joints in lieu of silicone grease filled sleeves or bulk encapsulated units. Taking a long term view, the possibility of aluminium conductor cables as an alternative to copper, cannot be overlooked, and the development of waterproof connectors would appear to offer a solution to the problems of aluminium conductor jointing such as soldering difficulties and corrosion hazards.

Looking to the future, with the possibility of filled cable eliminating the need for water barriers in joints and connector joints superseding bulk encapsulation, the field use of encapsulants would most likely be eliminated, a satisfactory sheath seal being achieved by taping, puttying or moulding with possibly the incorporation of a desiccant in the joint enclosure.

Aerial distribution seems unlikely to undergo significant changes in the foreseeable future, apart possibly from the introduction of a self-supporting drop wire. In this connection trials are currently in progress with a composite steel copper flat twin drop wire insulated with high density polythene, of a type widely used in the United Kingdom. Compared with the current design of drop wire, it is cheaper, lighter, less obtrusive and having no bearer wire, it is more suitable for internal wiring. The replacement of terminal connections by soldered joints in silicone grease filled sleeves or possibly by connector joints is also a likely future development which could reduce the fault hazard on aerial leads.

Whilst, however, the future of aerial distribution from Joint Use power poles seems assured for at least as long as the power authorities continue to reticulate aerially, on aesthetic grounds the elimination of poles and wires must be regarded as an ultimate objective. Already public opinion generally, and architects and town planners in particular, are exerting pressure on the power authorities and on the P.M.G.'s Department to underground their distribution plant and representations from subdividers for fully underground reticulation are not uncommon. To reduce the cost of such joint undertakings, the sharing of trenches is seen as a likely trend and already trial installations are under consideration with a view to establishing satisfactory joint practices. An essential requirement in such joint installations is the protection of the Department's cables which must necessarily be in close proximity to those of the power authority. A system based on 'pit and pipe' construction using rigid P.V.C. pipe as a conduit for the P.M.G.'s Department's cables would appear to offer an acceptable engineering solution. Not only would the insulating pipe provide the required electrical and mechanical protection, but if laid by the power authority at the time of placement of the power cables, the need for precise coordination of planning the cable layout schemes would be obviated. As 'pit and pipe' construction is already in extensive use, in many of the developing subdivisions, the adoption of joint use on this basis would not necessarily involve the Department in any radical changes in practices.

CONCLUSION

The past decade has seen a progressive swing from lead paper to plastic cable in the distribution network, and, in all but certain insect troubled rural areas, it has become the established standard type of distribution cable. The resulting economies in capital cost have been immense and its many engineering advantages have been amply demonstrated. However, experience has highlighted its severe limitations which, in many situations, have given rise to an unsatisfactory standard of performance and to high maintenance costs.

To exploit it to advantage, therefore, has necessitated discrimination in its application and has involved the development of new concepts in network design, and in installation and maintenance techniques which are far removed from the traditional practices applicable to lead paper networks and which are still in the process of evolution.

In particular, the protection of underground plastic cables against the ingress of moisture and the development of satisfactory jointing techniques are problems which have perplexed engineers throughout the world and which as yet remain only partially solved.

In aerial cables the same problems do not arise and aerial distribution systems, particularly where Joint Use can be practised, are providing a highly economic and reliable service.

However, the major application for plastic cable is below ground and current developments which aim to improve installation and maintenance practice will, it is expected, result in marked improvement in the performance of fully underground systems and reduce the costs of operation and maintenance.

Further developments towards waterproof cables with adequate protection against insect attack, simplification of jointing by suitable waterproof connectors, effective protection against mechanical damage and the introduction of more satisfactory fault localization equipment and methods will, it is hoped, make possible highly reliable underground distribution systems while the sharing of trenches with the power authorities should effect considerable economies in installation costs.

Doubtless the next decade will experience changes as revolutionary as the last, but there is little doubt that plastic distribution cable is here to stay and there are strong indications that plastic materials will in time replace the traditional lead sheath and possibly the paper insulation in the larger size cables on the exchange side of the pillar.

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2. Joint Use of Poles—Arrangement between the Electricity Supply Association of Australia and the Postmaster-General's Department, September, 1965.
3. G. F. Carboon, "A Portable Test Set for Linemen'; Telecom. Journal of Aust., June 1966, Vol. 16, No. 2, page 179.

MR. W. L. CAUDLE, B.A., A.M.I.E. Aust.

MR. W. L. CAUDLE

Mr. W. L. Caudle, Assistant Director (Engineering), Western Australia, joined the Department as telegraph messenger in South Australia, in 1938. After 2 years training as a junior mechanic and 4½ years service as wireless operator and wireless mechanic in the R.A.A.F., he was appointed Cadet Engineer, New South Wales. Mr. Caudle's initial engineering experience was in District Works Divisions in Sydney and in 1952-53 he was Divisional Engineer, Newcastle No. 2 Division.

After promotion in 1953 as Divisional Engineer, Central Division, Western Australia, Mr. Caudle formed the North West Project Division to extend telephone trunk facilities to a large part of the North West to meet the projected needs of the Weapons Research Establishment, Department of Supply. Since 1961 he has served as Supervising Engineer, Planning, Supervising Engineer, Country Regional Section, Supervising Engineer, Metro District and Primary Works Section, and Superintending Engineer, Plant Branch in the Western Australian Administration, before appointment as Assistant Director, Engineering, in 1966.

Mr. Caudle has been an active member of the Professional Officers Association, where he was President of the W.A. P.M.G. Engineers Group (1955-58) and a Central and Executive Councillor (1960-65). He has also taken an interest in the affairs of the Postal Institute, serving as a councillor for six years. A strong supporter of the Telecommunication Society of Australia, Mr. Caudle has been a Committee Member of the W.A. Division since its inception and is currently the State Division Chairman.

Mr. Caudle graduated as Bachelor of Arts from the University of Sydney in 1948, is an Associate Member of the Institution of Engineers, Australia, and is an Affiliate of the Australian Planning Institute.

AUTOMATIC JUNCTION TESTERS FOR STEP-BY-STEP EXCHANGES

W. F. CHEW, B.E. and N. E. QUIRK, A.M.I.E.Aust.***

INTRODUCTION

The introduction of rapid testers into step-by-step exchanges in N.S.W. was recently described by Bloxom and Way (Ref. 1). They mentioned briefly the provision of automatic junction testers in main exchanges; the purpose of this article is to describe, in more detail, step-by-step main exchange automatic junction testers and to give additional data on the introduction of automatic junction testers into step-by-step branch exchanges.

With specific reference to automatic junction testers, the advantages to be gained by the use of rapid functional testers with automatic printout of faults are:—

(a) All junctions outgoing from an exchange together with outgoing repeaters (main exchange only) and terminating group selectors at the distant exchange are quickly tested for functional operation at negligible cost. Some 70,000 step-by-step junctions are in use in the Sydney metropolitan area.

(b) Defective junctions can be quickly detected and taken out of service, thus reducing the in-service time of faulty equipment. This is of paramount importance when junction shortages exist.

(c) Testing can occur independently of staff attendance during the most suitable hours, i.e., the period when access to non-busy junctions is a maximum.

(d) The characteristic performance of the junction equipment can be derived, permitting more soundly based decisions about work needed to maintain standards of performance.

(e) Service personnel can maintain control over their exchange with minimum staff, yet with increased confidence. Experience would indicate that this situation is reached 2 or 3 months after the introduction of the rapid tester and will happen only when defectives are being cleared in a thoroughly reliable manner.

A practical example of the use of rapid functional testers in Sydney is at East Main Exchange, where pre 2000 and 2000 type equipment is installed. It has been found possible to nightly automatically test, with associated printout of faults, a total of 12,700 group selectors, 1940 final selectors and 4650 auto-auto repeater/junctions (3 Sodeco printers employed). A staff of three commencing duty at 7 a.m. retest faulty switches or junctions indicated on printout,

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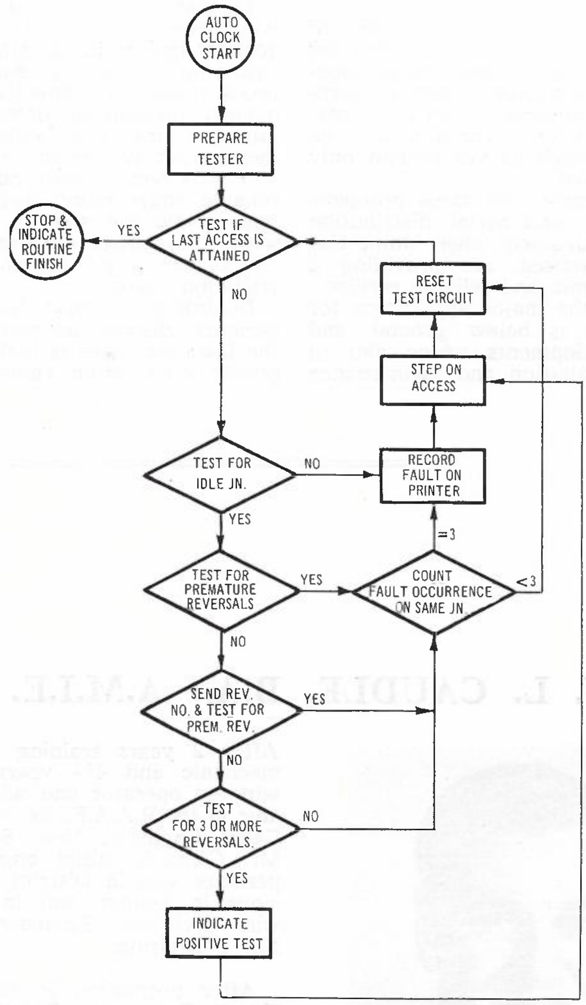


Fig. 1 — Test Function Flow Chart.

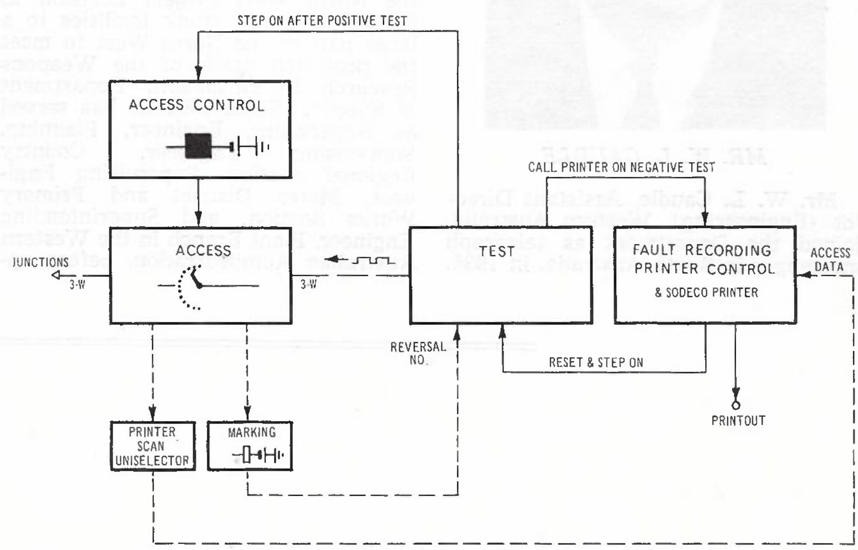


Fig. 2 — Basic Block Diagram of Junction Tester.

busy out defective equipment and rectify faults prior to the peak traffic load at 10 a.m. each day.

TYPES AND GENERAL PRINCIPLES

The three types of step-by-step automatic junction testers in N.S.W. are:—

(a) 2000 type Main Exchange Junction Tester.
(b) Pre 2000 type Main Exchange Automatic Junction Tester.
(c) Branch Exchange Automatic Junction Tester.

These testers have similar test functions and circuitry. The similarities will be reviewed, before describing the specific applications of each type of tester.

Common Test Functions

All types of automatic junction testers have the following test functions:—

(a) seize on idle repeater/junction via a 3 wire access but stop on a busy repeater/junction and record a 'busy' condition.
(b) impulse on the idle junction the reversal number (automatically pre-selected by the marking circuit according to the access switch location) corresponding to the junction routing.
(c) detect premature reversals before and between impulsing.
(d) test for 3 or more reversals after impulsing to indicate a positive test.
(e) retest a faulty junction twice (a total of 3 tests) before the fault is printed out. This test

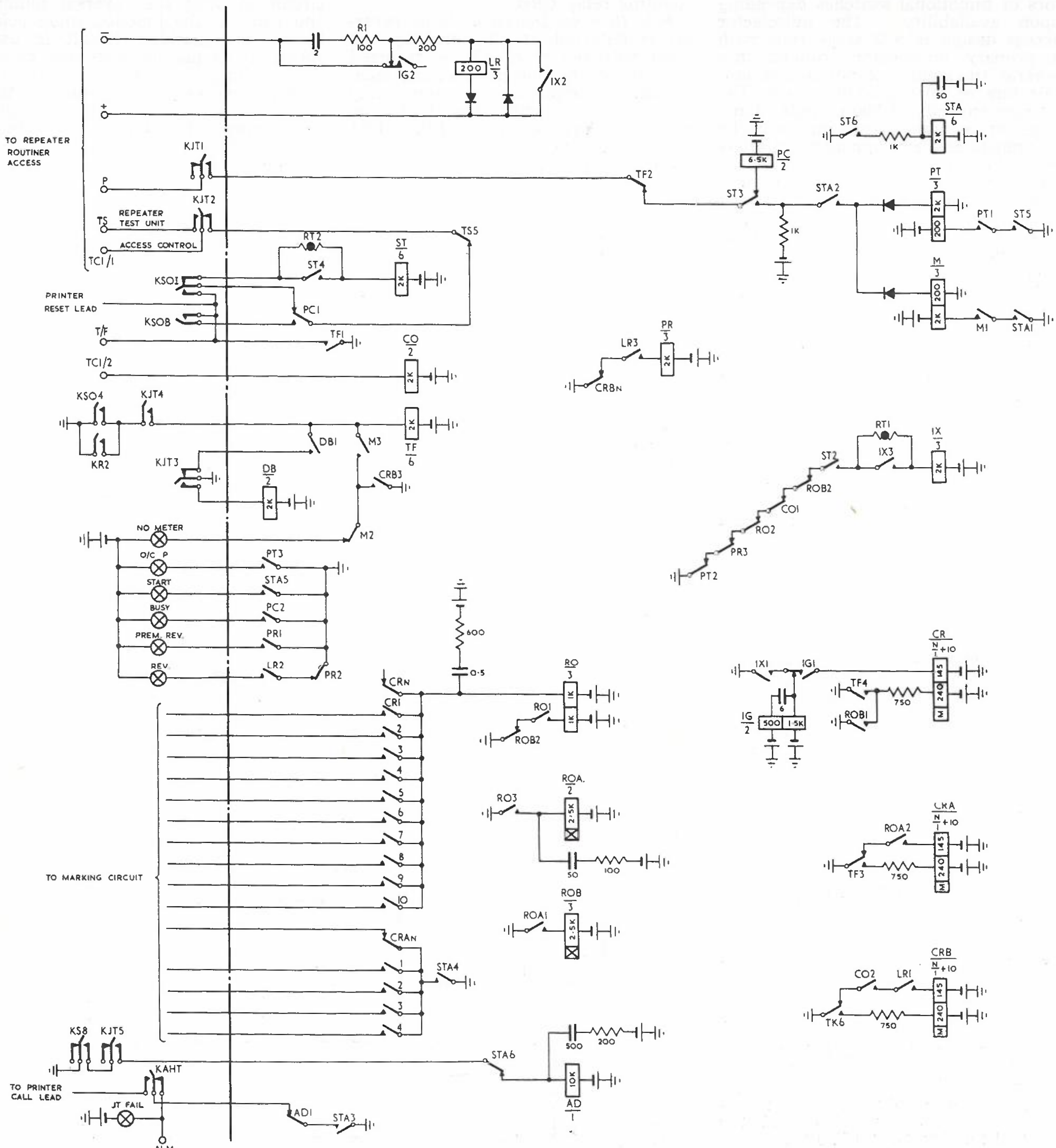


Fig. 3 — Basic Test Function Circuit.

is optional and if used minimizes faulty junction printouts due to a faulty group selector at distant exchange in latter stage of trunking.

Fig. 1 shows these test functions in flow chart form.

Functional Circuit Blocks

The complete tester circuit may be treated as a system of functional circuit blocks (see Fig. 2) as now described.

Junction Access Circuit: The access equipment comprises either uniselectors or bimotional switches depending upon availability. The uniselector access design is a 2 stage type with a primary uniselector trunked into several (maximum of 50) access uniselectors of 50 availability each. The average capacity of 300 outgoing junctions in a branch exchange can be accommodated by a primary uniselector and 6 access uniselectors. Bimotional selectors (100 or 200 outlets) are also used for junction access particularly where spare group selector access equipment assoiated with routiners is available in the exchange.

Access Control Circuit: A simple uniselector control circuit (7 Relays) and homing arcs on the access uniselectors are used on the branch exchange junction tester. Where spare bimotional switch access is available the standard access control unit for pre 2000 type routiners is used.

Test Circuit: This circuit contains all the elements required to perform sequentially the command functions listed in the flow chart (Fig. 1). The main circuit elements (Fig. 3) are:—

The Idle/Busy Test: On testing an idle repeater/junction, earth from the test start lead operates start relay ST via junction test key KJT 2, TF 5, and PC 1. This is followed by the looping and impulsing operations. Should the repeater/junction be busy, earth on the P-wire operates relay PC which subsequently opens the circuit for relay ST and discriminates fault types on the printer.

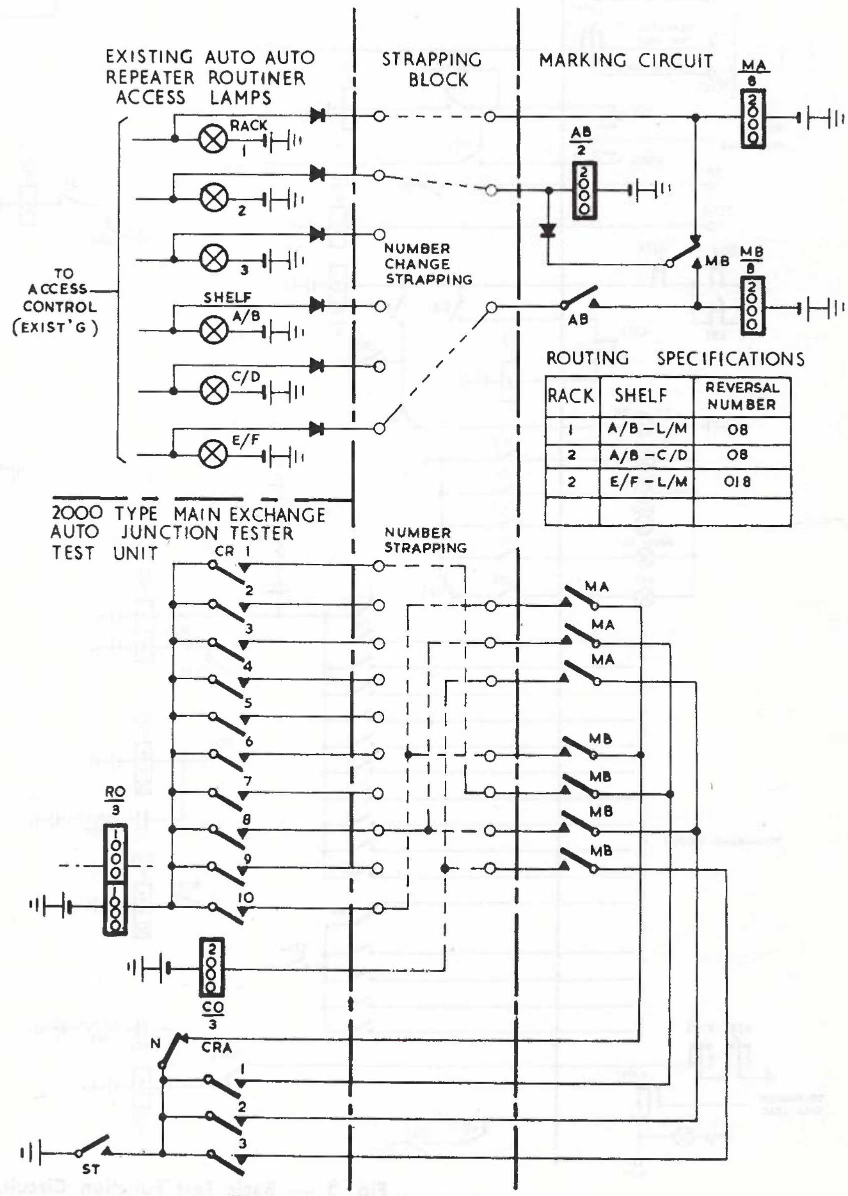
Test Start and Finish Control: Start relay ST operated completes the circuit of the impulsing start relay IX and subsequently operates the impulsing relay IG. At the end of a positive test, the third reversal received on the line causes CRB3 of the reversal counting relay CRB/1 + 10 to make and operate test finish relay TF. At the end of a fault recording operation, reset earth from the printer control operates relay TF to reset (TF1) the routiner and step on the access; to prevent (TF2) any operation of relay PC; to reset (TF3, 4 and 6) the 3 counting relays CR, CRA and CRB; and to prevent (TF5) relay ST from operating.

The Impulsing Circuit: Impulsing relay IG operates self-interruptedly as IX 1 completes its circuit. IG2 sends the impulses on the line and they are counted by IG1 with the counting relay CR/1 + 10. Assuming the marking circuit is strapped to send the reversal number "08", CR 10 operated on the 10th impulse completes the circuit for the interdigital relay RO which cuts off further impulsing by restoring (RO2) relay IX. RO3 operates interdigital pause relays ROA and ROB. ROA2 steps on the digit counting relay CRA/1 + 10. The 2nd digit is sent as ROB3 restores to re-operate relay IX. On the 8th impulse of the 2nd impulse train, CR8 makes to restart the interdigital pause function at the end of which CRA2 makes to operate the cut off relay CO. CO1 operated opens the circuit of relay IX to stop impulsing and CO2 prepares for the operation of the reversal counting relay CRB.

Line Reversal Detection: Line reversal is detected at all times by the diode-polarised relay LR. A reversed polarity on the line prior to the completion of impulsing operates relay LR and subsequently (by LR3) the premature reversal relay PR. LR1 counts the reversals on the counting relay CRB/1 + 10.

Retest Faulty Repeaters/Junctions before Recording: Faulty repeaters/ junctions are tested twice or 3 times to minimise the printouts of faults due to faulty terminating equipment. The circuit is not shown in Fig. 3 for simplicity, but in principle, 2 or 3 relays are used to enable the tester to reset and retest on the same access after the first fault is recognised. If the fault recurs on the 2nd test it is recorded on the printer otherwise the tester steps on for the next test.

Marking Circuit: To enable the test circuit to send the reversal number applicable to the junction route being tested, the marking circuit is used (operates in parallel with the access display lamp circuit) to mark the correct reversal number on the test circuit impulse/digit counting relays. An example of a typical marking is shown in Fig. 4. With a given junction routing specifications, the circuit is



RACK	SHELF	REVERSAL NUMBER
1	A/B – L/M	08
2	A/B – C/D	08
2	E/F – L/M	018

Fig. 4 — Sample Marking Chart.

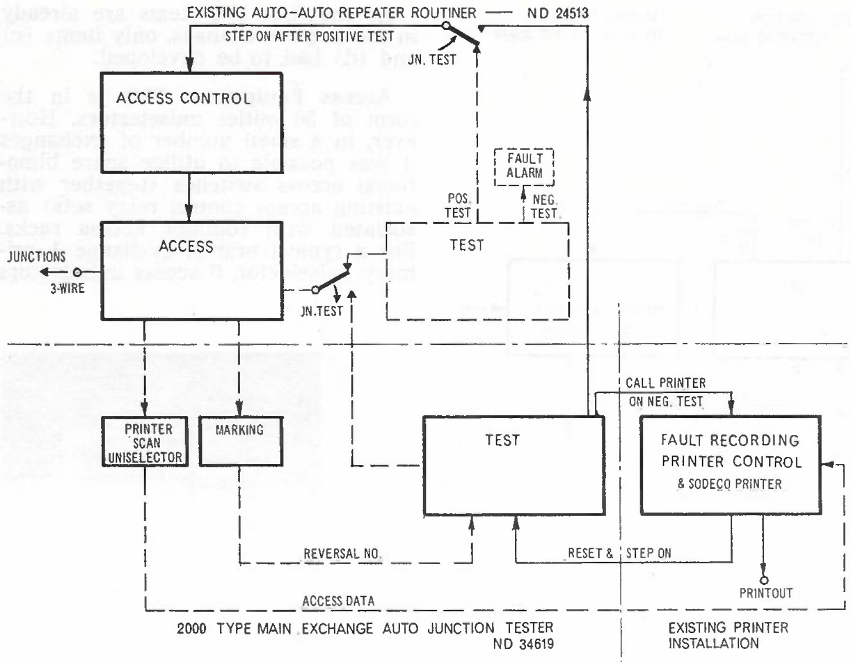


Fig. 5 — Block Diagram of 2000 Type Main Exchange Auto Junction Tester.

designed so that the marking relays MA (08) and MB (018) are operated on the appropriate access location. The changeover is effected by earth on the shelf lamp via the number change relay AB. Thus MA1 and MA2 are strapped to the CR contacts so that RO operates on the 10th impulse when CR10 makes for the first digit; and after the interdigital pause RO operates on the 8th impulse when CR8 makes. MA3 is connected to the cut off relay CO. The marking circuit can be built as a separate assembly.

Fault Recording Circuit: This circuit is made up of the existing printer control circuit, existing Sodeco printer and routiner or rapid tester finder (uniselector). The "existing" refers to the Sodeco printer installations associated with the group and final selector rapid testers. One additional uniselector (scan switch) is required to translate the required junction tester access data into pulses to feed into the printer. The details of this circuitry have already been described (Ref. 1).

Appendix 1 gives the N.S.W. Drafting Section Drawing Numbers of circuits referred to in this paper.

2000 TYPE MAIN EXCHANGE

With the provision of group and final selector rapid testers in main exchanges together with associated Sodeco printer installation the design of automatic junction testers appeared an economic and desirable proposition.

The existing auto-auto repeater routiner access circuit and the associated access control circuit were utilized with minor modifications so that access was made available to all repeaters/junctions at practically no cost. The existing access circuit was connected by 5 wires (—, +, P, test start and test finish) to the test circuit via a junction test key which could restore access to the existing routiner as required. Fig. 5 is a block diagram of the tester.

Modifications required to the AO-AO routiner test circuit for use as the junction tester were quite extensive so it was considered desirable to leave the existing routiner intact and design a test circuit solely for junction testing. This circuit, comprising 16 3000 type relays and 3 counting relays, was accommodated in a 20 relay jack-in base and is capable of performing all the test functions described previously.

A marking circuit with an average of 7 relays (dependent upon routing complexities) was accommodated on a 10 relay jack-in base. It was connected to the access display circuit (30 wire) and the impulse and digit counting relays of the test circuit (10 wire) via a strapping block, 10 x 20 terminal strip, to provide various strappings dependent on the necessary marking specifications of the repeater/junction routing.

As there were a number of AO-AO routiners installed in N.S.W. it was found advantageous to adapt the tester unit to mass production techniques. The 20 base test unit and the 10 base marking unit are mounted on a 17 inch shelf bar at the bottom front of the AO-AO routiner and the strapping block is mounted at the bottom rear of the routiner. Fig. 6 gives a front view of a modified AO-AO routiner for use as an automatic junction tester. The test unit and the marking unit relay set are shown at the bottom of the routiner. The junction tester runs through 800 repeater/junctions per hour.

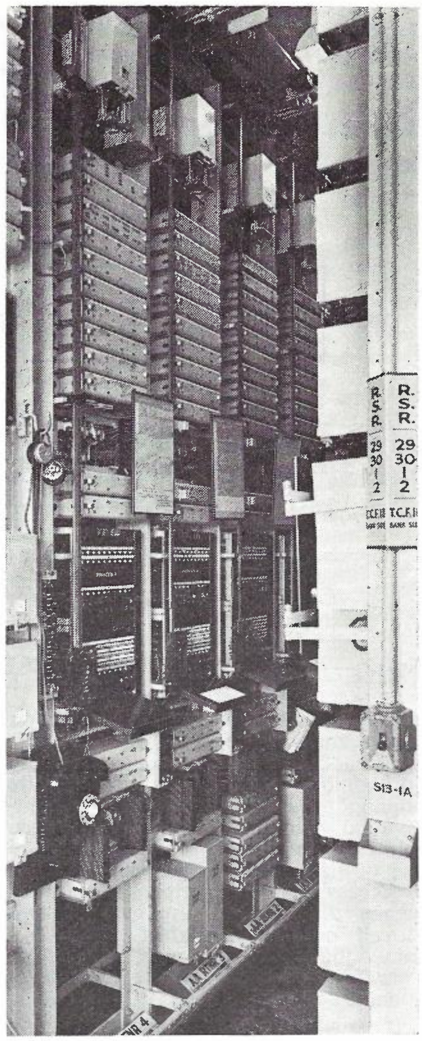


Fig. 6 — Modified Ao-Ao Routiner for use as a 2000 Type Main Exchange Auto Junction Tester.

PRE 2000 TYPE MAIN EXCHANGE

As AO-AO repeater routiners are not available in Pre 2000 main exchanges, the existing traffic distributors (T.D.'s) (junction hunters), each trunking to 25 repeaters are utilized as access equipment by the provision of 1 primary access uniselector (5 availability) trunked to 5 secondary access uniselectors (24 availability), which trunked to 120 (5 x 24) traffic distributors and finally to 3000 (5 x 24 x 25) auto-auto repeaters/junctions. A tandem uniselector (operated in parallel with T.D. under test) is used to display the junction access as mirrored by the T.D. wipers. Fig. 7 is a block schematic of the tester.

To free the 120 T.D.'s purely for junction testing it is necessary to effect a regrading of the pre 2000 type selector banks (10 availability) so that 120 latter choice T.D.s are rendered spare. The existing 4th meter wire to the T.D.s (via I.D.F.) is used

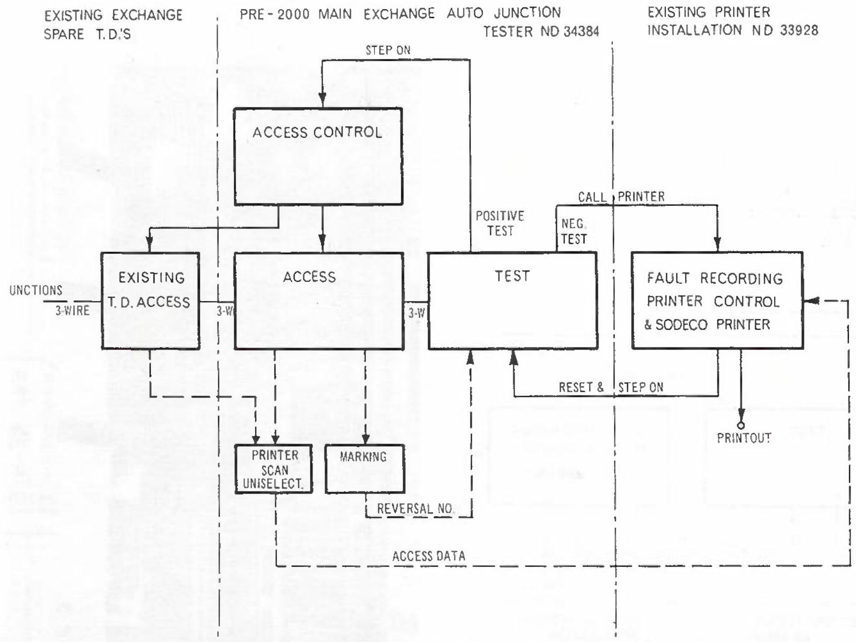


Fig. 7 — Block Diagram of Pre-2000 Type Main Exchange Auto Junction Tester.

as a control wire from the junction tester for stepping and homing purposes as it is necessary for each of the non-homing access T.D.s to be made homing type for identification of individual junctions by the Sodeco printer. It is to be appreciated that the use of the existing T.D.s as a means of access to the junctions necessarily means that due to the grading employed on the banks of the T.D.'s some junctions are multiple tested. This is considered of no great consequence.

It was necessary to manufacture a complete junction tester, comprising a test unit, a marking unit and an access control unit and these components were assembled on a 17 inch routiner rack.

The test unit is similar to the test unit described for the 2000 type main exchange junction tester and performs the same test functions except for a more closely monitored private wire to test for continuity on the —, + and private lines.

A printer scan uniselector (8 level) is provided to connect the junction tester access display lamps to the Sodeco printer control relay set.

The actual complete rack mounted junction tester comprises some 40 3000 type relays and 4 counting relays. Cost of manufacture was approximately $350.00, whilst installation manhours at the exchange are estimated at 80-100 manhours.

The tester takes 9 hours to test 2725 repeater/junctions (some are multiple tested) and runs nightly from 10 p.m. to 7 a.m. An average printout produces 41 registrations comprising 8 confirmed faults, 8 repeated faults due to the degree of multiple testing and 25 F.O.K.'s. This represents a fault rate of 0.3%, i.e., an average of 0.3% of the junctions are faulty at any time. A junction circuit may be faulty due to trouble at the originating or distant end.

Fig. 8 gives a view of the junction tester at East Exchange. The primary access uniselector (1 off), secondary access uniselector (5 off) and tandem uniselector (1 off) can be seen at top of the tester.

BRANCH EXCHANGE

Initial thoughts on the provision of junction testers in step-by-step branch exchanges were that a large proportion of junction circuit faults were due to faulty terminating group selectors in the distant main exchange and that provision of automatic junction testers would not be warranted, particularly if the distant main exchange was already equipped with group selector rapid testers. However, in practice, notwithstanding the extensive use of the rapid testers at the main exchange, junction faults were still being detected at branch exchanges in sufficient quantity to justify the provision of automatic junction testers at branch exchanges, provided the installation could be effected economically.

Utilization of existing exchange Traffic Route Testers (T.R.T.) as the test unit provided an economical solution, since junction testing occurs during the night when the T.R.T. is normally idle. Fig. 9 shows the block schematic of the branch exchange junction tester. In effect it consists of:—

(a) T.R.T. test unit (in situ)

(b) Sodeco Printer Installation (in situ)

(c) Access equipment and access control

(d) Marking Unit

As the first two items are already in use in all exchanges, only items (c) and (d) had to be developed.

Access Equipment: This is in the form of 50 outlet uniselectors. However, in a small number of exchanges it was possible to utilize spare bimotional access switches (together with existing access control relay sets) associated with routiner access racks. For a typical branch exchange 1 primary uniselector, 6 access uniselectors

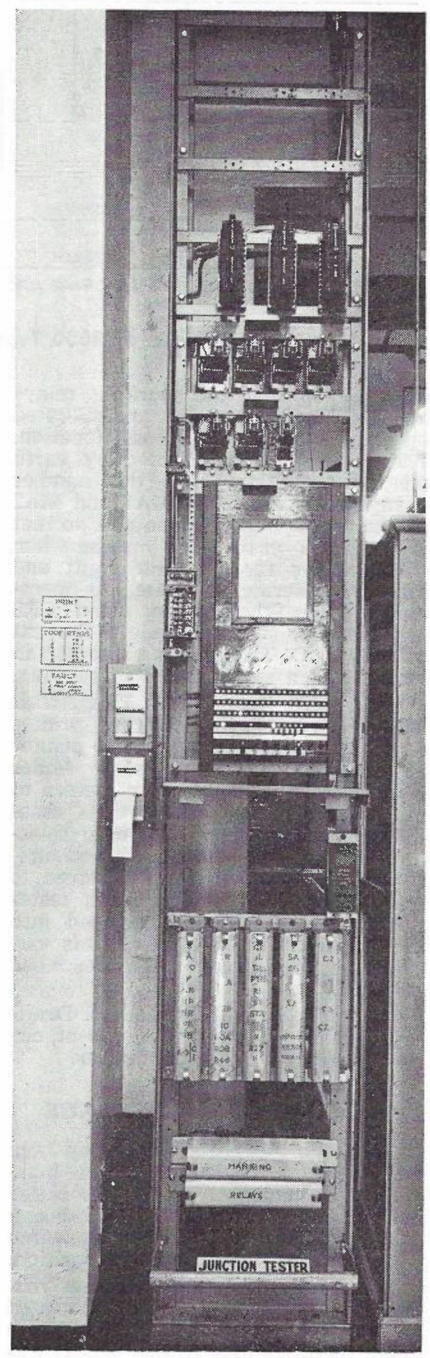


Fig. 8 — Pre-2000 Type Main Exchange Auto Junction Tester.

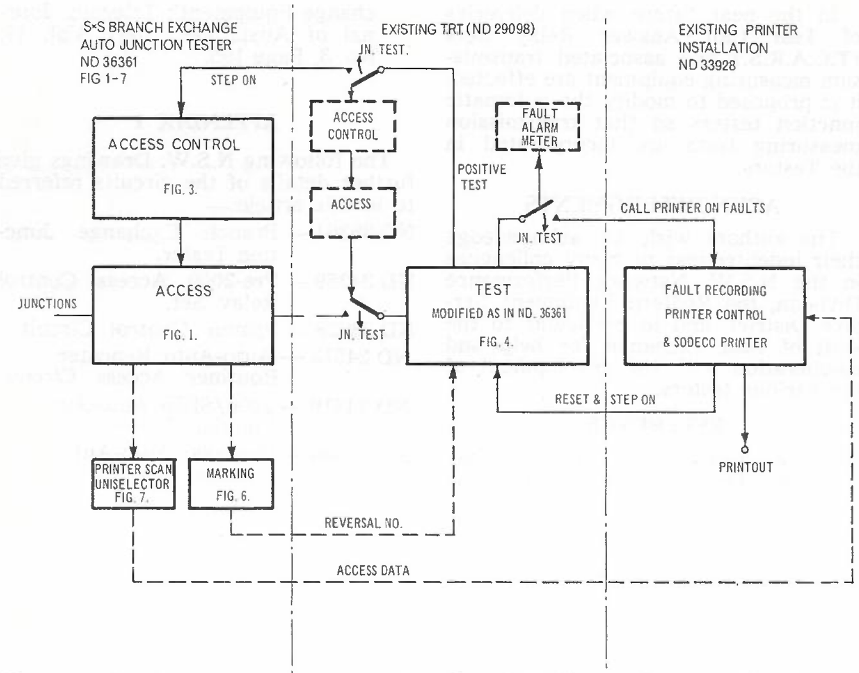


Fig. 9 — Block Diagram of Step by Step Branch Exchange Auto Junction Tester.

(junction distributors) and 1 tandem uniselector, operating in parallel with the junction distributors for access display purposes, are used. The existing T.R.T. outgoing lamp display is used for the secondary purpose of indicating the junction tester access display. Connection to the junctions is by a 3 wire circuit between the terminating blocks associated with each access uniselector and the T.D.F. or M.D.F. depending upon which is the most accessible.

The access control circuit contains 7 3000 type relays mounted in a 8/10 relay jack-in type base. The relays perform the function of test start (TS), test finish (JTF), routine final (RF), unequipped stepover (UE), busy condition monitor (BZ) and retest on faulty junction (RTT and JRR).

Marking Circuit: This is of the same design as the previous 2 testers but the T.R.T. is modified to work with the marking circuit which will now replace the marking function of the test number setting switches. These switches are set on position 10 for junction test operation with the marking circuit. Containing an average of 8 relays, the marking circuit is mounted in a 10 relay jack-in type base. A strapping unit is also associated with the circuit and the mounting layout is as described previously for the main exchange 2000 type junction tester.

It is of interest to note that the access uniselector equipment was mass produced. The 8 level 50 point uniselectors (recovered material) were tailed in a central depot to 25 x 8 terminal strips. The tailed units were mounted on frames made to exchange tester site requirements. The completed frames consisting of an average of 4 tailed uniselectors and blocks were supplied to the exchange for mounting and cabling to junctions.

The overall cost of providing a branch exchange automatic junction tester with printout of faults was in the vicinity of $500.00 per tester.

The tester is capable of testing 600 junctions per hour and analysis of fault printouts reveals a fault percentage of 0.1, i.e., on average 0.1% of the junctions are detected as faulty on a complete run through.

Fig. 10 shows the junction access equipment installed at Edgecliffe Branch Exchange whilst Fig. 11 shows the necessary marking and access control relay sets which were added to the Edgecliffe exchange T.R.T.

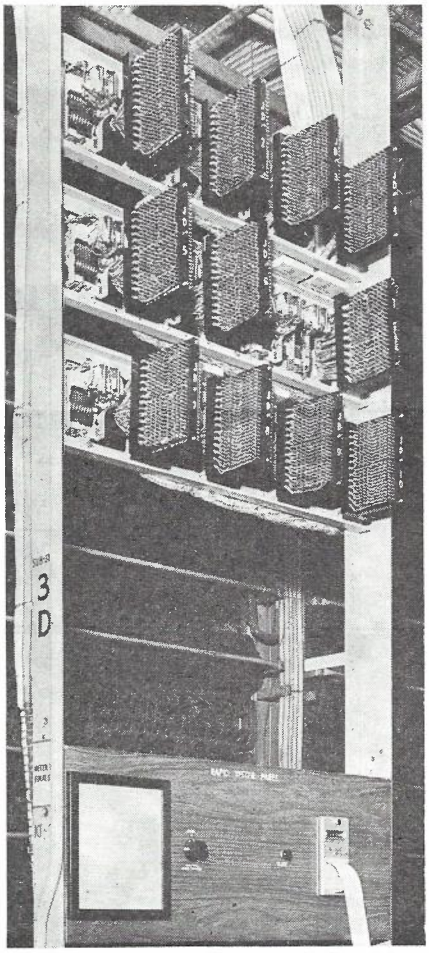


Fig. 10 — Access Equipment for Edgecliff Branch Exchange Auto Junction Tester.

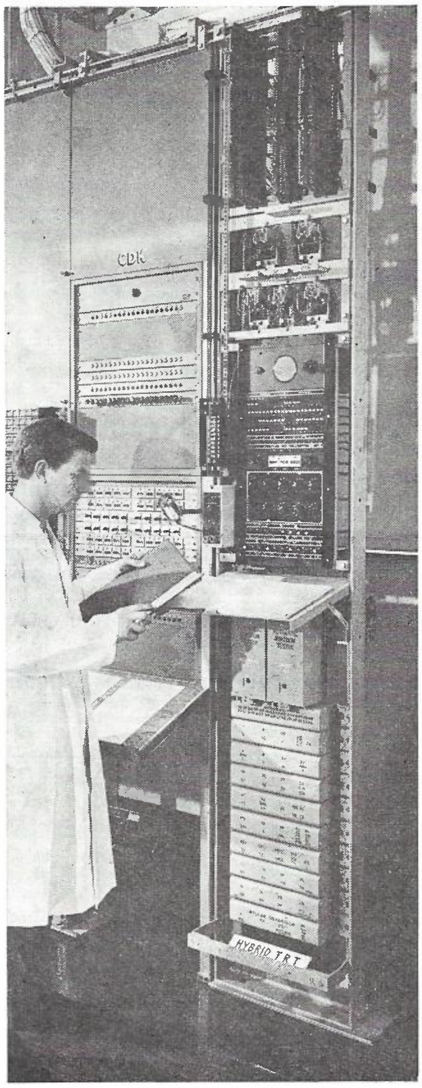


Fig. 11 — Modified T.R.T. at Edgecliff Branch Exchange.

CONCLUSION

A large proportion of step-by-step exchanges in the Sydney Metropolitan Network have already been equipped with automatic junction testers with printout of faults and it is expected that by September, 1968, all exchanges in the network will be similarly equipped.

The experience to date has been such that a decided improvement in performance at each exchange has resulted from the introduction of rapid functional testers and the supervising technician in charge of an exchange completely equipped with rapid testers (junction, group selector, final selector and D.S.R.) and associated printout of faults has been able to confidently maintain control of his exchange with a minimum of staff.

In the near future when deliveries of Test Call Answer Relay Sets (T.C.A.R.S.) and associated transmission measuring equipment are effected, it is proposed to modify the automatic junction testers so that transmission measuring tests are incorporated in the Testers.

ACKNOWLEDGMENTS

The authors wish to acknowledge their indebtedness to many colleagues in the N.S.W. Network Performance Division, the Redfern Equipment Service District, and in particular to the staff of East exchange for help and co-operation with the development of the various testers.

REFERENCE

1. L. J. Bloxom & P. C. C. Way, 'Rapid Testers for Step-by-Step Exchange Equipment'; Telecom. Journal of Aust., Oct. 1967, Vol. 17, No. 3, Page 195.

APPENDIX 1

The following N.S.W. Drawings give further details of the circuits referred to in this article:—

ND 36361 — Branch Exchange Junction Tester.

ND 34359 — Pre-2000 Access Control Relay Set.

ND 33928 — Printer Control Circuit.

ND 24513 — Auto-Auto Repeater Routiner Access Circuit.

ND 34619 — 2000/SE50 Auto-Auto Junction Tester.

ND 34384 — Pre-2000 Auto-Auto Junction Tester.

A COUPLING UNIT FOR CONVERSATION RECORDERS

The attention of readers is drawn to the omission of Mr. G. M. Casley's name as a joint author of the article with the above title published in the October, 1967, issue of the Journal. The Editors accept responsibility for this error and apologise for any embarrassment caused.

The opportunity is taken to make the following corrections to the published text:—

Table 2, Page 235:

The definition of item A_{LR} should be $\frac{V_R}{V_L}$.

The definition of A_{TR} should be $\frac{V_R}{V_T}$.

All quantities in the 'Value' column shown as dBx should be dB.

Table 3, Page 236:

In the 'Voltage (mV)' column the item 255 should be shown opposite V_{SW}.

Page 232, Column 1:

In the last two paragraphs under the heading 'Connections Made to the Unit' Fig. 4 should read Fig. 3.

AN AUTOMATIC ROUTINER FAULT PRINTER

*J. K. GERRAND, F.R.M.I.T., Grad. I.E. Aust., Grad. I.R.E.E. Aust.**

INTRODUCTION

Most step-by-step exchanges have automatic routiners which perform a series of tests to check the operation of each selector and repeater in the exchange in turn.

Numbered lamps on each routiner indicate which selector or repeater is being checked, and which test is in progress. The routiner stops when a switch fails any test, and operates an alarm. A technician then notes from the lamp display the number of the faulty switch and the test on which it failed, so that the fault may be cleared when convenient.

It would be useful to have a device which would print the details of each routiner stoppage by recording which lamps are lit, and then step the routiner on to the next switch. The advantages would be:

(a) Routiners at exchanges staffed only during the day could be run during the light traffic period at night when most switches are available for testing. This would greatly increase the amount of routine testing which could be done at such exchanges.

(b) Technicians in continuously staffed exchanges would not have to be on hand to record details of routiner stoppages; they could spend this time on other work.

(c) The risk of faulty selectors being overlooked or incorrectly recorded would be reduced.

To be of value the printer would need to operate with all routiners in an exchange at once, and should be sufficiently versatile to work with any type of routiner likely to be encountered.

Other important features to be considered were that the printer should be reliable, fairly cheap and small (all of these indicating that the circuit should be transistorised) and not too complex to install. The Fault Recording Indicator for Automatic Routiners (F.R.I.A.R.), which was finally evolved for use in the Melbourne Metropolitan area, fulfils these requirements adequately.

COMPARISON WITH OTHER TYPES OF AUTOMATIC PRINT-OUT

Several other types of automatic routiner print-out had been developed before the F.R.I.A.R. system was designed. These were considered in detail, and it was felt that each had disadvantages which would limit its usefulness or make it too costly. Only one of the systems studied had sufficient capacity to record the lamp display on all routiners likely to be encountered. This system (Ref. 1) used elaborate circuitry to control print-out on a teleprinter and would have been very expensive if new components had been used.

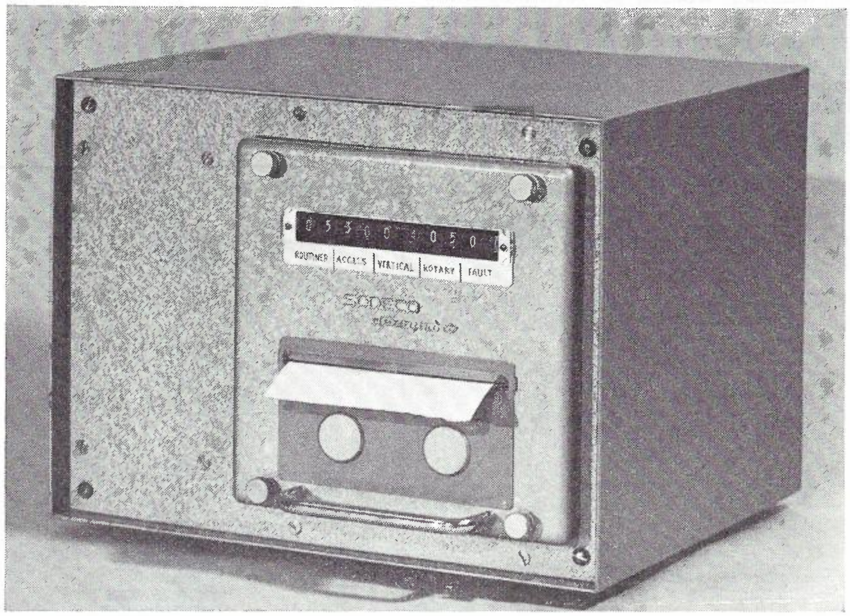


Fig. 1 — The F.R.I.A.R. Printer and Control Unit

The fault lamp capacity of the system described by Bloxom and Way (Ref. 2) is adequate for the rapid tester with which it is associated. However, with full routines and a wide range of access coverage, as is the situation in Melbourne, its capacity would not be great enough to record the information displayed by the routiner equipment.

The F.R.I.A.R. system was designed in an attempt to overcome these limitations. The Swiss-made Sodeco 10-track decimal digit printer (type PN 207) was chosen as the printing device because of its mechanical simplicity, ruggedness, small size, reasonable cost and simple control requirements.

The F.R.I.A.R. has sufficient capacity to work with up to 24 routiners simultaneously, each routiner having a maximum of 50 primary access lamps, 25 secondary access lamps, 25 tertiary access lamps and 45 fault (or test) lamps. The control circuit is entirely transistorised, so increasing reliability and reducing size. The printer and control circuit are contained in a 9½ in. x 7 in. x 8 in. cabinet (see Fig. 1).

DESCRIPTION OF THE F.R.I.A.R. SYSTEM

Control of Routiners

Two relays and an eight level, 25 outlet uniselector are wired into each routiner for which automatic print-out is required. In each routiner one of these relays, ST, is controlled by a 24 hour time switch, allowing the routiners to be started at night when an exchange is unstaffed. Tests can be omitted at weekends if desired.

The other relay, P, operates when the routiner stops on a faulty switch. All P relays are operated through a priority chain so that only one routiner at a time can call in the printer. Other routiners stopped on faults will wait their turn.

The Sodeco Printer

The basic unit of the Sodeco Printer is a number wheel displaying digits 1 to 0 which is stepped by an electromagnet and ratchet mechanism. A pair of normally closed contacts, R, open when the number wheel stands on position 'O'. The normally open T contacts close on position '9'. These are wired as shown in Fig. 2.

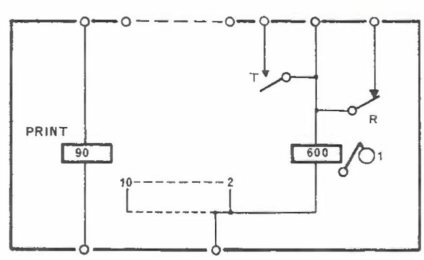


Fig. 2 — The Sodeco Printer

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Ten of these counting units make up the printer. There is also a printing hammer which brings the paper tape and ink ribbon up against the embossed number wheels, so recording the ten digits displayed by the ten counting units at that time. An electromagnet moves the hammer and advances the paper after each impression. The printer is easily removed from its case to enable the paper and ink ribbon to be renewed.

Calling the Printer

Refer to Fig. 3 for an explanation of the logic symbols used in the following description.

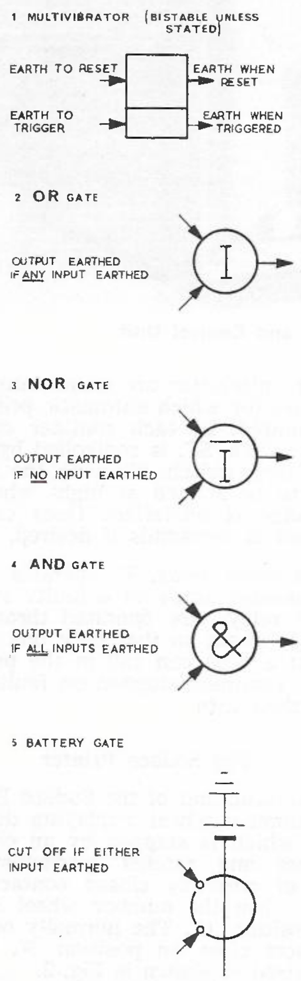

Fig. 3 — Logic Symbols used in Circuit Explanation.

When a P relay in any routiner operates, the printer call lead is earthed (see Fig. 4). The delay circuit allows time for other P relays to release if more than one had operated simultaneously, before passing earth to the NOR gate which has been holding the entire control circuit in the reset state. The delayed earth on the input of the NOR gate removes earth from its output and this allows the impulse generator (an astable multivibrator) to commence operating.

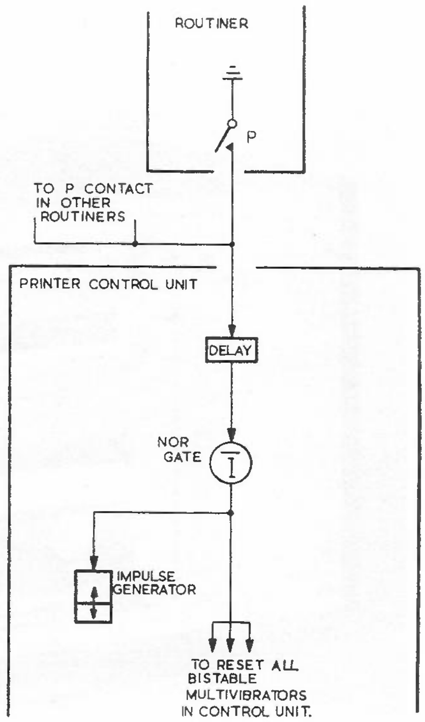

Fig. 4 — Printer Start Circuit

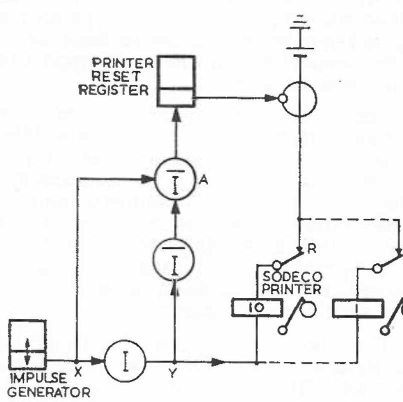

Fig. 5 — Printer Reset Circuit

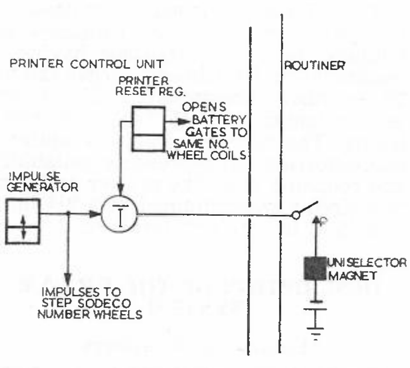

Fig. 6 — Stepping the Uniselector

Resetting the Printer to Zero

The impulse generator provides an earth impulsed at 10 i.p.s. which steps the Sodeco number wheels. As each number wheel reaches digit 'O' its 'r' contact opens and breaks its stepping circuit. (See Fig. 5).

The NOR gate, 'A', will earth its output only when neither of its inputs is earthed, that is, when X is not earthed and Y is earthed. This can only occur when all 'R' contacts in the printer are open so that the battery supply to Y through the number wheel coils no longer exists. Thus when all number wheels are set to zero, the Printer Reset Register is triggered, so cutting off the battery supply to the 'R' contacts of the number wheels.

Stepping the Uniselector

Fig. 6 shows how the the Printer Reset Register, when triggered, allows the extra uniselector on the routiner calling the printer to be stepped by the impulse generator. This register also allows battery to be connected to the coils of number wheels 1, 3, 5, 7 and 9, and these will step in synchronism with the uniselector.

Setting the Number Wheels

Consider the secondary access lamp number. There may be up to 25 secondary access lamps. These are wired to contacts 1 to 25 on arc 3 of the uniselector, as shown in Fig. 7. Assume lamp 17 is lit. The earth on lamp 17 will appear also on contact 17 of arc 3 of the uniselector.

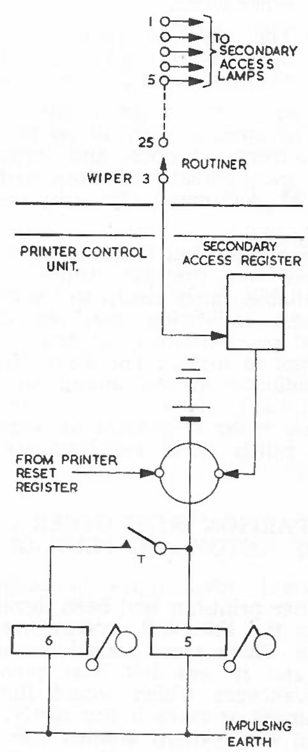

Fig. 7 — Setting Secondary Access Number

Number wheels 5 and 6 are used for the secondary access number. Wheel 5 steps with the uniselector. On digit '9' its 'T' contact connects battery to wheel 6, resulting in automatic counting of the decade. When wiper 3 on the uniselector encounters the earth on contact 17, the Secondary Access Register is triggered and remains so, cutting off the battery supply to number wheels 5 and 6. The secondary access display thus remains at '17' while the uniselector continues to step.

The process is more complex for fault and primary access lamps. Due to the probability of having more than 25 lamps for these displays, two uniselectors arcs are required. The logic circuitry used for setting up the primary access number allows any lamp from 1 to 50 to be recorded even though the uniselector takes only 25 steps. (See Fig. 8).

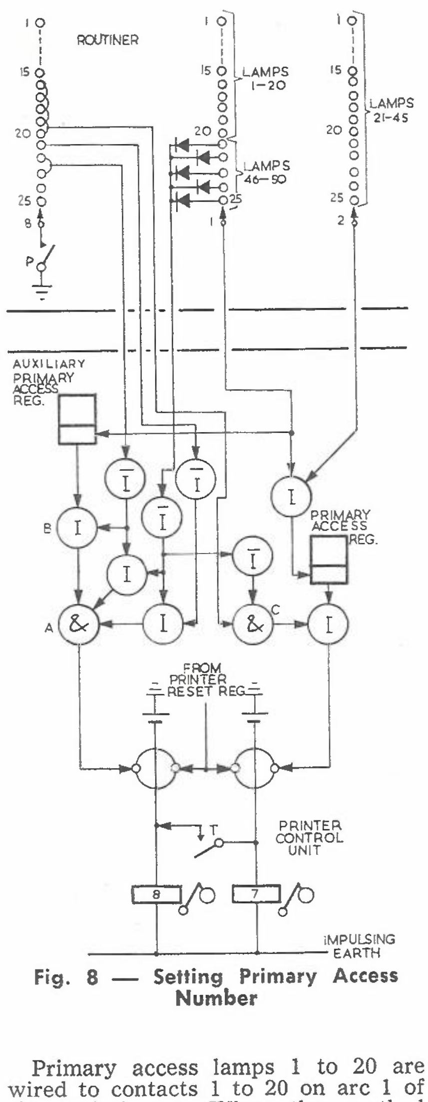

Fig. 8 — Setting Primary Access Number

Primary access lamps 1 to 20 are wired to contacts 1 to 20 on arc 1 of the uniselector. When the earthed contact is encountered by wiper 1, both Primary Access Registers are triggered. Number wheel 7 stops stepping and battery cannot be connected to wheel 8 because all inputs to AND gate 'A' are earthed. The primary access number is simply recorded in a similar manner to the secondary access number.

Primary access lamps 21 to 45 are wired to contacts 1 to 25 on arc 2 of the uniselector. If one of these lamps is lit, only the Primary Access Register will be triggered when the earth is encountered. Number wheel 7 stops when this happens. However, when wiper 8 passes over contacts 22 and 23, OR gate 'B' has earth on neither input, so AND gate 'A' has no earth on one input, and battery is connected to wheel 8 for two impulses. This adds twenty to the primary access number — the difference between the lamp numbers and the contact numbers to which they are wired.

Primary access lamps 46 to 50 are wired to contacts 21 to 25 of arc 1 of the uniselector, the difference in lamp and contact numbers thus being 25. Earth from the lamp which is lit appears, through a diode, on an input of AND gate 'C'. As wiper 8 passes contacts 16 to 20 it earths the other input of 'C', so cutting off battery from wheel 7 for five impulses. Then, as wiper 8 passes contacts 21, 22 and 23 it causes wheel 8 to step three extra times, in a similar method to that described above. In effect, this adds 30 to, and subtracts 5 from, the primary access number, so giving the correct display.

Similar circuitry sets up the tertiary access, fault and routiner numbers. All five numbers are set up together while the uniselector takes 25 steps.

Printing

The Routiner Identification Register is triggered before the uniselector reaches the 25th step. On contact 25, wiper 8 earths the other input of AND gate 'D', so triggering the monostable multivibrator and operating the Sodeco print magnet as shown in Fig. 9.

A sample print-out is shown in Fig. 10.

Resetting Routiner

The circuit which triggered the monostable multivibrator also triggers the Routiner Reset Register which holds earth on the routiner 'reset' and 'step-on' leads through a P relay contact. The routiner resets, releases its P relay and releases the printer control unit. This in turn causes all registers (or bistable multivibrators) in the circuit to reset. After a delay the P relays are again allowed to operate, and the whole printing cycle may be repeated with another routiner. The complete print-out, from calling the printer to release takes less than 5 seconds.

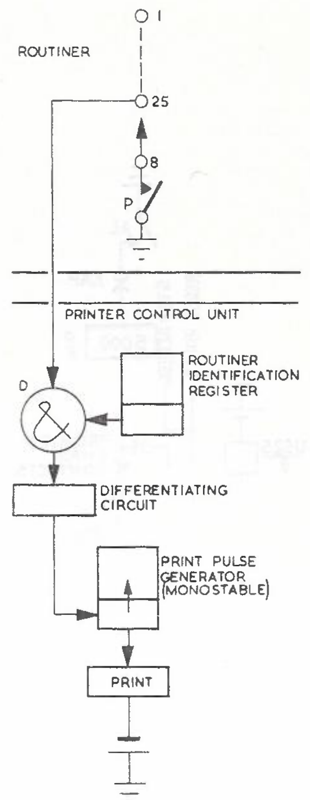

Fig. 9 — Operating Print Magnet

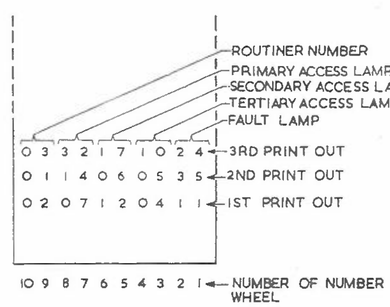

Fig. 10 — Sample Print-out

Complete Logic Diagram

The complete logic of the control unit is shown in Fig. 11. Some of the logic was simplified in the foregoing description. The control unit logic may appear to be more complex than necessary; this is because the unit was designed to be economical of components rather than logically simple.

CONSTRUCTION OF THE CONTROL UNIT

Printed circuit construction was chosen because the control unit is transistorised and has no relays. Two circuit boards were used. These can be seen in Fig. 12. All wires connecting to the unit enter through a plug and socket, allowing simple changing of control units if faults should occur. Constructional details were designed as part of the overall project.

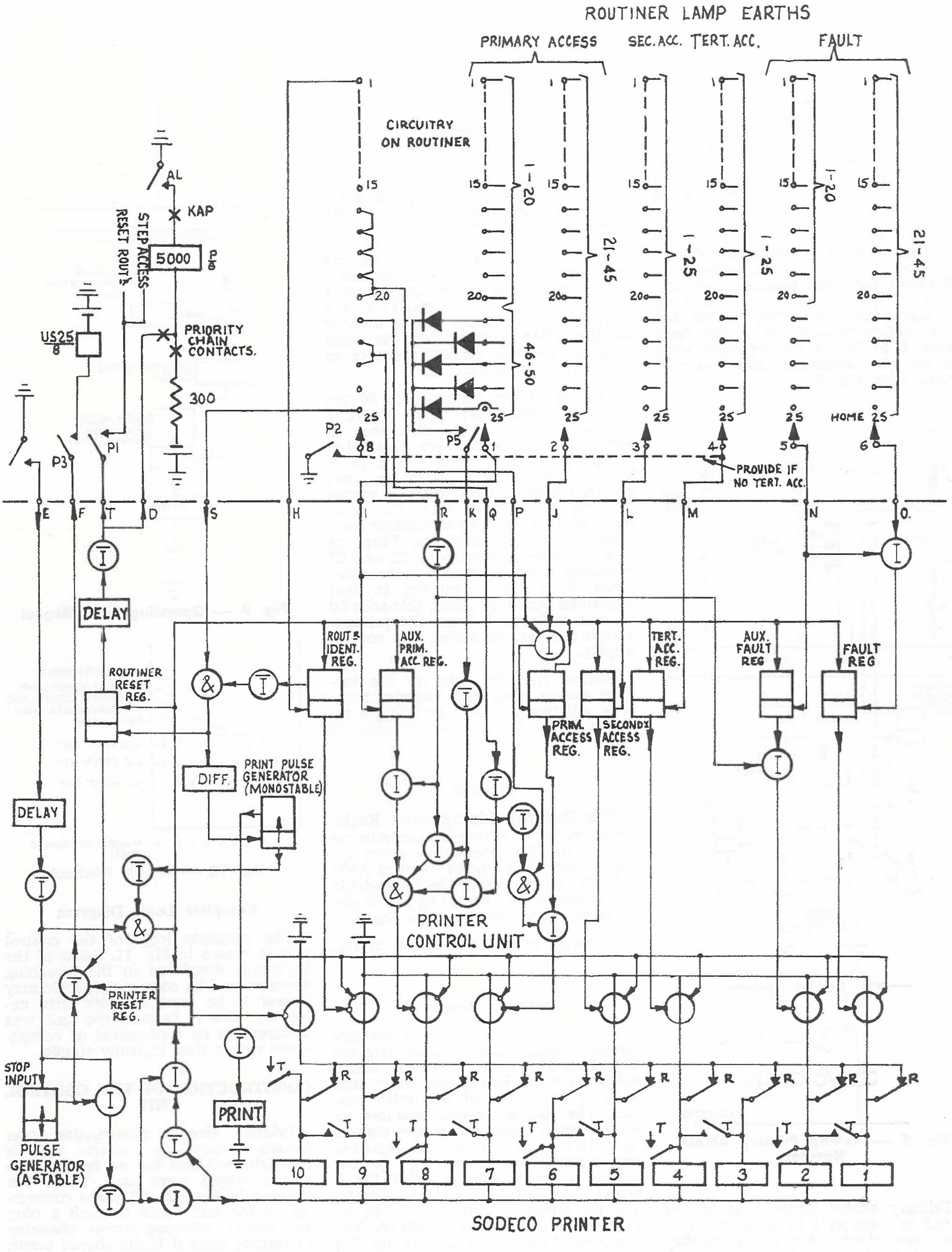

Fig. 11 — Complete Logic Diagram of the F.R.I.A.R. System

APPLICATION OF THE F.R.I.A.R SYSTEM

A F.R.I.A.R. has been installed at each of five Melbourne exchanges for a trial. No faults other than initial wiring mistakes have been found, and the system is proving to be as useful as it was hoped. It is now planned to install the system at all Melbourne exchanges having routiners. The installation at Russell Exchange is shown in Fig. 13.

The cost of the F.R.I.A.R. is expected to be of the order of $700 per exchange for the control unit and printer, plus $60 per routiner. These estimates include all materials and labour costs.

The versatility of the F.R.I.A.R. makes it relatively easy to extend its application to printing out information from equipment such as routiners for S.T.D. equipment, junction routiners and similar devices. This is due largely to the fact that very little modification of existing equipment is needed; merely connections to the display lamps, and to a few existing control leads.

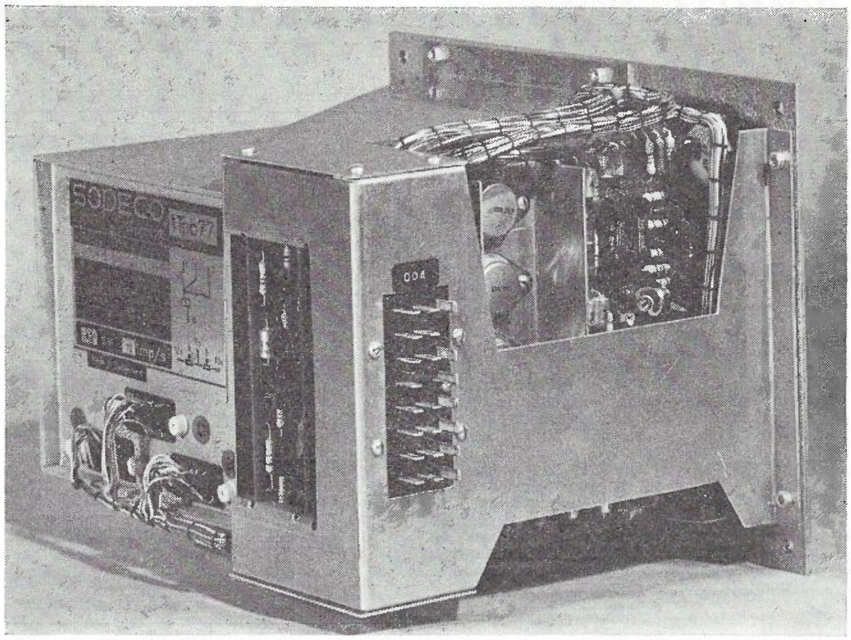

Fig. 12 — An Interior View of the Printer Control Unit

CONCLUSION

The F.R.I.A.R. meets adequately the need for an automatic routiner print-out system capable of operating with all types of routiner. It involves little modification to the routiners, can operate with up to 24 routiners simultaneously, prints up to 12 faults a minute, and is small and reliable. The printer and control unit require no routine maintenance. The system is simple to use and the print-out is easily understood.

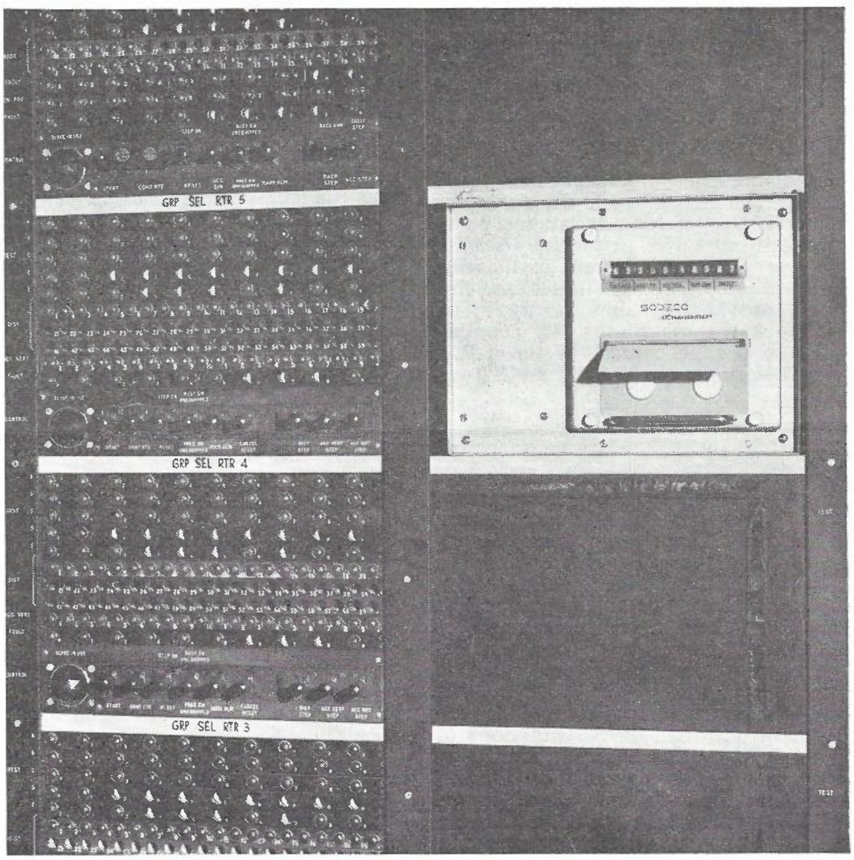

Fig. 13 — The F.R.I.A.R. Unit Installed on the Central Routiner Control Panel at Russell Exchange, Melbourne

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1. G. V. O'Mullane, 'An Automatic Fault Recorder for Automatic Routiners', Telecom. Journal of Aust., Feb., 1958, Vol. 11, No. 3, Page 68.
2. L. J. Bloxom and P. C. C. Way, 'Rapid Testers for Step-by-Step Exchange Equipment', Telecom. Journal of Aust., Oct. 1967, Vol. 17, No. 3, Page 195.

REMOTE CONTROL OF TRAFFIC ROUTE TESTERS

*J. G. HARRIS, B.E.**

INTRODUCTION

The development of the Automatic Disturbance Recorder (A.D.R.) is a significant advance in telephone exchange maintenance techniques in the Australian Post Office. Pettersson (Ref. 1) gives this description of the equipment and its first installation:—

> A.D.R. equipment converts the comprehensive supervisory information generated in crossbar exchanges to a form suitable for telemetering, and transmits this information to any desired location. The first exchange completely equipped with A.D.R. equipment was brought into service at Ingleburn, N.S.W., in December, 1965. Ingleburn, a non-staffed 1600 line A.R.F. 102 crossbar exchange, is situated on the periphery of the Sydney E.L.S.A. area and the supervisory information is telemetered to control and analysis centres in Sydney, some 27 miles distant. Telemetering and exchange control is performed, using a standard 50 baud telegraph channel.

The traffic route tester (T.R.T.), in various versions, has been in use in A.P.O. telephone exchanges for several years. It is a robot test call maker which can register the number of failures versus the number of attempted calls as a measure of grade of service or, when a call fails, hold the call and sound an alarm permitting tracing of the call and isolation of a fault.

Coupling the remote control facilities of the A.D.R. with the functions of the T.R.T. offered advantages, particularly at unstaffed or partially staffed exchanges. The concurrent installation of both equipments at Ingleburn, therefore provided an opportunity to investigate the possibility of coupling them to permit control of the T.R.T. from Liverpool, the nearby staffed exchange.

Two main functions are required to make remote control possible — the transmission of commands from the staffed exchange to the remote equipment, and passage of information back to the staffed exchange from the remote end. Thus the equipment to be described in this article was developed as an interface between the A.D.R. and the T.R.T. allowing passage of commands and fault information between them. It has been called a Translation Relay Set (T.R.S.). It should be noted that controlling the T.R.T. is only one of the functions of the A.D.R., others being transmission of alarms and crossbar throwout information. An identifier stage in the A.D.R. causes allotment, with due priority, to the function requesting transmission.

TRAFFIC ROUTE TESTER

To understand the functions of the T.R.S. it is necessary to appreciate the salient points of the particular type of T.R.T. for which it is designed. In the Telephone and Electrical Industries T.R.T., the type installed at Ingleburn, calls can be made from up to 95 lines which are broken into four sections of 24, controllable by 'A Section Cancel' buttons. Calls may be made to Answering Relay Sets in the Distant Exchange mode or to the same 95 local numbers as used for the calling parties, also controlled by four 'B Section Cancel' buttons. In the Distant Exchange mode the called party numbers can be set by rotary switches on the control panel of the T.R.T. or by strapping a program of calls onto plugs. A Sodeco counter-printer is used to print out information when a call fails.

* Mr. Harris is Engineer Class 2, City Exchange Service Division, N.S.W.

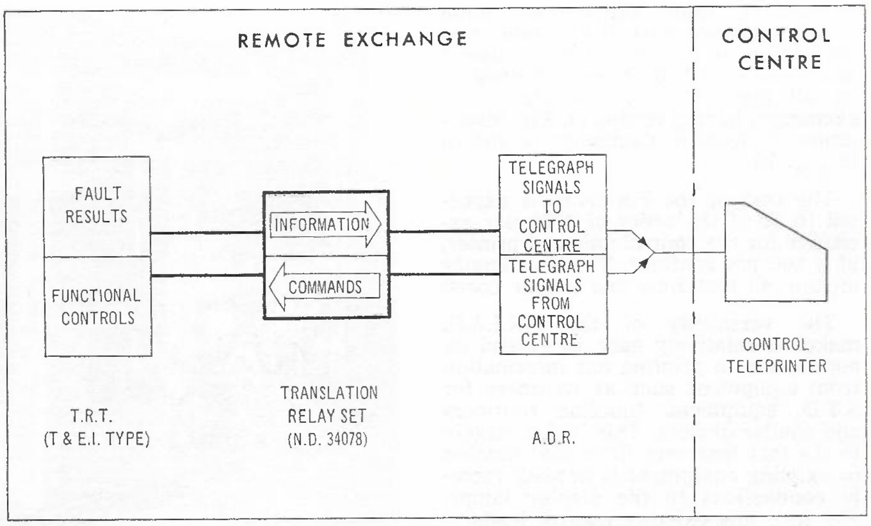

Fig. 1 — System Layout for A.D.R. to T.R.T. Translation

TRANSLATION RELAY SET

The T.R.S. provides a coupling between the A.D.R. and the T.R.T. It converts telegraphic commands from the controlling exchange via the A.D.R. into a form suitable to the T.R.T. and it arranges fault information into a suitable format for telegraphic transmission (from the T.R.T.) via the A.D.R. back to the controlling station (See Fig. 1).

COMMANDS

Commands may be sent from the control teleprinter via the A.D.R. into the T.R.S. thus controlling certain functions of the T.R.T., as below. The A.D.R. converts the telegraphically coded command into a 500 msec. earth pulse on an appropriately selected lead, thus operating relays in the T.R.S. which simulate key and relay operation in the T.R.T. (See Table 1 — Table of Commands).

'Mode' Commands: On sending any any one of the following 'Mode' commands, the T.R.T. is turned ON and operates in the required mode until turned OFF locally or by remote 'OFF' command or by completing one thousand calls:—

(a) Local grade of service

(b) Distant Exchange, Strapped Programme, grade of service

(c) Distant Exchange, Strapped Programme, trace

(d) Distant Exchange, Switched Programme, grade of service

(e) Distant Exchange, Switched Programme, trace.

'Off' Command turns T.R.T. off and resets 'total attempts' count relays to zero.

'Reset' Command causes the T.R.T. to continue making calls and is necessary after a printout of 'Call Failure' on a 'Trace' mode at the completion of tracing the fault.

'Interrogate' Command causes a printout. If a call is in progress, the printout will occur at the end of that call.

'Section Cancel' Commands: There are eight commands available to simulate the 'Section Cancel' buttons on the T.R.T. Four for the four A party sections and four for the four B party sections. These provide added flexibility in operating the T.R.T., say, into different parts of the exchange.

PRINTOUTS

The T.R.S. controls the order and format of the information extracted

TABLE 2: ADR — TRT PRINT-OUT FORMATS

(Each print-out is preceded by EXCH. (3 digits) + EQUIP. (3 digits) and is followed by TIME and DATE)

Circumstance	Cadence Pulses 1	2	3 4 5	6	7 8 9	10 11 12 13	14	15 16 17 18	Sodeco Pulses						Dialled Pulses	
	Mode		Total Attempts	+	No. of Faults this 100	A Sect. Cancelled	+	B Sect. Cancelled	A Sect.	A Line No.	Test Seq.	B Sect.	B Line No.	Fault Code	B Party Phone No.	A Party Phone No.
(a) Call Failure	2		536	+	02	1004	+	0000	2	05	17	1	01	04	523 3345	41 7294
(b) Each 100 Calls	3		400	+	05	0200	+	0000	1	02	00	1	01	00	523 3345	39 4283
(c) Interrogate:—																
(i) Call held for tracing	8		122	+	01	0034	+	000	1	20	00	1	01	00	523 6977	27 3104
(ii) Call in progress	1		321	+	00	1000	+	0204	2	13	00	1	02	00	523 7619	523 3091
(iii) Unit "Off"	0		000	+	00	0000	+	0000								

N.B.—If interrogated while a call is in progress and THAT call fails, print-out is similar to (a) above.

from the T.R.T. and passed on via the A.D.R. (See Table 2). It causes certain information, stored internally, within itself, to be scanned and transmitted by the A.D.R. Then the T.R.T. is caused to pulse out, firstly, the equivalent information it normally prints on its 'Sodeco' counter-printer and secondly the phone numbers (in decadic form) of the called and calling parties.

TABLE 1: COMMAND CODES

Function	Command Code	Corresponding Print-out Code if applicable
Cancel Section 1A	ΔA	1000 + 0000
,, ,, 2A	ΔB	0200 + 0000
,, ,, 3A	ΔC	0030 + 0000
,, ,, 4A	ΔD	0004 + 0000
,, ,, 1B	ΔE	0000 + 1000
,, ,, 2B	ΔF	0000 + 0200
,, ,, 3B	ΔG	0000 + 0030
,, ,, 4B	ΔH	0000 + 0004
Note: Any combination of Cancel commands can be sent successively, e.g.	ΔA, ΔB, ΔE, ΔH	1200 + 1004
Interrogate	ΔI	—
		Mode Code
Distant Exch., Strapped Program, Grade of Service	ΔJ	2
,, ,, Strapped Program, Trace	ΔK	3 (or 8 if Held & Tracing)
Local — Grade of Service	ΔL	1
Distant Exch., Switch Program, Grade of Service	ΔM	4
,, ,, Switch Program, Trace	ΔN	5 (or 9 if Held & Tracing)
OFF	ΔO	0
Reset	ΔP	—
N.B.: Δ is the symbol for the teleprinter character "blank".		

The T.R.S. translates these trains of pulses into a code form which enables the A.D.R. to send corresponding telegraph signals to line. The T.R.S. initiates these printouts in three circumstances, namely:

Every 100 calls, call failure, on interrogation by the control station.

This is achieved by placing 50 volts negative potential via 52 ohms on the call A.D.R. lead. When ready to transmit for the T.R.T., the A.D.R. generates cadence pulses sequentially on twenty leads into the T.R.S., thus scanning relay connections to code wires representing in turn, the mode in use, the number of calls attempted since being started, the number of failures in the present group of one hundred calls and which A and B (i.e., calling and called) sections have been previously cancelled. Spaces and plus signs are inserted for ease in reading. Next, the T.R.S. causes the T.R.T. to pulse out a replica of the pulses used to drive its own Sodeco counter-printer. When each digit train is complete the T.R.S. releases a code to the A.D.R. for telegraphic transmission. In that way the A party section and line numbers, the test sequence at which the call failed, the B party section and line numbers and the fault code are transmitted. In order to next printout the phone number of the B or called party, the dialling circuit of the T.R.T. is diverted into the T.R.S. and the T.R.T. is caused to repeat the digits which it had just dialled on the call that failed. During each interdigital pause the T.R.S. causes the A.D.R. to transmit the telegraph code corresponding to the decadic digit dialled. When transmission of the B party number is completed, the T.R.T. is caused to dial the number of the A or calling party. This is accomplished by forcing the uniselector in the T.R.T. which controls the digits to be dialled and which normally lines up with the B party, to line up with the A party. It is thus necessary when wiring the T.R.T. to preserve correspondence of A and B appearances of each line used. If this is done, then if line 13 is calling line 22, after the number for line 22 (B party) is transmitted, the digit uniselector is rotated from position 22 to position 13 and the digits corresponding to line 13 phone number and thus the A party, will be transmitted. After printout is complete the digit uniselector will be returned to the original B party position to preserve continuity of the sequence of calls.

In the Grade of Service modes the T.R.T. is automatically reset after printout and will continue to make calls. In the Trace modes the T.R.T. must be manually reset by command when tracing of the fault is completed.

OPERATIONAL TECHNIQUES

The T.R.T. under remote control can usefully perform most operations that a staffed exchange could undertake, except, of course, local tracing. However, it is very useful to take a daily run of, say, one hundred local calls on Local Grade of Service mode in order to supervise quality of service on internal switching. If a predetermined upper limit of failures per hundred calls is exceeded, a decision may be made to send staff to the exchange to conduct local trace runs on the T.R.T. or to take other corrective action.

Providing the rotary switches on the control panel of the T.R.T. and/or the programming plugs, which set the numbers to be called for the Distant Exchange modes, have been appropriately set on a previous visit to the unstaffed exchange, then a command for Distant Exchange, Switched or Strapped, Trace or Grade of Service may be sent. By thus setting these numbers one may check suspected routes for grade of service or alternatively perform trace by reading the printout of the called number on which failure occurred and arranging for a search over incoming lines from the exchange at the intermediate or terminating staffed exchange for trace tone sent out by the T.R.T.

A monthly network run, in which fifty calls are made to each of twenty or so exchanges scattered throughout the network is required for statistical purposes. This is accomplished quite easily by arranging for an appropriately strapped programming plug to be held at the exchange and inserted once monthly during a routine visit. The run may be thus remotely controlled and results compiled at the controlling exchange.

PHYSICAL DESCRIPTION

The relay set is constructed on a BCH crossbar relay base (six relays high) and contains eight Mix and Genest count relays, one A.E.I. miniature uniselector, forty-four relays and sundry diodes, resistors and voltage dependent resistors. It is connected to the A.D.R. and the T.R.T. by cables and certain modifications are made to the T.R.T. to accommodate this interworking.

CONCLUSION

A prototype of this equipment is working satisfactorily at Ingleburn Exchange near Sydney. The controlling teleprinter is located at Liverpool Exchange where some valuable experience has been gained in supervision of exchange performance from a remote point.

ACKNOWLEDGMENTS

Acknowledgment is made to Telephone & Electrical Industries Pty. Ltd. for use of information on their Traffic Route Tester. The author would also like to express appreciation for cooperation from the N.S.W. Drafting Section and the practical help and advice given by Mr. K. Sullivan of Ingleburn Exchange and Mr. K. Morris of the Country Installation Section.

REFERENCE

1. A. D. Pettersson, 'Automatic Disturbance Recording (A.D.R.) Equipment for Crossbar Exchanges'; Telecom. Journal of Aust., Feb. 1967, Volume 17, No. 1., Page 58.

CHANGE IN BOARD OF EDITORS

At its April meeting the Telecommunication Society of Australia appointed Mr. R. Clark to the vacancy on the Board of Editors caused by the resignation of Mr. C. W. Freeland.

Mr. Freeland became an Editor of the Journal in February 1966 and since that time has actively represented the interests of external plant readers. The Editors record their appreciation of his efforts and wish him well in his new appointment with the Public Service Board.

Mr. Clark, an Engineering Graduate of the University of Tasmania and Engineer Class 3 in the Headquarters Lines Section, has supported the Journal in the past as an author. His appointment to the Board of Editors will allow him to extend his efforts to the wider field of Journal representation on all external plant matters. Mr. Clark's early experience as an Engineer in the Department was gained in the Tasmanian administration and since 1958 he has played a prominent part in many external plant design and planning projects in the Headquarters Lines Section.

TRANSMITTING ANTENNA SYSTEMS FOR THE AUSTRALIAN NATIONAL TELEVISION SERVICE

W. E. BEARD, B.E.E.*

Editorial Note — This paper was presented to the Institution of Engineers, Australia, Conference on Communications in Sydney, August, 1966. It is published with the kind permission of the Institution.

INTRODUCTION

The Australian Government's plans to provide the Commonwealth with an efficient television coverage have developed rapidly since the first stations commenced transmitting in 1956. When the fourth phase of expansion is completed (which should be by the end of 1966 except for two difficult areas in North Queensland), there will be in service a total of 38 transmitters of 100 kW e.r.p., and one of 5 kW, radiating the national programme, as well as 43 commercial stations. It is estimated that these stations will cover 91 per cent of the population, with dual national and commercial services in most areas.

Transmitting facilities are provided and operated by the Postmaster-General's Department on behalf of the Australian Broadcasting Commission, but during this fourth expansion phase (which provides for 20 national and 15 commercial stations) the Department has undertaken to share basic facilities with commercial stations, and so the development of national and commercial services has become closely integrated.

Provision and maintenance of the antenna systems are included among the responsibilities of the Department, and this paper outlines its experience in handling the technical aspects of their provision and commissioning, with special reference to some of the more unusual problems.

HISTORY

By Government decision, the Australian Television Service is confined to transmitting on 13 V.H.F. channels in Bands, I, II and III. The Australian Broadcasting Control Board is charged with the responsibility of providing, from these 13 channels, an efficient frequency plan which will permit the establishment of a dual national/commercial service to the populated parts of the Commonwealth, including capacity for some additional future services in each area, consistent with a low level of mutual interference.

The map in Fig. 1 shows that the television services are concentrated within 200 miles or so of Australia's

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Fig. 1 — Location of National Television Stations.

eastern and southern seaboards. In some areas, particularly along the relatively highly populated coastal region of New South Wales, television services are very concentrated. Consequently, the A.B.C.B. has provided for directional radiation patterns and mixed polarizations to limit interference. On Band I generally, due to the incidence of long-distance propagation by sporadic E-ionization, the Board has found it advisable to set limits on above-the-horizon radiation in specified directions.

In pursuing its responsibility, the A.B.C.B. has considered it necessary, during the very rapidly developing third and fourth phase of television expansion, to specify closely each station's radiation patterns to conform to its overall frequency plan, and to provide for substantially identical coverage from the co-sited national and commercial transmitters. Therefore the Department has, as its starting point for establishing each antenna system, the radiation pattern specification (horizontal and vertical) provided by the A.B.C.B.

The first two phases of television expansion were confined to capital city areas of the six States. Here the A.B.C.B. specified omnidirectional patterns with horizontal polarization and the problems of the Department, insofar as antenna specifications were concerned, were generally straightforward. The provision of the antenna systems and their integration with the supporting structures was undertaken by the contractors responsible for providing all transmitting facilities.

With the third phase of television development, which provided transmitters for country areas (including Canberra), came the first of the directional patterns and vertically polarized transmissions. At the same time, for reasons of economy and efficiency, the Department placed individual contracts for the major items of plant equipment and took upon itself the detailed integration of all facilities. This brought about the setting up of a specialist group to handle all aspects of the design and provision of the outdoor plant, i.e. antennas, feeders and towers.

During the latter period of the third phase and throughout the fourth phase,

TABLE I

Installation Phase	Manufacturers	Total No. Supplied	Station	Technical Specifications: Channel	Band	Pattern O = Omni D = Directional	Dual or Single Channel	Polarization
1	Maroni WT Co. Ltd. (U.K.)	2	Melbourne Sydney	2 2	I I	O O	S S	H H
2	Marconi WT Co. Ltd. (U.K.)	3	Brisbane Adelaide Perth	2 2 2	I I I	O O O	S S S	H H H
3	Rohde & Schwarz (W. Germany)	1	Hobart	2	I	O	S	H
	Marconi WT Co. Ltd. (U.K.)	2	Bendigo Orange	1 1	I I	D O	S S	V V
	Rohde & Schwarz (W. Germany)	3	Canberra Launceston Lismore	3 3 6	II II III	O D O	S S S	V H H
	Siemens & Halske (W. Germany)	2	Ballarat Newcastle	3 5	II II	D O	S S	H H
	Co-El (Italy)	3	Latrobe Valley Wollongong Townsville	4 5A 3	II — III	D D D	S S S	H H H
	Denki Kogyo (Japan)	3	Shepparton Toowoomba Rockhampton	3 3 3	II II II	D D O	S S S	V H H
4	A.W.A. Ltd. (Aust.)	9	Bunbury Maryborough Tamworth Mildura Mt. Gambier Northam Taree Albany Dubbo	5, 3 6, 8 7, 9 4 1 2 1 2 5	II III III II I I I I II	O D D D D O D O D	D D D S S S S S S	H V H H H H V V V
	R.C.A. (Aust.) with Co-El (Italy)	8	Albury Pt. Pirie Wagga Grafton Swan Hill Warwick Bega Broken Hill Cairns (Interim)	1 1 0 2 2 1 8, 11 2 9, 10	I I I I I I III I III	D O O D O D O D D	S S S S S S D S D	H V H H V H V V H
	Rohde & Schwarz (W. Germany)	1	Griffith	7, 9	III	O	D	H
	Furukawa Co. (Japan)	1	Mackay	4	II	D	S	H

another significant development took place — the sharing of facilities with commercial stations. This happened largely because of the high cost of establishment of the stations at the difficult inland sites, coupled with the relatively low financial returns from the smaller population coverage. The Department and the individual commercial companies, both seeing the economic advantages, now share almost universally the mast or tower at each new site. In most cases, they share the building accommodation and internal plant equipment such as emergency power, monitoring facilities and test equipment, and in a few cases the antenna itself is shared, as the channel allocations permit. The technical advantages of co-masted antennas are further encouragement for the Department to enter into sharing arrangements.

PROCUREMENT METHODS

The Department relies heavily on the antenna manufacturing industry to design and supply the antenna systems, since it does not have the resources to undertake the development of the varied range of designs that is needed. Technical specifications are written into a schedule of equipment which is issued with invitations to tender, whereupon competitive tenders are examined for price and performance, and contracts are arranged accordingly.

This method of procurement has proved to be completely satisfactory and has efficiently provided all the antenna requirements during this rapid expansion period at a reasonable cost.

Up to the present time, the Department has installed, or has contracted for, antennas from the manufacturers, and with the characteristics listed in Table 1.

TYPICAL INSTALLATIONS

The antenna systems and the supporting structures are supplied to the Department on separate contracts, and it is advantageous if the antenna performance is not governed by the detail of the supporting structure. The screen backed dipole panel does largely meet this requirement and so it has been almost universally adopted by the Department as the basic antenna building block on all frequency bands. A typical panel is illustrated in Fig. 2 and a full array is shown in Fig. 3. Almost every antenna now installed for the National Television Service is an array of screen backed dipoles, arranged around a square support column, and tiered vertically to the required height. This height may vary from 65 to 150 ft. depending on channel allocation and radiation requirements. Except for one installation, all four faces are fitted with the same number of vertically spaced panels, but a limited degree of slewing of the panels is tolerated wherever it is dictated by the required horizontal radiation pattern.

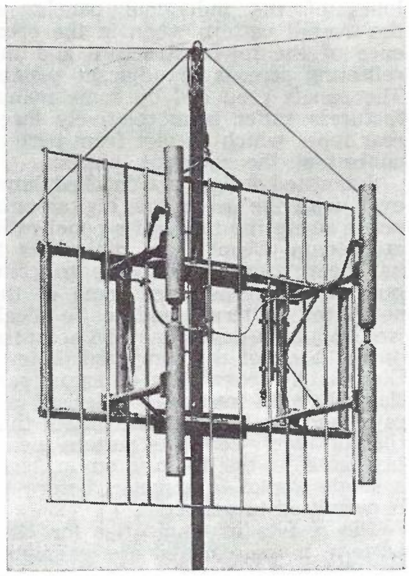


Fig. 2 — Typical Screen-Backed Dipole Panel — Band II.

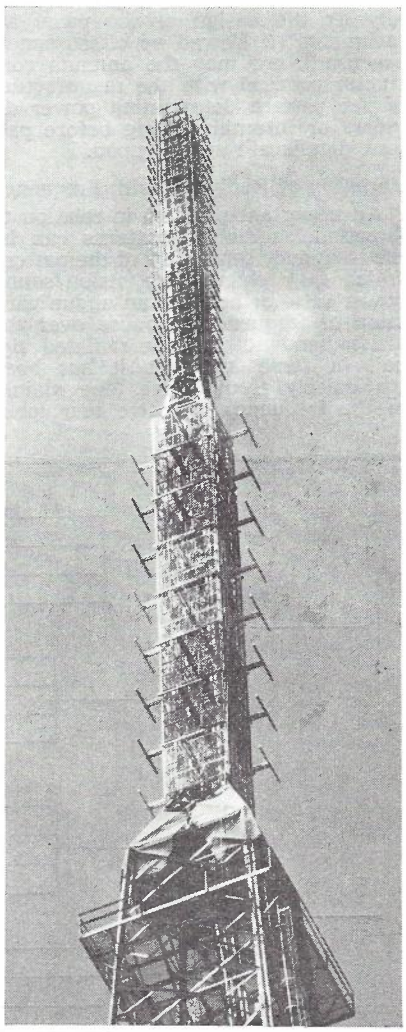


Fig. 3 — Rockhampton Television Station — Antenna Systems.

The antenna is divided into an upper and a lower section, each fed by a separate feeder as a security against an antenna or a feeder fault which may otherwise put the station out of commission. The two sections are not necessarily identical, but the aim is to make them equivalent in performance if possible.

The effective radiated power (e.r.p.) averaged over the horizontal plane is usually 100 kW. Transmitters on Bands I and II deliver approximately 20 kW peak vision power to the feeders and Band III transmitters deliver 10 kW so that the antenna gains are approximately 5 and 10 respectively, after deduction of feeder losses. The array heights are arranged to provide the required antenna gains, consistent with realization of the specified vertical radiation patterns. Approximately half the installations will have directional patterns in the horizontal plane, for which the maximum e.r.p. might be typically 300 kW. Standardisation of directional patterns has not been adopted, each antenna having been designed to the requirements of its service area. For the 33 antenna systems provided in the third and fourth expansion phases, no two combinations of antennas and support structures are identical.

Each of the fourth-phase antenna systems is required to share its supporting structure with a commercial company's antenna system. Wherever practicable, the antenna system itself is shared and is designed to carry the full power of both the national and commercial transmitters and to meet the specified impedance characteristics on both channels. The elimination of echo ghosts, which are apparent when two towers share a hilltop site, is an important engineering incentive toward sharing a single structure.

ANTENNA SPECIFICATIONS

A significant characteristic of Departmental specifications is the expressed preference for the screen backed dipole array mounted on a square support column, as discussed above. This arrangement is preferred for the following reasons:—

(a) It provides an accessible and safe structure for housing the antenna feed system, which the Department's technicians and engineers (who are generally not skilled riggers) may service efficiently and safely.

(b) A large aperture is required for the efficient realization of directional patterns, which have been specified for half the installations, and the large number of feed points in this type of array permits good control of the horizontal and vertical radiation patterns by a suitable distribution of current amplitudes and phases around the four faces and along the vertical aperture.

(c) The antenna performance is required to be independent of the support structure detail and this system largely meets this requirement because of the inbuilt reflector screens.

(d) The antenna performance is largely amenable to office analysis and so the Department is able to check the design more easily.

The advantages, except for the first, are not so apparent when an omnidirectional pattern is specified, and in general the main disadvantage in this case is the high loading on the supporting structure which leads to higher structure costs. However, it has been the Department's experience that this type of antenna system is just as cheap as, if not cheaper than, other tendered types of omnidirectional antennas such as super-turnstiles, slotted cylinders or arrays of dipoles on a specialized support structure. Possibly cheaper manufacturing costs are involved.

Although not expressed in the specification, the Department has a preference for panel arrays using full-wave radiators rather than half-wave dipoles, particularly where horizontally polarized directional patterns are specified. The wider aperture of the full-wave radiator panel leads to better control of the pattern and generally it has been proved that the impedance bandwidth is greater also. Full-wave radiator panels can be designed to cover a whole band rather than just a single channel, as is usual for half-wave dipole panels. Whilst this is of advantage to the contractor, it is equally of advantage to the Department, in that field adjustment is easier. This full-wave design is essential for dual-channel working now adopted for six of the installations. Again, the disadvantage is the generally higher wind load of the full-wave panel, which on Band I frequencies might outweigh the other advantages, particularly where omnidirectional patterns are specified.

EXAMINATION OF DESIGNS

When tenders are submitted, and during the course of the contract, the Department examines critically the offered antenna design for its electrical and mechanical features. Horizontal and vertical radiation patterns, electrical impedance characteristics, structural strength, feed system arrangements and durability are all considered. Since the antenna support structures are usually designed to meet the requirements of the antenna designer and are relatively more expensive items, the wind load of the antenna system, which largely influences the cost of the structure, becomes an important factor in the assessment.

HORIZONTAL RADIATION PATTERNS

Calculations

The horizontal patterns are not so easy to calculate, nor are the calculations as reliable as the vertical pattern calculations, because it is difficult to estimate the influence of the rear lobes of the individual panels on the overall pattern when in the presence of the tower structure and the reflecting screens of adjacent panels. The panels produced by some manufacturers suffer from relatively large rear lobes which detract from perfect control of the radiation pattern.

Submitted designs are checked, however, with the use of the digital computer, using the tenderer's panel radiation data. Despite the difficulties it has been found worthwhile to compute the patterns since some of the submitted patterns tend to be idealised. Whilst a design may be accepted on the basis of the computed pattern, there is the possibility of error, particularly with vertically polarised arrays, and the Department insists that the contractor conducts pattern measurements in the factory on at least a single tier of four panels before he is permitted to deliver.

The results of single tier (or bay) pattern measurements are examined in relation to the panel feed system design, to see the effect of the vertical stacking arrangement on the overall pattern, before the pattern is approved. The tower contractor may not finally fix the design of the panel attachments (if slewed or offset panels are used), nor may the antenna contractor proceed with the manufacture of the pattern determining power dividers or internal cabling before pattern details are agreed upon.

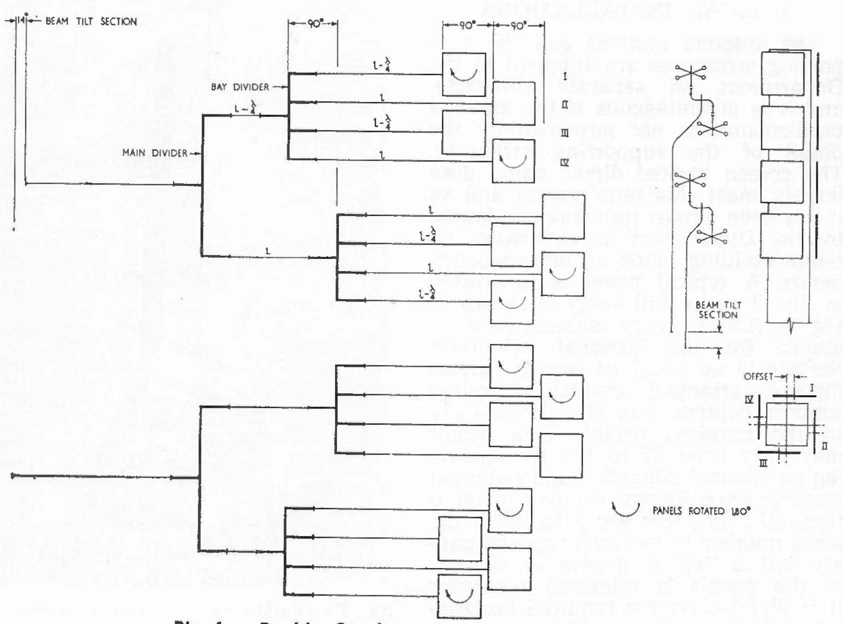
Variation of Radiation with Frequency

An important problem in relation to directional radiation patterns can be the frequency sensitivity of the pattern which may change the vision/sound power ratio or produce an undue variation of frequency response over the vision bandwidth of the radiated signal. In some instances it has been particularly troublesome, due mainly to the frequency sensitive rear lobes of the radiator panels. The Department has laid down a maximum departure of 1 db in the directivity in any direction as between the vision and the sound frequencies, but on occasion it has been forced to accept as much as 2 db after strenuous and unsuccessful efforts to gain an improvement. Usually in these cases, however, there is a choice of possibilities and the Department has either been able to relax the restrictions on the basic shape of the radiation pattern, or to arrange for the worst departures to occur at azimuth angles where the population density is low. These departures occur mostly at pattern minima, which are expected to be deeper on the single bay test array than on the full array, where slight geometrical and electrical variations throughout the antenna system would tend to round out the pattern troughs, and reduce the departures in a practical installation.

Effect of the Panel Feed Arrangements on the Radiation Pattern

The design of the feed system has an important influence on the overall radiation pattern, for whilst techniques may be adopted to provide the maximum degree of impedance compensation, they may have a detrimental influence on the radiation pattern. In other cases, the feed system may be designed to improve the overall pattern over that of a single bay of panels.

For example, many antenna systems (particularly omnidirectional systems) have the panels in each bay fed in phase rotation, or, for a four-sided structure, in phase quadrature. Phase rotation is achieved by a suitable arrangement of the lengths of the panel feeders. A typical feed system is shown in Fig. 4. This system produces a very good impedance match at the power divider which will be discussed



Rig 4 — Double Quadrature Antenna Feed System.

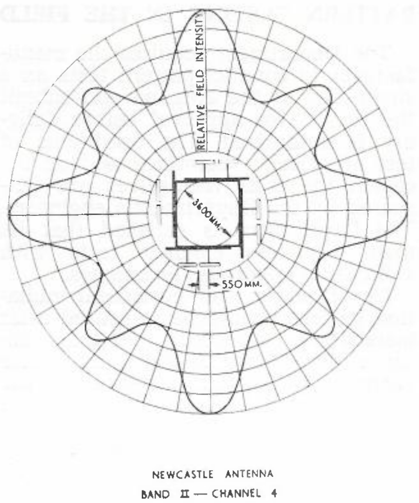


Fig. 5 — Omnidirectional Radiation Pattern Produced by Quadrature Feed and Offset Panels.

later, but the pattern will be distorted from that of an in-phase array. The distortion is largely corrected, as shown in Fig. 5, by offsetting the panels from the centre-lines of the support column in a clockwise or an anti-clockwise direction, depending on the sense of rotation of the fed phase. The result is that the pattern is corrected at the peaks which occur at every 45° of azimuth, leaving two asymmetrical minima in each quadrant. Typically the phases of the four panels in a bay are 0°, —90°, —180°, —270°, at vision carrier frequency, and the pattern is skew symmetrical about a major axis of the support column cross-section. However, at the sound frequency there is a progressive shift in phase as we proceed around the support column, which causes a pattern change, particularly in the fourth quadrant where the phase departure between the adjacent panels is greatest.

To overcome this problem, which is more important in dual band working, the Department has sometimes required the panels to be fed in the following manner, which minimizes the variation; viz. by setting cable lengths to produce the phases 0°, —90°, 0°, —90° and the sense of the feed to the third and fourth panels is reversed, usually by reversing the panels or their associated baluns. As a further compensation, the array of panels on two opposite faces of the support column are fed at constant phase (apart from the phase departures dictated by the needs of the vertical radiation pattern) and the panels on the perpendicular pair of faces are fed with alternately leading or lagging phase quadrature through the array height. The radiated wave is corrected in phase by the appropriate alternate reversal of the panels. With an even number of bays, the horizontal pattern is thus made more nearly symmetrical and has a smaller dependence on frequency.

Whilst quadrature feed in each bay is conducive to a better impedance match of each bay and of the whole array, it must be used with proper attention to the effect on the radiation pattern. For instance, in each bay the admittances presented by adjacent identical panels (which are fed in phase quadrature) to the bay power divider are reciprocal, and depending on the conductive component of the admittance in each branch at this point, the power will divide accordingly. If the panels themselves are not perfectly matched to their branching feeders over the channel band, then the power will divide unequally at the junction at some frequency and an elliptical pattern may be produced rather than a (nominally) circular one. The ratio of the axes of this ellipse will generally change with frequency and the radiated signal will vary accordingly. For example, a pair of panels with impedance reflection coefficients of 10 per cent would create a power division ratio of 1.2/0.833 or 1.44/1 instead of 1/1 and there could be as much as a 3 db variation in directivity on the pattern axes over the channel band. The Department requires that panels be matched quite closely to their nominal impedance values over the channel band to prevent the occurrence of poor vision sideband frequency response in the radiated signal, and a panel impedance reflection coefficient of 2½ per cent is generally sought in the absence of any compensatory measures.

This problem may be overcome by the use of double quadrature feed, where the power dividers in adjacent bays are displaced in time phase by 90°, again by a suitable arrangement of feeder lengths. In this way, the power division ratio of any two adjacent panels in a particular bay, is reversed in the adjacent bay and the elliptical pattern distortion is compensated. The other advantages of double quadrature feed are discussed in relation to antenna impedance.

VERTICAL RADIATION DIAGRAMS

Computations

Designs submitted by tenderers are accompanied by the data concerning the power and phase distribution over the vertical aperture. The Department generally requires each quadrant to have the same distribution of power and phase, and the assumption is made that the vertical pattern is constant at all angles of azimuth. This is not strictly correct but the error is considered to be small. From the given data, the vertical radiation pattern is calculated on the digital computer and the average gain and e.r.p. of the array are automatically derived also, by integration of the vertical pattern.

The average radius of the horizontal pattern is also computed by integration of the horizontal radiation diagram, and this is equivalent to the average e.r.p. as calculated by the vertical pattern integration. From this figure, the e.r.p. at any azimuth angle may be obtained by scaling the horizontal diagram, and so the precise amplitude of the horizontal diagram is established. These computations are carried out at both the vision and the sound carrier frequencies in each channel.

Beam Tilt and Null-Fill Requirements

In general, the vertical radiation pattern is specified to have a small amount of beam tilt and a certain degree of null-filling at specified angles of depression, according to the requirements of the service area. Beam tilt is specified to put the peak of the radiated lobe into the main service area, and where this is close to the transmitter (such as occurs at Hobart) a substantial tilt, up to 5°, is specified. Also, since the pattern develops a series of minima (or nulls) and minor lobes as higher angles of depression are traversed, it is prudent either to ensure that pattern nulls do not fall into populated areas or to fill out the nulls by suitable distributions of current amplitude and phase over the vertical aperture of the antenna. A typical vertical pattern is shown in Fig. 6.

The main lobe usually covers the service area quite well on Bands I and II, where low-gain antennas are used and in-phase arrays are adequate. It is of benefit, however, to introduce some null-fill to reduce the gradient of the main lobe at high angles of de-

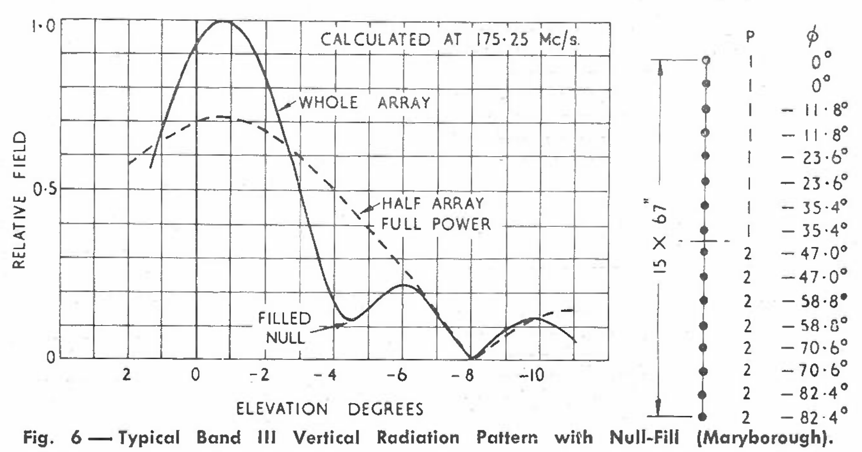


Fig. 6 — Typical Band III Vertical Radiation Pattern with Null-Fill (Maryborough).

pression because of the high frequency sensitivity of the pattern as the first null is approached.

Null-Fill Problems

Special null-fill problems have been met on some low band antennas, a particular instance occurring at Canberra. This antenna had a severe null-fill problem because the close-in service area was surrounded by nearby hills and the A.B.C.B. was anxious to reduce the "ghosting" effects of reflections from the hill slopes.

The specification called for 50 per cent null-fill at 10° depression and only one tendered design met this condition with the requisite gain. Unfortunately, the severe upward beam tilt of the upper antenna half in this design produced a null in the service area when a fault condition required the lower half to be switched out of service. The design has now been changed to an in-phase array and only one half is used at a time, the other acting as a standby. The overall gain is some 15 per cent lower than specified but it could be improved and the null-fill requirements could be met if a small fraction of power could be fed to the standby half. The costs and the labour effort required to effect this change have not been warranted in view of the large number of new installations requiring attention. Since the coupling between the half-antennas is not negligible and could affect the predicted result, special measurements must be undertaken before amendments can be specified.

Null-fill becomes comparatively more difficult to meet on Band III antennas, particularly on those with highly directive patterns and vertical polarization, which require a large vertical aperture and therefore a narrow beam. Whilst some natural null-fill occurs at high angles of depression due to the different path lengths of the radiation from the top and bottom of the antenna to a receiving location, there are difficulties at moderate angles at some sites. A special problem of this nature occurred at Maryborough where the null-fill specification and the gain requirements were in conflict.

The adopted design placed the first pattern null just beyond 5° depression angle and, first of all, an accentuated beam tilt was necessary to meet the pattern specification. This is a dual-band antenna and the inward movement of the null at the top of the upper channel due to the sharpening of the main lobe would have threatened a departure from the pattern specification. A technique which has been adopted in such cases is to feed the lower half of the antenna through an extra half-wavelength of feeder and to correct the phase of the radiation by reversing the sense of feed to the panels, or by using a main power splitter that produces out-of-phase currents to the twin feeders. Since at the null angle the signal path lengths (cable path plus space path) to a distant observer are equal for both antenna halves, the null angle does not change with frequency, but the centre of the main lobe depresses slightly as the upward frequency change causes the lobe to narrow. The worst departure of radiated signal with a change of frequency now occurs at the horizontal (or above) but since the vertical pattern gradient is low here, the percentage change in radiated signal is comparatively small, and well within acceptable tolerance. This technique may be adopted also for those Band 1 antennas with high apertures and relatively high bandwidth/centre frequency ratios.

Above-the-Horizon Radiation

The vertical radiation patterns specified by the A.B.C.B. for low-band antennas impose severe restrictions on above-the-horizon radiation, and special measures have had to be taken to meet these requirements. Briefly, the method is to produce some beam tilt together with a sharpening of the main lobe and a power and phase distribution which reduces the levels of the upper side lobes, especially within 15° of the horizon.

The sharper main lobe has been obtained by using a higher aperture. Normally the higher aperture would require more panels, and this would be an advantage because of the added control created by the additional feed points, but the higher antenna cost and the higher costs due to the extra load on the structure caused the Department to seek a solution with the same number of panels as for a normal array. The panel spacing is increased and in some cases is greater than one wavelength, which creates high angle side lobes. These might be considered to be troublesome but experience has not confirmed this. The upper side lobes within 15° of the horizon have been considerably reduced and the specifications have been met quite well in all instances.

The adopted solutions are not necessarily the most efficient and since these decisions were made a computer programme has been developed which is capable of synthesising a vertical pattern, optimised within certain restrictions. Briefly, the programme varies current amplitude and phase angle for each panel and the panel spacing in turn to minimise the departure of the pattern from the specified limits. The range of choice of these variables is limited to avoid absurdities and undesirable power ratios or phasing between adjacent panels. It is certain that this process would have produced better designs than those adopted hitherto, in that unwanted sidelobes and the array heights would have been smaller. The technique has just begun to be used and could be adapted to horizontal pattern synthesis.

PATTERN TESTING IN THE FIELD

The Department requires the manufacturer to conduct pattern tests on a single bay of the antenna and submit the results for approval before delivery is authorised. The conditions of test are closely examined and on occasion the tests themselves are witnessed by the Department's engineers. The Department is satisfied that its main suppliers conduct tests with sufficiently rigorous techniques.

Nevertheless, the horizontal radiation pattern should be measured after installation, wherever possible, because the effects of panel-impedance variations and the presence of the support structure and guy ropes are difficult to estimate.

Pattern measurements are usually carried out by the substitution technique. Typically a mobile receiver (or transmitter) is set up at a particular azimuth angle in the service area and the received signal from the main transmitting antenna (or to this antenna) is measured. A standard antenna of known gain, such as a dipole, set up above the antenna under test is then switched in and the measurement is repeated. The ratio of the measured signal levels is the gain of the antenna. This test largely eliminates the effect of ground reflections on the measurement because of the similarity of the signal paths to the mobile receiver.

A number of measurements are taken at selected points along a radius, sufficiently far out to permit the effects of the vertical radiation pattern to be ignored, and the average of the measured gain figures is the gain adopted for that angle of azimuth. A typical set of results, together with calculated and factory-measured patterns are shown in Fig. 7.

Vertical patterns are not usually tested in the field since a thorough

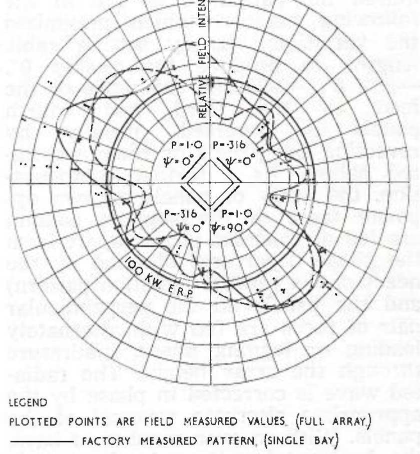


Fig. 7 — Horizontal Radiation Pattern — Calculated and Measured Diagrams (Maryborough).

BEARD — T.V. Antennas

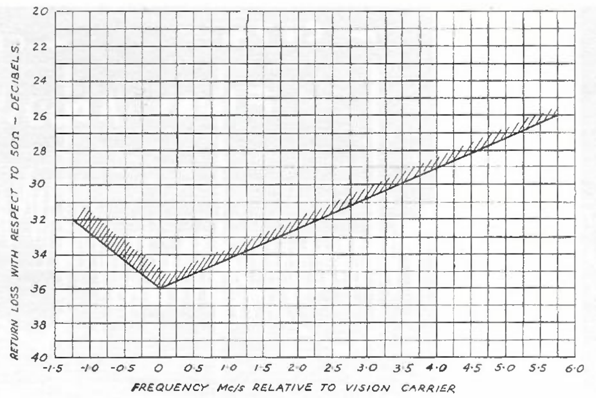


Fig. 8 — Limit of Permissible Impedance Mismatch.

check is made by calculation, and the lengths of the coupling cables and the power divider orientations are checked by physical examination during antenna assembly. It is considered that this method is sufficiently reliable and probably more accurate than field measurements. However, it is usual to seek the angle of the first pattern null (or minimum) and compare this against the calculated angle, as an overall check on the installation.

IMPEDANCE

Specifications

The impedance characteristics of the antenna are considered to be extremely important because of the possibility of reflections in the main feeders and the subsequent "ghosting" effects. The specified impedance characteristic is given in Fig. 8 and has been adopted from the original work of the B.B.C. The Department aims for an impedance reflection coefficient of 1.5 per cent at vision carrier frequency and permits a progressive relaxation towards each end of the band up to approximately 5 per cent. The majority of antennas installed meet this requirement quite well, but there have been some difficulties in notable cases, particularly with the directional antennas where internal impedance compensations are not always available, and with some uncompensated half-wave panel arrays.

Impedance Compensation Techniques

The principle of phase rotation feed is adopted wherever possible to eliminate the mismatch of the individual panels. This is a very powerful technique which may reduce the reflections at a bay power divider to a tenth or so of that at the panel input connection. The main component of the remaining bay mismatch is the resultant of differences between the admittances of pairs of panels, which eventually add statistically at the main divider. However, there are some associated problems, as discussed in the section on horizontal radiation pattern. The technique is less effective for directional radiation patterns owing to the unequal current division at the bay dividers.

For omnidirectional patterns, the technique balances out side/side couplings in each bay and the effects of any symmetrically applied condition causing mismatch, e.g. snow covers on the dipoles or bay/bay couplings. It is not so effective against mismatching due to icing, however, since experience indicates that icing occurs mainly on the windward face.

A refinement to the technique is the use of a "double quadrature" feed system design, as mentioned previously, which also puts the individual bay power dividers in phase quadrature. With this arrangement, the components of the panel reflections which do not pass through the bay divider the first time and are re-reflected at the panel, do pass through the second time because they are then in phase, but are in turn compensated out at the main divider. The technique can be applied with perfection only to an antenna with all tiers in phase, and is less effective when de-phasing is applied over the vertical aperture for beam tilt and null-fill purposes, Also, the array should have an even number of panels. Since many of the antennas consist of multiples of six tiers and a good impedance match is required in each half, double quadrature feed is not used in these cases.

Instead, the three bay dividers in each half are arranged at 60° intervals in phase rotation. Then again, the mismatches at the bay dividers are compensated at the main power divider. Another advantage of this technique is that the single matching stub which is usually placed at each bay divider to permit final adjustment to the overall impedance, is now able to produce impedance changes largely complementary to those of the stubs in the other bays, with the consequence that the range of control of the overall impedance becomes much wider. If the bay dividers are all fed in phase, then all stubs would appear to be in parallel and the degree of impedance adjustment would be considerably limited. This latter facility may be incorporated into a four-bay antenna if the bay dividers are placed with phase lags of 0°, —45°, —90°, —135° instead of 0°, — 90°, 0°, —90°, whereupon the impedances looking into the branches of the main divider are again complementary. As before, any de-phasing over the vertical aperture would detract from the ideal condition. These compensation techniques are especially important when dual channel working is adopted.

For dual channel operation another problem appears. The main antenna impedance adjustments usually take place at the bay power dividers. Due to their electrical separation from the panels via the panel feeders and the change of impedance of the panels themselves from one channel to the other, the stub adjustments are frequency sensitive and generally are not equally effective on both channels simultaneously. In such cases, it is usual to specify the average electrical length of the panel feeder so that together with the change of phase of the panel impedance when changing from one channel to the other, it totals a half-wavelength phase change at the difference freqency between the two vision carriers. In this way the panel impedances at both frequencies are more nearly the same at the bay divider and the stub has substantially the same effect on each channel.

A further adjustment device is sometimes used, especially for dual channel working. This is a "patch section" comprising a short length of transmission line whose inner conductor diameter may be effectively altered and which is placed just above the input connection to each half antenna. This is used as a two (or three) stub matching device to trim any residual mismatch.

Impedance Measuring Techniques

Impedance measurements and adjustments are almost wholly carried out with the test instruments at the station end of the main feeder. The aim of the adjustments is to reduce the reflections in the main feeders and this is the basis of the adopted measuring technique. It has been called the "Vari-Sweep" technique after the trade name of a swept oscillator which is the test instrument used. A high output level sawtooth-swept r.f. oscillator, is coupled into the main feeder. At the r.f. output connection of the instrument, a detector is bridged across the line and the rectified output is applied to the amplifier of a simple oscilloscope whose sweep is synchronised with the oscillator frequency sweep and is calibrated in megacycles. As the frequency varies, the input impedance to the feeder varies cyclicly at a rate which depends on the feeder length, and at an amplitude depending on the reflection coefficient of the discontinuity. Near end mismatches which may occur, vary at a much slower rate and can easily be ignored, or corrected if required. The amplitude is calibrated by inserting a known mismatch (usually 9.1 per cent) at the far end in place of the antenna, and adjusting the Y-amplifier gain with the aid of a

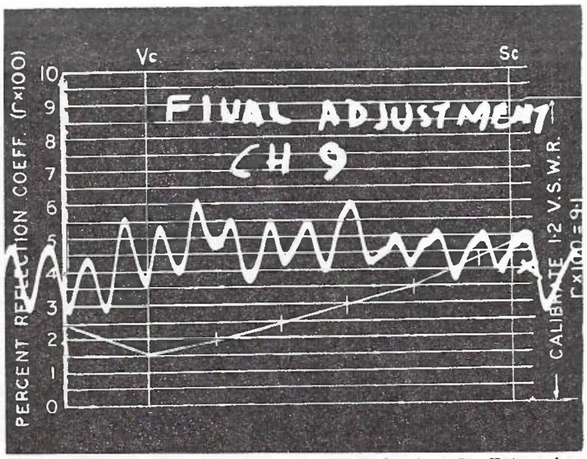


Fig. 9 — Typical Display of Antenna Reflection Coefficient by "Vari-Sweep" Method. (Note — The Reflection Coefficient is given by the Amplitude of the Display Envelope.)

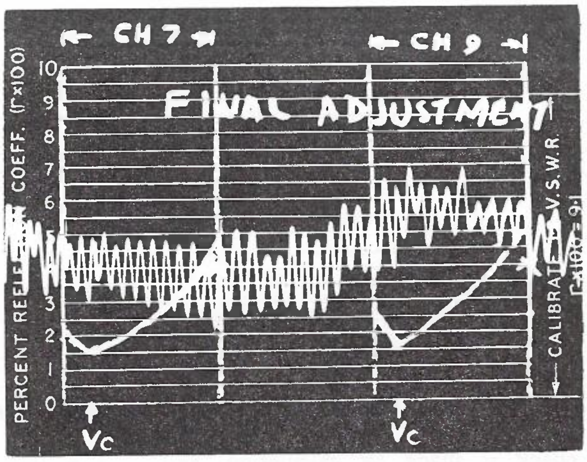


Fig. 10 — Display of Reflection Coefficient of Dual-Channel Antenna — "Vari-Sweep" Method.

calibrated graticule over the oscilloscope face. The vision and sound carrier frequencies are marked on the graticule.

The display is an oscillatory waveform whose envelope height varies in accordance with the change of reflection coefficient over the swept frequency range, as shown in Fig. 9. The effects of feeder losses are eliminated by the calibration process, but, of course, the effects of cable irregularities remain. These are usually small enough to cause no serious difficulty, but if serious they can be detected and their positions approximately located. The antenna mismatch characteristics over the channel band may be seen immediately, and so may the effect of an antenna adjustment. The display may be photographed for record purposes or to provide a temporary reference during adjustment, with the aid of a "Polaroid" camera. The technique permits rapid adjustment to the optimum matching condition, and reflection coefficients can be measured with an inaccuracy of ½ per cent or less. It also permits the rapid location of intermittent and other fault conditions.

For dual channel working the frequency sweep is extended so that the effect of an adjustment may be observed on both channels simultaneously. A special graticule is used when adjusting these antennas, as indicated in Fig. 10.

The Department has found this to be a very powerful measuring technique for matching the antenna directly to its own feeder, and has significant advantages over other techniques. It saves many manhours on adjustments and on measurements which might otherwise be required to be undertaken at the antenna itself and under bad weather conditions. Since the antenna system adjustment seems inevitably to become the last important operation before a station is ready for transmission, it is doubly important to save time on the antenna adjustments.

Field Adjustments

The antenna impedance matching operations generally involve adjustment of the bay power divider stubs and adjustments to the patch sections (if used) at the inputs to the main dividers. Omnidirectional antennas are particularly simple to adjust to a very good impedance match, due to their inbuilt compensations. However, on some directional antennas, tedious adjustments have had to be carried out on the installed arrays, due to the lack of inbuilt compensation in the feed systems and the quite dominating effect of the internal couplings between panels, especially where single or double dipole panels are used. The coupling effects between bays are of the order of 5 per cent, whilst between panels in a bay, they may be about 2½ per cent. These couplings are of the same order of magnitude as the reflections from a matched array and unless compensated out they prevent the attainment of a good impedance performance. Inter-bay couplings between 4-dipole panels are less serious in their effect since the inter-dipole coupling is taken into account in the design of the panel and the centre-to-centre spacing between adjacent panels is greater.

The adjustment technique in such cases is to alter the impedance of the panels individually, usually by "wing patches" or small capacitative stubs applied to the balanced dipole feed lines, or by distorting the feed lines, to produce an impedance match at a common connection between adjacent bays. Fortunately, the coupling between pairs of bays is small enough not to be noticeable in the overall impedance measurement. Final tuning may be done at the bay dividers in the usual fashion, when looking into the main antenna input connection. Quadrature feed in each bay (if used) will permit wing patches in one face to have the complementary effect to the patches on the adjacent face, and good impedance control is available. A bad feature of this situation, however, is the possible loss of control of the radiation pattern due to incorrect power division at the bay power dividers, as discussed earlier, although experience indicates that the effect is not serious.

Similar problems have been met with when using omnidirectional in-phase arrays when no compensation is incorporated into the design. When half-wavelength dipole panels are used, the problem is accentuated by the closer panel spacing (since only single dipoles are placed on a panel) and the relatively narrower impedance bandwidth. Again, tedious adjustments have had to be made to the individual panel dipole feeds to obtain the best match when looking into the main feeder with the "Vari-Sweep" instrument.

RADIATED ECHOES

Twin transmitters are installed at all stations of the National Service, to improve the reliability of transmission, and each may be coupled separately to each half of the antenna system. This was the arrangement for the transmitters installed in the second phase of development but it has proved to cause transmission problems. Rapid phase fluctuations between the carriers emitted by the two transmitters, thought to have been caused by mechanical vibrations or intermittently by faulty components, have set up a vertical flutter in the radiated beam which creates rapid fluctuations in the brightness of the received picture particularly affecting viewers located low down on the flank of the main beam. To overcome this problem, the transmitters are now combined in a diplexer which delivers their combined power into a common feeder, before it is split again at a T-junction into the twin main antenna feeders. In this way, the currents to each antenna half may fluctuate but they are in correct phase at all times and the antenna radiation

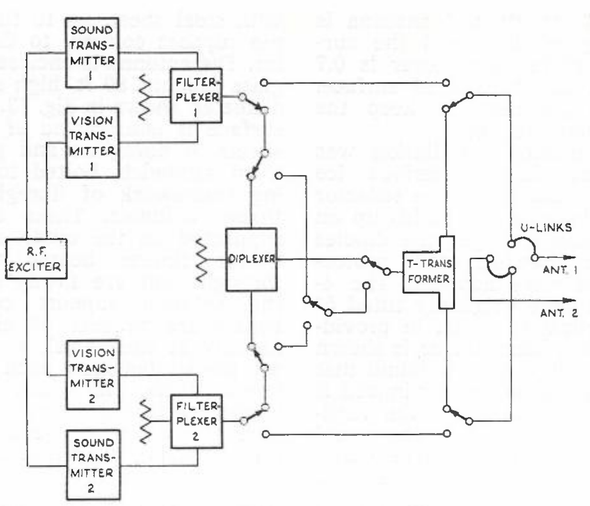


Fig. 11 — Typical Connections for Twin Transmitter, Twin Antenna Television Station.

pattern will remain stationary. The usual arrangement is shown in Fig. 11.

Now whilst this arrangement solves one problem, it sets up others. Echoes from the antenna returning down one of the main feeders will encounter the T-junction splitter and suffer part-reflection, part-transmission through to the common feeder to the transmitters and part-transmission across the junction to the other main antenna feeder. The echo components now returning up the twin feeders are opposite in phase since there is a phase reversal at the junction. If the two antenna halves have absolutely identical impedances and are excited with identically equal currents, all the echo energy appears in the common transmission line, as would occur if a single antenna feeder were installed throughout. However, this balancing action does not generally occur, due to differences in layout of the two antenna sections, due to unequal primary excitation of the two sections, or due simply to the inbuilt imperfections of the impedance determining components of the antenna and feeders. It can be shown that the vector sum of the echoes in the twin feeders as presented at the T-junction passes through to the transmitters, whilst the vector difference of the echoes stays within the twin feeders and in returning to the two antenna sections, excites them anti-symmetrically, and in the same ratio as the primary excitation.

Now the reflected energy which passes through the junction to the transmitters is re-reflected by them and returns through the junction and the twin feeders to the antenna system. Since all these returning echoes traverse the same path as the main signal, they excite the antenna in the same manner and the radiation pattern of the "ghost" signal is precisely the same as the pattern of the main transmission. Thus the echo level in the common feeder is a faithful representation of the magnitude of the "ghost" which might be apparent to the viewer anywhere in the service area. The same is not true of the echo components which remain in the twin feeders. Since they arrive back at the antenna out-of-phase, their radiation pattern is distinctly different to the pattern of the main signal, and the relative "ghost" level is substantially reduced in the plane of the main beam. However, it is substantially increased, relative to the main signal, in the regions of the main signal pattern nulls, and the received "ghost" level may be intolerable.

In general, there is a variation of the feeder "ghost" level as observed over the service area, and monitoring at the station in the feeder or at any one remote receiving location cannot indicate faithfully the "ghost" levels at other parts of the service area. In the absence of special attention this situation could have occurred at Maryborough where part of the service area is illuminated by radiation near the main pattern null, and the 2/1 ratio of excitation of the antenna halves, dictated by the need to fill out this null, is conducive to the production of this "anti-symmetrical" echo owing to unbalanced coupled power between the two halves of the antenna.

Two complementary methods have been adopted by the Department to control these radiated echoes. The first is a method used by others, and reported in the literature (Ref. 2) where the twin transmitters are excited in quadrature phase and the antenna feeder currents are brought back into phase by inserting an extra quarter-wavelength of line in the feeder of the leading phase transmitter before it enters the diplexer. Then the echoes, returning from the transmitter, arrive at the diplexer out of phase because one component has twice traversed the extra quarter-wavelength of line. The echo energy then passes into the diplexer balancing load rather than into the common feeder to the T-splitter. This arrangement is being introduced into some of the Department's twin transmitter installations where it is expected to produce worthwhile improvements in the transmission quality. A notable example of the need for this arrangement is at the Department's transmitter at Orange, where the antenna was damaged by ice build-up caused by failure of the heating system. The impedance altered so much that the reflection coefficient rose to about 20 per cent. After the above arrangements were incorporated into the paralleling equipment, a notable reduction in the level of the re-radiated echo was observed. The improvement may be enhanced by adjusting the length of the common feeder between the diplexer and the T-splitter so that the r.f. phase of the re-transmitted echo is in quadrature with the main signal, which makes the echo least visible.

The other (complementary) method of improving the radiated transmission characteristic aims to eliminate the reflection of echoes at the T-splitter. The T-splitter is replaced by a hybrid splitter (an inverted diplex) with a high degree of isolation between the output ports, and high return loss at all ports. Then no echo energy can pass across the junction to the opposite feeder but will divide into the other branches without reflection. As before, the sum of the echo components arriving at the junction will pass through to the transmitter, but the difference components will pass into the balancing load where they are absorbed. All ports have a return loss of 30 db or so, and second reflections are negligible. The arrangement eliminates the disadvantages of the simple T-junction at the cost of some complexity. These units are also being installed at some of the Departments stations, particularly where dual-channel antennas are incorporated, as a precaution against non-compliance with the antenna impedance specification on one or other or both channels.

Proper application of these techniques may permit a relaxation to the antenna impedance specification, or at least permit a mismatched but otherwise useful antenna to be retained in service until it is convenient to service it, for instance, when icing affects the impedance or when a dipole is damaged by ice. The Department has just recently installed such arrangements in a few of its stations and has not yet had the opportunity to gauge the average improvement in practice or to estimate the effect the technique may have on future antenna specifications.

ANTI-ICING MEASURES.

Mt. Wellington (Hobart)

The first station to be installed at an elevation of over 4,000 ft., where icing is likely to occur during the winter months, was at Mt. Wellington, near Hobart. The very first winter after transmission commenced has proved to be the worst over the

5 years the station has been in service, and very heavy icing at that time caused considerable damage to the antenna and the tower. The weather conditions in this region are such that, at times, winds at a temperature just below freezing point and loaded with super-cooled moisture, may blow across the mountains and deposit the moisture in the form of a heavy glaze ice on the antenna and the structure. At this particular time the ice built up on the reflector screens to over a foot in thickness. It soon thawed when the weather changed and fell in a great slab, estimated by eye-witnesses to weigh over 20 tons, and damaged horizontal members of the tower structure and crushed the main feeders. Other damage, due to the weight of ice, occurred to the antenna dipoles and to parts of the feed system on the tower.

After the damage was repaired, steps were taken to prevent a recurrence. It was decided to heat the antenna system and accordingly "Pyrotenax" heating cables were installed in the tubular members of the reflecting screens. Although heating of the dipoles would have been desirable because of their vulnerability to ice build-up, it was decided to confine heating to the screens only because of the limited capacity of the electrical installation. The power consumption of the 75-ft. Band I antenna is approximately 85 kW, and the surface density of heating power is 0.7 watt per sq. in. of exposed surface. This is just sufficient to keep the heated members ice-free.

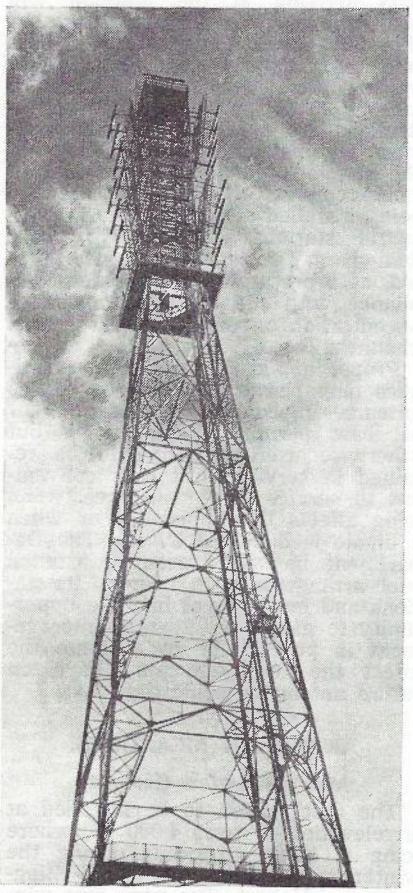


Fig. 12 — Band I Antenna at Mt. Wellington, Hobart, When Panels Were Tilted.

Since the heating installation was completed, no further serious ice build-up has occurred on the reflector screens, but because ice builds up on the dipoles, and damages the dipoles beneath when thawing, other protective measures were adopted. The 4-dipole panels were originally tilted 5° from the vertical to assist in providing the required beam tilt as is shown in Fig. 12, but it was soon found that the ice damage could be minimized if the panels were brought to the vertical position so that falling ice would strike the adjacent dipole more gently instead of one on a lower panel with greater momentum. This change was incorporated, with a slight reduction in e.r.p. at the beam tilt angle, but with a reduced incidence of subsequent ice damage.

At present, a combined temperature/humidity indicator is installed which detects the onset of icing conditions and automatically switches on the heating power.

Mt. Barrow (Launceston)

The problems at Mt. Wellington had a direct influence on the planning for the Mt. Barrow antenna installation. This station is also at an elevation well over 4,000 ft. and is subject to icing conditions. To prevent damage to the structure, it is clad all over with steel sheet, up to the bottom of the support column, to deflect falling ice. The antenna is enclosed in a fibreglass radome, 80 ft. high and 22 ft. in diameter, shown in Fig. 13. The radome surface is constructed of overlapping sheets of fibreglass and polyurethane foam sandwich, bolted to a supporting framework of fibreglass-enclosed timber columns. These columns are supported on the outer ends of cantilever timber beams which pass through, and are firmly attached to, the antenna support column. The beams are in sets of eight, spaced radially at each level, and there is a set placed between each bay of antenna panels. The whole arrangement is flexible and permits a certain degree of flexure of the surface under the prevailing wind forces. The whole project was completed and installed within twelve months of conception, the design and construction being placed under the direction of a consulting civil engineer.

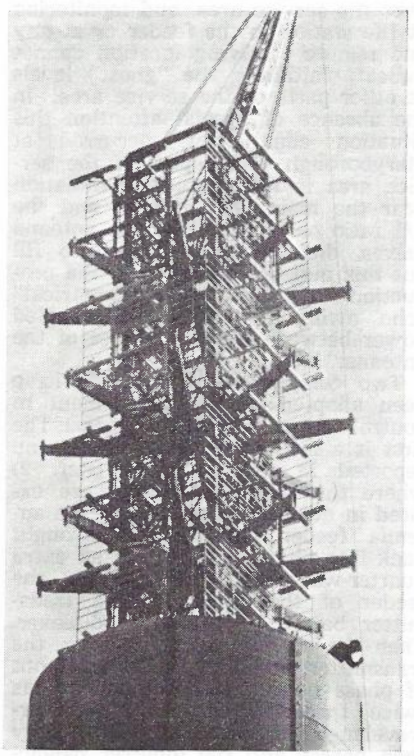


Fig. 13 — Band 11 Antenna at Mt. Barrow, Tasmania — Radome in Course of Construction.

This radome has been very successful in keeping the antenna ice-free and in protecting maintenance personnel from the ice and the almost continuous wind and other unpleasant winter conditions. However, some trouble has been experienced with water penetration to some of the timber members which, unfortunately, have proved to be imperfectly protected by the fibreglass cladding.

Mt. Canobolas (Orange)

This station is 5,000 ft. above sea level and a 180 kW heating installation is built into the radiators and reflectors. The antenna is an array of batwing radiators and associated reflector screens. The original heating system design was unsuccessful in that water penetration caused many failures as soon as winter conditions set in. As a result, ice build-up caused mechanical damage to the antenna and the heating system, and transmission during the winter of 1964 was sustained only with difficulty. Since then, the heating system has been rebuilt to an improved design and the vulnerable antenna feed points and associated stub arrangements on part of the system have been protected with fibreglass surrounds as an experimental measure to compare the two types of protection. In addition, special antenna feeding arrangements have been incorporated into the transmitter design, as described previously.

Brown Mountain (Bega-Cooma)

All the experience with the above stations has been taken into account in planning for the Bega-Cooma antenna installation sited at Brown Mountain in the Snowy Mountains area. The Band III antenna chosen for this station uses steel sheet reflecting screens, which when bolted to the support column, clad it all over and fully protect the inside space from ice penetration when the top is also closed in. The feed system installed inside the support column is quite safe from ice damage and mainten-

ance staff also has full protection. An individual fibreglass shell over the front surface of each panel protects the dipoles and their feeders from ice build-up.
The shells are bolted around their periphery to their reflector screens. Access from inside the support column to the dipole feed points is available through holes in the reflectors under the radome shells. The whole arrangement is economically priced and is expected to be a very successful solution to the icing problem for Band III antennas. The arrangement is illustrated in Fig. 14.

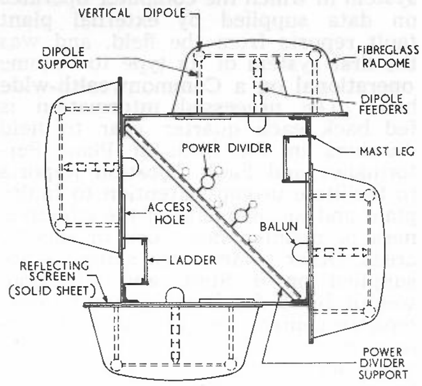


Fig. 14 — Cross Section of Support Column of Bega-Cooma Antenna, Brown Mountain, Showing Ice Protection Radome Arrangement.

CONCLUSION

A number of high-power television transmitting antenna systems have been installed by the Department over the last few years and this paper has concentrated on some of the more important and intricate technical aspects of the Department's work in this field, in the hope that others may profit from its experience.

ACKNOWLEDGMENTS

Any success the Department has had in meeting its installation commitments and raising its standards of transmission has been due to the efforts of a large number of people. Firstly, the antenna contractors, who have ably met difficult delivery targets and have taken the responsibility for the design and construction of the antennas, have had a vital role. Then there is a large body of linemen, technicians and engineers in all States who have installed, tested and adjusted the antennas to a demanding performance specification and a still more demanding timetable, under sometimes extremely unpleasant weather conditions and usually at some personal discomfort and risk.

Acknowledgments are especially due to the author's colleagues, Messrs. D. G. Rodoni and L. H. Parker, for the skill and insight they have brought to the field of television antenna design and testing, and through whose efforts much of the experience recorded above has been gained and formulated.

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TECHNICAL NEWS ITEM

DATA TRANSMISSION OVER COMBINED TERRESTRIAL AND SATELLITE CIRCUITS

The Pulse Systems Division of the P.M.G. Research Laboratories recently conducted a series of high-speed data transmission tests using a terrestrial circuit between Melbourne and Cooby Creek combined with a circuit via the Applications Technology Satellite, ATS-1.

Part of N.A.S.A.'s (National Aeronautical and Space Administration) scientific investigations, ATS-1 is in a synchronous orbit 22,300 miles above the Pacific Ocean. It can be tracked simultaneously by tracking stations at Rosman and Mojave in the U.S. and at Cooby Creek in Australia.

Voice frequency channels, which had been especially equalised for the duration of the experiment, connected the tracking station equipment at Cooby Creek, about 14 miles north of Toowoomba, Queensland, to the Laboratories in Melbourne. The experiment was aimed at evaluating a voice frequency bandwidth transmission link via a satellite and examining its suitability as a transmission path for high speed data by the measurement of circuit distortion, noise, level variations, absolute delay and error-rates at 1,200 and 2,400 bits/second.

Four tests were conducted on each of five consecutive days, three of the four daily tests incorporating 'busy hour' conditions on the terrestrial link. In a typical test a special data signal was generated and modulated into a form suitable for transmission over a voice channel. This was transmitted by carrier system from Melbourne via Brisbane to Toowoomba and by cable to Cooby Creek where the signal was further modulated and transmitted to the satellite. The satellite then returned the data via a separate circuit following the same route back to the Research Laboratories where they were examined for errors.

Two modes are available for the satellite operation. In the Frequency Translation (FT) mode, information is frequency modulated on the UHF carrier and undergoes only a frequency shift in the satellite transponder. In this mode, only one earth station may transmit at any time, however reception may be by any Station including the transmitting Station. In the Multiple Access (MA) mode, information is transmitted 'Uplink' by single sideband amplitude modulation. This method of modulation requires less bandwidth and consequently is more attractive where a number of earth stations require access simultaneously. In the satellite, each received signal is demodulated, all signals are assembled into a composite signal, phase modulated on the UHF 'Down-link' carrier and broadcast to all Stations. To enable satisfactory demodulation of the single sideband signal at the satellite, a frequency control loop is set up which locks the earth station local oscillator to that of the satellite. Due to the long round trip propagation delay, it is difficult to eliminate jitter from this control loop and hence from the received signal.

(Continued on page 192)

COMPUTER APPLICATIONS IN EXTERNAL PLANT

*J. J. HARRISON, B.Sc.**

INTRODUCTION

The recent decade has seen an upsurge in the application of computer and new mathematical or operations research techniques to a variety of complex problems in the telecommunications field. This article briefly discusses the impact that these developments have had in the external plant field generally and outlines some typical areas of application. It then goes on to detail the specific use of a computer technique to establish design principles for the provisioning of main subscribers cables.

GENERAL

The development of digital computers with their great capacity for rapid computation, data processing and information storage and retrieval, coupled with the fact that they can be programmed to perform the simpler repetitive clerical functions, has opened a wide field of application in the external plant area of telecommunications planning, design and operations. At the same time the growing complexity and extent of the A.P.O. external plant network give emphasis to the difficulties of effective control of the network, of optimizing capital investment, of evaluating and integrating new techniques and of setting design standards. These difficulties will not be overcome effectively by the methods of the past, that is by the use of empirical design rules based on necessarily restricted research and study coupled with the limitations imposed by manual methods of processing data and maintaining records. For the future, however, computer techniques give promise of powerful assistance, which is further underlined by the successful and useful application described later in this article.

The computer has obvious potential for the collection, recording and processing of data concerning the external plant network, and additionally can be programmed to supply management with the necessary indicators and statistical information for effective control. In theory at least it is not difficult to visualize the elements of a computer system which would handle all external plant records now kept manually, allocate plant for new requirements or subscribers, produce cable or other plant occupancy statistics, draw attention to portions of the network requiring relief and provide other relevant statistics. In practice this presents a rather immense problem in data processing, particularly as the system must be co-ordinated with other recording needs of the network.

In the mathematical area the computer gives scope for the ready evaluation of complex design formulae. It also opens the way for greater attention in design to cost and performance optimization. This can be achieved either by the detailed evaluation of a large or exhaustive number of possible plans, or by the application of special mathematical or operations research type techniques, to determine the optimum arrangement. In most instances the application of these techniques by manual methods is so time consuming as to be impracticable.

External plant field design is affected to such a large extent by local and sometimes unpredictable factors, that it seems in many applications the use of computer techniques will always need to be heavily tempered by the judgment of an experienced designer. However, the ability to cost and compare numerous alternatives by computer should lead to more informed, and less intuitive judgments. In addition as computers find growing application in the field of recording, forecasting and statistical analysis, it will be possible to refine the input data of design programs to accurately take account of more variables. In the future then it might be expected that the use of computers for recording, control and computational processes will enable advantages to be taken of marginal economies in design by optimizing provision or by enabling the most economic mode of provision to be adopted. For full advantage to be taken of this opportunity an appropriate range of external plant materials and suitable alternatives must be readily available.

AREAS OF APPLICATION

To date there has not been an intense application of computer techniques to external plant problems. The efforts early in the 1960's to optimize the junction networks of the larger cities (Ref. 1) have of course been reflected in continued application of computer methods to the complex problems of optimizing the dimensioning and routing of junction circuits, and this has flowed over to the external plant area of junction provision. However, the local subscribers area surrounding the exchange is yet largely an un-tapped source of possible applications.

In general, applications to date have been of a rather specific and limited nature for example where it has been found necessary for complex studies in order to define design rules or to solve some particular field problem or, on the data processing side, where clear benefits can be foreseen for limited system design and programming effort. In the main the mathematical applications have entailed the development of a mathematical model to describe the specific problem and the use of the great computational speed of the computer to determine the optimum arrangement either by investigating an exhaustive number of possibilities or by the use of other programming techniques.

Typical Applications

The following are typical of the areas and problems to which computer techniques have been applied:—

A.L.F.A. — External Plant Fault Analysis: This is a data processing system in which the computer operates on data supplied by external plant fault reports from the field, and was the first system of its type to become operational on a Commonwealth-wide basis. The processed information is fed back each quarter year to field divisions in the form of Plant Performance and Fault Location Reports to facilitate prompt attention to faulty plant and for oversight of the effectiveness of maintenance work in specific areas. Other summarized statistics are supplied on a State and Commonwealth basis for more general maintenance control, and so that plant performance can be given its due weight when such matters as plant improvement, material design, and changes to constructional practices are being considered. The system is further detailed in Ref. 2.

Determination of Economic Provisioning Periods for Main Subscribers Cables: This is the subject of the latter portion of the article. The study involves the examination of the economics of a large number of cable provisioning plans to determine optimum provision for particular subscribers development patterns and under other variable conditions.

Optimum Inductive Loading of Subscribers Cable Pairs in Rural Exchange Areas: This involved the construction of mathematical models to simulate typical variations in subscriber density and exchange area size. The computer was then programmed to generate an exhaustive series of feasible layouts for conductor gauge, conforming to transmission standards with varying use being made of loading. The variable costs associated with each layout were examined to determine the optimum application for loading.

General Economic Appreciation of Various Methods of Providing Subscribers Services: The approach was similar to that described above, except that the program was very much more complex and wide ranging in that it explored the economics of a number of existing and new techniques in varied combination. For instance only one of the many plans evaluated was the use of a simple transmitter amplifier, coupled say with the application of 2½ lb. conductor cable where possible, with inductive loading on longer lines as necessary. Results obtained from this program are providing useful economic data as background for decisions concerning the optimum methods of meeting transmission standards in subscribers provision.

Review of Spacing Standards for Voice Frequency Loaded Trunk and Junction Cables: The performance of

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loaded cable is affected by irregularities in spacing of coils, in mutual capacity of the cable, in inductance of the loading coils and the effect of D.C. current, by the amount and location of capacitative build out, and the varying interaction of these factors depending on just how they combine in an actual case. A large number of actual layouts were simulated using Monte Carlo techniques and the transmission performance of each one was evaluated by a program of the type described in Ref. 3. This gave a useful impression of the performance likely from the application of a particular set of loading standards. (For further details on simulation and Monte Carlo techniques see Ref. 4).

Economics of Aerial Route Replacement by Cable: This program evaluates for a practical situation the economics of replacing existing subscribers aerial construction by cable. It takes into account such factors as maintenance costs, fault history, subscribers growth rate, and ground conditions for cable laying.

Cable Supply and Stocking: The computer has been utilized to process cable ordering data, and provide statistics of usage. In combination, operations research techniques have been applied to optimize purchasing costs by placement of orders to best advantage between a number of suppliers, and inventory control techniques which will optimize stock holdings are now being investigated. The main elements of this program are fully operational, and output is proving most useful to management.

Layout of Transposition Sections and K-Factor Calculations for Open Wire Trunk Routes: The computer is applied to perform the tedious K factor calculations which give a quantitative measure of pole spacing irregularities and to assist in the optimizing of transposition section layout to achieve a low K-factor with a minimum of alteration in pole positions. The calculations by manual methods are a lengthy operation with optimization very difficult, if not impossible. This is now a library program. (Ref. 5).

Investigation of Higher Frequency Working on Open Wire Trunk Routes: Computations were performed to extend the near end type unbalance versus frequency data to cover working up to a frequency of 300 KHz over an 8 mile transposition section. (Ref. 6).

Cable Crosstalk Balancing Simulation Study: When cable is to be used for junction or trunk purposes, within quad capacity unbalances, and hence crosstalk, are minimised by capacity balancing techniques. This program operates on a normalized distribution curve for capacity unbalances (within quad) for a particular cable quality specified by the standard deviation of unbalance from the mean, and simulates the unbalances which would be obtained for a succession of cable lengths in a field installation. The effects of various balancing standards and techniques are then simulated, and a measure of the crosstalk performance of the end product computed. By simulating a large number of samples it is possible to determine the effects of variations in cable quality, balancing standards and length of circuit.

Lightning Protection for Cable: This application is typical of many others, where the computer plays a minor though virtually indispensable role in the study, enabling the rapid evaluation of complex formulae. (Ref. 7).

OVERSEAS DEVELOPMENTS IN NETWORK DESIGN

The trend for the future might be indicated by progress in the Bell Telephone Laboratories of the United States, where standard computer programs for use by planning and field engineers have been developed. These programs are used as computational tools and are designed to accept as input the same data that the engineer would normally gather for planning purposes. They can generate, design and cost an exhaustive number of alternative plans, or can be used to compare specific alternatives. The techniques are being applied in specific project design for main cable works (Ref. 8), and in long term area planning (Ref. 9). In the former application the engineer broadly describes the alternative plans, but the computer performs the functions of determining conductor gauge requirements and the size and timing of cable and duct instalments, that is, it performs the task of optimizing design for each alternative. Hence the engineer is assisted in the achievement of optimal design, and is provided with a reliable basis for the making of a final decision.

The British Post Office is well advanced in its investigation of the feasibility and economics of a computerized line plant recording and control system. The indications are that the system will be extended to give assistance in the design and layout of subscribers relief. For example in the case of main subscribers' cable the need for relief would be assessed within the computer system and a program would be available to optimize the layout of relief giving the best compromise between factors such as economic provision periods, minimum unusable pairs, conductor gauges and date of exhaustion of pairs to cabinets and other outdoor cross-connection units along the route.

While there is no available evidence that other overseas administrations are operating standard design programs of this type, there is general awareness that external plant design, layout and organisation are potential fields of application. A major deterrent to the development of design programs of the type in operation in the United States is the substantial investment required in terms of programming resources when so many other areas are also capable of fruitful exploitation. In addition if field benefits are to be derived from such programs they must be capable of wide use even by staff without detailed knowledge of computer techniques, and this requires a high degree of sophistication in programming to restrict the demands made on the user.

PROVISIONING PERIOD PROJECT

General

While many of the applications listed earlier are described in detail in the References, there is no fully documented example of how the computer can be programmed to generate and compare feasible provisioning plans which cater for given development data, perform routine economic calculations and carry out such practical tasks as choosing the most suitable duct in which to instal a new cable. The project described in the remainder of this article, while fairly simple in concept, does serve to illustrate these features and give some indication of the practical optimization of which computer techniques are capable.

Provisioning Periods

External plant is normally provided in instalments to meet forecast development. The period of time for which each instalment of plant is designed to last before augmentation is termed the design 'Provisioning Period'. There is a theoretical optimum provisioning period for each situation where plant is being provided to meet future demand, and this is the period which minimizes total value of all costs calculated over a given study period according to a given set of economic costing rules. This study is particularly concerned with deriving optimum provisioning periods for main subscribers cable, but the treatment and many of the factors discussed apply in a general way to other forms of plant provision.

The term 'provisioning plan' will be used to describe the complete sequence and timing of cable and duct installations necessary to satisfy development over the study period which is the period or number of years over which the costs of alternative plans are compared. 'Cable provisioning plan' will be used to refer to the cabling portion of this plan. The initial cable instalment of the optimum provisioning plan is the important one since this determines the immediate commitment.

It has been usual in the A.P.O. for provisioning periods to be determined after qualitive consideration of all the factors affecting each situation, bearing in mind that periods of 8 to 10 years are appropriate on average to main subscribers cables, and periods of 20 years to distribution cables. With these rather arbitrary methods of choosing provisioning periods, the optimization of costs and layout is very much dependent on the experience and skill of the designer. However, the advent of computer techniques gives the opportunity for more precise study of the interacting factors, and for the definition of more adequate design guides. This development of more sophisticated design guides might be considered a first step in the process of applying computer design methods to individual layouts or projects.

Refs. 10, 11, 12, 13 detail a variety of mostly mathematical approaches to the provisioning period problem and are useful for determining the relative influence of the main factors affecting the optimum provisioning period. However, in general, these approaches do not consider the effects of duct and re-arrangement costs and are limited to treatment of linear and exponential growth patterns.

Purpose of Project

This project was undertaken primarily in an effort to set more adequate and precise guidelines concerning provisioning periods, to be incorporated in the standard A.P.O. engineering instructions on main subscribers cable design and layout. The availability of this more detailed information should enable optimum provisioning period considerations to be integrated more confidently with the other factors affecting the determination of cable sizes in subscribers main cable reticulation schemes. This aspect is covered in more detail in Ref. 14.

Use of Computer

A purely mathematical approach to the problem becomes most complex when it endeavours to take account of a wide range of growth patterns and other conditions. The alternative is to determine the optimum provisioning plan by trial and error or other techniques involving the detailed cost evaluation of a very large number of plans. The manual calculations involved in this procedure are extremely, if not prohibitively lengthy, a fact which immediately suggests the use of a computer. This view is reinforced, by the fact that revision of the study will be necessary from time to time to take account of changes in costs and financial policy.

The problem then becomes merely one of programming the computer to generate a series of feasible provisioning plans which will include the optimum one, to perform the necessary economic calculations for each plan in turn, to select the minimum cost plan and to introduce some tests or provide some controls so that as little computer time as possible is wasted in costing plans which are far from the optimum. This does in fact briefly describe the technique employed.

Factors Considered

The factors which have an effect on the determination of economic provisioning periods are:—

(a) The growth rate and pattern of subscribers development.

(b) The structure and magnitude of cable installation and maintenance costs, which are of course influenced by cable conductor gauge.

(c) Cable and subscriber rearrangement costs or any other fixed costs which are incurred at the time of each augmentation.

(d) The standard cable size range, and the minimum practical provisioning period.

(e) The duct costs where they vary with different cable provisioning plans.

Having regard to the purpose of the work, the standard A.P.O. method of performing economic comparisons (see Ref. 15) is adopted and standard lives, maintenance charges and interest rates have been used. The results can claim no greater accuracy than the basic input data, and are very much dependent on the interest rate (5%) adopted for the economic calculations. This emphasises the point made earlier concerning the importance of accurate statistical analysis to determine input data and other parameters, if precise studies of this nature are to yield realistic results. On the other hand use of a computer program does allow parameters such as the interest rate to be varied to gauge the effect on results, and decisions can be made in the light of this knowledge.

A study period of 25 years is employed as this coincides with the standard life of cable in duct, and gives reasonable emphasis to costs in the future having due regard to possible changes in technology and other uncertainties. A longer study period would tend to increase the optimum provisioning period and vice versa.

The principal gauge used for main subscribers cables is 4 lb. per mile, but there is also considerable usage of 10 lb., so that results were obtained for both of these gauges.

The basic mathematical form of the economic computations is outlined in Appendix I which also gives some indication of how the main factors are accounted for. This is enlarged upon in the following sections.

Subscriber Development Patterns

Subscribers development figures are usually supplied in practice at base year, 8 years and 20 years. The pattern of development for a cable reticulation area can take a variety of forms for example:—

(a) Minimal or slow growth initially, accelerating as the area develops, or re-develops towards the latter half of the 20 year period.

(b) High initial rate as area develops, tapering off in later years.

(c) Uniform development near linear.

There can be infinite variation in these patterns and in theory the program could be adapted to accept any required development curve. However, since the results of this study are intended for general application it was decided to consider only three rather simple development curves which approximately reflect the conditions (a), (b) and (c) above, and give a guide as to the relative effects of slow or fast initial growth compared with the linear growth to the same 20 year figure.

Thus for each 20 year development figure the three growth curves shown in Fig. 1 were considered viz.:

(a) Linear growth (Lin.)
Formula:—DEV = DB + (D20-DB) YE/20.

(b) Exponential Growth (Expon.) — where growth at 8 years is 50% less than that achieved with linear growth.
Formula:—DEV = DB + (D20-DB) (Exp. (.095YE) — 1)/5.685.

(c) Logarithmic Growth (Log) — where growth at 8 years is 50% greater than that achieved with linear growth.
Formula:—DEV = DB + (D20-DB) LOG (.2YE + 1)/1.609.

where DEV is development at year YE
DB is development at base year
D20 is development at 20 years

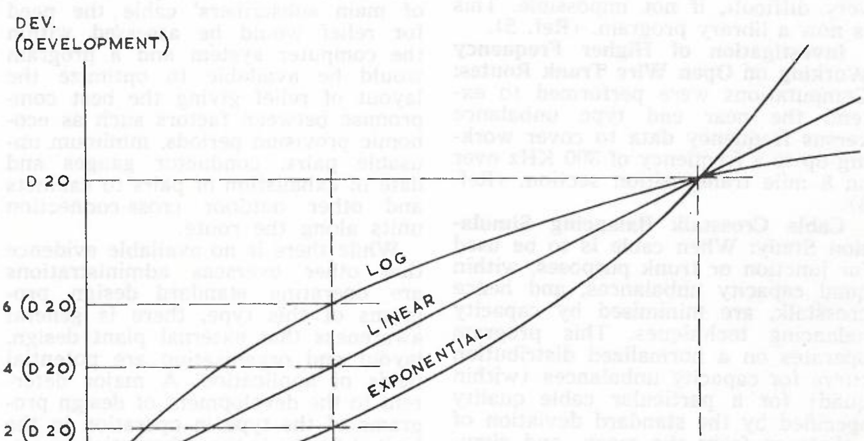

Fig. 1. — Growth Patterns

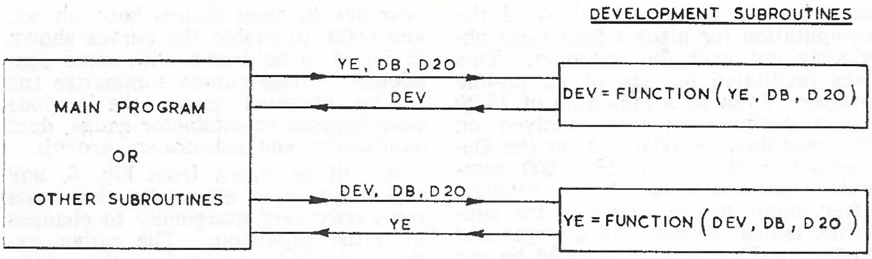

Fig. 2. — Schematic of Development Subroutines

The exponential and logarithmic curves chosen are considered close to the limits of deviation from linear growth which would be generally experienced along a cable route, although this would not necessarily be true for the exchange area as a whole.

In practice subscribers development is usually converted to pair requirements by the application of a factor or the addition of an allowance to cover flexibility or other minor needs. However, this allowance may vary according to local conditions and in this study it has been assumed that the development data represent pair requirements rather than subscibers development figures.

In the computer program the formulae for the curves are written into subroutines such that the main program or other subroutines can call on one development subroutine to determine the development requirement at a particular year and another to determine the year at which a particular development will be achieved. (Fig. 2).

Structure of Cable Installation Costs

The provision costs for large size cable (200 pairs and over) can with reasonable accuracy be written in the form $(A + BP) per unit of route distance (in this case per mile) where A and B are constants and P is cable size in pairs. The constant 'A' comprises the larger portion of the basic costs common to all installations such as planning and administration, transport, time to set up, etc., as well as a certain component of the cost of the cable itself. The term 'BP' allows for an incremental increase in cost proportional to the number of pairs being provided. If 'A' is relatively high there is a heavy penalty associated with each instalment and longer periods are indicated. A high 'B' will discourage advance provision and hence shorten the optimum period.

The main program operates on cost constants, A, B which form portion of the input data, to calculate the capital cost of installation of specific cable sizes, and hence capital recovery and maintenance annuities. The conductor gauge of the cable being installed affects constant 'A' only very slightly if at all, whilst B is altered quite significantly by a change from say 4 lb. to 10 lb. conductor.

Details of cost and other input data are included as Appendix II.

Cable Re-arrangements

In A.P.O. networks, relief is not usually purely additive and generally involves a component of cost for operations necessary to affect subscribers and pair re-arrangements and cut-overs or transfer of subscribers to new pairs at the exchange. The structure of these costs would be expected to be of the form $(L + RS) where R and L are constants and S is the number of units (subscribers or pairs) to be re-arranged. For purposes of this study L is neglected, and each instalment but the first is charged with the cost of re-arranging the number of subscribers equal to half its size. These costs are treated as fixed charges occurring at particular years and are converted to present value on this basis. In instances where relief is planned to be additive only, not involving any changes to existing layout or subscribers pair connections, these costs would generally be negligible.

Re-arrangement costs are independent of route length, whilst other costs are per mile unit and thus increase with the length of cabling. Hence in this general study re-arrangement costs are effectively given their actual weight for a feed of one mile length. For shorter feeds their influence would be increased, and for longer feeds it would be reduced.

Cable Sizing

In theory there would be an infinite number of cable provisioning plans to meet a given development pattern over 25 years. However, in practice the choice in pair provision is limited by the available range of standard cable sizes, and it was decided to limit the search for the optimum cable provisioning plan accordingly. In addition three years was considered the minimum practical provisioning period for subscribers cable even under conditions of fast growth, and plans involving shorter periods than this were not investigated.

The sizing operation and the generation of alternative cable provisioning plans is performed mainly by Subroutine Sizer. This sub-routine operates on:—

(a) The range of standard cable sizes for the particular gauge of conductor under consideration (see input data of Appendix II).

(b) A subroutine which rounds off odd pair requirements to the nearest standard cable size above.

(c) The subroutines governing the development patterns to determine requirements and the timing of relief.

It sets the first four cable instalments to the nearest standard cable sizes above those necessary to provide for development over the first and three ensuing three year periods, according to the particular development pattern under study. The fifth and later cable instalments (if any) are set to a value approximating the optimum cable size assuming linear growth over the period from the end of the fourth provisioning period to 25 years. In each case the year in which each cable must be provided in order to keep demand satisfied is also calculated.

The main program provides for the cable sizes for the first four periods to be systematically increased one at a time so that provisioning plans for each possible combination and permutation of cable sizes over these four periods, are costed at present value.

The elements of Subroutine Sizer are shown in the Program Schematic (Fig. 3).

Duct Availability and Costs

In the A.P.O., main subscribers cables are generally accommodated in ducts of nominal 4in. diameter. The choice of cable provisioning periods of course affects the number of separate cable sheaths to be laid over a given time period, and hence the requirements in duct or conduit accommodation. Thus duct costs will vary with cable provisioning period, tending to decrease with longer periods and vice versa, and it is essential that where duct provision is involved the costs be included in the total cost expression to be optimized, as shown in Appendix I.

There are a number of difficulties in bringing duct costs into a general study of this nature, not the least of which is the wide variation with local conditions and laying methods. In addition the extent to which duct costs will affect the decision on cable provisioning will depend on duct availability along the particular route being considered. For example if adequate ducts are existing such that choice of provisioning period will not affect duct provision costs within the 20 year period, then duct costs could influence the decision little if at all. On the other hand duct considerations would have a rather more profound effect where space is at a premium. Having this in mind, and also to give an impression of the maximum effect which duct costs could have the following three typical conditions were investigated:—

(a) Duct costs ignored, i.e., not a factor

(b) Duct requirements for 25 years installed with first cable

(c) Duct space available for first instalment cable irrespective of size, but ducts required with second instalment to meet remainder of the 25-year cable provisioning plan.

Duct costs together with information concerning the cabling capacity of 4in. ducts, assuming a maximum of two cables, are stored in the computer memory. Subroutine DCOST uses this information to pack the cables of a provisioning plan into ducts in the most efficient manner, and then computes the duct requirements to present value costs of the duct installation as illustrated in Fig. 3.

Each provisioning plan is charged only with the proportion of duct space occupied, e.g., a 4in. duct has capacity for two 600/4 cables, if only one is installed the duct still has spare capacity for 600 pairs or 600/1800 = 1/3 of duct capacity is still available, thus the particular provisioning plan is charged with only 2/3 of a duct. This procedure does not conform to the practical situation but is a means of making some allowance for greater flexibility allowed by the scheme providing a larger surplus in cabling capacity through unused cabling space. This method also enables the duct penalty to be accounted for in a smooth manner, rather than in disjointed jumps which would be the case if duct requirements were computed to the nearest whole number of ducts above, and is more appropriate to a generalized study of this type.

The Main Program

The main program, the layout of which is illustrated schematically in Fig. 3, controls the subroutines discussed under previous headings, performs the cost computations and prints the results.

In a single run the program generates a feasible cable provisioning plan, then computes the present value of all costs for this plan under the three conditions of duct availability. It compares this particular cost with the previous lowest cost obtained for plans with the same initial provisioning period, and retains detail of the lower cost plan. The cable provisioning plan just costed is then modified to yield another feasible plan to be costed. This is done in a systematic manner which ensures that all combinations of cable sizes in the vicinity of the optimum one are examined.

After having exhausted all the feasible plans for a particular 20-year development figure assuming exponential growth, the program automatically steps on in turn to work from the linear and logarithmic curves. Thus for each 20 year figure nine different combinations of duct conditions and development patterns are studied for a particular cable gauge.

The program was written in Fortran A and run on the CDC — 160 — A computer at the P.M.G. Research Laboratories. The definition and cost evaluation of each cable provisioning plan for three duct conditions occupied from six to twelve seconds, and because of the large number of alternative plans to be considered, computational time was excessive. Three switch controls were written into the program, so that the operator could interrupt the sequence and avoid the computation for plans which were obviously not near the optimum. This was facilitated by use of an on-line printer. Even so a minimum of 15-20 hours computation was involved on this machine. A trial run on the Department's Honeywell 1800/200 computer installation at North Sydney, after minor modifications to the program, indicated that with a larger and faster machine this time could be cut to about one-twentieth, that is to around 1 to 1½ hours for the full study.

The Results. (See Fig. 4.)

By the end of a run the computer will have determined, for each particular set of conditions with regard to subscribers development, ducts and cable gauge, the minimum cost plan which can be achieved for initial pair provision equal to each standard cable size taken in turn. In practice the program itself will determine that initial provision in certain ranges is too far from the optimum to be costed, and the operator also has the facility of interrupting the sequence if desired.

As shown in Fig. 5 the results were plotted manually—total present value of all costs against cable size of first instalment — to allow estimation of the optimum size of the first instalment for a particular development pattern. These optimum cable sizes were then plotted against the appropriate 20 year development to give the graphs of optimum initial cable size versus average annual development rate over 20 years. Sufficient runs were made within the range of 20 year development figures between 400 and 6000, to enable the curves shown in Fig. 4 to be drawn with some confidence. These curves summarize the results obtained under the various combinations of conductor gauge, duct availability and subscribers growth.

It will be noted from Fig. 5, and this is typical of all results, that costs react only very marginally to changes in initial provision. The rather extreme flatness obtained in this study is explained by the fact that the second and to a lesser extent the later instalments will always compensate for an initial cable size which is either too small or too large. However, where a provisioning period policy is determined, each instalment at its time of provision would be considered in isolation and a policy of too long or too short provisioning periods would be repeated in each instalment of a plan, leading to more significant cost differences than indicated in Fig. 5, although the curves would retain an essentially flat character in the vicinity of the minimum.

The results of Fig. 4 confirm a number of features which would have been expected intuitively or from theory:—

(a) The optimum provisioning period reduces as development rate increases.

(b) The influence of duct costs is to increase the optimum period.

(c) For the same 20 year figure, the optimum initial cable size is least where growth is exponential and greatest where it is logarithmic. Linear growth gives a result, intermediate between the two.

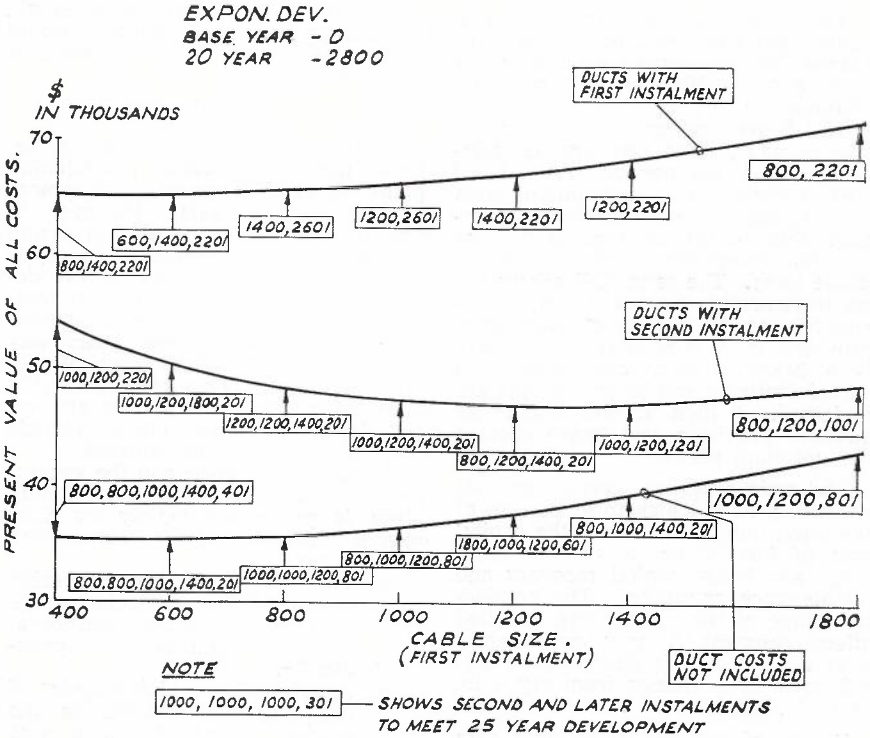

Fig. 5. — Plotting of Results

PROVISIONING PLAN   Notation Used

CABLE SIZES INSTALLED	C(1)	C(2)	C(3)	......	C(10)
YEAR OF INSTALLATION	Y(1)=0	Y(2)	Y(3)	......	Y(10)

NOTES ON PROGRAM

1. Input data consists of:- Standard Cable sizes, Information concerning capacity of 4" duct, Interest Rate, Plant Cost Information.

2. Maintenance and capital recovery factors for economic evaluation purposes.

3. Development at base and 20 years (for this study development at base year is zero.)

4. Refers to development sub-routine which makes computations according to LOG, LINEAR or EXPON curves as appropriate.

5. Sizer is a sub-routine which generates the first provisioning plan and completes later plans beyond the point where a size has been changed.

6. This is to eliminate needless repetition of computations since the first one, two or three instalments of successive plans are often the same.

7. The number of subscribers to be re-arranged in conjunction with each cable instalment is computed.

8. All installation, maintenance and re-arrangement costs occurring during the 25-year period are included.

9. Sub-routine DCOST computes duct needs and evaluates P.V. of duct costs over 25 years for the two conditions of duct availability.

10. Total present value of all costs under the three duct conditions are computed.

11. Full details of the provisioning plan, duct requirements and total costs under the three conditions are printed.

12. This is for use as described in Note 6. Details are retained only until comparison made.

13. The progressive minimum cost plan for the particular initial cable instalment C(1) is retained in detail for print out when all plans for particular C(1) have been examined.

14. These switches give manual control over the sequence of plans to be examined, e.g. C(1)'s far from optimum can be stepped over.

15. This is the section of the program which modifies the plan just costed to produce another feasible plan in the series. Examines C(4) and C(5). If C(4) ≠ maximum cable size and C(5) ≠ 0, then steps C(4) to next highest standard cable size. If above conditions not met, repeats for C(3) and C(4), and if necessary for C(2) and C(3), and C(1) and C(2).

    Employs a round-off subroutine which rounds odd cable pair values to the nearest standard size above.

16. Prints details of the minimum cost plans for the series of plans having the same initial cable size C (1).

17. If C(1) cannot be increased further because there is no larger standard cable size or because 25 year development has been exceeded, moves to make a new series of computations on another development curve but using same base and 20 year figures.

18. If computations completed for the three development curves, moves to read new set of development data.

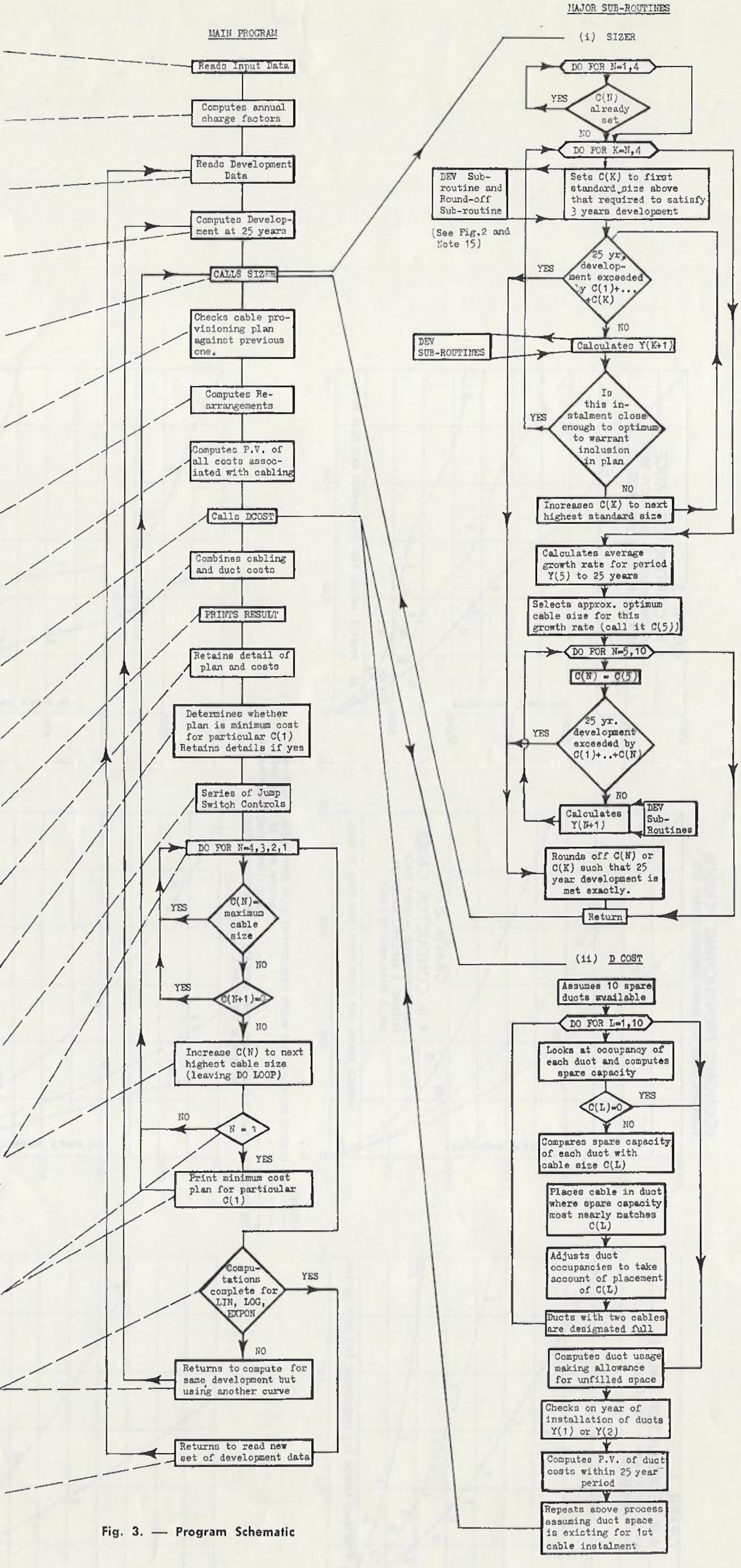

Fig. 3. — Program Schematic

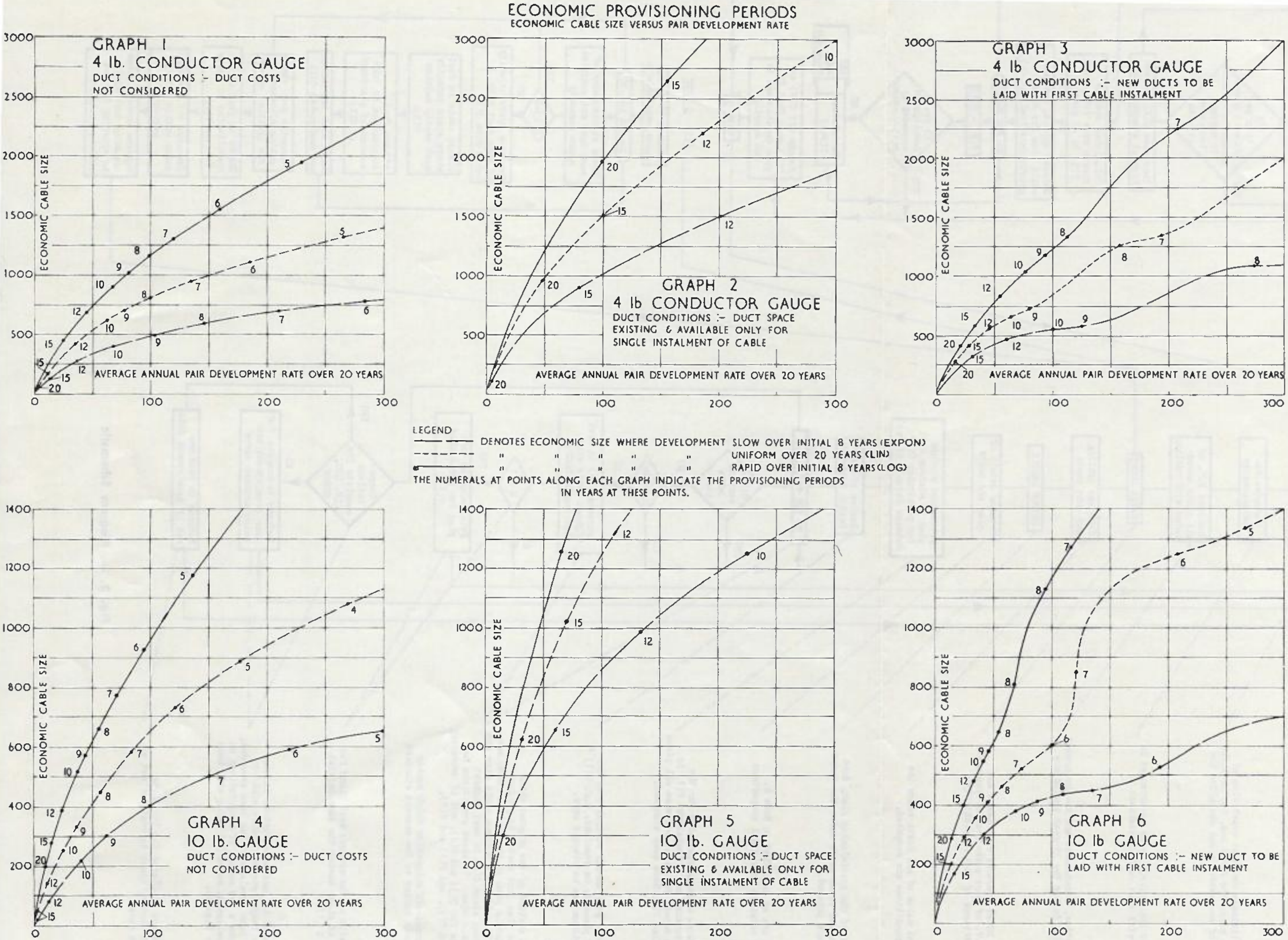

Fig. 4. — Summary of Results

(i) In each graph the development rate refers to pair requirements (not subscribers), and thus must include flexibility and other allowances. The rate is an average, merely the twenty year figure divided by 20, assuming zero at base year.

(ii) If initial requirements (at start of first year) are not zero, e.g. waiting applicants or existing cable to be replaced, these requirements would need to be added to the economic cable size obtained from the graph.

(iii) Where ducts are existing, the economic cable sizes of Graphs 1 and 4 should be used, unless the size chosen will affect duct relief within the 20 year period. In the latter eventuality the optimum size will lie between that given by Graphs 1 and 2 or Graphs 4 and 5.

(d) Heavier and more costly conductor gauge has the effect of reducing provision periods.

An interesting feature of the graph for new ducts with first instalment is the inflexion occurring around the point where maximum duct occupancy is obtained with two equal sized cables (for 4 lb. — two 600 pairs, for 10 lb. — two 400 pairs). This factor has the effect of holding the optimum cable size in the vicinity of 600 for 4 lb. or 400 for 10 lb. over a wide range of growth rates, i.e., the curve tends to cling to the area of cable sizes which make efficient use of duct space. Similarly there is some tendency for inflexion around sizes 1400 for 4 lb. and 600 for 10 lb. which are the largest sizes considered to leave sufficient space for the installation of a second cable in the duct.

Conclusions

(a) A computer program has been devised by which it is possible to compute the economic (or optimum) provisioning periods for main subscribers cables under varying conditions of costs, financial policy, subscriber growth patterns and duct availability.

(b) This study has been based on average costs and conditions. The results must be integrated with other layout needs, and will often be modified by local conditions. The study serves to illustrate the great potential of computer techniques as a tool to assist in achieving the economic optimum in external plant design.

(c) The results have been reduced to a series of graphs (economic cable size versus average pair growth rate over 20 years) which are of practical interest. There is the facility for review at regular periods (perhaps biennially) or whenever there is a major change in costs or financial policy, merely by running the program with appropriate data.

(d) The program is relatively inefficient in the use of computer time and the results require some manual processing to estimate optimum points and convert to graphical form. The problem may respond to more advanced programming of operations research techniques, and a shortened version would have more potential for library use for particular situations.

(e) The shortened version could also have some application as a subroutine for more comprehensive programs which are almost certain to be developed in the future to assist in achieving the optimum in subscribers network design.

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APPENDIX I

Brief Mathematical Statement of Provisioning Period Problem

Symbols

$\$(A + BP)$ Inclusive Capital Cost (I.C.C.) of installing P pairs over one route mile (A, B constants)

RI Interest Rate Factor

S Plant Life Factor (of I.C.C.)

(RI + S) is capital recovery factor

M Maintenance Factor (of I.C.C.)

\$D Duct Costs — Present value of annuity over study period of 25 years.

$F(t_1 - t_2)$ The factor which converts to equivalent present value, a series of annual charges commencing in year t_1 and terminating in year t_2 (calculated from formula as required)

Q(t) Factor converting to present value a fixed cost occurring at year t in study (calculated from formula as required)

\$R Cost of rearranging one subscriber from an existing to new cable.

TPV Total present value of all costs over a 25 year study period.

The optimum provisioning plan will minimize TPV where:—

$$TPV = (RI + M + S)\,((A + BP_1)\,F(t_1 - 25) + (A + BP_2)\,F(t_2 - 25) + \ldots + \ldots + (A + BP_N)\,F(t_N \text{ to } 25) + \tfrac{1}{2}R\,(P_1\,\phi(t_1) + P_2\,\phi(t_2) + \ldots + P_N\,\phi(t_N)) + D$$

and where the general provisioning plan involves installing.

P_1 pairs at year t_1 (base year)
P_2 pairs at year t_2
. .
. .
. .
P_N pairs at year t_N

as required by the particular development curve.

(Note: If the number of re-arrangements is greater than half the existing pairs at the time of installation of an instalment, then the number of re-arrangements is reduced to half the existing pairs.

i.e. if $\frac{1}{2} P_K > \frac{1}{2} (P_1 + \ldots + P_{K-1})$.

Then the number of pairs to be re-arranged is put equal to $\frac{1}{2} (P_1 + \ldots + P_{K-1})$.

The calculations are performed for:

1. D = O, i.e., duct costs not a factor
2. D computed assuming that ducts are provided with the first cable instalment with capacity to house all cables to be installed over the 25 year period.
3. D computed assuming there is existing duct space for first instalment of any size, but new ducts required with second instalment to house second cable and others required over the 25-year period.

APPENDIX II

Summary of Input Data

(i) **Standard Cable Sizes and Duct Capacity**

		4 lb.	10 lb.
SCS	(1)	0	0
	(2)	200	200
	(3)	300	300
	(4)	400	400
	(5)	600	600
	(6)	800	800
	(7)	1000	1000
	(8)	1200	1200
	(9)	1400	1200
	(10)	1800	1200
	(11)	2400	1400
	(12)	3000	1400
		4 lb.	**10 lb.**
CAP	(1)	3000	1400
	(2)	600	400
	(3)	800	400
	(4)	800	400
	(5)	600	200
	(6)	400	0
	(7)	300	0
	(8)	300	0
	(9)	200	0
	(10)	0	0
	(11)	0	0
	(12)	0	0

Note: (a) SCS (N) is the standard cable size. CAP (N) is the maximum cable size which will fit in a 4in. duct with SCS (N), e.g., SCS (9) matches with CAP (9) to fill a duct.

(b) The combination capacities have been arrived at conservatively and allow for a maximum usable duct diameter of 3.3 inches, and the difficulty of hauling a large diameter cable over an already installed comparatively small diameter cable.

(ii) **Plant Costs**

Cable Installation 4 lb. \$(3000 + 13.5P) per mile
10 lb. \$(3000 + 21.3P) per mile where P is cable size in pairs.
(Costs assume lead sheathed cable with copper at \$870 per ton).

Cable Rearrangement \$2 per circuit rearranged.

Dust Costs \$(16500 + 4250D) per route mile
D is number of ducts in nest.

(iii) **Interest Rate**
.05 (5%)

(iv) **Development Data**
As required to obtain necessary output within the range of 20 year requirements between 400 and 6000 pairs, as shown below:

	Base Year	20 Year
Starting at	0	400
Ending at	0	6000

TECHNICAL NEWS ITEM (Continued from Page 183)

The experiment was conducted on both MA and FT modes as it was expected that the jitter on the MA mode could well be an embarrassment to phase or frequency modulated data signals.

The results of the tests are summarised as follows:—

(a) Attenuation and Group Delay Distortion. This did not change significantly over the period of the experiment, nor was there a significant difference between the terrestrial loop and the satellite loop.

(b) Linearity and Overload. The circuit response was measured to be linear to within ± 0.3 dB from 0 dBm0 to —30 dBm0 for each of the three loops tested. Overload of the complete loop occurred at a level of + 6 dBm0 or greater. Compandors were included in the satellite link.

(c) Near-end Crosstalk. No significant difference was noticed between the terrestrial and satellite circuits, the average crosstalk attentuation measured being 49 dB.

(d) Noise.

(i) The Impulse noise did not vary significantly throughout the experiment.

(ii) The average level of the Psophometrically weighted noise for the three loops was as follows:—

Terrestrial: —47.5 dBm0p

M.A. Mode: —45.4 dBm0p

F.T. Mode: —46.0 dBm0p

(e) Absolute Delay. This measurement was the fastest and easiest way to determine where the circuit was looped. The relevant times round the loops were:—

Looped at the V.F. point (Cooby Creek) : 28 mS.

Looped through the Multiplexer (Cooby Creek) : 30 mS

Looped through the Satellite (either mode) : 294mS

(f) Error rates. After excluding all errors for which an explanation was available, the error rate was better than 1 error in 10^6 transmitted bits except for transmission at 2,400 bits/sec. on M.A. mode, which gave 1 error in 2 x 10^5 transmitted bits. This higher error rate (although still acceptable) was probably due to the greater jitter in this mode.

The conclusion that can be drawn from the results obtained in this experiment is that data transmission via a satellite is feasible. Of the two modes of satellite transmission available, the F.T. mode is preferable to the M.A. mode because of its greater inherent stability. Despite the difference however, both speeds of transmission tested (1,200 and 2,400 bits/sec) had normally acceptable error rates on either of the satellite modes.

In general, the combined terrestrial and satellite circuit differed little in performance from a long terrestrial circuit with the exception of the long propagation delay. In practical point-to-point transmission rather than a loop transmission, the round trip delay will be of the order of 600 mS, via the satellite. — I.D.

A PUBLIC TELEPHONE FOR 20 CENT S.T.D. CALLS

*A. L. G. MONSBOURGH, B.E.**

INTRODUCTION

A public telephone for handling 20 cent STD calls (20c. STD PT) was developed during 1966 as an interim measure to take advantage of the STD network for handling peak demands for trunk calls between holiday resorts and their associated capital cities. A high proportion of the trunk traffic increase at holiday times in these areas is derived from public telephones rather than private subscriber's instruments, so that in the absence of an STD PT there is a very large increase in trunk operator traffic compared to the requirement during most of the year. It was not considered desirable to provide trunk operator facilities sufficient to handle the peaks at these centres since the expected early availability of a standard STD PT in place of the present multi-coin instrument would make them redundant. The development of the STD PT is nearing completion (Ref 1) and the 20c. STD PT was introduced to avoid expenditure on operator facilities which would have only a short useful life.

METHOD OF OPERATION

The 20c. STD PT instrument is always installed in association with at least one multi-coin instrument for making local and operator assisted trunk calls (Fig. 1). It is coloured a striking orange for ease of recognition and is a standard multi-coin instrument with the coin gauging plate replaced with a plate which receives 20c. coins only (Fig. 2). No other changes to the instrument itself are required. At locations where a number of multi-coin instruments are used the 20c. STD PT is generally substituted for all except a few of the multi-coin instruments since most traffic at times of peak demand is trunk traffic (Fig. 3). The installations are thus inexpensive, the instruments readily available, and their operation is familiar to users. The operation of the 20c. STD PT is the same as for the multi-coin instrument except that only one value of coin may be inserted. The subscriber inserts a single 20c. piece before commencing dialling and when the called subscriber answers, depresses button 'A' — this transfers the coin to the coin tin and at the same time permits him to be heard by the called party. If there is no answer the caller depresses button 'B' and retrieves the coin. There is no provision made to prevent the user inserting more than one 20c. piece — but only 20c. worth of time can be received on each call. There is also no provision to prevent a subscriber making a local call for 20c. if he wishes.

* Mr. Monsbourgh is Engineer Class 2, Exchange Equipment, Headquarters.

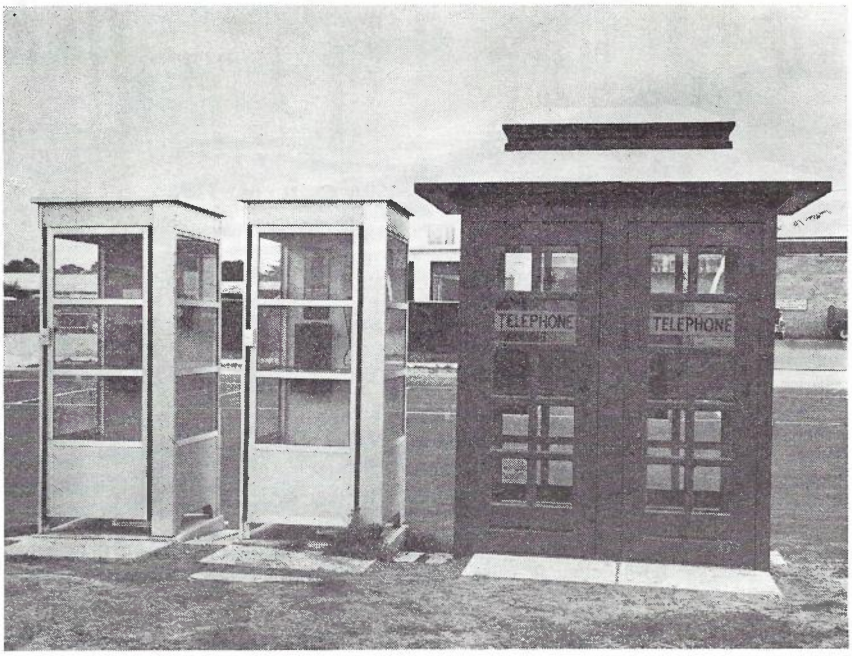

Fig. 1 — Typical Combined Installation of 20c. STD and Multi-coin Instruments.

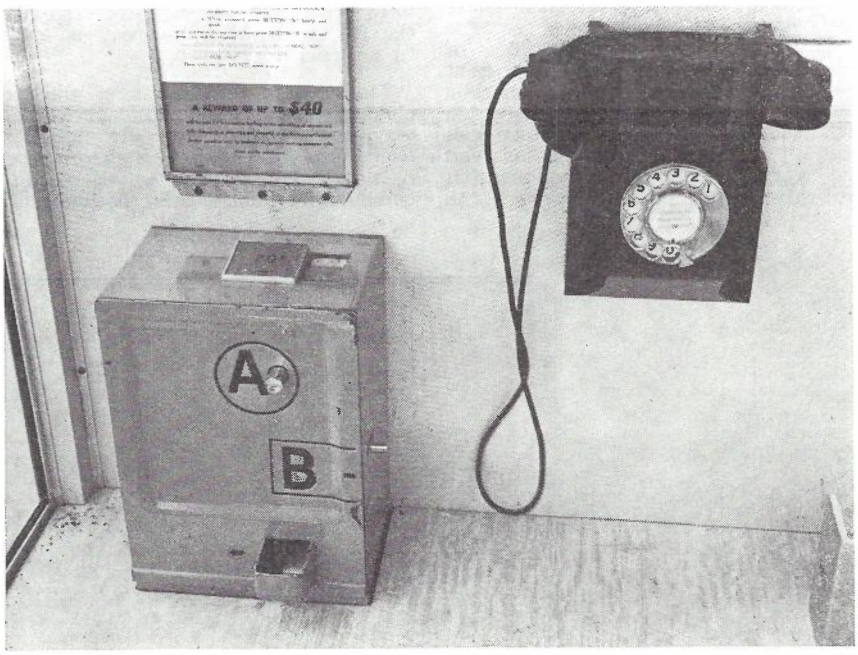

Fig. 2 — View of 20c. STD PT Showing the Coin Gauging Plate Used.

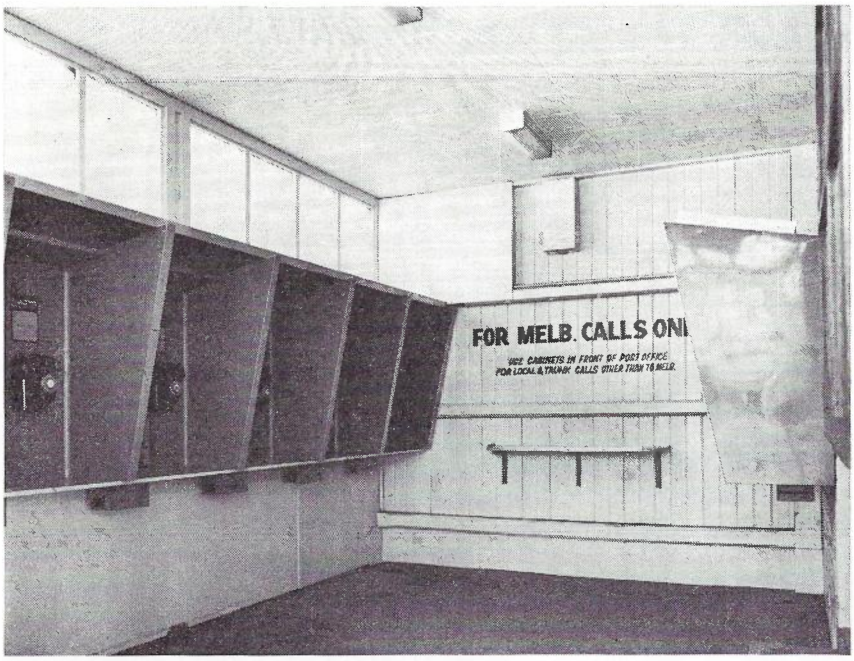

Fig. 3 — An Installation of Nine 20c. STD Instruments at Sorrento, Victoria. Three Multi-coin Instruments for Local Calls and Trunk Calls Other Than to Melbourne are also available.

CIRCUIT OPERATION

Associated with each instrument at the exchange there is a relay set which has the function of counting the multimetering pulses received while the call is in progress. It is set to disconnect the call after a fixed number of pulses have been received. On the second last metering pulse the relay set also transmits a warning tone to both subscribers, indicating that the call is soon to be disconnected. With the present unit fee tariff of 4c. this occurs when approximately 80% of the call time has elapsed. At present the instruments are used only on calls between two fixed charge zones so that the operating instructions can readily indicate the period between the warning tone and disconnection and other information. However, the design of the instrument does not prevent calls to any destination normally available on STD for private subscribers at the same exchange. On disconnection a short break in the line occurs, followed by dial tone when the exchange equipment is re-seized. A further call may then be dialled, but if it is to the same subscriber the called party must have replaced his telephone. PT identification tone is also applied to the call until the called party answers so that the PT is identified if a call is made to an operator.

There are two circuits of the exchange relay sets, one for step-by-step exchanges the other for ARF and ARK exchanges. The step-by-step relay set uses a B.P.O. No. 4 uniselector to count meter pulses, the crossbar relay set uses a chain of the Ericsson RAH relays. Whenever the unit fee tariff is changed, the relay sets must be re-strapped to count the number of unit fee periods whose value is the closest divisor of 20c.

APPLICATIONS

The telephones have been in use over two Christmas holiday periods and have been successful in handling Christmas traffic. As an example, one group of nine telephones has averaged 50 calls/day over a two week holiday period. Peak rates of 100 calls/day have been obtained at some locations. Initially some complaints were received that the warning tone was not being heard, however the frequency has been increased to 900 c/s and the 500 milli-second continuous tone now appears adequate. Special arrangements were made for frequent collection of the 20c. coins to reduce losses if the instrument was broken open and possibly also to reduce the likelihood of instruments being damaged through attempts to steal coins. At the design stage some consideration was given to a technique in which a call would be continued indefinitely so long as sufficient additional coins were inserted. However, due to the mechanical complications which would result from having to signal from the telephone to the exchange each time a new coin was inserted, this approach was not pursued since it was not practical to consider modifications to the coin mechanisms in the telephone in the limited time available for development.

The exchange line relay sets and the modifications to the multi-coin PT were designed in the Engineering Works Division at A.P.O. Headquarters and the field trials were undertaken by technical staff at Russell exchange in Melbourne and Maitland exchange in N.S.W.

REFERENCE

1. A. A. Rendle, 'An STD Coin Telephone'; Telecom. Journal of Aust. Feb. 1968, Vol. 18, No. 1, Page 40.

TECHNICAL NEWS ITEM

EXPERIMENTAL WORK WITH QUARTZ CRYSTALS

In the Research Laboratories of the Postmaster-General's Department a small team is engaged on experimental production of quartz oscillator crystals and design of oscillator circuits. Quartz crystal controlled oscillators are still the best means for obtaining high frequency stability and accuracy at a reasonable cost. The success of these devices may be attributed to the very high Q values that are obtained with quartz crystals — values up to several million being developed in really high-quality units — and the comparative insensitivity of the quartz crystals to changes of air pressure, humidity, temperature, etc. Quartz resonators now available commercially allow direct control of suitable oscillators from a few hundred Hertz to over 100 Mega Hertz.

The whole range of operations, from cutting the raw quartz to sealing the completed crystal resonators in vacuum enclosures, is carried out in the laboratory, so that complete control of all operations is possible. Either natural quartz or the newer 'synthetic' crystal quartz is used. The synthetic quartz is produced in the United States and latterly in England, by dissolving and recrystallising chips of the natural material which are otherwise of no use because of their small size. Enormous pressures are necessary in this process to allow worthwhile rate of solution of quartz to occur at a reasonable temperature. Even so, a period of about a month is normally required to 'grow' a batch of synthetic crystals. This form of quartz is attractive to the user, as it is free of the many imperfections which occur in the natural material, and it is prepared in sizes and shapes to suit the particular type of quartz plates required. However, it usually has a higher level of impurity than the natural crystal, which leads to a greater internal loss, and hence the Q of resonators made with synthetic quartz is somewhat lower than is obtainable from natural quartz plates.

Quartz is very hard, rather like glass, and diamond wheels must be used to saw rectangular blanks from the bars or slabs of raw material. As the frequency versus temperature performance of the finished resonator is primarily determined by the angle at which the plate is cut from the crystal block, the sawing operation must be closely controlled, and angles are held to an accuracy of one minute of arc. Measurement of the angles between the sawn surfaces and the three axes which define the particular crystal form are made with an X-ray diffraction set. This device actually measures the angles between a surface and sets of atomic planes within the surface of the quartz.

The diamond saws produce minute cracks in the surfaces of the blanks, and this damaged material, up to several thousandths of an inch deep, is removed by lapping. This term describes an abrasive process which employs a thin paste of abrasive powder in oil or water in machines designed to keep the plates very flat, and maintain the angle developed at the sawing stage. For high frequency use, the plates are converted to discs by grinding a loaf of the rectangular blanks between centres. While a diamond wheel has been used for this operation, the present method is to use an ordinary aluminium oxide grinding wheel with a fairly soft bonding agent. During grinding this wheel breaks down quite rapidly, continuously exposing sharp new chips of abrasive which cut the quartz fairly freely. Again it is necessary to remove the damaged layer by lapping. Lapping of the surfaces is continued, using finer abrasive 'grits', until the required thickness is achieved. The term 'grit' as used by the manufacturers of the abrasive is rather misleading, as the powders are extremely fine—the coarsest in use in the laboratory being about 600 mesh, i.e., capable of just passing through a hypothetical sieve with 600 holes per lineal inch, while the finer powders are measured in microns. When finished, the quartz plates look like glass.

Over the years, a major difficulty with high frequency oscillator plates, which represent the greatest proportion of crystals in use, has been to limit the effects of 'coupled modes' on the performance of a plate. This phenomenon is due to absorption of energy by a variety of vibration modes, usually associated with length and width of the earlier rectangular plates, and quite distinct from the simple thickness shearing mode which it is desired to establish. These coupled modes cause very rapid frequency changes, and change of 'activity', of a crystal as temperature varies. It has been found that by making the plates circular rather than rectangular, and by making at least one of the surfaces spherical (convex), this problem can be completely eliminated, at least so far as oscillator crystals are concerned. A lot of work has been done in the laboratory to develop this technique, with very satisfactory results.

The finished quartz plate, then, has one surface flat and the other convex; it is highly polished, and woud make a good low-powered lens. At this stage the plate will oscillate, between a pair of metal plates connected to an oscillator, at a frequency a little higher than finally required. The driving electrodes are then formed in the quartz surfaces by the vacuum evaporation process—gold is evaporated from heated tungsten filaments in a vacuum; the gold condenses on all exposed surfaces, including the quartz, through masks which define the required shape and size. The gold condensed on the quartz adds to the effective mass of the plate, and so causes a lowering of frequency. This process can be closely controlled by connecting the electrodes to an oscillator, so that the amount of gold laid down is used to finally adjust the crystal's resonant frequency.

A problem here is that with normal vacuum equipment using oil-diffusion and rotary pumps, there is always a small amount of oil vapour present in the vacuum chamber, which condenses on the quartz surface. This is very effective in damping the vibration, thus lowering the Q value of the plate, and also contributes to slow changes of frequency with time. A new pumping system is being developed in the laboratories which is based on an ionic pump. This device is completely dry, in that no oil whatever is used, and relies on the gettering ability of titanium metal for its pumping action. The titanium is continuously deposited on the inner surfaces of the pump by sputtering the metal from the cathode by the action of gas ions accelerated by high voltage in a gas discharge. This discharge is maintained down to extremely low gas pressures by use of a magnetron type discharge, and the pump is capable of some four orders of decreased pressure over a normal oil-diffusion pump. For laboratory use, the main advantage is, however, the cleanliness of the pumping process.

The crystal unit is then mounted by a pair of wires in a glass envelope, which is heated and pumped out by the vacuum system, and finally sealed off. The all-glass holder makes a true hermetic seal protecting the crystal plate, its electrodes and connecting wires from any effects of moisture, corrosion and pressure changes. Crystal units mounted in this way are essentially permanent items, and give good service for many years. Units made in the laboratory over twelve years ago (the first produced) are still in service in the department.

At present the laboratory team is working on H.F. crystals and oscillators having very high stability. The crystal units operate at 5 MHz and have Q values of over 1.5 million. The circuitry is all solid-state, and designed to operate on floated batteries to allow continuous operation despite mains power disturbances. Though the project is far from complete, results are promising, with day by day frequency changes of experimental oscillators of less than a few parts in ten thousand million. These oscillators are quite small, occupying about the same space as a standard 5 in. high relay rack, and power consumption including that for the temperature controlled oven is about 1.5 watts.—L.H.M.

OUR CONTRIBUTORS

R. W. E. HARNATH

R. W. E. HARNATH co-author of the article 'The Relaying of Television Programmes in Australia', began his career in a bank, and studied accountancy. After two years in Army Signals and four years in the R.A.A.F. 'Tels. and Radar', he completed a Rehabilitation Training Scheme Associate Diploma in Radio Engineering at the Royal Melbourne Technical College in 1950. In 1947 he joined the engineering staff of Trimax Transformers Pty. Ltd., and was responsible for the electrical and mechanical design of a wide range of communications equipment, and negotiations with various Departments and private firms. He joined the Department in 1955, entering the Long Line Equipment Section, Central Office, where, since 1959, he has been Divisional Engineer, Specifications, in the Works Programme Sub-section.

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J. K. GERRAND, author of the article 'An Automatic Routiner Fault Printer', joined the Postmaster-General's Department in 1962 as a Cadet Engineer. Since completing the Associateship Diploma of Communication Engineering at the Royal Melbourne Institute of Technology in 1963, he has been engaged on Engineer Class 1 duties in the Metropolitan Service Section, Victoria. He spent two years on semiconductor and relay circuit design work with the Metropolitan Service Laboratory; the remaining years in field work and the development of the F.R.I.A.R. system, the subject of this article. He is a Graduate Member of the Institution of Engineers, Australia, and of the Institution of Radio and Electronics Engineers, Australia, and has completed the Fellowship Diploma in Communication Engineering.

J. B. POTTER

J. B. POTTER, co-author of the article, 'The Relaying of Television Programmes in Australia', graduated from the Royal Melbourne Technical College, in 1955 as a Fellow in Communication Engineering. He was awarded the Sir Ernest Fisk Prize and Kernot Medal. He joined the Postmaster-General's Department in the Pulse Techniques Division of the Research Laboratories, carrying out investigations concerned primarily with advanced Television Testing methods and associated equipment design. In 1963 he was promoted to lead this research group, a position which he relinquished in 1965 to join the staff of The University of Melbourne as Lecturer in Electrical Engineering. In 1961 Mr. Potter graduated B.Sc. from the University of Melbourne and in 1964 received the M.App.Sc. degree for a thesis based on his work at the Research Laboratories. He is an Associate Member of The Institution of Radio and Electronics Engineers, Australia.

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J. K. GERRARD

J. J. HARRISON

J. J. HARRISON, author of the article 'The Application of Computers in External Plant', joined the Victorian administration of the P.M.G.'s Department as a Cadet Engineer in 1948. After graduating Bachelor of Science at Melbourne University he took up duty as Engineer Class 1 in Metropolitan District Works during 1952. The following year he commenced a period of five years as Engineer Class 2 in Transmission Planning, concerned with the oversight of trunk external plant planning for the State and preparation of major trunk proposals. Interspersed in this time, was a half-year period on special duties with the group responsible for radio broadcasting of the 1956 Melbourne Olympic Games. After a further four years on external plant work Mr. Harrison was promoted in 1962 as Engineer Class 3, Lines Section, Headquarters, where he is responsible for network design aspects of subscribers and junction urban external plant. Mr. Harrison has a Certificate in Concrete Technology from the Royal Melbourne Institute of Technology and has studied Post-Diploma subjects in computer techniques at the Caulfield Institute of Technology.

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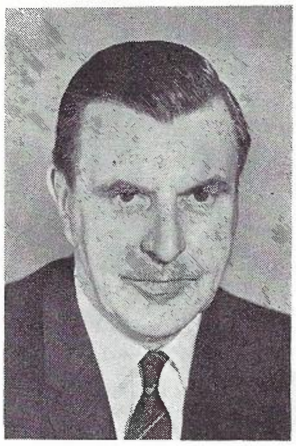
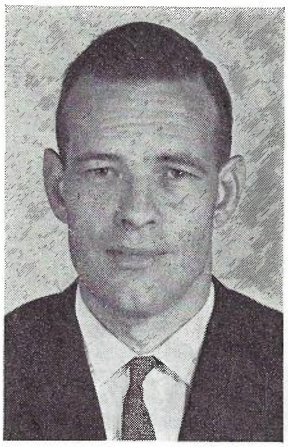
R. A. READ, author of the article 'A Decade of Plastic Cabling', joined the British Post Office as Youth in Training in 1930 at the Research Station where he served for 6 years in the Physics, Chemistry and Metallurgy Section. In 1936 he passed the B.P.O. competitive examination for Assistant Engineers and was posted to Leeds where he served as Assistant Engineer External Plant until 1940. He was seconded to the Malayan Telecommunication Department in 1940 as Assistant Controller of Telecommunica-



R. A. READ



F. W. WION

W. E. BEARD

tions and after 4 years as prisoner of war he returned to Malaya to assist in rehabilitation of the Telecommunication services and remained there until 1961 when he retired as Director of Telecommunications for the Federation of Malaya. He joined the Postmaster-General's Department as Group Engineer in the Lines Section in 1961 and was engaged mainly on investigations in connection with power co-ordination. In particular he led a joint working group which was largely responsible for framing the arrangement for the Joint Use of Poles which was agreed between the Department and the Electricity Supply Association of Australia in 1965. He was promoted to his present position of Engineer Class 3 in the Subscribers Distribution Division in 1966 where he has specialized largely on plastic cable practices.

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A. L. G. MONSBOURGH, author of the article 'A Public Telephone for 20 cent S.T.D. Calls', joined the Postmaster-General's Department as a Cadet Engineer in 1958. After graduation in 1962 as B.E. at the Melbourne University he spent four years in the Traffic Engineering Division (Metropolitan) of the Victorian Planning Branch, working mainly on the automation of the Junction Provision Statement and on the development of data recording equipment for making traffic measurements in crossbar and step exchanges. In 1966 he transferred to the Telephone Exchange Equipment Section at Headquarters, where he has been employed as a Class 2 Engineer, concerned mainly with design problems in relay sets for ARF exchanges.

F. W. WION, author of the article 'Electronic Exchanges with Stored Programme Control', jointed the Postmaster-General's Department in 1950 as a Cadet Engineer. He subsequently gained the degrees of Bachelor of Electrical Engineering and Master of Engineering Science at Melbourne University. Mr. Wion joined the Research Laboratories in 1956 and became Engineer Class 3, Electronic Switching Division, in 1963. His work during this period was largely concerned with the design and development of semiconductor switching circuits, and the study and assessment of electronic exchange developments. He attended the Intermediate course of the Australian Administrative Staff College in 1964. Mr. Wion transferred to the Planning Branch, Victorian Administration in 1967, where he is engaged in local and trunk exchange planning for the Metropolitan area.

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A. L. G. MONSBOURGH

W. E. Beard, author of the article 'Transmitting Antenna Systems for the Australian National Television Service', is an Engineer Class 3 in the headquarters radio section where he is currently taking charge of a sub-section planning the provision of equipment for the National Broadcasting and Television Transmitting Stations. He graduated in electrical engineering from the University of Melbourne in 1947 and immediately joined the Department's Research Laboratories where he was initially engaged on the development of frequency standards and associated equipment. In 1952 he transferred to the propagation division to undertake development of radio propagation measuring equipment and conduct path propagation surveys. In 1954 he took charge of the radio plant investigation division and development of multi-channel V.H.F. radio telephone systems between Tasmania and the mainland, as well as ionospheric and tropospheric scatter links for scientific research.

In 1961 Mr. Beard transferred to the radio section at headquarters to undertake planning and provision of antennae and structures for television stations. More recently he has been concerned with the development of television translator and low power services for the more remote areas.

Mr. Beard was the Department's representative at the Commonwealth Broadcasting Conference in Canada, in 1963, and in 1966 attended the Asian Broadcasting Union General Assembly in Singapore. After the 1963 conference he studied world developments in television transmitting plant.

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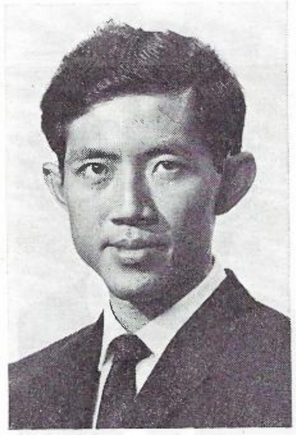
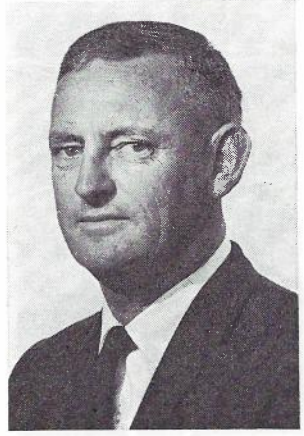
J. G. HARRIS, author of the article 'Remote Control of Traffic Route Testers', joined the Postmaster-General's Department in 1955 and is currently an Engineer, Class 2 in the City Exchange Service Division, Sydney. He has been actively concerned

J. G. HARRIS



W. F. CHEW



N. E. QUIRK

with the development of automated testing aids for Exchange Maintenance and with the establishment of Subscriber District Centres, particularly in regard to data processing as an aid to management. He obtained a Bachelor of Engineering Degree (Mechanical & Electrical) from the University of Sydney in 1957.

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W. F. CHEW, co-author of the article 'Automatic Junction Testers for Step-by-Step Exchanges', arrived in Australia from Singapore in 1960 and obtained his Bachelor of Engineering Degree at the Sydney University in 1964. He took up temporary employment with the Postmaster-General's Department in 1965 as an Engineer Class 1 in the Redfern Equipment Service Division, Sydney, where he has been engaged on special project work for the improvement of maintenance methods in automatic telephone exchanges.

N. E. QUIRK, co-author of the article 'Automatic Junction Testers for Step-by-Step Exchanges', joined the Postmaster-General's Department in 1940 as a technician-in-training. After qualifying as an engineer he was promoted as a Group Engineer in 1954. For the last 12 years he has been engaged on work in the equipment service and internal plant planning fields, and in 1967 was promoted to his present position of Engineer Class 3, Redfern Equipment Service.

ANSWERS TO EXAMINATION QUESTIONS

Examination No. 5633, 1st July, 1967, and subsequent dates to gain part of the qualification for promotion or transfer as Senior Technician (Telecommunications), Transmission Equipment, Postmaster-General's Department.

PART B — RADIO COMMUNICATION EQUIPMENT

QUESTION 9.

Describe in detail the electrical design of a telesignalling system used in conjunction with radio systems operating in the 4GHz, 6GHz or 7GHz bands. (7GHz = 7,000 megacycles per second.)

ANSWER 9.

(A number of different systems are in use; this answer describes one type only and more detail is given than is required to obtain good marks.)

A telesignalling system is provided with a radio telephone system to allow the remote supervision and control of an attended or unattended station from a central location (Control Station). In a typical system, a telesignalling transmitter is located at the remote station and a telesignalling receiver is located at the control station. Sections of the transmitter and receiver form part of a frequency modulated carrier telegraph channel which can have a nominal operating frequency of from 420Hz to 3180Hz (in 120Hz steps). With other channels used for telesignalling it forms part of a carrier telegraph system which is interconnected via a conventional voice channel bearer. The voice channel is normally obtained by a radio link. Each telesignalling system is capable of handling a number of information signals, generally 16 or 32.

The telesignalling system transmits 25Hz pulse 'telegrams' from the supervised station to the control station. These conditions are displayed by lamps at the control station. The 16 (or 32) conditions are continually scanned; a synchronising pulse is inserted at the end of each scanning to prevent the display of false information due to out-of-synchronism between the transmitter and receiver.

The main elements of the transmitter are shown in Fig. 1. It comprises two main parts — an encoder and a telegraph channel.

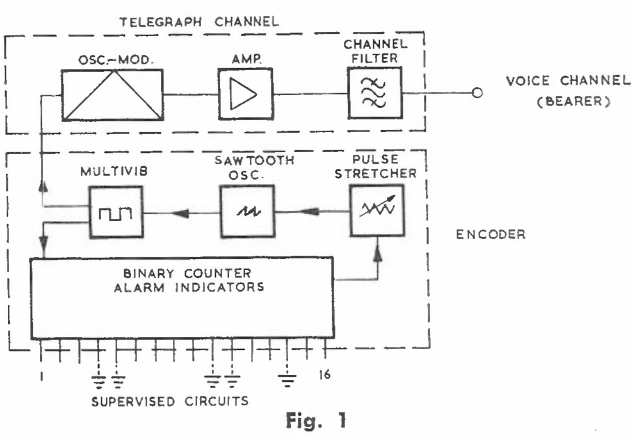


Fig. 1

Encoder. The oscillator generates a saw-tooth pulse train with a periodicity of 20mS. This is applied to a multivibrator which produces rectangular pulses with 20mS half-periods. These pulses drive a binary counter, which at the end of 16 pulses generates a signal which is applied to a pulse-stretching circuit and the saw-tooth oscillator. This causes a pulse at the output of the multivibrator, with a negative period stretched from 20mS to 50mS which represents the synchronising pulse.

At the same time the counter causes the scanning of the condition of the supervised circuits. A fault condition on any one of the circuits is represented by a grounded input to that circuit. Each time a grounded input is encountered, a signal is transmitted to the pulse-stretcher to cause a stretching of the positive half-period from 20 mS to 50 mS. This means that circuits without faults allow pulses with equal half-periods and circuits with faults cause a positive half-period of 50 mS and a negative half-period of 20mS. A typical pulse train, with faults on outlets 4, 5, 10, 11 and 14, is shown in Fig. 2.

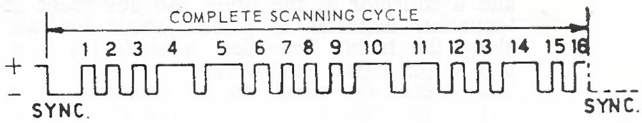


Fig. 2

Telegraph Channel. The pulse train generated by the encoder is applied to the frequency modulator of the telegraph channel and the positive and negative half-periods cause deviations of ±30Hz from the nominal telegraph channel frequency. The frequency modulated output is applied to the telegraph channel bearer via an output amplifier and channel band pass filter.

The main elements of the receiver are shown in Fig. 3. It comprises three main parts — a telegraph channel, a carrier fail alarm circuit and a decoder.

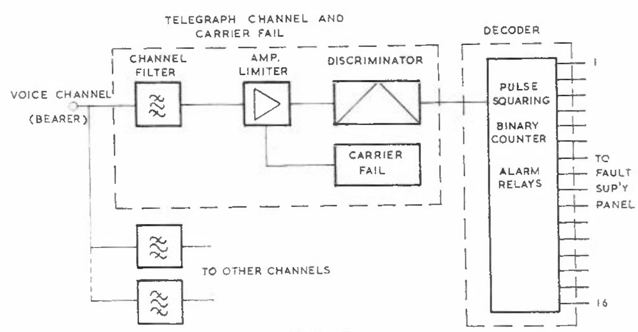


Fig. 3

Telegraph Channel and Carrier Fail Circuit. The input signal is applied from the telegraph bearer via a channel band pass filter and amplifier limiter to the discriminator. The carrier level is monitored at the amplifier limiter and should the level fall by a predetermined amount, a carrier fail lamp and relay operate. The relay contacts introduce an external alarm.

Decoder. The output of the discriminator is applied to a pulse squaring device and drives a binary counter. The synchronising pulse sets the binary counter to zero and the following circuit condition information is applied to the alarm relays.

The reception of 50 mS positive half-period pulses causes the operation of the appropriate alarm relays which operate lamps on the fault supervisory panel for the particular remote station.

QUESTION 10.

Use the following headings to describe a travelling wave tube and a modulator klystron:

(*i*) *Physical construction.*

(*ii*) *Electrical operation and characteristics.*

(*iii*) *Detailed steps you would take when placing a new tube in service.*

ANSWER 10.

Travelling Wave Tube (Fig. 4).

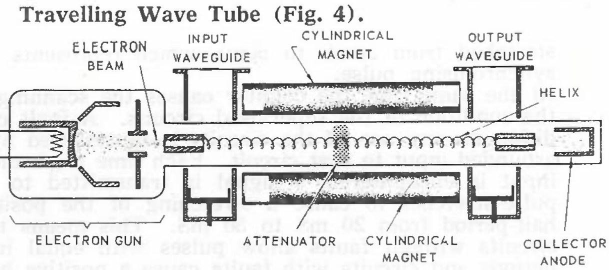


Fig. 4

(i) A long glass tube containing a spiral (helix) wire has an electron gun assembly at one end and a collector at the other. An absorbent attenuation material is placed about half-way along the helix. Provision is made for input and output signal connections.

(ii) The microwave signal to be amplified is injected into the T.W.T. from the input waveguide, and travels at a high speed around the helix wire to the output termination (waveguide output). The helix effectively slows down the forward progress of the signal along the tube.

The electron gun, attached to one end of the helix, produces a focused beam of electrons which are directed through the centre of the helix at an initial velocity slightly greater than the axial velocity of the spiral wave. The beam current is controlled by the positive potential on the collector. The magnetic field from the magnets along the length of the tube prevents the beam from spreading.

When the electrons in the beam enter the helix, they are accelerated or decelerated by the alternating electric field associated with the microwave signal wave. Electrons acted upon by a positive electric field take energy from the field and are accelerated. When acted upon by a negative field, the electrons give up energy to the field and are decelerated. This has the effect of causing the electrons in the beam to form into periodic groups or bunches. More electrons are retarded than are accelerated, and the excess energy given up by the retarding electrons is transferred to the modulating microwave signal. The bunching of the beam electrons by the modulating signal and the transfer of energy from the retarding electrons to the signal is called interaction. This interaction is continuous and cumulative and is the basis for amplification. The signal removed from the output may be in the order of 40dB higher than the input signal.

In the wave's propagation along the helix, reflections may be set up which cause standing waves. The attenuator reduces these reflected waves on the helix to prevent spurious oscillations.

(iii) The voltages are disconnected before inserting the tube in its container. The tube is inserted carefully as magnetic fields in the container may shift the tube and cause it to strike the sides of the container. The voltages are reapplied at a minimum and gradually increased to the operate point. The input and output waveguides must be matched. Helix current must be kept low.

Modulator Klystron (Fig. 5).

(i) The klystron consists of a cathode, a focusing electrode at cathode potential, a re-entrant cavity resonator that also serves as an anode (through which the electron beam passes), and a repeller electrode at a negative voltage with respect to the cathode. A coaxial line is loop coupled to the cavity to pick off the output.

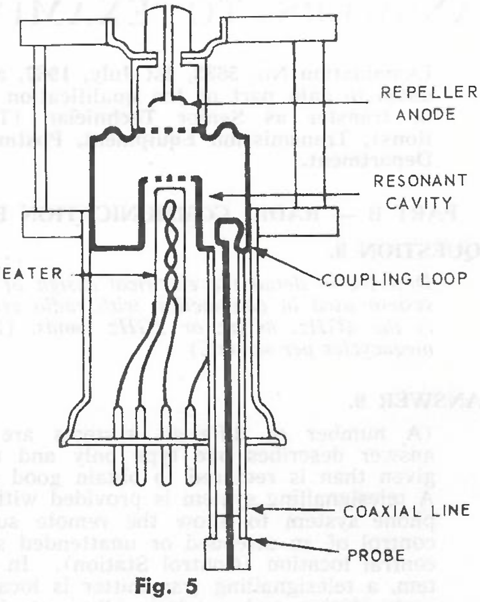


Fig. 5

(ii) The klystron acts as an oscillator at microwave frequencies. The re-entrant cavity is adjustable and forms the resonant circuit which governs the frequency of operation. The electron beam through the cavity sets up electric and magnetic fields, the energy in the two fields interchanging to produce an oscillation which is maintained (to overcome losses) by the energy associated with the electron beam.

The modulating signal is applied to the repeller electrode where it controls, to some degree, the electron beam and this varies the frequency of oscillation of the klystron about its rest frequency. The frequency modulated output energy is obtained from the cavity by means of the coaxial loop coupling.

(iii) Voltages must be removed before inserting the new klystron. Care must be taken not to distort or damage the resonant cavity. The cavity is tuned to the required frequency.

QUESTION 11. (a)

Complete the table below to show the approximate frequency limits and the type of electromagnetic wave propagation normally used in the bands listed.

ANSWER 11. (a)

Band	Frequency Limits	Type of Propagation
L.F.	30— 300kHz	Ground wave.
M.F.	300—3,000kHz	Ground wave, with ionospheric reflection of sky wave after dark.
H.F.	3— 30MHz	Ionospheric reflection of sky wave.
V.H.F.	30— 300MHz	Space wave.
U.H.F.	300—3,000MHz	Space wave.
S.H.F.	3— 30GHz	Space wave.

QUESTION 11. (b)

Describe the four major types of fading which affect the performance of radiotelephone systems.

ANSWER 11. (b)

The four major types of fading are two-ray (two-path) fading; multi-ray (multi-path) fading; duct-fading; and obstruction fading.

These are described in Miscellaneous Note MLR 051, paragraph 4.5.

Examination No. 5636, 1st July, 1967, and subsequent dates to gain part of the qualifications for promotion or transfer as Senior Technician (Telecommunications), Control Systems, Postmaster-General's Department.

PART A — ELECTRONIC CONTROL TECHNOLOGY

(Reasons appearing with the answers are given for clarification only. They were not required in the examination answers).

QUESTION 1.

The five strobed toggles drawn in Fig. 1 are connected to form a ring counter. The gated output for count 1 is also illustrated. When the power is switched on, assume that all toggles will be in the reset state. The counter starts counting when the 'START' signal becomes logical 1.

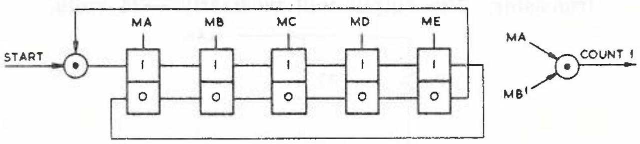


Fig. 1

QUESTION 1. (a)

How many different states does this counter have?

ANSWER 1. (a).

A five toggle ring counter has 10 different states.

QUESTION 1. (b)

Draw the gated output for:
(i) Count 4.
(ii) Count 5.
(iii) Count 6.

ANSWER 1. (b).

See Fig. 2.

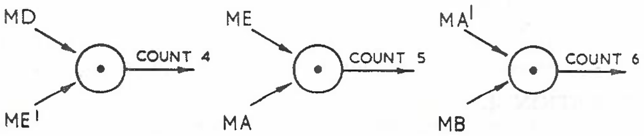


Fig. 2

QUESTION 1. (c)

On what count will the above counter stop if the 'START' signal becomes logical O on:
(i) Count 3.
(ii) Count 6.

ANSWER 1. (c).

The counter will stop on count 0 in both cases.

QUESTION 1. (d)

One situation in which this form of counter would be used is where a large number of counts are required to be gated out. Why is this?

ANSWER 1. (d).

A ring counter is used when a large number of counts need to be gated out because only 2 diodes are required for each gating regardless of the number of toggles in the counter.

QUESTION 1. (e)

It is required to have a counter capable of counting from 0 to 5.
(i) Draw a different form of counter from the one shown above that will do this.
(ii) Which type of counter would be used for this purpose? Why?

ANSWER 1. (e).

(i) The chain counter in Fig. 3 has 8 different states and is therefore capable of counting from 0 to 5.

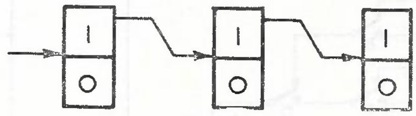


Fig. 3

(ii) A three toggle ring counter would be used as both it and the chain counter would have the same number of toggles but the ring counter in general requires less diodes to gate out counts.

QUESTION 2. (a)

Explain what is meant by an 'exclusive OR' circuit and an 'equivalence' circuit for two logic signals. Write down the logic conditions for each in terms of Boolean algebra.

ANSWER 2. (a).

An exclusive OR circuit has a logical 1 output if, and only if, the two input signals are different (i.e. one input is logical 1, the other is logical 0). $AB' + A'B = 1$.

An equivalence circuit has a logical 1 output if, and only if, both the inputs are the same (i.e. both logical 1 or both logical 0). $AB + A'B' = 1$.

QUESTION 2. (b)

Draw two different forms of an equivalence circuit for two signals A and B. You may assume that the inverse signals are also available directly.

ANSWER 2. (b).

Any two of the circuits in Fig. 4.

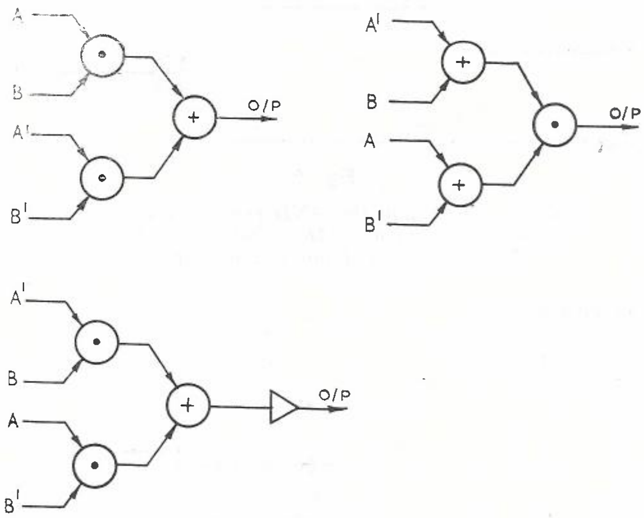


Fig. 4

QUESTION 2. (c)

For the relay tree illustrated in Fig. 5:
(i) Explain why the relay tree is folded.
(ii) Identify counts X and Y.

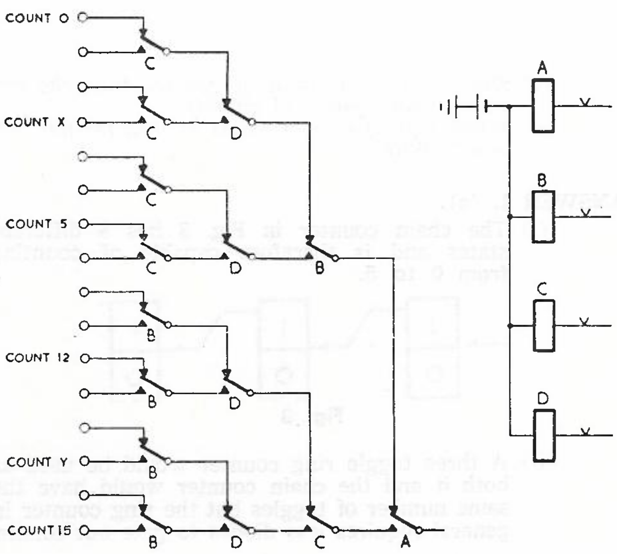


Fig. 5

ANSWER 2. (c).

(i) Relay trees are folded to distribute the contact load over the relays.

(ii) X = 6

Y = 11

Reason: D + B = 5 = 4 + 1

D + A = 12 = 8 + 4

Both D and 4 are common, therefore

D = 4

B = 1 and A = 8

And as A + B + C + D = 15

C = 2

Count X = C + D = 6

Count Y = B + C = A + 11

QUESTION 3. (a)

(i) *Draw the circuit of the logic gating illustrated in Fig. 6, showing all necessary components. Use negative logic and indicate suitable values and polarities for the power supplies and the logic levels.*

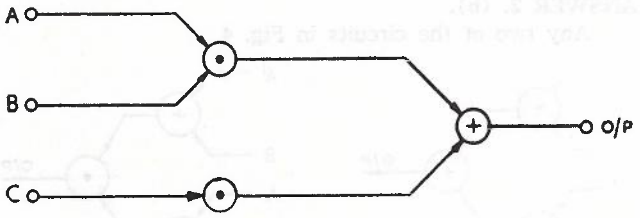


Fig. 6

(ii) *Assuming that the AND resistors are 11K and the OR resistors are 33K, what would be the output voltage if the C input was open circuit?*

ANSWER 3. (a)

(i) See Fig. 7.

Logical 1 = —6V

Logical 0 = 0V

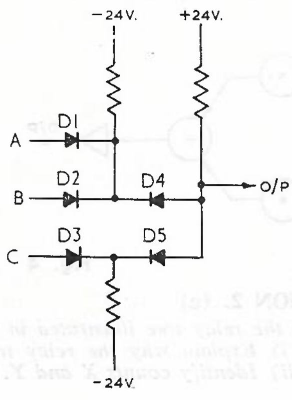


Fig. 7

(ii) If C is open circuit, 48 volts are divided across 11K + 33K, so that the output is at —12 volts. This is not affected by either 0 volts or —6 volts through the OR diode D4, which is reverse biassed in either case.

QUESTION 3. (b)

Draw the circuit of a typical P.E. cell unit used in the automatic letter sorting system, comprising a transistor amplifier with a P.E. cell in the base circuit. Explain how the output conditions are obtained for light and no light on the cell.

ANSWER 3. (b)

See Fig. 8.

If there is no light falling onto the P.E. cell, the transistor. The output will be nearly —24 volts. the output is nearly 0 volts. When light falls on the photo diode, it will develop a small positive voltage at the base of the transistor, sufficient to cut off the transistor. The output will be nearly —24 volts.

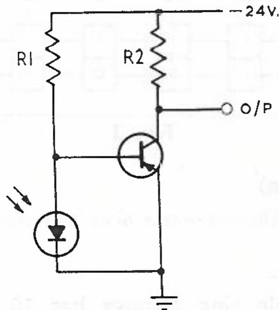


Fig. 8

QUESTION 3. (c)

In solenoid driver circuits using S.C.R.'s, protective circuitry for the S.C.R.'s is usually provided to counter two different effects. State what these two effects are and how they may arise. What is the form of the protection provided?

ANSWER 3. (c)

One effect is excess current through the S.C.R. due to a short circuited output. The protection against damage from this cause is provided by a series fuse. Another effect is excess reverse voltage due to the back e.m.f. of the driven solenoid when the operate signal is removed. For protection the output is clamped to a fixed level, e.g., by using zener diodes.

QUESTION 4.

Fig. 9 represents one type of flip-flop used in automatic letter handling plant.

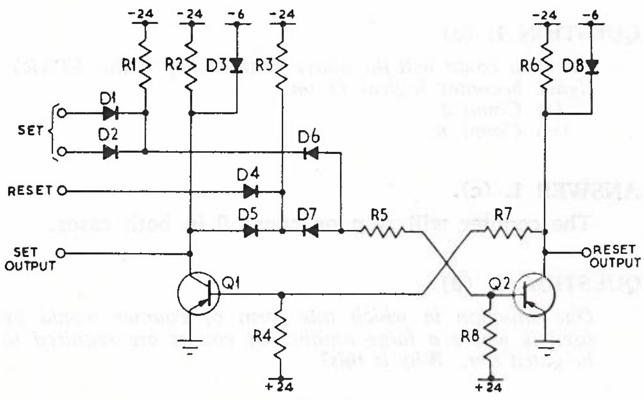


Fig. 9

QUESTION 4. (a)

(i) *Determine the input logic conditions required to set it and to reset it.*

(ii) *Is the output state of the device determined when all the inputs are logical 1?*

ANSWER 4. (a)

(i) Setting the flip-flop requires logical 1 on both set inputs. The reset input is irrelevant. Resetting the device requires a logical 0 on the reset inputs, and a logical 0 on at least one of the set inputs.

(ii) When all inputs are logical 1 the flip-flop is set.

QUESTION 4. (b)

Explain in detail how the flip-flop is set.

ANSWER 4. (b)

Both set inputs are made logical 1. The output of the AND gate D1 — D2 — R1 will then be logical 1 and this will make the output of the OR gate D6 — D7 — R5 + R8 logical 1. i.e. —6 volts, irrespective of its other input. The values of the resistors R5 and R8 are such that in this case the voltage divider R5 — R8 will give a negative voltage at the base of Q2. This turns Q2 fully on, causing the voltage at its collector to go towards 0 volts. This in turn places a positive voltage at the base of Q1 through the voltage divider R7 — R4. Q1 will turn off causing its collector to go towards —24 volts, but limited by D3 to —6 volts. The device is now in the set state, with the set output logical 1 and the reset output logical 0. (NOTE: To maintain the flip-flop in this state it is necessary either to keep the set inputs logical 1 or to make the reset input logical 1, before removing the set signal. With the reset input logical 1, the AND gate D4 — D5 — R3 will have logical 1 at its output and therefore the OR gate D6 — D7 — R5 + R8 will also have logical 1 as its output. Thus Q2 will be kept conducting).

QUESTION 4. (c)

What is the function of diodes D3 and D8 in the above circuit? Explain how they achieve this function.

ANSWER 4. (c)

D3 and D8 limit the logical 1 signal to —6 volts. As the collector goes more negative than —6 volts, these diodes are biassed conducting and will clamp the collector voltage to —6 volts plus their forward drop by passing the current necessary to drop the other 18 volts across R2 or R6.

QUESTION 5.

In Fig. 10, the A and B relays each have a release time of 200 milliseconds and their operate time may be considered to be negligible.

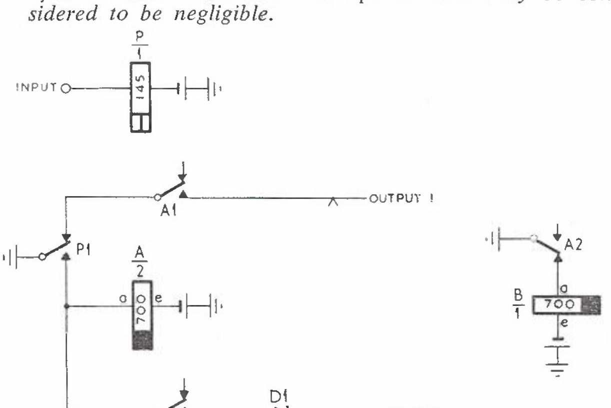


Fig. 10

QUESTION 5. (a)

A series of earth pulses are applied to the input which is normally open circuit. The earth pulses are 400 ms long with a pause of 600 ms between each.

(i) *What is the signal at OUTPUT 1 due to the pulses at the INPUT?*

(ii) *What is the signal at OUTPUT 2 due to the pulses at the INPUT?*

(iii) *What is the purpose of D1 at OUTPUT 2?*

ANSWER 5. (a)

The sequence diagram for the circuit is shown in Fig. 11.

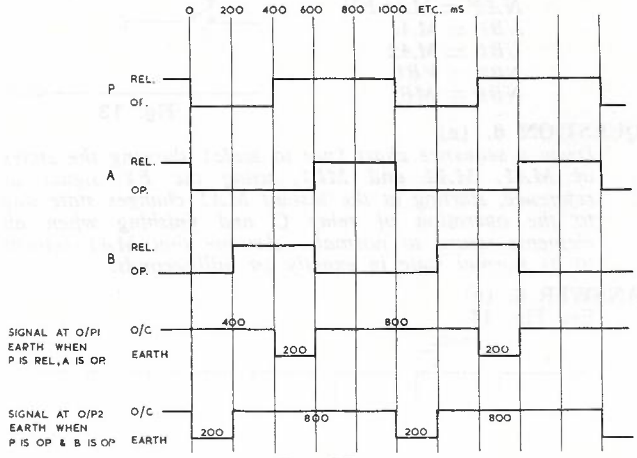


Fig. 11

(iii) To isolate relay A from OUTPUT 2.

QUESTION 5. (b)

For Fig. 12 answer the following:

(i) *How are the operate and release lags of the M relay affected by C1?*

(ii) *What is the purpose of R_1?*

What would be the effect on the operate and release lags if the resistor R_2 was placed in the position of:

(iii) *Link X?* (iv) *Link Y?* (v) *Link Z?*

(iv) *Which would be the best position to place R_2? State why.*

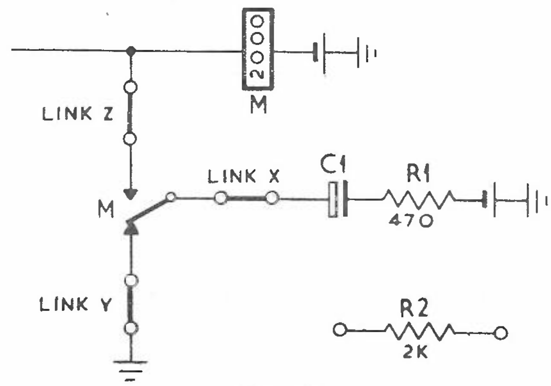


Fig. 12

ANSWER 5. (b)

(i) C1 does not affect the operate lag; increases the release lag;

(ii) R1 limits the current drawn by the capacitor;

(iii) R2 in the position of link X does not affect the operate lag; increases the release lag;

(iv) R2 in the position of link Y does not affect the operate or the release lags;

(v) R2 in the position of link Z does not affect the operate lag; increases the release lag;

(vi) The best position for R2 is link Z as it increases the release lag while still allowing for fast recycling of the M relay.

QUESTION 6.

The signals LC1 and LC2 are derived as shown in Fig. 13.

They constitute the input to the circuit represented by the logic given below.

The signal FY is a special signal which is logical 1 for one bit time (10 microseconds) every 10 milliseconds, and logical 0 for the rest of the time.

NA1 = MA2.LC1.FY
NA1′ = LC2.FY
NA2 = MA1′
NA2′ = MA1.FY
UB1 = MA1
UB1 = MA2
NB1 = VB1
NB1′ = MB1

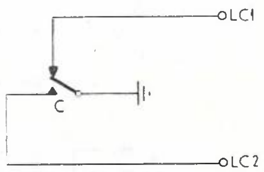


Fig. 13

QUESTION 6. (a)

Draw a sequence chart (not to scale) showing the states of MA1, MA2 and MB1, using the FY signal as reference, starting at the instant MA1 changes state due to the operation of relay C and finishing when all elements return to normal. Assume that MA1 returns to its normal state in exactly 40 milliseconds.

ANSWER 6. (a)

See Fig. 14.

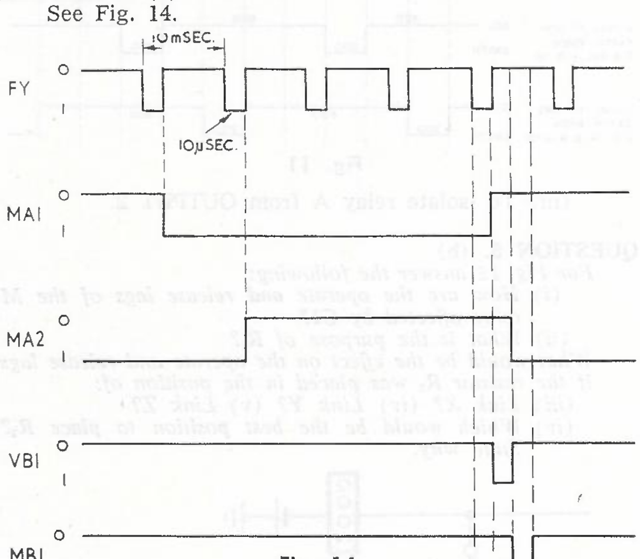


Fig. 14

NOTE: If the input of a strobed toggle becomes logical 1, the toggle will change state on the next strobe pulse.

QUESTION 6. (b)

(*i*) *What is the minimum interval for which the C contact has to be made to cause an output pulse?*

(*ii*) *What is the maximum interval for which the C contact may be made without causing a change in the output pulse? Briefly explain.*

ANSWER 6. (b)

(i) The minimum interval for which the C contact has to be made to cause an output pulse on MB1 is 1 bit time (10 microseconds), if it just coincides with an FY pulse.

(ii) The maximum interval is 10 milliseconds, if the C contact making just misses the previous FY pulse and has to wait for the next one.

The two cases are illustrated in Fig. 15.

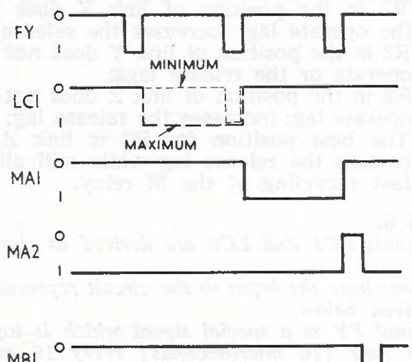


Fig. 15

PART B—AUTOMATIC MAIL HANDLING EQUIPMENT

QUESTION 1.

The circuit in Fig. 16 has been extracted from the Pitney Bowes facer canceller control and power schematic.

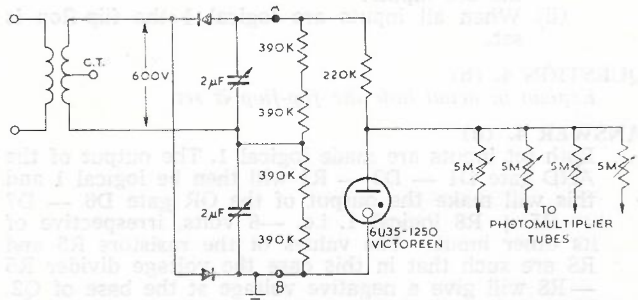


Fig. 16

QUESTION 1. (a)

(*i*) *Assuming the circuit opened at points A and B, calculate the value and polarity of the voltage at point A and explain how this is obtained.*

(*ii*) *What is the maximum value of the voltage available to the photomultipliers? Explain how this value is achieved. Why is this type of circuit required to supply the photomultiplier H.T.?*

ANSWER 1. (a)

(i) Voltage at A $= 2 \times \sqrt{2} \times 600$
$= 1700$ volts approx.

Polarity is negative.

This voltage is obtained by voltage doubler action. One capacitor charges up to the peak transformer secondary voltage in the half cycle when its series diode is forward biassed, and the other capacitor charges up to the same voltage in the other half cycle. The voltages are additive and the polarity depends on the direction of the diodes.

(ii) Maximum voltage available to photomultipliers is 1250 volts, limited to this value by the gas filled regulator tube, which, once struck, maintains a constant voltage across itself, dropping the excess voltage across the 220K resistor. This arrangement supplies a constant voltage to the photomultipliers to ensure a constant gain once the sensitivity is set.

QUESTION 1. (b)

Detail the method of adjusting the 5 Megohm sensitivity control of the photomultiplier tube for optimum performance. Mention the other control associated with this adjustment, and briefly indicate which part of the circuit is affected by this control and in what way it affects the operation of the machine.

ANSWER 1. (b)

The sensitivity control is adjusted in conjunction with the phosphorescent special amplifier trigger level control. The trigger level is set at 2.0 volts and the sensitivity is adjusted such that most, but not all, letters are gated properly. The phosphorescent trigger level is then re-adjusted to 0.6 volts.

The trigger level setting determines the voltage required at the output of the photomultiplier to trigger the special amplifier. A high trigger level ensures that no false output will be obtained from envelopes and other small signals but also requires a higher signal from the stamps for them to be recognised.

QUESTION 2. (a)

With the aid of the Pitney Bowes facer canceller circuit reproduced in Fig. 17, explain in detail how a letter blockage is detected in the brush station of this machine.

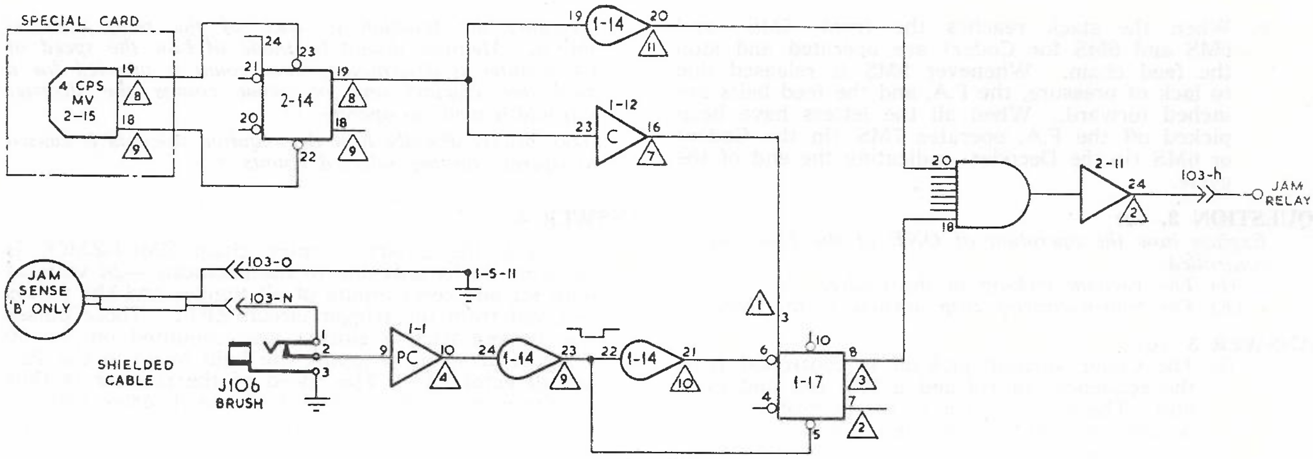


Fig. 17

ANSWER 2. (a)

While a piece of mail is obscuring the brush station photo cell the photo cell preamplifier output 1-1-(4) is at logical O. The preamplifier output is doubly inverted and a logical zero, indicating mail presence, is applied to the set sampled input of the jam flop 1-17-6.

The 4- cycle per second multivibrator combination 2-14 . . . 2-15 causes a positive going pulse edge to appear, via the clock amplifier 1-12, at the jam flop clock input 1-17-(1) when flop 2-14 sets every 250 mS.

If the presence of a piece of mail is being detected at the time the positive going clock signal arrives, the jam flop will set and the gate driver input 2-11-18 will be made logical 1. However, as the jam flops change of state comes about when flop 2-14 sets, there is a logical zero at gate driver input 2-11-20 at that time.

After half of the period of the multivibrator, or 125 mS, the inverter output 1-14-(11) and gate driver input 2-11-20 will be made logical 1 again. The gate driver output 2-11-(2) becomes logical 0 and the jam relay operates.

QUESTION 2. (b)

What is the:
(i) minimum,
(ii) maximum,
time taken to detect a blockage in the brush station?

ANSWER 2. (b)

(i) When a piece of mail obscures the brush station photo-cell just before flop 2-14 sets and maintains this condition until flop 2-14 resets the blockage is detected in the minimum time of 125 mS, i.e., half the period of the 2-14 flop output.

(ii) When a piece of mail obscures the brush station photo-cell, just after flop 2-14 sets there is a 250 mS delay until flop 2-14 sets again and generates the required positive going clock pulse out of inverter 1-12; a further 125 mS must elapse before flop 2-14 resets and thus the blockage is detected in the maximum time of 375 mS.

QUESTION 3.

NOTE: Answer this question for EITHER the Coder OR the Decoder. At the beginning of your answer to part (a) nominate which of the two you are considering.

QUESTION 3. (a)

Draw a schematic diagram of a stacker feeder and include and name each of the following:
(i) Stacking and feeding arms in their normal positions.
(ii) All microswitches.
(iii) Edging and feeding belts.
(iv) Drive chains.

ANSWER 3. (a)

See Fig. 18.

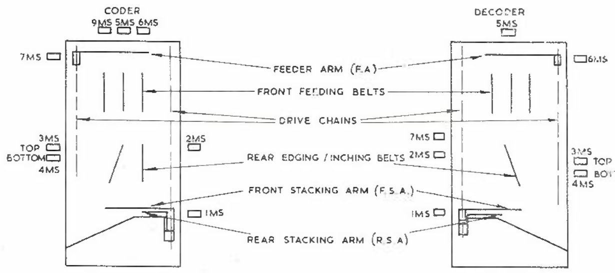


Fig. 18

QUESTION 3. (b)

Describe one typical cycle of the stacker feeder. Give the condition required to start the cycle and indicate at what time(s) in the full cycle the components you have included in the diagram are operated and what effect operating each of the microswitches has.

ANSWER 3. (b)

Initial condition for stacker feeder cycle to begin:— No letters in the front stack, F.S.A. off-normal, and no letters entering the rear stack (for the Decoder this usually means that 7MS has been operated).

The cycle then begins and the stacker feeder goes through the following steps:

1. Both chains begin to drive, causing the F.A. to raise and move rearwards and the R.S.A. to move forwards, pushing the stack and the F.S.A. in front. Feeding and edging belts are running.
2. Stacker chain, edging and feeding belts stop when the R.S.A. operates 2MS.
3. On its way back the F.A. operates 3MS, drops down behind the R.S.A. and begins to drive forward. When 4MS is operated by the F.A., the stacker chain restarts.
4. The R.S.A. is driven past 2MS and releases it and then pivots up. The front feeding belts begin driving.
5. The stack is driven to the pick-off by the F.A. where the F.S.A. pivots up and is driven rearwards by the stacker chain. It picks up the R.S.A. and both return to their normal positions operating 1MS.

6. When the stack reaches the front, 5MS (and 6MS and 9MS for Coder) are operated and stop the feed chain. Whenever 5MS is released due to lack of pressure, the F.A. and the feed belts are inched forward. When all the letters have been picked off the F.A. operates 7MS (in the Coder) or 6MS (in the Decoder) indicating the end of the cycle.

QUESTION 3. (c)

Explain how the operation of ONE of the following is controlled:

(*i*) *The vacuum pick-off in the Coder.*
(*ii*) *The binary diverter drop solenoid in the Decoder.*

ANSWER 3. (c)

(i) The Coder vacuum pick-off is controlled from the sequence control and a P.E. cell and lamp unit. The S.C.R. driver to the pick-off solenoid is operated on the selected counts. As the pick-off belt moves off-normal, the light beam to the controlling P.E. cell, which is normally made through on aperture in the belt, is broken. This keeps the S.C.R. switched on and the belt driving until the beam is re-made.

(ii) The Decoder binary diverter drop solenoid is operated by an S.C.R. solenoid driver which is controlled by the allotter relay 1C and relay D in the intermediate store. 1C operates, selected by the allotter counter, on every second letter. The S.C.R. is switched on when 1C operates, and at the same time the operating earth is removed from D, which is slow to release. When D does release, the S.C.R. is switched off and the flap returns to its normal position.

QUESTION 4.

With the aid of the diagram in Fig. 19, explain in detail the operation of the diverter counter (coder or decoder), including the function of each of the relay contacts shown. Mention should be made of how the speed of the counter is determined, what count is inserted for a particular channel and on what counts the diverter solenoid is made to operate.

Also, briefly describe how the required solenoid is caused to operate on the selected counts.

ANSWER 4.

Normally the binary counter chain ZMC1-ZMC6 is counting backwards due to the balanced —24 volts at both set and reset inputs of all toggles and the pulses received from the trigger circuit ZPT1. These pulses are derived from a slotted disc, mounted on the 30 Channel diverter, chopping the light beam to the P.E. cell detector ZP6. The speed of the counter is thus synchronised with the speed of the diverter belt.

When the allotter selects the particular counter, the negative voltage is removed via CA4 but is still extended to all toggles via T1 (H2).

In the meantime the intermediate store relays 1D—5D (1B—5B) are set up according to the sorting information, for channel n, say. When the T (H) relay is operated from the sequence control, the -24 volts via T1 (H2) is removed from the toggles and count n + 32 is transferred into ZMC1 to ZMC6 via the D contacts. Due to the unbalance of voltages at the set and reset inputs of the toggles, the counter does not begin to count until T (H) releases, which occurs when the letter cuts the light beam to the P.E. cells on the diverter entry slide.

With balanced inputs, the counter begins to count back from n + 32. Counts 32-22 are gated out to operate the required diverter solenoid via a pre-amplifier, an S.C.R. solenoid driver, and the relay tree set up for channel n in the corresponding diverter store.

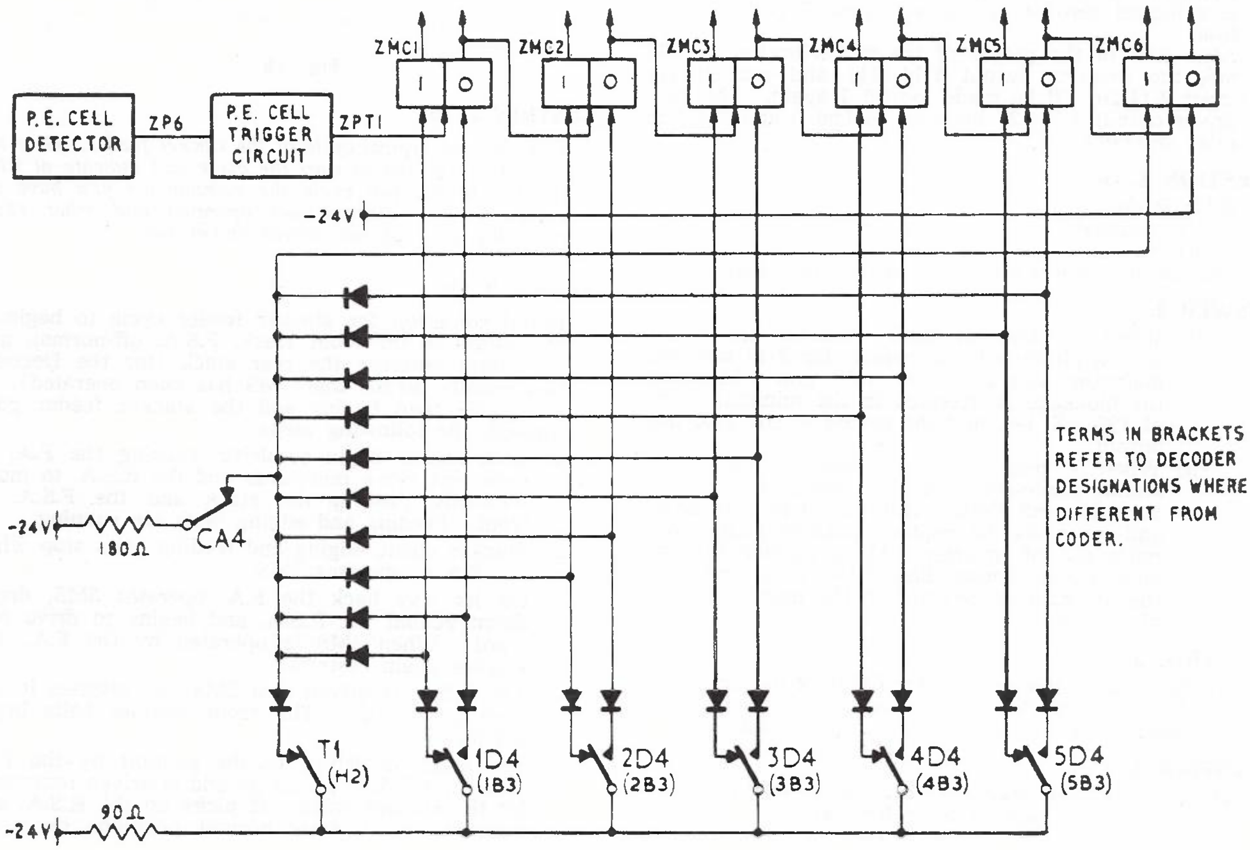


Fig. 19

QUESTION 5.

Fig. 20 represents one of the inputs to the logic alarm in the coder.

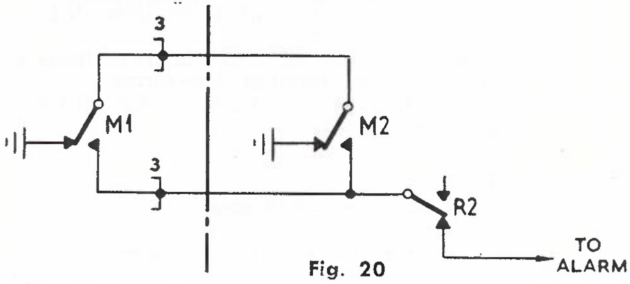


Fig. 20

QUESTION 5. (a)

(*i*) *How many M relays are there in one Coder and in which section of the circuit are they located?*

(*ii*) *What is the main function of the M relays?*

ANSWER 5. (a)

(i) There are four M relays in one coder; one in the A section of the Intermediate store and one in each of the three printer stores.

(ii) The M relays, in conjunction with the check codes, test the operation and release of the code relays in the stores with which they are associated.

QUESTION 5. (b)

(*i*) *Explain fully the operation of the circuit.*

(*ii*) *Give one example of a fault condition detected by this circuit.*

(*iii*) *What is the function of the R2 contact?*

ANSWER 5. (b)

(i) When a check code is in the store, the M relay in that store is released. When a code other than a check code is in store the M relay in that store is operated. The circuit given tests that a check code is either in all stores mentioned in (a) (i) or in none of them. If all M relays, in one coder, are not in the same state, the alarm is operated.

(ii) This circuit would detect any fault which prevents a code relay or an M relay, in the stores mentioned in (a) (i), from operating or releasing.

(iii) The R2 contact disconnects the above checking circuit from the alarm lead while the information in store is being changed, preventing maloperation of the alarm during this period.

QUESTION 5. (c)

(*i*) *What is the duration of the operate pulse to the R relay and when in the machine sequence does it occur?*

(*ii*) *The machine sequence in the coder is controlled from two binary counter chains. What is the number of toggles in each of the counter chains, and why was this method preferred to using a single counter chain having an extra toggle?*

ANSWER 5. (c)

(i) The R relay operate pulse is 80 mS long. It occurs on counts 0-1 of the first counter in the sequence control of the operator who initiated the sequence OR on counts 20-21 of the first counter of the other operator.

(ii) There are five toggles in each counter chain in the Coder Sequence Control.
Two counter chains, each approximately one second long, are preferable to one counter chain two seconds long as the machine cycle may be recommenced each second rather than every two seconds.

QUESTION 6.

With the aid of Fig. 21, describe the operation of the code staticiser in the Decoder. Start your explanation at the time the prepulse leaves F3 and finish it at the time the signals are sent to the relay store.

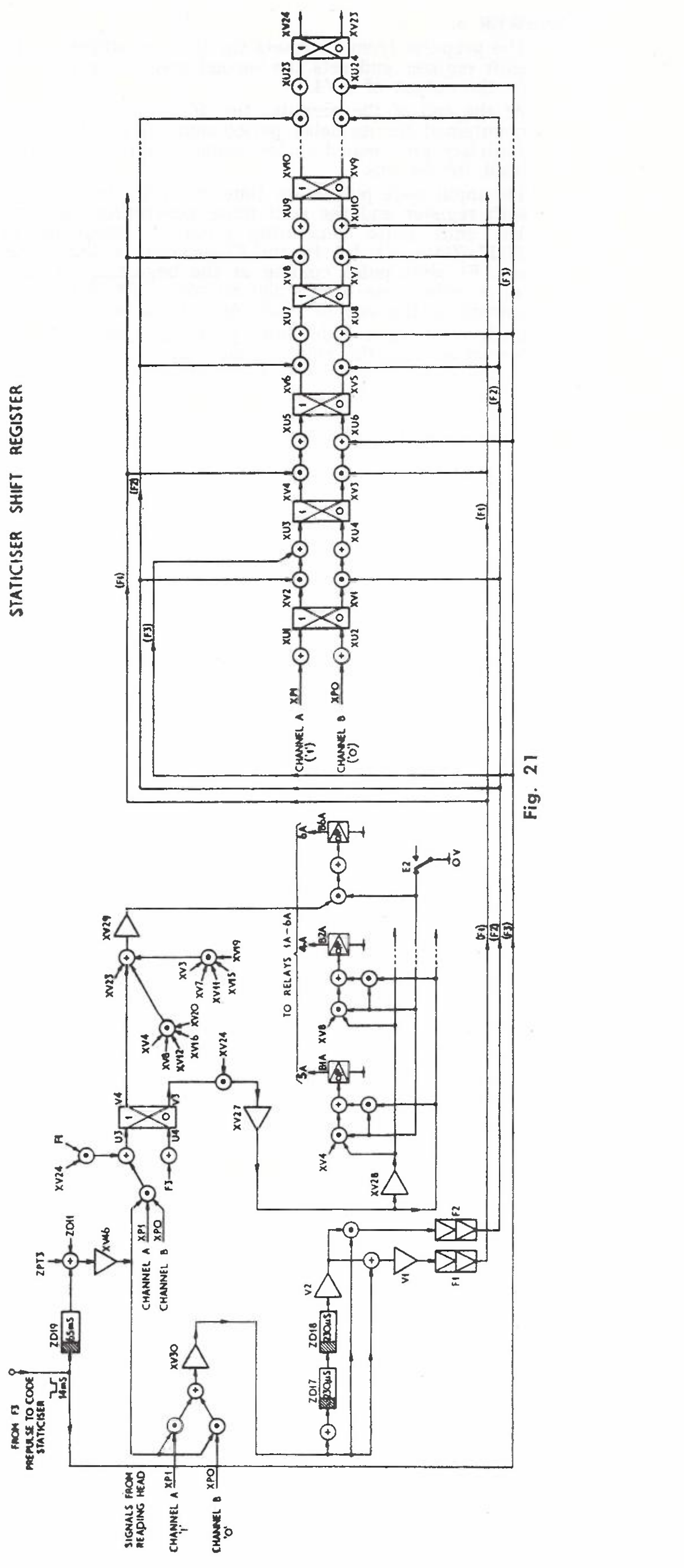


Fig. 21

ANSWER 6.

The prepulse from F3 resets the last ten stages of the shift register and sets the second stage, causing a '1' on the output of XV4.

At the end of the prepulse the '0' output of ZD19 is maintained for its delay period and the inputs to the staticiser are opened to the signals from the reading head for 56 mS.

The input code pulses are simultaneously fed into the shift register and the shift pulse generating circuitry. The shift pulse generating circuitry consisting of ZD17, ZD18, V1, V2, F1 and F2 produces a 230 microsec. F1 shift pulse coming at the beginning of each input code pulse and a 230 microsec. F2 shift pulse coming at the end of each input code pulse.

Each valid input code pulse puts the appropriate information into the shift register, generates two shift pulses and transfers the information in the register two stages forward.

When 5 valid code pulses have been received the original '1' is set on XV24 and the 5 code pulses should be stored on XV20, XV16, XV12, XV8 and XV4. With XV24 a '1', XV28 is a '1' and the gates into amplifiers B5A to B1A will be prepared so that when the E contact opens the stored code is transferred onto relays 1A to 5A.

QUESTION 7. (a)

It is required to display a pulse of approximately 30 microseconds so that its length may be measured and its leading edge observed. The pulse is non-repetitive and occurs 27 milliseconds after the only available C.R.O. trigger.

Explain how you would do this and state the settings you would use on all timing controls.

ANSWER 7. (a)

Use a storage oscilloscope and set the VARIABLE time base control to calibrate. Set the Delay time-base to 10 mS/div. and the DELAY TIME MULTIPLIER to 2.7. Switch to the delayed sweep mode, automatic and external triggering, and set the Delayed or A time-base to 5 microsec./div. Set the control to the STORE mode, single sweep, and use the available trigger to start the sweep.

NOTE: In a practical situation the 27 mS could not be presumed to be so accurate that the C.R.O. could be set up without checking the exact delay time required.

QUESTION 7. (b)

Draw a diagram showing the exact position the pulse would occupy on the screen.

ANSWER 7. (b)

See Fig. 22.

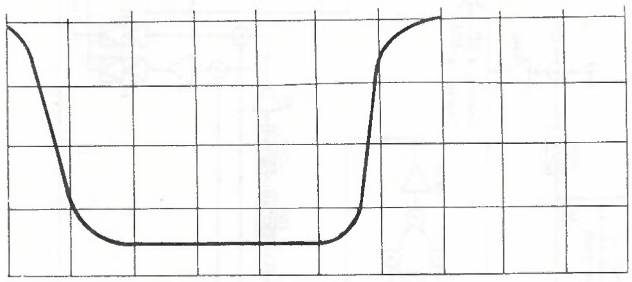


Fig. 22

QUESTION 7. (c)

State three advantages of calibrated sweep delay over magnification.

ANSWER 7. (c)

Three of the following:—

(i) Greater ratios of effective magnification.
(ii) Elimination of 'time jitter' or 'time drift' of displayed waveforms.
(iii) Greater accuracy of time interval measurements between displayed waveforms.
(iv) Better long-term accuracy of the displayed time-base.

QUESTION 7. (d)

When using a dual trace oscilloscope:

(*i*) *What operational mode would you use to aisplay two low frequency signals simultaneously?*
(*ii*) *State two methods of obtaining a time related display of two signals.*

ANSWER 7. (d)

(i) Vertical amplifiers in the chopped mode.
(ii) Two of the following:—
1. Chopped mode.
2. Trigger on channel one only.
3. External triggering.

QUESTION 8. (a)

With reference to the Stream Feed, explain the functions of the Queue-counter and the Despatch-counter. What is the stepping signal for each of the counters and when does it occur, and how is the appropriate stacker feeder selected to receive the next stream of letters?

ANSWER 8. (a)

The Queue-counter allocates queue positions to machines in the order in which their rear stacker becomes empty. Each time the machine calls for mail and a queue position is allocated, the QR relay in the machine control circuit causes the Queue-counter to be stepped onto the next count.

The Despatch counter counts the number of streams despatched to the Coding positions. It is stepped by relay LS which operates when the beam to the LLA P.E. cell is broken by a stream and releases when the VV relay re-operates at the completion of a despatch. To select the next stacker feeder to receive mail the machine queue positions store (V-Z store) is compared with the Despatch-counter relays (DV-DZ). When all the corresponding relays coincide the D relay in the machine operates and inserts the number of that machine into the P store. The information in the P store determines the next position to receive a stream.

QUESTION 8. (b)

In the Stream Feed circuitry:

(*i*) *How is the failure of the P.E. cell lamp for an MP relay detected? What is the quickest way of locating the faulty machine?*
(*ii*) *What happens when a motor overload operates? How is this achieved?*

ANSWER 8. (b)

(i) When the light source for a particular MP P.E. cell fails, the LF relay in series with the power supply which supplies that group of light sources will release, bringing up the 'Despatch Inhibit' condition. By checking which of the seven LF relays is released, the fault can be localised to a group of 5 to 7 light sources. (The faulty group is also indicated on the Display Panel).
(ii) When a motor overload operates on the Stream Feed transfer the whole transfer is stopped. This occurs because the control circuit to the contactor controlling all the transfer motors is through all motor overloads in series.

QUESTION 8. (c)

Draw a block diagram showing the essential features of the Coder Trainer equipment.

ANSWER 8. (c)

See Fig. 23

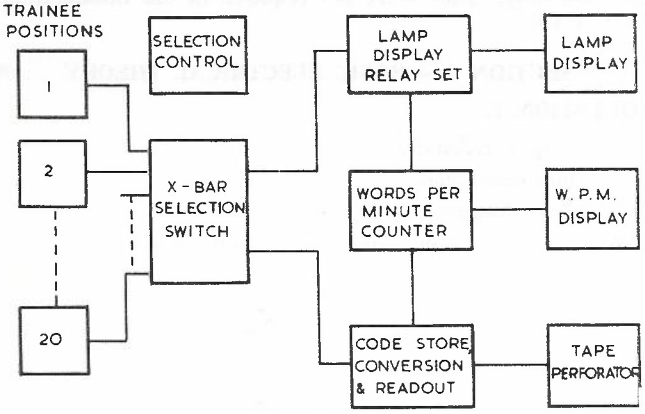


Fig. 23

QUESTION 8. (d)

In the Coder Trainer:
(i) What is the function of the serialiser and why is it necessary?
(ii) How is the trainee operator's tape checked?
What are the two ways of indicating an error in the operator's tape?

ANSWER 8. (d)

(i) The serialiser converts the five bits read simultaneously by the five fingers of the tape reader to a serial form and sends it to the teleprinter at a rate which suits the teleprinter.
(ii) The trainee operator's tape is checked against a master tape by simultaneously reading the two tapes. The operator's tape is also typed out by the teleprinter. Errors are indicated by the error counter and an X printed at the end of a line in which an error occurred.

QUESTION 9.

The following logic applies to the operator's equipment in the Register Translator Room:

DIGIT DISTRIBUTOR

$US1 = XMA01'.XMA02'$
$US1 = XMA03'.XMA04'.XMA05'$
$US2 = L6.L7$
$US2 = VS1.MD2$
$US2 = VS1.MD3'$
$US3 = L6.L10$
$US3 = L7.L10$
$US4 = VS1$
$NJ1 = MJ2'.VS2.FZ$
$NJ1 = MJ2'.VS3.FZ$
$NJ2 = MJ1.FZ$
$NJ1' = L6.L7.L9.L10$
$NJ2' = MJ1'$
$UJ1 = MJ2, MD2$
$UJ1 = MJ2.MD3'$
$UJ2 = MJ1.L8$
$UJ2 = MJ2'$
$ND1 = MD3'.VJ2.FR2$
$ND2 = MD1.VJ2.FR2$
$ND2 = MD1.VS4$
$ND3 = MD2.VJ2.FR2$
$ND3 = MD2.VS4$
$ND1' = MD3.VJ2$
$ND1' = MR1$
$ND2' = MD1'.MJ1'.MJ2$
$ND2' = MR1$
$ND3' = MR1$
$UD1 = MD1.L8$
$UD1 = MD3.L8$
$UD1 = VJ1$
$UD2 = MD2.L8$
$UD2 = MD1'.L8$
$UD2 = VJ1$
etc.

ADDRESS STORE

$XNA01 = VD1.L1$
$XNA02 = VD1.L2$
$XNA03 = VD1.L3$
$XNA04 = VD1.L4$
$XNA05 = VD1.L5$
$XNA06 = VD2.L1$
$XNA07 = VD2.L2$
$XNA08 = VD2.L3$
$XNA09 = VD2.L4$
$XNA10 = VD2.L5$
$XNA11 = VD2.L1$
etc.
$XJA01' = FR1$
$XJA02' = FR1$
$XJA03' = FR1$
$XJA04' = FR1$
$XJA05' = FR1$
$XJA06' = FR2$
$XJA07' = FR2$
$XJA08' = FR2$
$XJA09' = FR2$
$XJA10' = FR2$
$XJA11' = FR1$
etc.

COMPARISON CONTROL

$NC2 = MC1$
$NC2' = MR1$
$UR1 = MJ2'.L9$
$UR2 = MC2'.L9$
$NR1 = VR1.VR2.MD2'.MD3$
$NR1 = L11$
$NR1' = MR1$
$ER1 = MR1'$
$ER2 = MR1'$

With the aid of the above logic describe how the first bit of information is inserted into the Address Store from the instant an alpha keystroke is made. Before this keystroke the Address Store was full and a translation had been obtained.

ANSWER 9.

Address store full implies that the Digit Counter is on Count 5.
i.e., MD2 is reset.
MD3 is set.
A translation had been obtained implies that MC2 is set.
Make alpha keystroke:
L6 and L7 become logical 0 while keys are pressed
VS3 becomes logical 1
MJ1 sets on next FZ pulse
MJ2 sets on the following FZ pulse if keys are still pressed — ensures that keystroke is valid.
VR1 becomes logical 1
MR1 sets (as VR2.M02'. MO3 was already logical 1)
FR1 and FR2 become Logical 0 and reset the Address Store.
Digit Counter toggles MD1, MD2 and MD3 are all reset.
MR1 resets itself one bit after setting
VJ1 becomes logical 0 when the Digit Counter resets.
VD1 becomes logical 1 and the information on the signal wires L1—L5 is set into the address store toggles XMA01—XMA05.

When the keys are released:
- L6 and L7 return to Logical 1
- MJ1 resets and MJ2 resets one bit later
- While MJ1 is reset and MJ2 is set:
  - VJ2 goes to logical 1 for 1 bit time
  - MD1 is set, stepping the Digit Counter onto the next count.

The circuit is now ready for the next keystroke.

QUESTION 10. (a)

Draw a diagram showing the distribution of 1 bit of address information from the read head on the magnetic drum to the operators frames. At each feed-out point show the number of elements fed from that point. Designate all components and indicate in which section of the equipment they are located.

ANSWER 10. (a)

See Fig. 24.

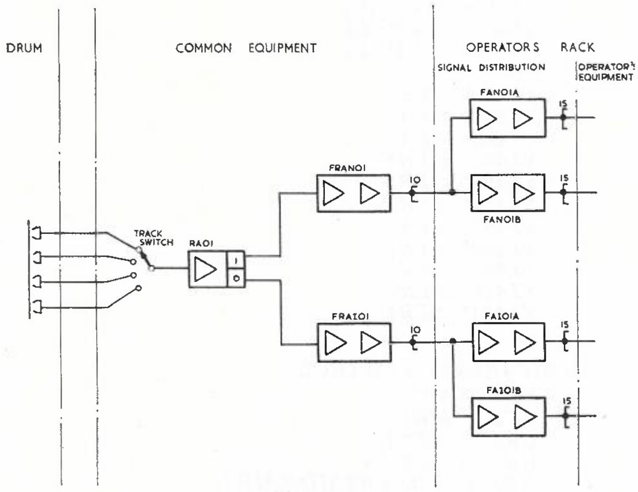


Fig. 24

QUESTION 10. (b)

(*i*) *Name the section of the operators' equipment in which use is made of the address information thus distributed. To how many operators is this information available at any one time?*

(*ii*) *What is the total number of address buffers connected to the input of the section referred to in* (*i*), *and where do the signals to each of these buffers originate?*

ANSWER 10. (b)

(i) The address information is made use of in the COMPARATOR and is available to all 150 operators simultaneously.

(ii) There are 56 address buffers connected to the comparator, 50 originating from the 25 address tracks of the drum and 6 from the 3 State Code Generator toggles.

QUESTION 10. (c)

Lamps for rack 1-5 and frame 38 are glowing on the Routine Program Panel. In reference to your diagram in part (a) above, state in what section of the equipment this fault would be located. Give your reason. What would be the nature of the fault condition detected by the Routiner?

ANSWER 10. (c)

The fault is affecting all five racks and is therefore located in the COMMON EQUIPMENT section or further back. The fault condition detected by the Routiner is a permanent logical 0.

Examination No. 5645, 22nd July, 1967, and subsequent dates for Appointment, Promotion or Transfer as Technician (Telecommunications), Control Systems, Postmaster-General's Department.

PAPER No. 1

(Reasons appearing with the answers are given for clarification only. They were not required in the examination answers.)

SECTION A — BASIC ELECTRICAL THEORY

QUESTION 1.

In Fig. 1, calculate:

(*a*) *Total resistance.*

(*b*) *Power dissipated in* R_2.

(*c*) *Resistance seen from the primary side if* $E_p = 55V$ *peak.*

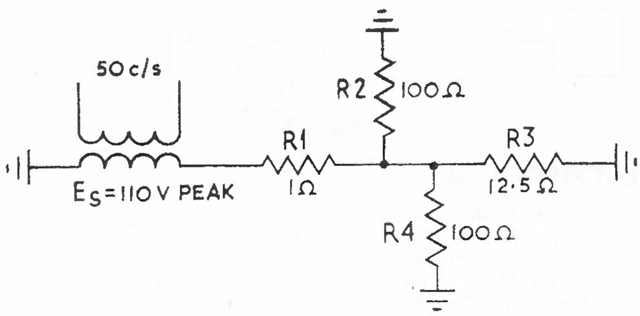


Fig. 1

ANSWER 1. (a).

$$R = R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}}$$

$$= 1 + \frac{1}{\frac{1}{100} + \frac{1}{12.5} + \frac{1}{100}}$$

$$= 1 + \frac{100}{1 + 8 + 1}$$

$$= 1 + 10$$

$$= 11 \text{ Ohms.}$$

ANSWER 1. (b).

$$\text{Voltages across } R_2 = \frac{10}{11} \times 110 \text{ volts peak}$$

$$= \frac{100}{\sqrt{2}} \text{ volts R.M.S.}$$

$$\text{Power} = \frac{E^2}{R}$$

$$= \frac{(100/\sqrt{2})^2}{100}$$

$$= \frac{10000}{2 \times 100}$$

$$= 50 \text{ Watts.}$$

ANSWER 1. (c).

$$\frac{Rp}{Rs} = \left(\frac{Np}{Ns}\right)^2$$

$$Rp = \left(\frac{Np}{Ns}\right)^2 \times Rs$$

$$= \left(\frac{Ep}{Es}\right)^2 \times Rs$$

$$= \left(\frac{55}{100}\right)^2 \times 11$$

$$= \frac{11}{4}$$

$$= 2.75 \text{ Ohms.}$$

QUESTION 2.

In Fig. 2, calculate:

(a) Capacitance of C_2.

(b) Charge in C_1.

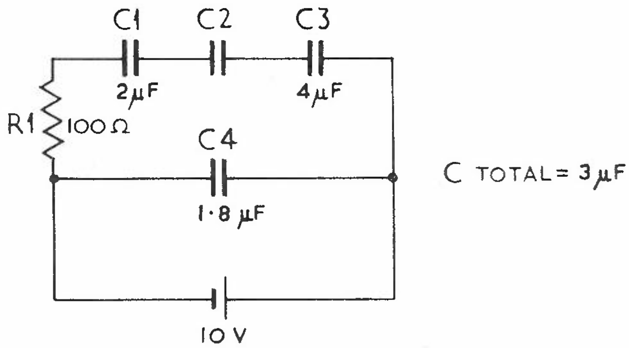


Fig. 2

ANSWER 2. (a).

Total C = (Series combination of C_1, C_2 and C_3) + C_4

$$\frac{1}{\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}} = C_T - C_4$$

$$= 1.2\mu F$$

$$\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3} = \frac{1}{1.2}$$

$$\frac{1}{2}+\frac{1}{C_2}+\frac{1}{4} = \frac{1}{1.2}$$

$$\frac{1}{C_2} = \frac{1}{1.2} - \frac{1}{2} - \frac{1}{4}$$

$$= \frac{10-6-3}{12}$$

$$= \frac{1}{12}$$

$$\therefore C_2 = 12\mu F.$$

ANSWER 2. (b).

CHARGE ON C_1 = total charge in branch

$= C \times V$

$= 1.2\mu F \times 10$ Volts

$= 12$ coulombs.

QUESTION 3.

For the series circuit in Fig. 3:

(a) Does the circuit current I lead or lag the applied voltage? Draw a vector diagram (not to scale) to illustrate your answer.

(b) If $I = 480$ mA, what is the voltage drop E_L across the inductance L?

(c) Assuming the supply to be 50 cps, calculate the inductance of L.

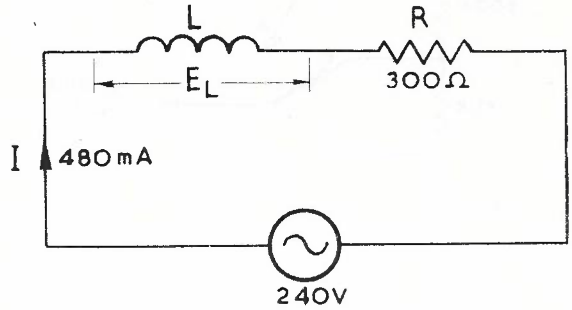


Fig. 3

ANSWER 3. (a).

Circuit current lags applied voltage by the phase angle θ (see Fig. 4).

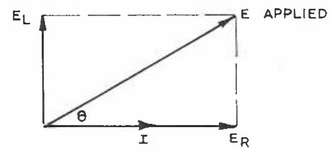


Fig. 4

ANSWER 3. (b).

$$\text{Circuit impedance } Z = \frac{E}{I}$$

$$= \frac{240V}{480mA}$$

$$= 500 \text{ Ohms.}$$

From right angled triangle (Fig. 5),

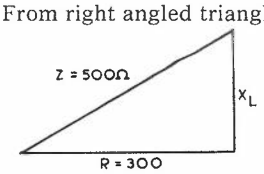


Fig. 5

$X_L = 400\Omega$

$E_L = IX_L$

$= 480mA \times 400\Omega$

$= 192$ Volts.

ANSWER 3. (c).

$$X_L = 2\pi fL$$

$$\therefore L = \frac{X_L}{2\pi f}$$

$$= \frac{400}{100\pi}$$

$$= \frac{4}{\pi}$$

$$= 1.27 \text{ H.}$$

QUESTION 4.

(a) In what circumstances is a vacuum-tube voltmeter the most appropriate meter to use?

(b) Fig. 6 shows the multiplier used in a V.T.V.M. for range selection.

Assuming the grid impedance to be infinite, answer the following:

(*i*) *To what ranges do the contact positions A, B, C and D correspond?*

(*ii*) *What is the input impedance of the meter on each range?*

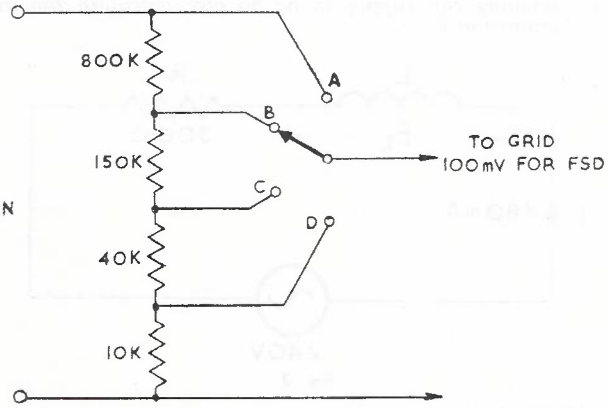


Fig. 6

ANSWER 4. (a).

(i) When minimum loading of the circuit under test is required, i.e., when measuring the P.D. across a high impedance.

(ii) When measurements are to be made over a wide range of frequencies.

ANSWER 4. (b).

(i) A — Input magnitude is the same as signal to grid, therefore it corresponds to the 100mV range.

B — When signal to grid is 100mV, input voltage E is given by:

$$\frac{100\text{mV}}{E} = \frac{150 + 40 + 10}{800 + 150 + 40 + 10} = \frac{200}{1000}$$

$$\therefore E = 100\text{mV} \times \frac{1000}{200} = 500\text{mV}.$$

C — When signal to grid is 100mV, E is given by:

$$\frac{100\text{mV}}{E} = \frac{40 + 10}{1000} = \frac{50}{1000}$$

$$\therefore E = 100\text{mV} \times \frac{1000}{50} = 2 \text{ Volts}.$$

D — When signal to grid is 100mV, input E is given by:

$$\frac{100\text{mV}}{E} = \frac{10}{1000}$$

$$\therefore E = 100\text{mV} \times \frac{1000}{10} = 10 \text{ Volts}.$$

Therefore the ranges are:

A — 100mV

B — 500mV

C — 2V

D — 10V.

(ii) The input impedance is the same on each range and is equal to the total resistance of the multiplier. Since the grid resistance is infinite, it does not load the multiplier.

∴ Input Impedance = 1 Megohm.

QUESTION 5.

Describe the operation of the monostable multivibrator in Fig. 7.

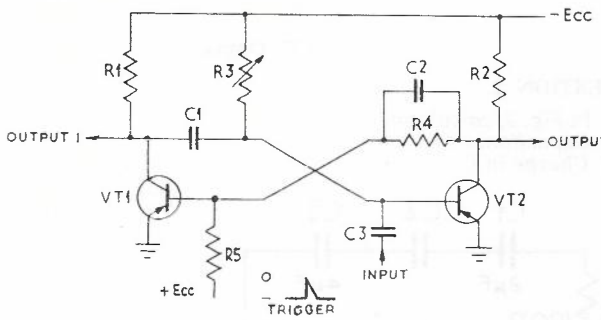


Fig. 7

ANSWER 5.

Normally VT2 is saturated (ON) by the negative voltage applied through R3, and the earth potential on its collector is extended via R4 to the base of VT1 to keep it OFF.

When a positive going trigger pulse is applied to C3, the base of VT2 goes positive and VT2 is turned OFF. Ecc is now extended to the base of VT1 via R3 and R4, turning it ON and changing its collector voltage to 0 Volts.

This positive going change is reflected on the other side of C1, causing the voltage on the base of VT2 to be raised by 24 volts, from 0 to +24 volts. C1 immediately begins to discharge through VT1 and R3, tending to bring the base of VT2 to —24 volts.

As soon as the base of VT2 becomes slightly negative (the time depends on the time constant of R3 and C1), VT2 is turned on again, turning VT1 OFF, and returning the circuit to its normal state.

QUESTION 6.

(*a*) (*i*) *Draw the actual circuit of a two input AND gate feeding into a single input OR gate. Specify suitable values and polarities for the power supplies assuming that logical 1 is — 6V and logical 0 is 0V.*

(*ii*) *Explain how the AND gate functions.*

(*b*) *For Fig. 8 state whether the output is logical 1, logical 0 or indeterminate (i.e., depends on inputs other than the one specified) for each of the following cases:*

(*i*) *I1 = 0.*

(*ii*) *I2 = 0.*

(*iii*) *I2 = 0.*

(*iv*) *I3 = 0.*

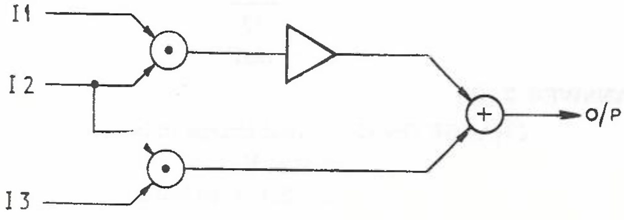


Fig. 8

ANSWER 6. (a)

(i) See Fig. 9.

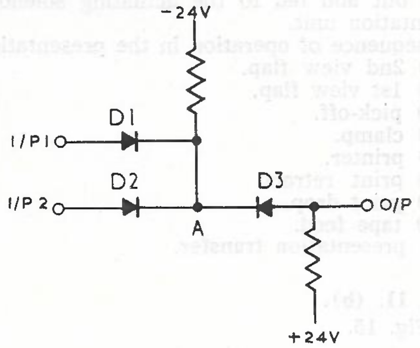


Fig. 9

(ii) The output of the AND gate always goes to the input whose voltage is furthest from the resistor backing voltage. For example, when input 1 is 0 volts and input 2 is —6 volts, point A will go to 0 volts. The diode D2 is reverse biassed and will not conduct. If either one or both inputs are 0 volts, the output will be also 0 volts. To get logical 1 (—6V) out, both inputs must be at —6V.

ANSWER 6 . (b).

(i) logical 1.
(ii) indeterminate.
(iii) logical 1.
(iv) indeterminate.

QUESTION 7.

(*a*) *For the counter shown in Fig. 10 draw a diagram to show how counts 4-7 can be gated out in the simplest form.*

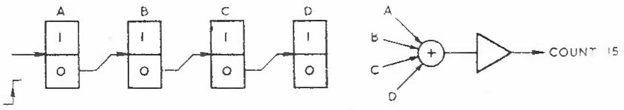


Fig. 10

(*b*) *Give the conditions of the MA toggles necessary to set MB1, given that:*
UP1 = MA1.MA2
UP1 = MA1'.1
NB1 = VP1

ANSWER 7. (a).

From the gating for count 15 it is seen that the reset state of each toggle is the significant one. Therefore the counter is a forward counter.

	A	B	C	D
Count 4	1	1	0	1
5	0	1	0	1
6	1	0	0	1
7	0	0	0	1

For counts 4 to 7, toggle C is reset and toggle D is set.
Therefore gating for counts 4-7 is as shown in Fig. 11.

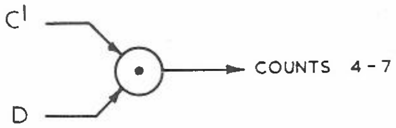


Fig. 11

ANSWER 7. (b)

To set MB1, VP1 must be logical 1, therefore UP1 must be logical 0.
Each input to the OR gate in front of VP1 must therefore be at logical 0.
From the second input MA1'.1 = 0, MA1' must be logical 0; i.e. MA1 must be set.

.:. From the first input MA1. MA2 = 0, as MA1 is already logical 1, MA2 must be logical 0.
The required conditions are:
MA1 set
MA2 reset.

QUESTION 8.

(*a*) *Draw a diagram of a photomultiplier tube and the associated biassing network, giving approximate values of components. Designate the output.*

(*b*) *Explain the operation of the photomultiplier. How can its sensitivity be varied?*

ANSWER 8.

(a) See Fig. 12.

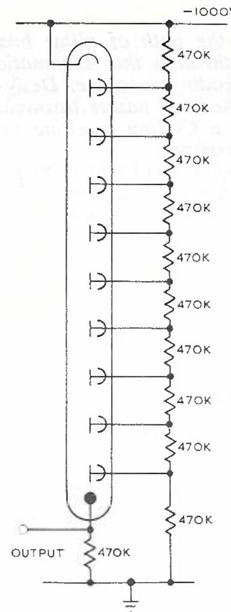


Fig. 12

(b) The photomultiplier consists of of a photoemissive cathode, several dynode stages and an anode. When light falls on the cathode it emits electrons. The dynodes are biassed progressively more positive and have a surface coating which facilitates secondary emission. In this way the weak current due to the light signal may be increased up to several million times. Finally the current is collected at the anode, and variations in the light input are reflected as changes in voltage drop.
The sensitivity of the photomultiplier is varied by varying the value of the high tension supplied.

QUESTION 9.

For the relay circuit in Fig. 13, describe what takes place when a 1-second earth pulse is applied to the INPUT.

The description should be in a series of steps. If more than one operate or release action occurs at the same time they should be described in the same step. State the reason for any operate or release lags.

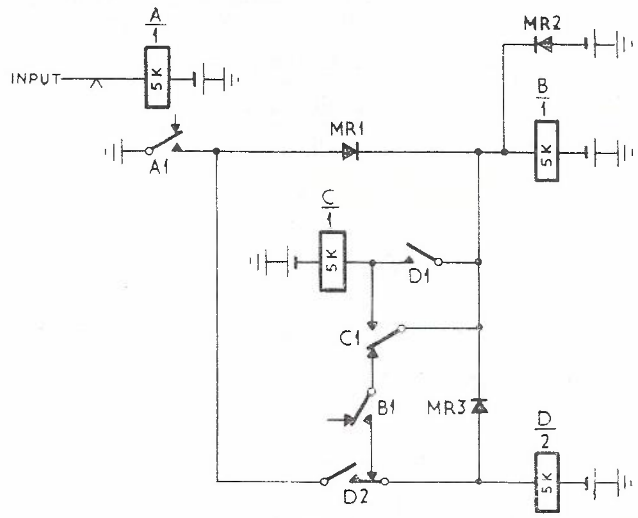


Fig. 13

ANSWER 9

A operates
B operates, via eth., A1 op and MR1.
D operates, via eth., A1 op, MR1, C1 norm., B1 op and D2 norm.
C operates, via eth, A1 op, MR1 and D1 op.
D held, via eth, A1 op and D2 op.
C held, via eth, A1 op, MR1 and C1 op.
A releases
D releases
B and C held by current due to their back e.m.f. through the coil and MR2.
B and C release after back e.m.f. dies down.
MR1 and MR3 block slugging effect of MR2 from D.
MR3 blocks operate earth via A1 and MR1 to D.

QUESTION 10.

(*a*) *Draw a block diagram showing the path of pillar box mail from the Culling machine through the Automatic Letter Handling Plant to the Decoding machine. Designate all machines and transfers the mail passes through.*
(*b*) *List the procedure for switching a Coding machine on ready for an operator to begin coding.*
(*c*) *Briefly describe how a coding machine calls for and receives mail. How is it ensured that the machine which has been waiting the longest receives mail first?*

ANSWER 10. (a).

See Fig. 14.

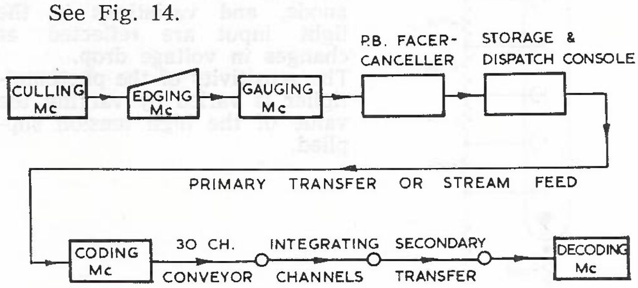


Fig. 14

ANSWER 10. (b).

Switch on main A.C. switch and heater switch on A.C. control panel. Turn on D.C. isolater. Press heater button and start button on front console.

ANSWER 10. (c).

When the rear stacker of a coding position is empty, i.e. the F.S.A. is in the normal position, a signal is sent to the stacker feeder control and the position is allocated a place in the queue by the queue counter. As the streams are despatched, they are counted by the despatch counter. As the despatch counter steps, the streams are sent to the coding positions in the order that they were allocated places in the queue, ensuring that stacker feeders are filled in the order that they called for mail.

QUESTION 11.

(*a*) *Describe how the presentation sequence is controlled in the Coder. List the sequence of operation of the various components in the presentation unit.*
(*b*) *Draw a block diagram to show how one particular flap in the presentation unit is caused to operate, the first block representing the sequence control unit and the last block the flap actuator. (You need not give actual time of operation.)*

ANSWER 11. (a).

The presentation sequence in the coder is controlled by two binary counter chains in series. The counters are operated by positive going edges obtained from the mains through a squaring circuit. Each count is 40 mS long. When a translation is obtained the first counter begins counting. The required counts are gated out and fed to the actuating solenoids in the presentation unit.

The sequence of operation in the presentation unit is:

(i) 2nd view flap.
(ii) 1st view flap.
(iii) pick-off.
(iv) clamp.
(v) printer.
(vi) print retract.
(vii) print drop.
(viii) tape feed.
(ix) presentation transfer.

ANSWER 11. (b).

See Fig. 15.

QUESTION 12.

Explain how a letter passing through the Coding machine is timed and diverted into the correct channel after it has been released from the presentation transfer unit.

Fig. 15

ANSWER 12.

The translation information, Co, having passed through the intermediate stores, is passed into the diverter store selected by the allotter and sets up the relay tree to operate the appropriate solenoid on the 30 channel diverter. The same information is also sent to the diverter counter, which will set to the number of the channel plus 32. When the letter is released from the presentation unit and cuts the light beam to the P.E. cells on the slide (ZP1 and/or ZP2), the diverter counter starts counting backwards. Its counting rate is synchronised with the diverter speed by means of a slotted disc on the diverter roller chopping a light beam to derive the counting pulses. On the counts of 32 to 22, an operate pulse is sent to an S.C.R. which, through the relay contact tree, operates the solenoid. This means that the flap opens when the letter is almost two flaps away from it, and it closes about two flaps after the letter is diverted into the 30 channel conveyor.

QUESTION 13.

A letter is coded for TAMWORTH (primary code 4, secondary code 9) by the operator at position 10 of suite 2 of the Coders.
(*a*) *Draw a diagram showing the coded information as it would appear on the envelope.*
(*b*) *Describe how the code marks are detected by the reading head in the appropriate Decoder.*
(*c*) *How does the Decoder check if the information read by the reading head is valid?*

ANSWER 13. (a).

See Fig. 16.

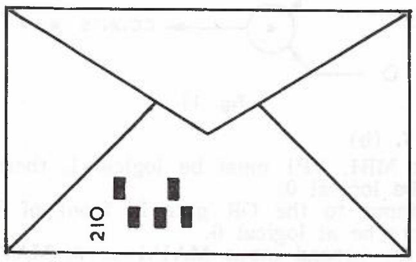


Fig. 16

ANSWER 13. (b).

First the letter is illuminated by the U.V. light, which make the phosphorescent code marks glow. Then it passes in front of the reading aperture, where the '1' line and the '0' line are scanned separately. The lens for each is connected to a photomultiplier via an optical fibre. The time delay between illumination and scanning ensures that only long persisting phosphorescence will be detected. The glow from the marks cause the photomultiplier to conduct, giving a voltage pulse at the anode. The pulses are shaped by an amplifier and passed to the logic section.

ANSWER 13. (c).

The information from the photomultipliers is checked in the code staticiser and shift register section. Whenever the code is invalid (not a 5 bit complementary code) a relay in the first intermediate store (relay 6A) is inhibited, causing the letter to go to Reject.

QUESTION 14.

(*a*) *What is the purpose of the Comparator in the Register Translator?*

(*b*) *With the aid of the diagram in Fig. 17, explain the operation of the Comparator.*

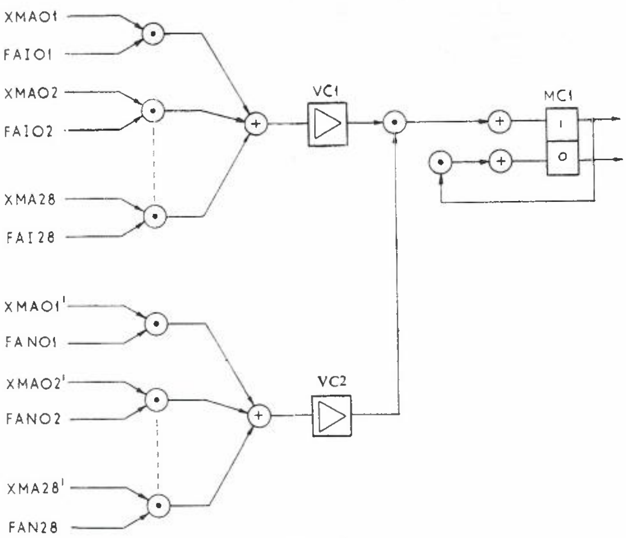


Fig. 17

ANSWER 14. (a).

The purpose of the comparator is to compare the information in the address store with the information stored on the address tracks of the drum, and to produce a signal opening the translation gate when a comparison is found.

ANSWER 14. (b).

The signals XMA01 — XMA28 and XMA01' — XMA28' are signals from the address store, representing the actual code stored and its complement, respectively. The signals FAN01 — FAN28 and FAI01 — FAI28 are buffered signals from the magnetic drum, representing the information being read and its complement, respectively. Each AND gate compares a pair of these signals, its output going to logical zero if either signal or both inputs are logical zero. When all AND gates feeding into the OR gate preceding the inverters VC1 or VC2 have logical 0 as their output, the OR gate output will also be logical 0 and the inverter's output will be logical 1. When both inverters have logical 1 outputs, the AND gated combination fed to the toggle MC1 is also logical 1. This will only occur when an exact comparison for the address information is found on the drum. Then the toggle MC1 sets indicating that a comparison has been found. MC1 resets itself 1 bit later.

PAPER No. 2

QUESTION 1.

When an earth is applied to the INPUT of Fig. 1, the current drawn from the battery is 40 mA. Find the resistance of the relay R.

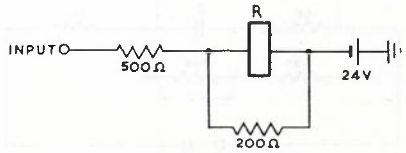


Fig. 1

ANSWER 1.

$$R = \frac{E}{I}$$

$$= \frac{24 \times 1000}{40}$$

= 600 Ohms.

The resistance of the relay in parallel with 200 Ohms = 100 Ohms.

Resistance of relay = 200 Ohms.

QUESTION 2.

If the current through R5 in Fig. 2 is 10 mA, what is the current through R1?

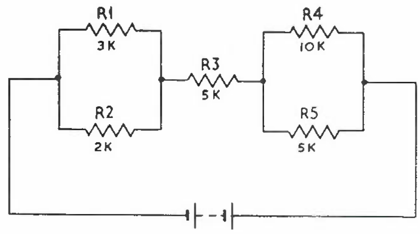


Fig. 2

ANSWER 2.

Current through R5 = 10mA.
Current through R4 = 5mA.
Total Current = 15mA.
Current through R1 = 2/5 of 15mA.
= 6mA.

QUESTION 3.

Find the potential at A with respect to earth in Fig. 3.

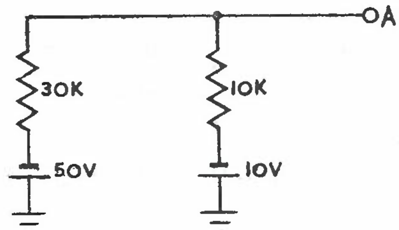


Fig. 3

ANSWER 3.

See Fig 4.

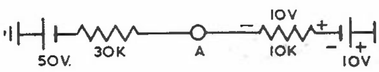


Fig. 4

Potential across 40kOhms = 40V
Potential across 10kOhms = 10V
Potential at A = —20V

QUESTION 4.

Given that the voltage drop across the 10k resistor in Fig. 5 is 6V, find the voltage across the capacitor, C.

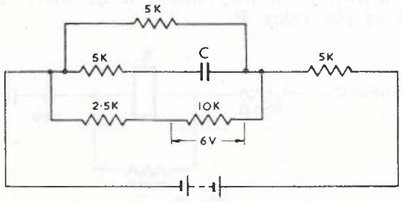


Fig. 5

ANSWER 4.

P.D. across 10kOhms resistor = 6V
P.D. across 2.5kOhms resistor = 1.5V
This total voltage of 7.5V is across C.

QUESTION 5.

If the voltage accross the 100 Ohms resistor in Fig. 6 is 15V, what is the primary current?

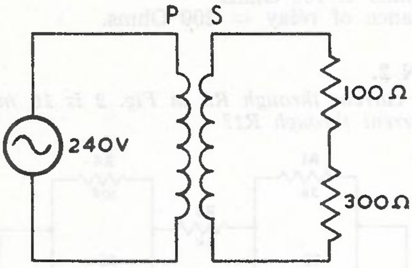


Fig. 6

ANSWER 5.

P.D. across 100Ohms = 15V
P.D. across 300Ohms = 45V
Secondary Voltage = 60V

$= \frac{1}{4}$ of Primary Voltage

Primary Current $= \frac{1}{4}$ of Secondary Current

$= \frac{60}{400} \times \frac{1}{4}$

= .03725A.

QUESTION 6.

(*a*) *What is meant by the expression 'P-type material'?*
(*b*) *Show with the aid of a sketch how a piece of PN material may be biassed conducting.*

ANSWER 6.

(a) P-type material is that in which the majority carriers are holes.
(b) See Fig. 7.

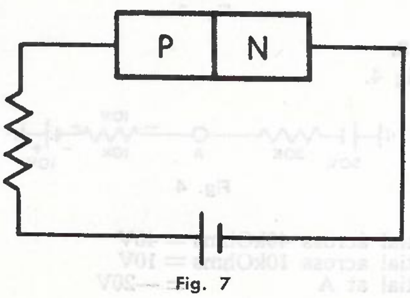


Fig. 7

QUESTION 7.

(*a*) *What is the facility provided on some storage oscilloscopes (e.g., Tektronix 564) to assist in storing fast repetitive wave-forms?*
(*b*) *List two precautions when using the storage mode on an oscilloscope.*

ANSWER 7.

(a) Integrate.
(b) Two from the precautions listed below:
(i) Use minimum beam intensity required to produce a clear display.
(ii) Turn intensity control to minimum when changing plug-ins.
(iii) Do not increase beam intensity to store fast rising portions of waveform.
(iv) Avoid repeated use of the same area of screen.
(v) Do not leave the display on the CRT screen when the display is not needed.
(vi) Don't leave the display switches at 'Store' when the storage mode is not needed.

QUESTION 8.

You wish to observe a sine wave with an oscilloscope. The magnitude of the sine wave as measured with an AVO is 20 volts. State the setting of the vertical amplifier sensitivity you would use and briefly explain why.

ANSWER 8.

RMS Voltage = 20V
Peak Voltage = 20 x 1.414
= 28.28V
Peak to Peak Voltage = 28.28 x 2
= 56.56V

Vertical amplifier setting would be 10V/cm and the display would be the maximum height at which the whole waveform could be observed, i.e., at 5.656 cms.

QUESTION 9.

Identify the count at the output of the gating for the forward counter shown in Fig. 8.

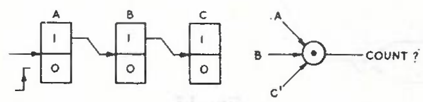


Fig. 8

ANSWER 9.

A.B.C′ = 1.2.4′ = 3.

QUESTION 10.

Complete the gating in Fig. 9 to give the same count out as the gating in question 9. Designate the inputs.

Fig. 9

ANSWER 10.

The gating required, as shown in Fig. 10, is determined by using De Morgans Theorem.

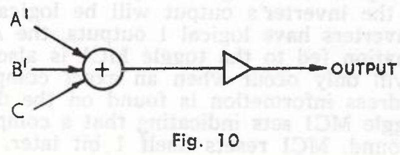


Fig. 10

QUESTION 11.

What do the Pitney Bowes symbols in Fig. 11 designate?

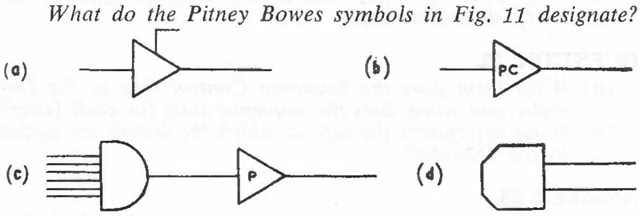


Fig. 11

ANSWER 11.

(a) Driver or non-inverting amplifier.
(b) Photocell preamp.
(c) Gate driver.
(d) Astable multivibrator.

QUESTION 12.

Give two conditions by which a Pitney Bowes flip-flop may be set.

ANSWER 12.

Logical 0 on the 'D.C. set' input.
Logical 0 on the 'sampled not' input preceding the application of a clock signal.

QUESTION 13.

(*a*) *Complete the diagram of the 8" long envelope in Fig. 12, indicating the zones for the lead system of the Pitney Bowes facer canceller.*
(*b*) *State the reason for each zone.*

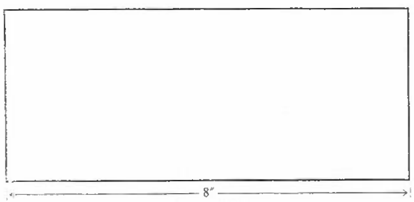


Fig. 12

ANSWER 13.

(a) See Fig. 13.

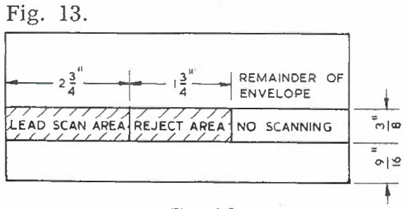


Fig. 13

(b) The leads scan area is the zone in which the stamp may be cancelled and gating signals controlled. The reject area is the zone in which there is still time to control gating signals, but the zone is outside the area which may be cancelled by the die.
The no scanning zone is the zone in which there is insufficient time to control gating.

QUESTION 14.

(*a*) *State three functions of the Gauging machine.*
(*b*) *State two functions of the Culling machine.*
(*c*) *State the purpose of the Tilting Channels.*

ANSWER 14.

(a) Three from the functions listed below:
 (i) To reject letters which are too long.
 (ii) To reject letters which are too high.
 (iii) To reject letters which are too thick.
 (iv) To reject letters which are too stiff.
(b) To remove articles which are not letters.
To remove letters which are obviously oversize.
(c) To cause the letters to lie on their long edges.

QUESTION 15.

There are two P.E. cells on the 30 Channel Diverter which are activated by light beams passing beneath the diverter through slots in the chutes.
(*a*) *What is the purpose of the beams?*
(*b*) *State the conditions under which the associated alarm operates.*

ANSWER 15.

(a) (i) To detect blockages in the 30 channel diverter.
 (ii) To detect blockages in the 30 channel conveyor.
(b) (i) If beam is not broken within a set time (1½—5 secs.) after the beam at entry section is cut.
 (ii) If beam is broken for longer than a set time (2 sec).

QUESTION 16.

How are the timing pulses derived in the following sections of the letter sorting system:
(*a*) *Coding Machine?*
(*b*) *30 Channel Diverter?*
(*c*) *Register Translator?*

ANSWER 16.

(a) A 50 cycle signal from mains supply drives a bistable circuit via a squaring circuit. The output of the bistable provides the timing pulses.
(b) From a disc shutter at the end of the 30 channel diverter, which provides pulses at a rate proportional to the diverter speed.
(c) From the strobe tracks on the drum.

QUESTION 17.

(*a*) *Give three conditions which will inhibit pick-off on a Coding machine.*
(*b*) *List three different cases in which a letter will be passed to the reject channel of a Coding machine.*

ANSWER 17.

(a) Three from the following:
 (i) When the heaters have not come up to heat.
 (ii) When there is a logic alarm.
 (iii) When there is a 30 channel diverter blockage alarm.
 (iv) Tape empty.
 (v) Tape broken.
(b) (i) When the operator presses the reject key.
 (ii) When the required channel is inhibited.
 (iii) When the diverter flap of the required channel fails to operate.

QUESTION 18.

(*a*) *What are the check codes for the Coding machine and when are they obtained?*
(*b*) *Which section of the equipment do the test codes test and for what type of fault?*

ANSWER 18.

(a) (i) 00000 and 11111.
 (ii) They are obtained when the operator presses the reject key and receives a translation.
(b) The test code checks that all equipment from the translation store to the diverter store is capable of producing two states.

QUESTION 19.

In relation to the interconnections between the Register Translator and a Coding machine:
(*a*) *How many wires carry signals from the Translation Store and what is their destination in the Coder?*
(*b*) *How many wires originating from the keyboard are signal wires and how many are control wires? To what section in the R.T. room are the signal wires connected?*

ANSWER 19.

(a) Twenty wires to the three printer stores and A section of the intermediate relay store.
(b) Five signal wires to the address store. There are also seven control wires.

QUESTION 20.

What is the function of the following equipment in the Register Translator?
(*a*) *Routiner.*
(*b*) *State Code Generator.*

ANSWER 20.

(a) To continuously routine the buffer amplifiers and read amplifiers.
(b) The function of the state code generator is to save space on the magnetic drum, by providing the state code output itself.

QUESTION 21.

(*a*) *List the procedure for starting the B head on a Decoding machine with both the a.c. and d.c. switched off.*
(*b*) *What is the effect of isolating a Decoder head?*

ANSWER 21.

(a) Switch on common a.c. switch and common d.c. isolator at head A. Release d.c. control isolator at the B head. Press start button.
(b) Stops letters from entering the stacker feeder of that head, but does not affect cycling or pick-off.

QUESTION 22.

What are the purposes of the following items in the Decoder?
(*a*) *Staticiser.*
(*b*) *Programme Switch.*
(*c*) *The two P.E. cells just in front of the Buffer Stacker deflector.*

ANSWER 22.

(a) The staticiser converts serial input into parallel output and checks for invalid codes.
(b) The programme selector positions the reading apertures so that the appropriate code (C1, C2 or C3) may be read.
(c) They pick up a gap sufficiently long to operate the entry deflector flaps.

QUESTION 23.

(*a*) *What form does the Sequence Control take in the Decoder and when does the sequence start for each letter?*
(*b*) *What determines the rate at which the letters are sorted in the Decoder?*

ANSWER 23.

(a) The sequence control consists of a train of timing circuits, whose gated outputs provide all the control pulses. The sequence starts when the light beam in the reading head is broken.
(b) Letters are sorted at the rate at which they are picked off by the vacuum pick off.

QUESTION 24.

What action is taken by the Decoder when a letter permanently blocks the following P.E. cells?
(*a*) *Brush Station P.E. cell.*
(*b*) *Diverter entry P.E. cell.*

ANSWER 24.

(a) The reading head motor is switched off.
(b) The reading head motor and the 30 channel diverter are switched off.

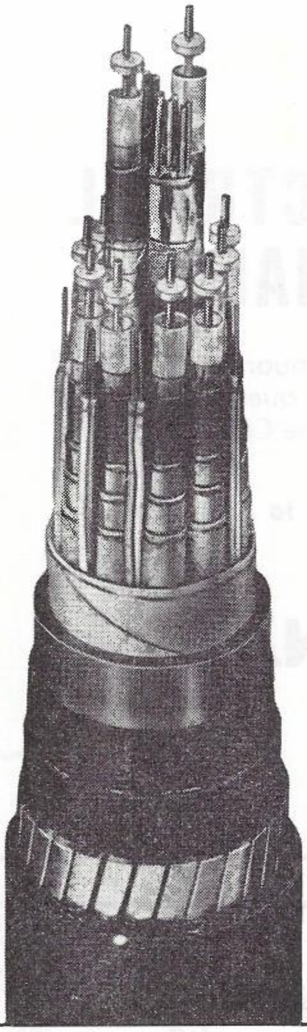
QUESTION 25.

One of the light wires is broken in a Decoder head. What would happen to letters being sorted in that head? Briefly explain why.

ANSWER 25.

All letters being sorted by the head would be rejected. When either the code or its complement is not recognised, the code is not established as valid.

SIEMENS



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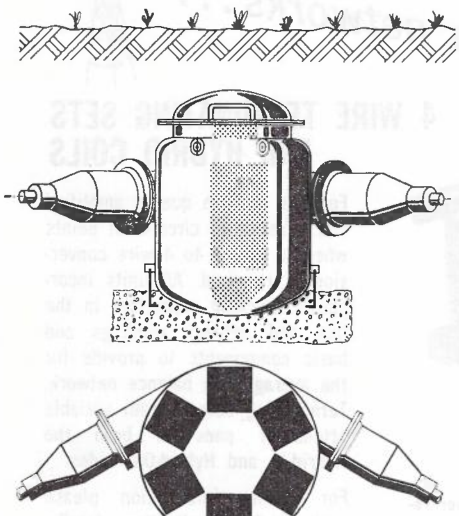
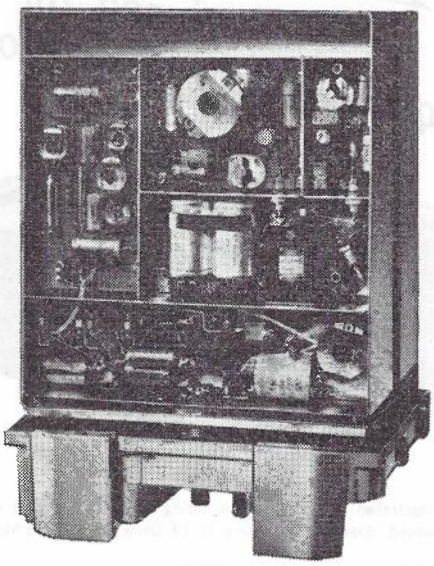
Siemens universal repeater insets not only fit into the Siemens containers illustrated, but also into the smaller containers designed by the APO for applications in Australia with locally made coaxial cable. Siemens coaxial transmission equipment is on order for a number of routes in Australia, amongst them the 600-mile Perth/Carnarvon link in Western Australia.





For additional information contact

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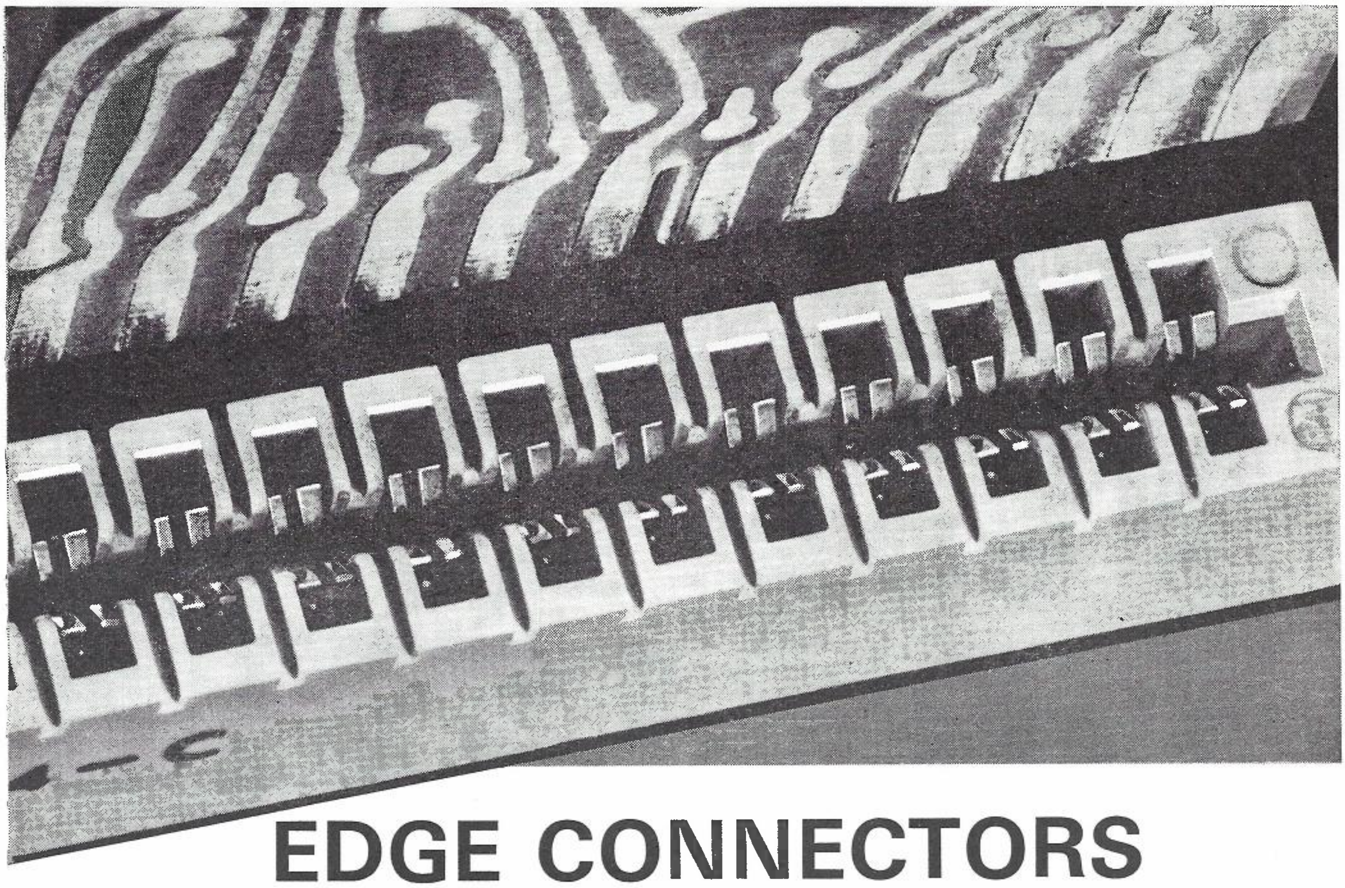
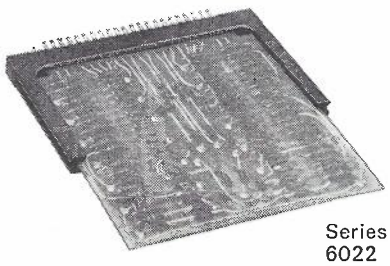


EDGE CONNECTORS



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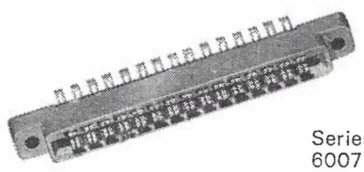

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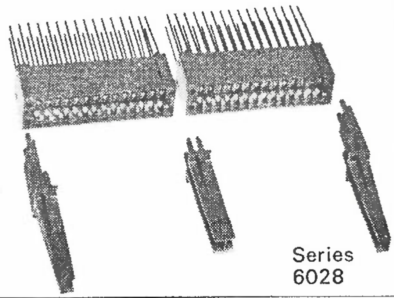

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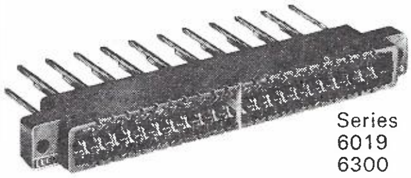

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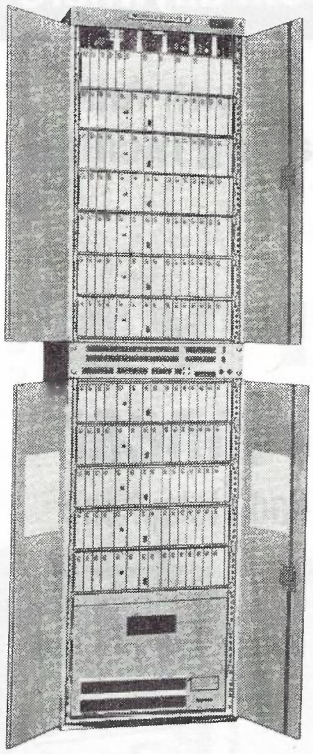

This system has transmission capacity five times that of conventional systems. It can transmit not only a 50-baud signal but also 75-baud and 1200-baud signals. Employment of differential phase modulation provides excellent performance with respect to noise and line interruption.

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THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

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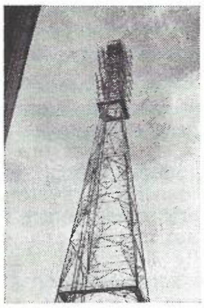

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ABSTRACTS: Vol. 18, No. 2

CHEW, W. F., and QUIRK, N.E., 'Automatic Junction Testers for Step-by-Step Exchanges'; Telecom. Journal of Aust., June, 1968, Page 158.

The functions and circuits of equipment which allows automatic and rapid testing of junctions to 2000 and pre-2000 type main and branch exchanges are described. A particular feature is the out-of-hours use of the Traffic Route Tester for junction testing.

BEARD, W. E., 'Transmitting Antenna Systems for the Australian National Television Service'; Telecom. Journal of Aust., June 1968, Page 173.

The paper describes the work of the Postmaster-General's Department in providing and installing high-power transmitting antenna systems for the National Television Service, with particular reference to antennas installed during the third and fourth phases of television expansion.

As the number of installed stations has grown, there has been a corresponding development of complexity and sophistication in design to cope with problems of interference and raised standards of performance. Special attention is given in the paper to methods by which antenna designs are checked for compliance with radiation pattern and impedance specifications and to problems of feed system design. Methods of impedance compensation and adjustment are described and the techniques of field measurements of antenna performance are outlined.

The presence of echoes in split antenna feed systems may produce enhanced ghost effects in the radiated signal and the introduction of special echo suppressing techniques is described. Anti-icing measures for four different antenna systems are discussed.

ELLIS, A. G., HARNATH, R. W., KITCHENN, R. G., and POTTER, J. B.; 'The Relaying of Television Programmes in Australia'; Telecom. Journal of Aust., June 1968, Page 121.

The paper outlines the development of television relay facilities in Australia and briefly describes the various transmission and switching media in use and planned. Performance objectives are developed, compatible with C.C.I.T.T. recommendations, performance of available equipment and the long distances encountered. Finally, test techniques used by the Post Office to ensure conformity with performance objectives are described, together with performance data. Likely developments are also discussed.

GERRAND, J. K., 'An Automatic Routiner Fault Printer'; Telecom., Journal of Aust., June 1968, Page 165.

Equipment which provides automatic print out of routiner test results is described. Known as Fault Recording Indicator for Automatic Routiners (F.R.I.A.R.), the device can work with up to 24 routiners simultaneously. A transistorized control circuit ensures compact size and reliable operation.

HARRIS, J. G., 'Remote Control of Traffic Route Testers'; Telecom., Journal of Aust., June 1968, Page 170.

The coupling of Automatic Disturbance Recorder equipment with a Traffic Route Tester to facilitate remote supervision of unstaffed exchanges is described. The transmission of commands from a staffed exchange and the receipt of information from the unstaffed exchange is achieved by means of a Translation Relay Set, the general principle of operation and physical construction of which, is described.

HARRISON, J. J., 'Computer Applications in External Plant'; Telecom. Journal of Aust., June 1968, Page 184.

This paper briefly discusses the impact that computer and operations research type techniques have had in the external plant area of telecommunications, and outlines some typical applications. It then goes on to detail the specific use of a computer technique to establish design principles for the provisioning of main subscribers cables.

MONSBOURGH, A. G. G., 'A Public Telephone for 20 cent S.T.D. Calls'; Telecom. Journal of Aust., June 1968, Page 193.

This paper briefly describes the facilities, and circuit operation of a public telephone for 20c. S.T.D. calls used to handle traffic peaks from holiday resorts.

READ, R. A., 'A Decade of Plastic Cabling'; Telecom. Journal of Aust., June 1968, Page 147.

Plastic cable has been introduced into the distribution network in the A.P.O. on a progressively increasing scale during the past decade. The article traces the resulting changes in technology and reviews the experience gained. It examines current objectives for improvement of the network and discusses developments and future trends towards the advancement of these aims.

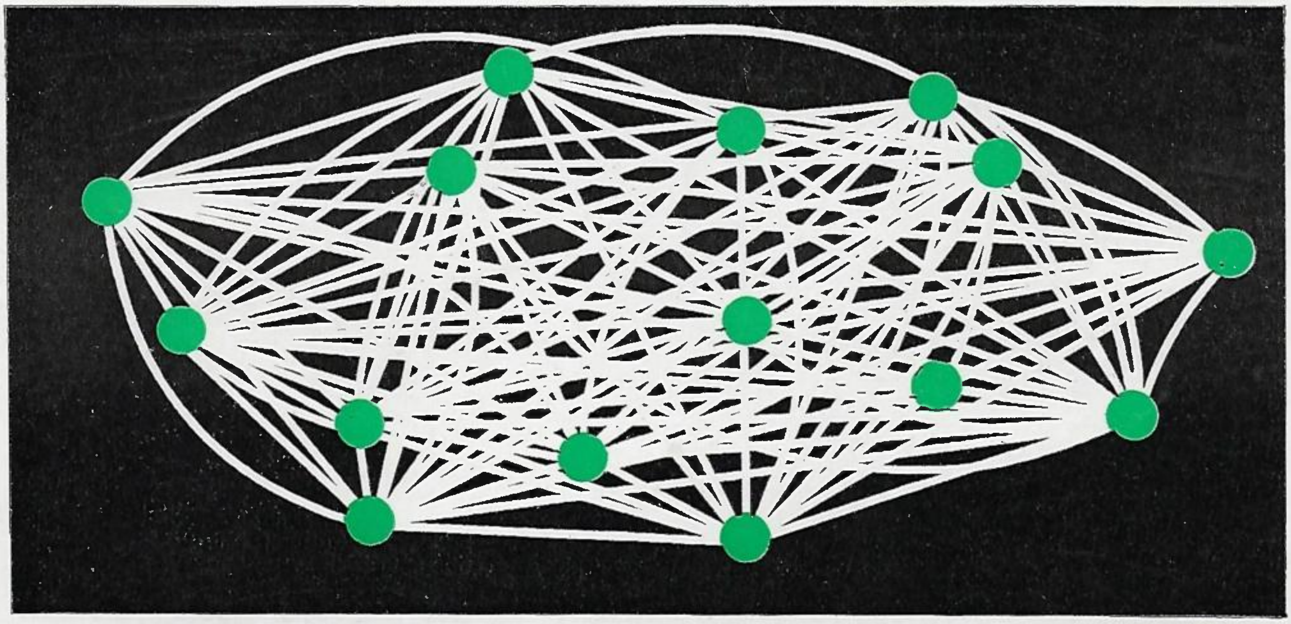
F. W. WION, 'Electronic Exchanges with Stored Program Control'; Telecom. Journal of Aust., June 1968, Page 141.

The use of computer type machines as processors in electronic exchanges is discussed in general terms, with particular reference to fully processor controlled systems.

Requirements of the processor network interface are reviewed; processor operation and program instructions, organization and requirements are briefly discussed. Approaches to reliability in operation and some maintenance aspects are briefly reviewed.

M. D. ZILKO, 'Service Assessment Facilities'; Telecom. Journal of Aust., June 1968, Page 137.

One of the methods used by the A.P.O. for assessing the service performance of the telephone network and the subscriber satisfaction with the service is the manual sampling of live telephone traffic. This article outlines the general procedure and facilities for the sampling of local and S.T.D. traffic.



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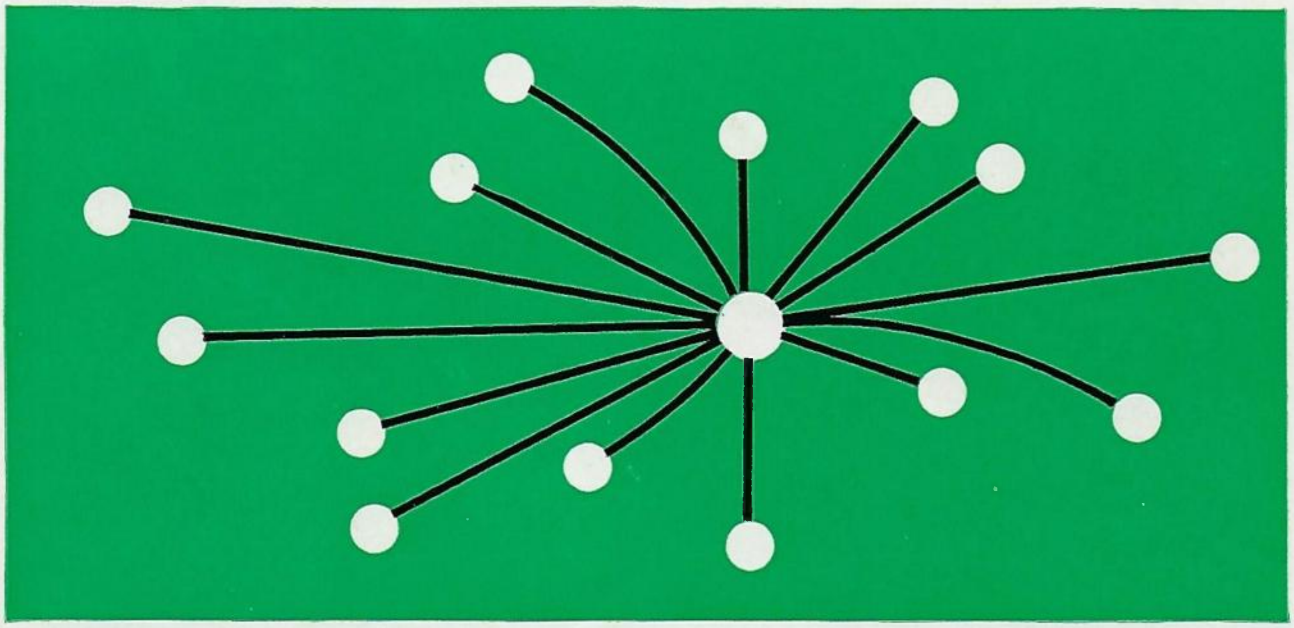

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