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IN THIS ISSUE

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JUNE, 1971


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The TELECOMMUNICATION JOURNAL of Australia

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A BRIEF INTRODUCTION TO DIGITAL DATA TRANSMISSION TECHNIQUES

*B. M. SMITH, B.E., Ph.D.**

INTRODUCTION.

Data transmission has become a rapidly expanding component of the traffic in the telephone network since many large public and private institutions have the need for a rapid transfer of information between widely scattered computing and data processing installations. Data transmission is not of course restricted to the telephone network and is used widely in military and space communication facilities.

Some examples of data communication over the telephone network are:—

(a) a bank with a central computer linked directly with the tellers in the bank's branches;

(b) a Stock Exchange quotation service for the rapid transfer of the prices of securities to stockbrokers and financial institutions;

(c) time-sharing computers where several independent operators have access simultaneously by telephone lines to a large computer;

(d) reservation networks for airlines, hotels and motels;

(e) transmission of meteorological data.

Digital data transmission refers to the transmission of information in a digital rather than an analogue form over a communication channel. The information to be transmitted may already be in digital form (e.g. the output from computers) or may be an analogue signal that is sampled at discrete time instants and then converted into digital form.

In this paper a discussion of some of the basic concepts underlying data transmission is given and these concepts are illustrated by examples from data transmission systems which use the telephone network. A list of definitions of data transmission terms is given in Table 1.

TABLE 1: DATA TRANSMISSION TERMS.

Modem	:	a unit for modulating the data into a form suitable for transmission over an analogue transmission channel and for the demodulation of the received signal.
Binary	:	having two possible states.
Bit	:	the elementary unit of information associated with the outcome of a binary event.
Symbol, Digit	:	the basic signalling element of a data transmission system; it will have two or more states.
Baud	:	the number of symbols transmitted per unit time.
Intersymbol Interference	:	overlapping of neighbouring symbols making their correct detection more difficult.

BITS, BAUDS AND BANDWIDTH.

A large number of data processing devices (e.g. computers) operate with binary notation in which information that is fed into and out from the computer must be coded into a sequence of elements, with each element in the sequence having only two possible states, which are often referred to as 0 or 1. For example, the state of these elements may be whether there is or is not a hole in a particular location in a paper tape or computer card.

Since data transmission is concerned with the digital transmission of information, a brief introduction to the unit of information is appropriate. Consider a given element in a binary sequence which can be either 0 or 1; then when this element has been received the uncertainty about its state has been removed, or alternatively some information has been received. If the two states are equally likely, the amount of information that has been received is defined to be one bit, which is a corruption of the words 'binary digit.' In short, a bit is the information associated with the outcome of an equally likely binary event.

Most simple communication systems transmit this binary data in binary form, as, for example, a telegraph system. Thus the communication rate can be expressed in bits/sec. With the advent of computers and other terminal equipment which can produce a very large volume of data in a given time, the need to increase the information rate of a channel occurs and initially this can be done just by increasing the repetition rate of the binary data sequence.

However, in a channel with a limited frequency bandwidth (e.g., a telephone channel occupying 300 Hz to 3400 Hz) there is some upper limit to the signalling rate after which the binary data elements or symbols interfere with each other and cause errors. This phenomenon occurs because the bandwidth of the signals no longer fits inside the channel bandwidth and is known as inter-symbol interference. The maximum rate at which the symbols can be transmitted without any inter-symbol interference at the sampling instants has been shown by Nyquist to be twice the bandwidth of the channel for an ideal channel with no distortion, although in practice one must be satisfied with rates less than this.

Thus for an ideal channel of bandwidth W Hz, with no delay distortion, the maximum symbol rate that can be sustained without any intersymbol interference at the sampling instants is given by

$$R = 2W \text{ baud} \quad \ldots\ldots \quad (1)$$

where R is the symbol rate. The unit of the symbol or signalling rate is the baud. It may be noted that Nyquist's relation concerns intersymbol interference at the sampling instants and bears no relation to the information rate in bits/sec.

Consequently to achieve higher data rates in a channel of limited bandwidth, more than two states or levels must be allowed in each symbol to be transmitted. Assuming that the total power of the transmitter is limited, this means that as the number of possible states in a symbol is increased, the states come closer together and are more sensitive to an error due to noise. Hence, summing up the preceding discussion, the maximum symbol rate is determined by the channel bandwidth and the number of possible states in each symbol that can be reliably detected is limited by the ratio of the signal power to noise power. The signalling or symbol rate is specified in bauds and is only equal to the bit rate for a binary system.

To see how the information rate (in bits/sec) of a transmission channel with multilevel symbols can be calculated, consider the following simple examples:—

(a) if binary data is grouped into pairs, called dibits, then each dibit can have four possible states (see below), which can be identified with four level transmission:

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dibit	level
00	A
01	B
11	C
10	D

(b) similarly an eight level system corresponds to grouping the binary data into threes, called tribits:

tribit	Level
000	A
001	B
010	C
100	D
011	E
101	F
110	G
111	H

From these simple examples it can be inferred that a symbol with m possible levels is equivalent to q bits where

$$m = 2^q \quad \ldots\ldots \quad (2)$$

Taking logarithms to base '2' of both sides of (2) gives

$$q = \log_2 m \quad \ldots\ldots \quad (3)$$

That is, the information q, in bits of an m-level symbol, with each level equally likely, is given by (3). The logarithmic expression in (3) can be demonstrated to advantage by considering n consecutive symbols each of m possible levels; then intuitively we would expect n $\log_2 m$ = nq bits of information to be contained in these symbols. But n symbols of m levels can have m^n possible states and hence contains $\log_2 m^n$ bits, which is identical to n $\log_2 m$, as above.

The received signal after having been distorted and filtered by the communication channel will typically appear as in Fig. 1, if it is a binary signal. It is often useful to form an 'eye-pattern' from this signal by superimposing segments of the received signal many times on an oscilloscope, where each trace is triggered at the same point in time in relation to the symbol boundaries. The formation of a binary eye pattern is also shown in Fig. 1. In general the more open the eye-pattern the greater the immunity from error, although in the next section an exception to this is given. As expected, non-binary symbols give multi-level eye-patterns with the number of vertical eye-openings being one fewer than the number of levels in the symbol.

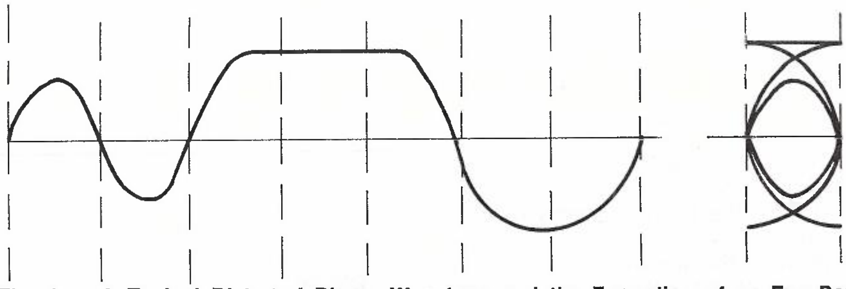
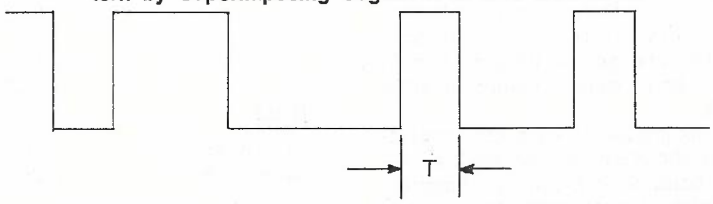


Fig. 1. — A Typical Distorted Binary Waveform and the Formation of an Eye Pattern by Superimposing Segments of this Waveform.



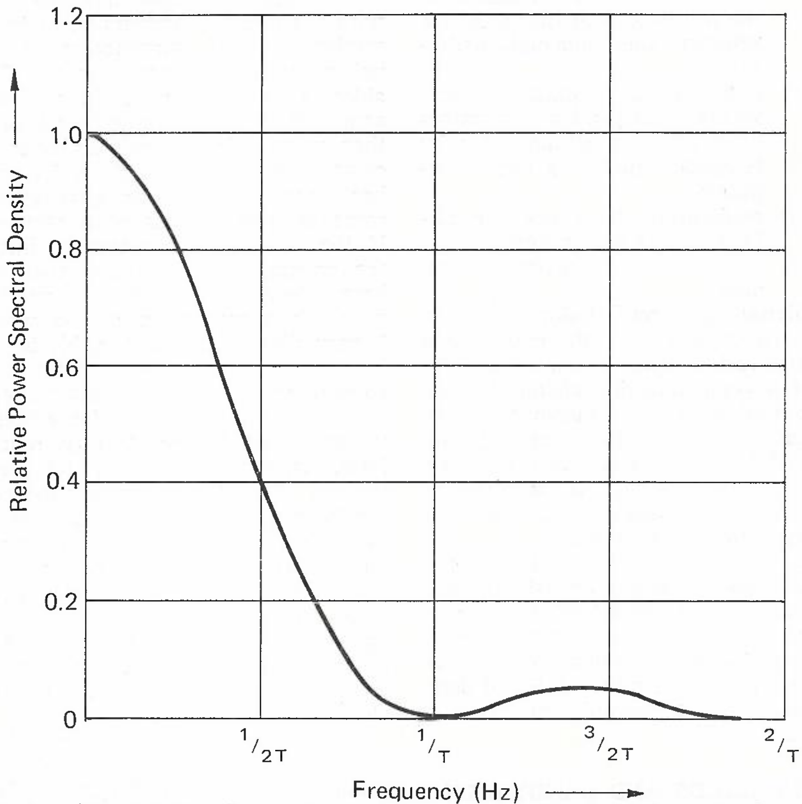


Fig. 2. — The Relative Power Spectral Density of a Random Binary Rectangular Pulse Sequence.

MODULATION.

Where there is a direct physical line with a d.c. path between the transmitter and receiver it is possible to transmit the data directly as a sequence of pulses whose rate and number of levels are determined by the bandwidth of the circuit and the noise on the line. The d.c. path is necessary since the power spectral density of a sequence of random pulses extends to d.c. (Ref. 1, p. 320). For example, the power spectral density of rectangular binary pulses of random sign is shown in Fig. 2.

However, in many cases the communication channel may have a bandwidth that does not extend down to d.c.; for example, a telephone channel extends from about 300 Hz to 3400 Hz. This precludes the direct transmission of the baseband pulses which have a frequency spectrum extending down to d.c. and to circumvent this problem the frequency spectrum of the signal must be shifted up above the lower cut-off frequency of the channel.

This operation is called modulation and is performed by modifying some parameter (e.g. amplitude, phase, frequency) of a sinusoidal carrier by the data sequence, where the frequency of the carrier is located in the passband of the channel. The location of the carrier frequency and the maximum symbol rate are determined by the passband of the channel.

At the receiver, the reverse process called demodulation is performed to obtain the transmitted data. Often the functions of modulation and demodulation are contained in the one unit of equipment, which is then referred to as a modem.

The characteristics of different types of modulation are now discussed in the context of data transmission, with special reference to data transmission over the telephone network. For several of the modulation techniques, relations between the error probability and the signal-to-noise ratio for gaussian (normal) noise are presented. Although other forms of noise are experienced on communication channels (especially on the telephone network where impulse noise predominates) these relations are widely used for the following reasons. Gaussian noise is easy to generate and has simple statistics, whereas impulsive noise has no such simple model. Furthermore, because it is the large peaks of the gaussian noise which cause the data transmission errors, the ranking of modems with respect to their error performance in the presence of gaussian noise often does not change when impulsive type noise is encountered.

Frequency Modulation (FM).

This is a widely used method of modulation in data transmission, especially for low data rates up to 1200 bit/sec. in the telephone network. It is also called frequency-shift keying (FSK).

Digital frequency modulation can be carried out in two ways; firstly there can be a number of oscillators, one at each signalling frequency, to which the transmitter output is switched depending on the input data. The second technique switches the frequency of a single oscillator between the different signal frequencies, whilst maintaining continuous phase in the oscillator output. The second technique has an advantage in that the continuous phase in the transmitted signal gives a narrower frequency spectrum than the first method with its attendant phase discontinuities.

For a random binary data sequence the power spectral density of the output of an FM transmitter with continuous phase has been calculated (see Bennett and Davey, 1, chapter 18). Furthermore, it can be shown from this result that a peak-to-peak frequency deviation of about 0.6 to 0.7 times the bit rate leads to a well-shaped spectrum, resulting in a high efficiency of transmission in terms of occupied bandwidth. For example, the modems used in the A.P.O. DATEL service at 1200 baud have two signalling frequencies at 1300 Hz and 2100 Hz, giving a ratio of frequency difference to bit rate of 800/1200 = 0.67. Similarly at 600 baud, the carrier frequencies are 1300 Hz and 1700 Hz and the ratio is 400/600 = 0.67. Fig. 3 shows the relative power spectral *density* of the 1200 baud FM signal with random binary data and signalling frequencies of 1300 Hz and 2100 Hz. It may be noted that there are no discrete frequency components at either 1300 Hz or 2100 Hz, but only a finite power spectral density at these frequencies. This explains why this signal sounds noise-like, with no discrete frequency components.

If the signalling frequencies of 1300 and 2100 Hz are retained but the data rate is reduced to 600 baud, a radically different spectrum as shown in Fig. 4 is obtained and which still requires about the same bandwidth.

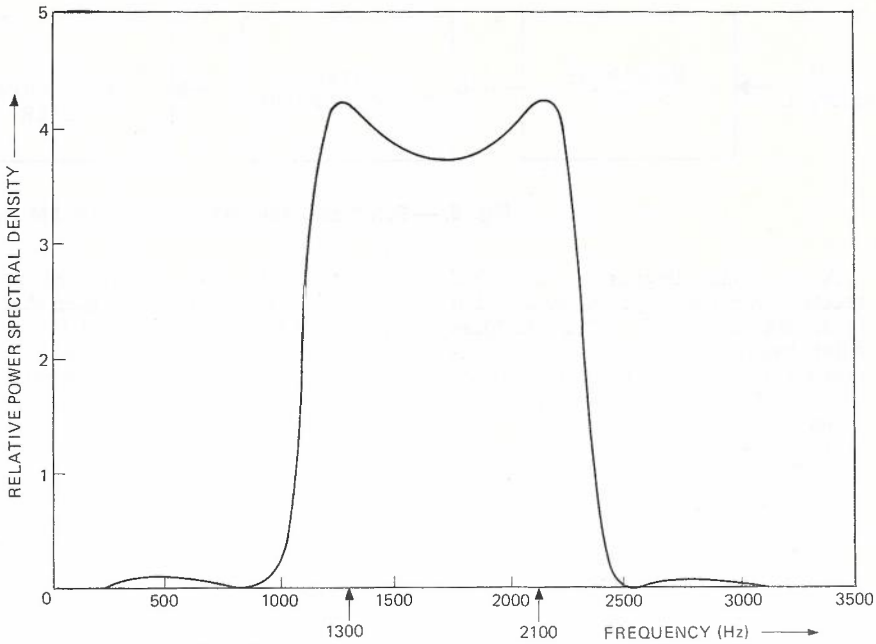


Fig. 3 — The Relative Power Spectral Density of a Random Binary FM Signal at 1200 Baud, with Signalling Frequencies of 1300 Hz and 2100 Hz.

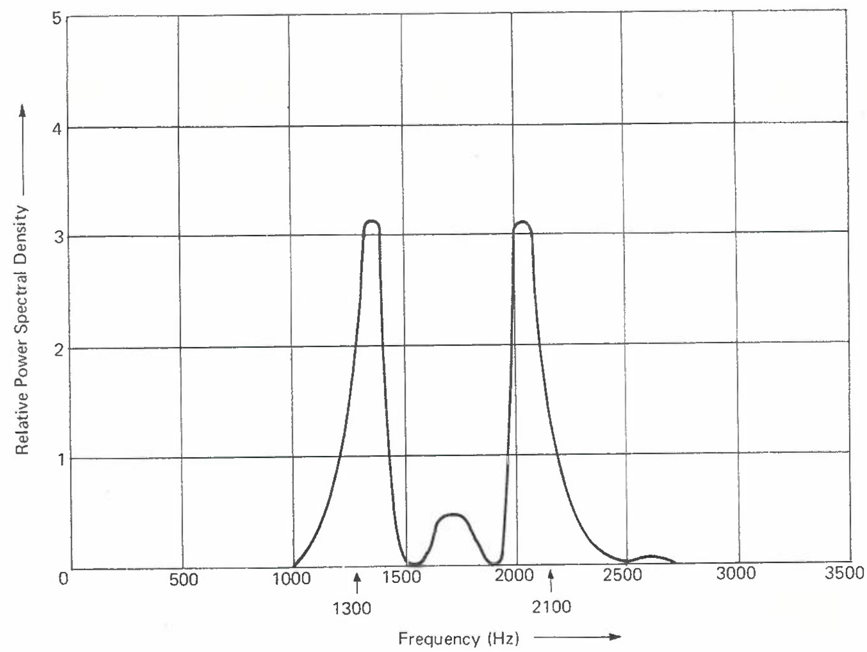


Fig. 4. — The Relative Power Spectral Density of a Random Binary FM Signal at 600 Baud, with Signalling Frequencies of 1300 Hz and 2100 Hz.

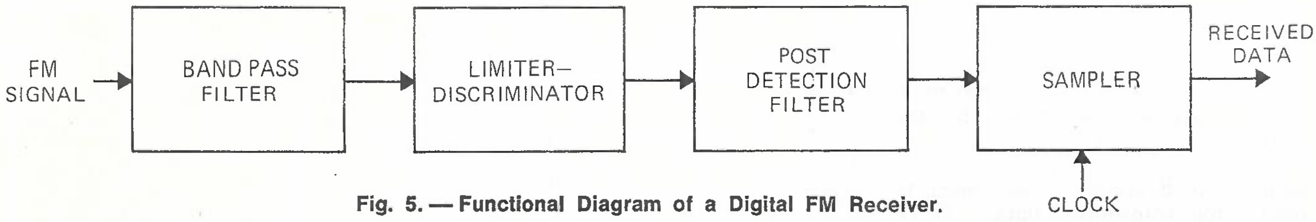


Fig. 5. — Functional Diagram of a Digital FM Receiver.

A functional diagram of a typical receiver for this type of modulation is shown in Fig. 5. The bandpass filter has the important role of removing noise from the signal outside the signal's spectrum, without significantly distorting the signal. That is, the filter needs to have as narrow a bandwidth as possible without filtering too severely an FM signal with a spectrum as in Fig. 3.

The limiter has the function of hard limiting the input signal and any noise that passes through the bandpass filter. Thus the instantaneous frequency of the signal fed to the discriminator is the frequency of the sum of the FM signal plus the filtered noise. The resulting instantaneous frequency is not a linear function of the noise and consequently the calculation of the error rates due to the noise is a relatively difficult problem.

However, there is a simple approximate approach to the error behaviour of a binary FM system which gives a result that is relatively accurate and gives some insight into what causes an error.

This approach is based on the 'capture effect' in FM receivers whereby the average frequency of the sum of two sinusoidal signals is equal to that of the stronger signal (Ref. 2, Section 5.4). Hence if the noise envelope exceeds the signal envelope it will to a large extent determine the instantaneous frequency in the discriminator. Given a bandpass filter symmetrical about the two binary signal frequencies, we will assume an equal probability of the instantaneous frequency of the signal plus noise being closer to a given one of these frequencies when the noise envelope exceeds the signal envelope. If it is closer to the frequency opposite to that transmitted, an error will occur. For white gaussian noise the probability that the envelope of the noise exceeds the signal can be shown to be $\exp(-\rho)$ where ρ is the signal-to-noise power ratio (SNR). Hence for this form of noise the probability of a bit error is given by

$$Pe = \tfrac{1}{2}\exp(-\rho) \qquad (4)$$

More detailed analysis gives a result that is very close to the above relation (see Ref. 3, Section 8.2).

Equation (4) has been plotted on Fig. 6, from which it can be seen that a SNR of 8.4 (9.2 dB), the error probability is 10^{-4}. Note that the SNR is not plotted in dB. It is important to realise that the error probability is highly dependent on the FM signal envelope amplitude, although this parameter does not appear on the 'eye-pattern' of the discriminator when there is no noise. Thus when assessing the likelihood of errors in an FM signal, both the signal envelope and eye-pattern should be observed.

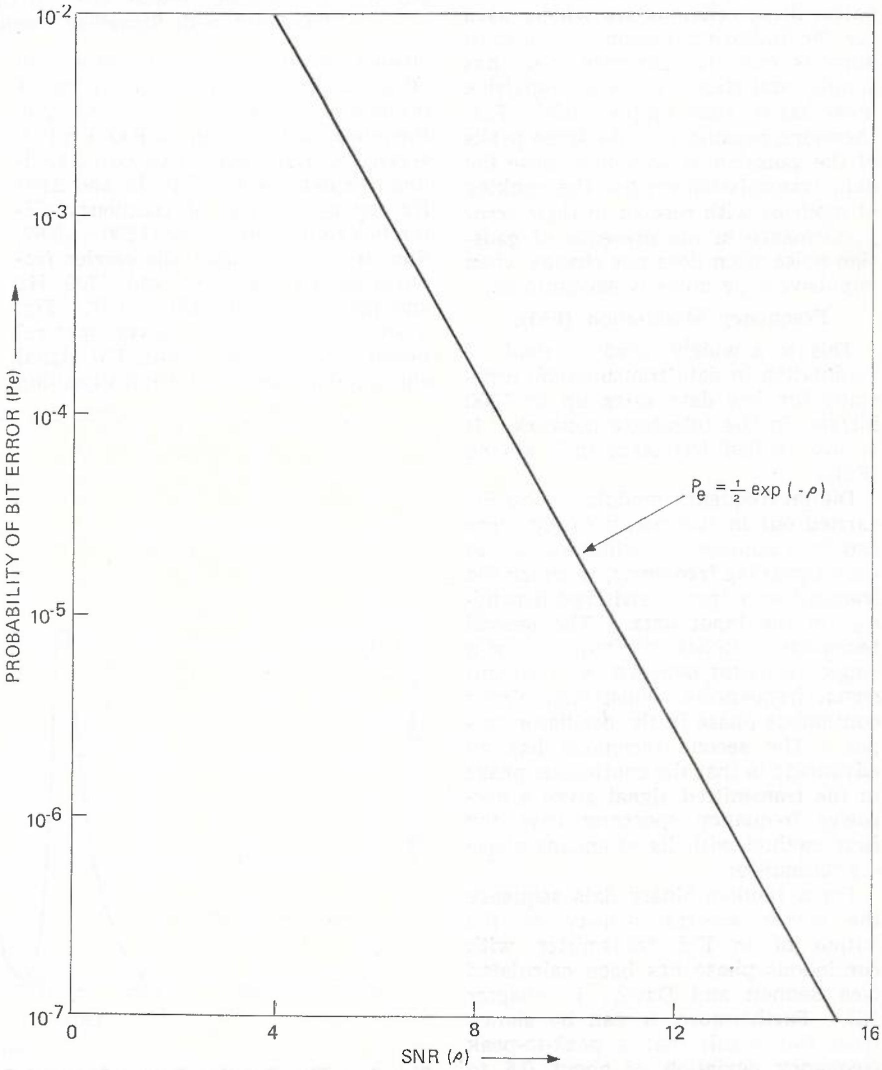


Fig. 6. — The Probability of Error as a Function of the Signal-to-Noise Ratio of a Binary FM System.

Phase Modulation (PM).

In data transmission over the telephone network at 2400 bit/sec, it is possible to use binary FM at 2400 baud, but with twice the bandwidth requirements relative to 1200 baud operation. However, it has been found in practice that it is better to use phase modulation at 1200 baud with four possible phases to give a data rate of 2400 bit/sec. This is done by grouping the incoming binary data sequence to be transmitted into dibits which are then encoded into four pos-

TABLE 2: ALTERNATIVE CODING CONVENTIONS.

Dibit Pattern	Phase Change	
	Alternative A	Alternative B
00	0°	45°
01	90°	135°
11	180°	225°
10	270°	315°

sible phases depending on the particular dibit.

To avoid the problem of having to transmit a reference carrier phase against which the phase of the signal can be compared, the information is transmitted as a phase change and this form of modulation is often referred to as differentially coherent phase shift keying (DCPSK). The two internationally agreed alternative coding conventions used in these modems are shown in Table 2.

A phase modulated signal with the instantaneous phase jumps as set out in Table 2 will have a wide frequency spectrum and it is normal to adopt measures to limit the spectrum of the signal. For example, after phase modulation filtering may be used or alternatively the carrier may be amplitude modulated and the phase jumps applied when the carrier is a minimum. A typical power spectral density using the latter technique for a 1200 baud four-phase modem (2400 bit/sec.) is shown in Fig. 7.

There are several techniques that can be used in demodulating the phase-modulated signal, but when demodulating for example, a four-phase signal, the basic procedure is to divide the circle representing 360 deg. into four quadrants as shown in Fig. 8. The correct phase vectors are situated at the centres of the quadrants or 'decision regions' and if the demodulated phase falls inside a given quadrant, the phase vector associated with that quadrant is assigned to be the decision of the receiver.

The added noise can be represented by the vector, n(t), as shown in Fig. 8. As long as the resulting phase vector falls inside the quadrant, the correct decision will be made. For gaussian noise, the probability of an incorrect decision for four-phase modulation is plotted in Fig. 9 as a function of the SNR.

The coding of the phase changes shown in Table 2 has been chosen so that the two phase shifts on either side of a given phase shift corresponds to dibits differing in only one digit from the dibit corresponding to the given phase shift. Normally if the noise causes an error in the detection of the phase shift, the incorrectly detected phase shift will be one on either side of the correct one rather than 180 deg. different, and hence the bit error rate is minimised for a given symbol error rate.

A further interesting point emerges from the differentially coherent phase modulation system in that the comparison of these two successive phases can be made before or after these phases are quantised in the receiver. If the phases are first quantised and then successive phases subtracted to give the phase change, an error in detection in a given phase will affect two successive subtractions and hence two dibits will be in error with probably only one bit in error per dibit due to coding of the phase changes (see Table 2). This means that errors will tend to occur in pairs. However, if

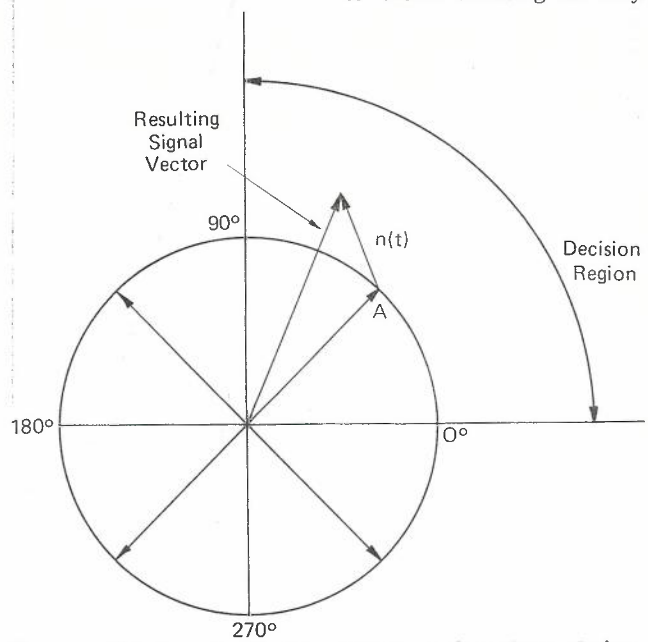


Fig. 8. — The Decision Regions of a Four-phase Data Modem.

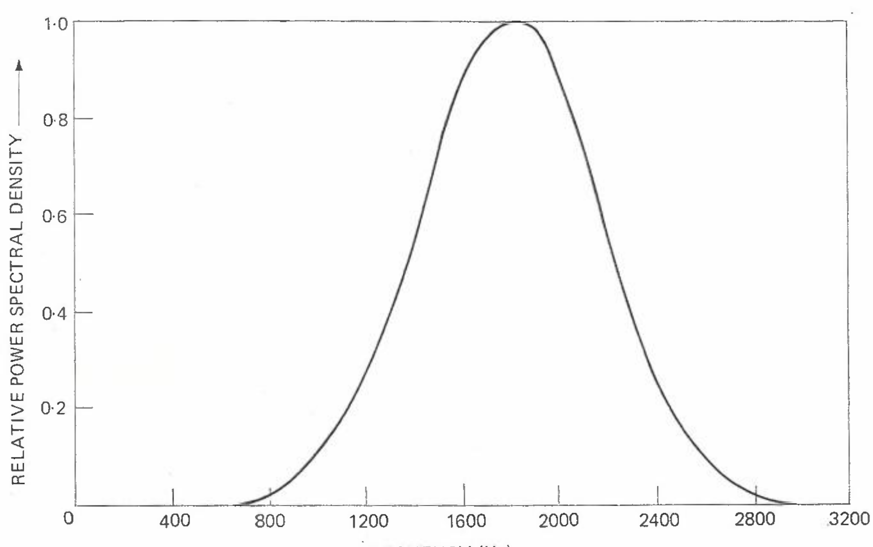


Fig. 7. — The Relative Power Spectral Density of a Particular Four-Phase Data Modem Operating at 2400 bit/sec.

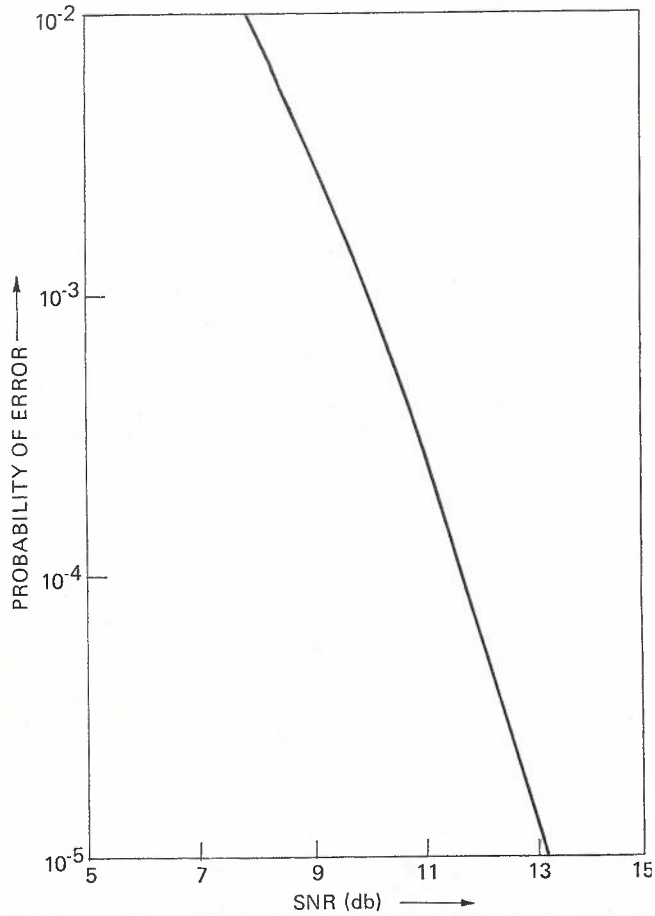


Fig. 9. — The Probability of Error as a Function of the Signal-to-Noise Ratio of a Four-phase System.

the successive phases of each dibit symbol are first subtracted and then quantised to the changes shown in Table 2, then the likelihood of double errors is considerably reduced.

Amplitude Modulation (AM).

Although amplitude modulation is perhaps the easiest form of modulation to understand and analyse, it has not been widely used for data transmission on the telephone network, especially at the slower speeds where frequency and phase modulation are more reliable and economical. However, at higher speeds multilevel AM is preferred, especially as the linear nature of this form of modulation facilitates the design of automatic equalisers for correcting the effects of frequency distortion.

In AM data transmission it is normal to conserve bandwidth by transmitting only one sideband of the AM signal (SSB) or one sideband with just a vestigial part of the other sideband (VSB). Alternatively quadrature AM can be used where two independent carriers, 90 deg. apart, are independently amplitude modulated, retaining both upper and lower sidebands, and then synchronously demodulated by two carriers 90 deg. apart as used by the transmitter. Double sideband transmission is necessary to prevent inter-channel interference between the two carriers. The capacities of SSB and quadrature AM are the same, because, although the necessity for double sidebands halves the baud rate of the latter system, there are effectively two parallel channels giving the same overall data rate.

When one considers Fig. 5 for four-phase modulation it can be seen that a given phase vector can be resolved into two components in quadrature; so that each of the four possible phase vectors can be made up of two quadrature two-level AM signals. Consequently four-phase modulation can be regarded as two-level quadrature AM; for example, the spectrum shown in Fig. 7 follows from considering the phase-modulated signal as quadrature AM.

A typical high-speed data modem for the telephone channel uses VSB AM with a carrier frequency of about 2.8 kHz and a modulation rate of 4800 baud with four levels giving a data rate of 9600 bit/sec. With this carrier frequency the lower sideband will be the main one transmitted.

AM is a linear form of modulation and the output from an AM receiver can be regarded as a linear sum of the individual signal symbols transmitted. This fact is used in adaptive equalisers (see next section) which are often associated with this type of data modem.

Other variations on the above forms of modulation are used. For example it is possible to combine amplitude and phase modulation to give a modem with four phase states and two amplitude levels giving effectively eight possible levels per symbol.

CHANNEL IMPAIRMENTS.

When transmitting data over a communication channel there may be a wide variety of impairments which can degrade the channel and increase the likelihood of errors in the received data. However, it is possible to classify these impairments into several categories based on their effects rather than their causes. The most important channel impairments experienced in the telephone network fall into the following classifications.

Additive Disturbances. — These include:

(i) Gaussian (background) Noise. In general this is at a very low level and is not usually significant in data transmission on the telephone network. However, in some situations such as receivers for spacecraft communication this type of noise is dominant. This form of noise is widely used by designers and analysts of digital communication systems for the reasons given in the previous section on modulation.

(ii) Impulse Noise. This is due to switching transients in the telephone exchanges, lightning, and other similar disturbances. Its characteristics are far less defined than gaussian noise and there is not at the present time any simple model of this form of noise. The usual technique of measurement is to count the number of pulses in a given time that exceed fixed levels.

(iii) Sinusoidal and other periodic disturbances.

Linear Distortion. — As its name suggests this form of distortion linearly transforms the transmitted signal on its passage through the communication channel. The characteristics of linear distortion are usually specified in the frequency domain by amplitude and delay (phase) curves. Linear distortion can be caused by the attenuation of cables, the delay in carrier filters, echoes due to mismatches, etc.

Since speech is not sensitive to delay distortion, the telephone network has developed without this parameter being specified, but when data is transmitted over the network the delay distortion can very seriously degrade the signal especially for high data rates. Some form of equalisation of the delay will then be needed. The effect of linear distortion on data transmission is to cause interference between adjacent symbols of the received data. Normally this intersymbol interference is insufficient to cause errors by itself but rather it makes the data more susceptible to noise disturbances.

The most common form of equalisation used on the network brings the attenuation and group delay of the channel within some given range over the bandwidth of interest. For example, Figs. 10 and 11 show the C.C.I.T.T. recommendation M102 attenuation and group delay characteristics for special quality telephone circuits.

As linear distortion can cause intersymbol interference, it is better to adjust the equalisation to minimise this interference at the sampling times of the receiving data modem rather than attempt to fit the frequency response of the channel into some arbitrary criterion. Because the inter-symbol interference is more easily represented in the time domain than the frequency domain, the form of the equaliser that best minimises the inter-symbol interference is a transversal filter which gives weighted versions of the original signal at a range of delays. (See Fig. 12.) In fact, it is this form of equaliser that lends itself to being made adaptive by observing the inter-symbol interference in the data and adjusting the weighting at the various delays to minimise this interference.

Other Impairments: The communication channel may distort the signal in a non-linear fashion, which can give rise to inter-modulation products and harmonic distortion.

Other important classes of impairments experienced on a communication channel are frequency and phase variations. On the telephone network these effects are the result of using carrier systems. A constant frequency shift due to a difference between the modulator and demodulator oscillator frequencies of a carrier system is not important in data transmission provided it is small. However, above about 10 Hz some data modems cannot track the frequency shift and hence cannot function.

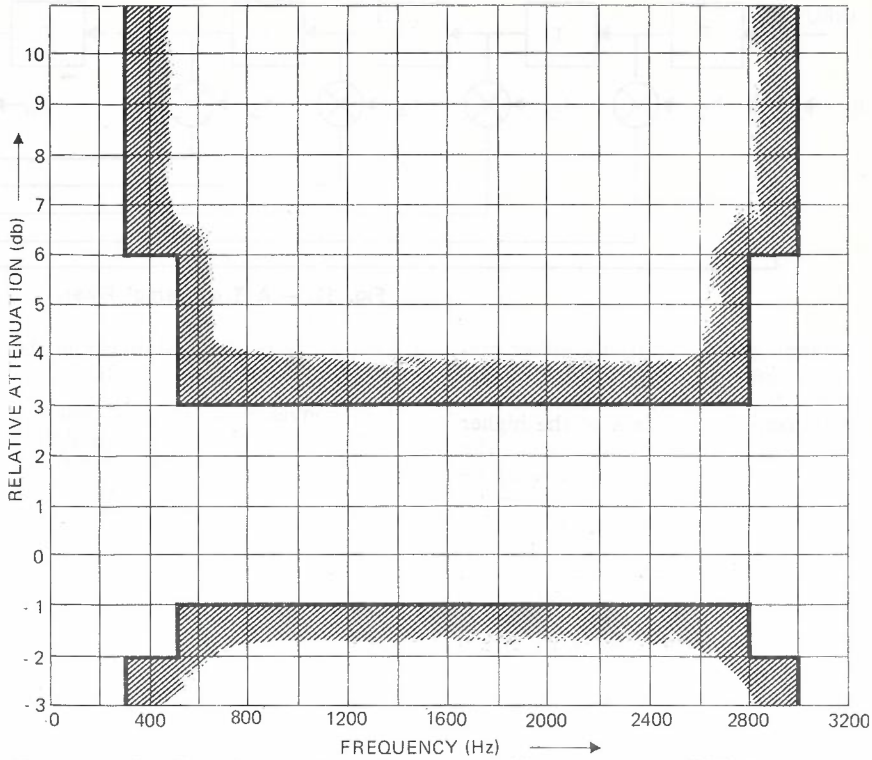


Fig. 10. — The Bounds on Attenuation as Specified by the C.C.I.T.T. (Recommendation M102).

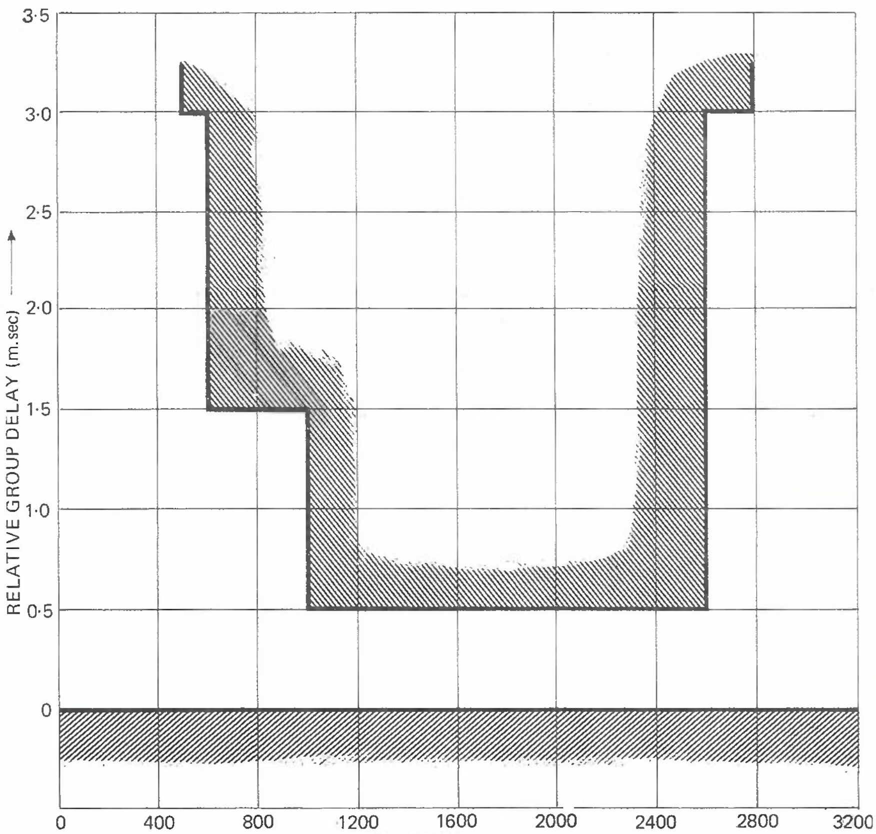


Fig. 11. — The Bounds on Group Delay as Specified by the C.C.I.T.T. (Recommendation M102).

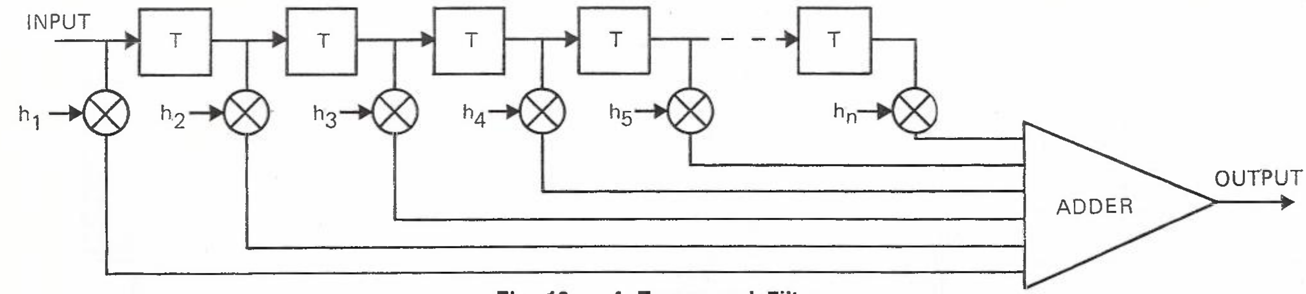


Fig. 12. — A Transversal Filter.

Channel phase variations, either random, periodic or isolated jumps, are thought to be a major impairment to the transmission of data at the higher rates on the telephone network. The effect of these phase variations — commonly called phase jitter — on data transmission will depend on the type of modulation being used as well as the statistics of the phase variation; for example, the phase jitter on a channel carrying a frequency modulated signal appears at the output from the FM receiver as additive noise.

As well as phase variations, a communication channel may be susceptible to amplitude variations such as fading and breaks. Once again the effect of these variations on data transmission will depend on the type of modulation being used, as well as the statistics of the amplitude variations.

TESTING DATA TRANSMISSION SYSTEMS.

In a synchronous data transmission, where the signal at the receiver is not fully regenerated after retiming, but is a squared up version of the demodulated analogue waveform, it is usual to characterise the effect of the communication channel on the received signal in terms of telegraph distortion. Basically this measures the variations of the data transition instants from the undistorted times (see Fig. 13).

It is conventional to allot 100 per cent. as the total bit duration and then as can be seen in Fig. 13 an error will occur when the distortion exceeds 50 per cent., assuming an ideal sampling clock at the middle of the bit period. More telegraph distortion can be tolerated in electronic equipment than in mechanical equipment which effectively samples the bit over a longer duration.

In most higher speed data modems, a clock waveform is extracted from the received signal and used to retime the data with resulting low telegraph distortion. However, the data may still contain errors due to noise and hence the criterion of performance of these modems in a given channel is their error rate. This error rate is specified, for example, as one error per 10,000 received bits or an error probability of 10^{-4}. A block error rate is often measured where a block error is said to have occurred if there is one or more errors in a predetermined length of data called a block. The comparison of the block error rate and the bit error rate can give some idea of how the errors are distributed. For example, if the bit errors are widely distributed, then the bit and block error rates are close together, while if the bit errors cluster together, then many occur in a given block and the two rates will differ widely.

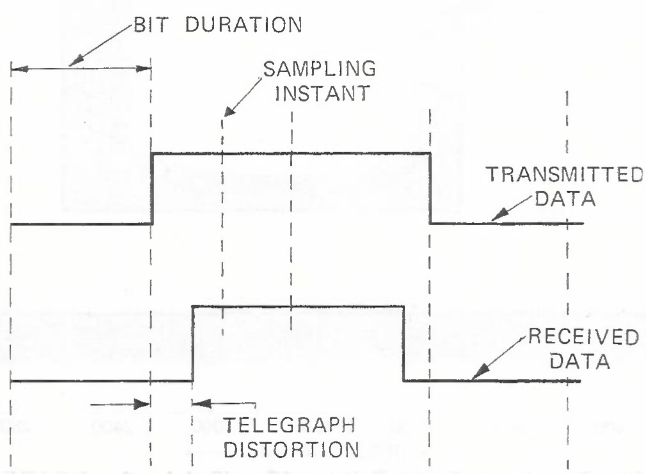


Fig. 13. — The Definition of Telegraph Distortion.

Although this is a simple technique, it is relatively crude and for a better understanding of the distribution of bit errors a more detailed recording and analysis of the error events is needed. Also it may be noted that if multi-level modulation is used and then decoded back to binary, the error events occur in the multi-level symbols and this will then impose certain properties on the binary error distribution. For example, the four-phase differential phase-keying system often gives double errors because a comparison between the present and the previous symbols is used. Hence an error in the present symbol will affect this decision and the following one, when the present symbol becomes the previous symbol.

For testing data transmission systems, a data sequence with the following properties is needed. It must be easily generated and have characteristics similar to that of random data; furthermore it should have a finite length and be predictable so that the same sequence can be generated at the receiver, synchronised to the incoming sequence and matched bit by bit to detect errors in transmission. A maximal length shift register sequence commonly referred to as a binary pseudo-random signal fulfils these reuirements and is widely used in A.P.O. data tests. The usual sequence length is 511 bits generated by a 9-bit feedback shift-register.

Although much information about the performance of a data transmission system can be obtained from the distribution of errors, a more complete understanding of the causes of these errors is only obtained when the analogue waveforms of the signal and noise are observed, especially at the point where the decision is made. For example, observation of the eye-pattern may yield considerable information about the distortion of the signal and its immunity to noise.

CONCLUSIONS.

Data transmission in the telephone network is growing rapidly in both quantity and system complexity as users aim for higher rates of reliable information transfer. This paper briefly outlines some of the characteristics of currently used data transmission systems, especially in regard to the different modulation and demodulation techniques that are possible. Of course not all techniques have been discussed and the reader should refer to the references cited if further information is required.

ACKNOWLEDGEMENT.

The author wishes to thank Mr. J. Semple for his constructive criticism during the preparation of this paper.

REFERENCES.

1. W. R. Bennett and J. R. Davey, 'Data Transmission'; McGraw-Hill Book Co., New York, N.Y., 1965.
2. J. J. Downing, 'Modulation Systems and Noise'; Prentice-Hall, Englewood Cliffs, N.Y., 1964.
3. R. W. Lucky, J. Salz and E. J. Weldon, 'Principles of Data Communication'; McGraw-Hill Book Co., New York, N.Y., 1968.

TECHNICAL NEWS ITEM

I.R.E.E. CONVENTION, MELBOURNE, 1971 — THE A.P.O. CONTRIBUTION

The Institution of Radio and Electronics Engineers (I.R.E.E.) held its 13th National Radio and Electronics Engineering Convention in Melbourne during the period 24-28th May. 1200 delegates from all Australian States and a number of overseas countries attended the technical paper sessions and 12,000 professional and technical people visited the $5 million display of electronics and communication equipment held concurrently with the technical sessions.

The Convention was officially opened by Sir Donald Anderson, C.B.E., Director-General of Civil Aviation and the keynote speaker at the opening function was Dr. B. M. Oliver, Vice President, Research and Development, of the Hewlett-Packard Company of U.S.A. who spoke on "Society and Technology in the Seventies". The professional staff of the Australian Post Office, with 24 authors presenting papers in 11 of the 29 sessions, provided a significant contribution to the success of the Convention.

Two sessions were given over entirely to Post Office papers. In Session 2 F. Hailstone, B. Penhall, and R. Monks described the field trial of a V.H.F. radio solution to the problem of providing economical telephone service to remote areas of Australia. In the same session A. Edwards described the Post Office technical requirements for Commonwealth-wide application of radio to the problem and discussed the influence of modern technology on equipment design — for example it is now possible to design solid-state radio equipment with continuously-operating receivers without placing impracticable or uneconomical demands upon the primary energy sources.

Session 26 was entirely devoted to papers from the Post Office Research Laboratories on T.V.-phone and T.V. conferencing developments. An introductory session by A. J. Seyler drew attention to the fact that the basic conception and many of the basic inventions influencing current developments date back to the 19th century. J. L. Hullett discussed the factors influencing the choice of technical standards for the T.V.-phone and R. Dempsey described the problems being faced in the reticulation of a visual telephone service to subscribers. H. Bruggemann and J. L. Hullett described the A.P.O. closed-circuit television conferencing facility set up in Melbourne during 1970 and discussed the technical difficulties which have had to be faced in preparing for a possible commercial application of the service.

During the Convention, parties of visitors visited the Post Office Research Laboratories to view work being carried out in television telephony and in the provision of services for instrument calibration and environmental testing.

THE NEW AUSTRALIAN DIAL (D.M.S.)

*J. COMPANEZ, A.M.I.E. (Aust.)**

INTRODUCTION

The dial is the means by which the subscriber connects his telephone line to other lines in the automatic network. With the introduction of Subscriber Trunk Dialling, the network available to direct dialling has increased enormously, and very soon the possibility of subscriber dialling between countries or even continents will be commonplace. Therefore, the dial is one of the most important items in the automatic telephone system. The primary function is to interrupt the line loop with pulses of about ±5% precision.

NEED FOR A NEW DIAL

Until recently a number of different imported dials have been used in the Colorphone telephones. The new dial was necessary because the dials in use till now have not been sufficiently stable in pulsing performance; they require regular service attention, and are expensive to purchase and recondition. In the eight years since the introduction of the Colorphone, three different dials have been used in telephones, but none had suitable performance to be locally made as the A.P.O. standard.

In June 1963, the P.M.G.'s Department placed a developmental order with Amalgamated Wireless Australasia Pty. Ltd for a new Australian made standard dial based on ideas patented by the late R. J. W. Kennell.

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DESIGN FEATURES

Most of the parts of the new dial (Fig. 1) are made of plastics for better wear, lower friction coefficients and weight, ease of manufacture and low price.

The design chosen is a mixture of the B.P.O. No. 21 ten lobed pulsing cam, trigger dial modernised by a patented unilever trigger and controlled by a governor which can be steplessly set to any speed by means of a knurled nut. The governor is driven by spur gears, avoiding the end thrust of worm drives. The highly reliable, sturdy and sensitive clutch is located in the main gear wheel. The main spring is of wire 48 in. long wound in 3 layers and provides a uniform driving torque.

Design Specification

The outside appearance and overall dimensions of the dial were chosen to resemble dials previously used in Colorphones so that there will be interchangeability without obvious differences.

For the electrical performance, much stricter limits were imposed. In the past, dial performance was specified by speed and ratio. In practice, only average speed is measured by the test equipment so that any variation in the length of each individual break or make pulse is not evident. The equipment at the exchange is sensitive to each break and make pulse length, and it is these time intervals that have been specified for the new dial.

For a nominal speed of 10 pulses per second and a break to make ratio of 2 : 1 the acceptance limits are set at:

Break 62 — 75 ms
Make 31 — 37 ms

The maximum allowable spread in any train of 10 pulses is 5 ms for break periods and 4 ms for make periods.

The interdigital pause was chosen to occur before the start of the pulsing with an inbuilt delay of 200 ms which geometrically corresponds to 2 spaces on the finger plate at a speed of 10 pps.

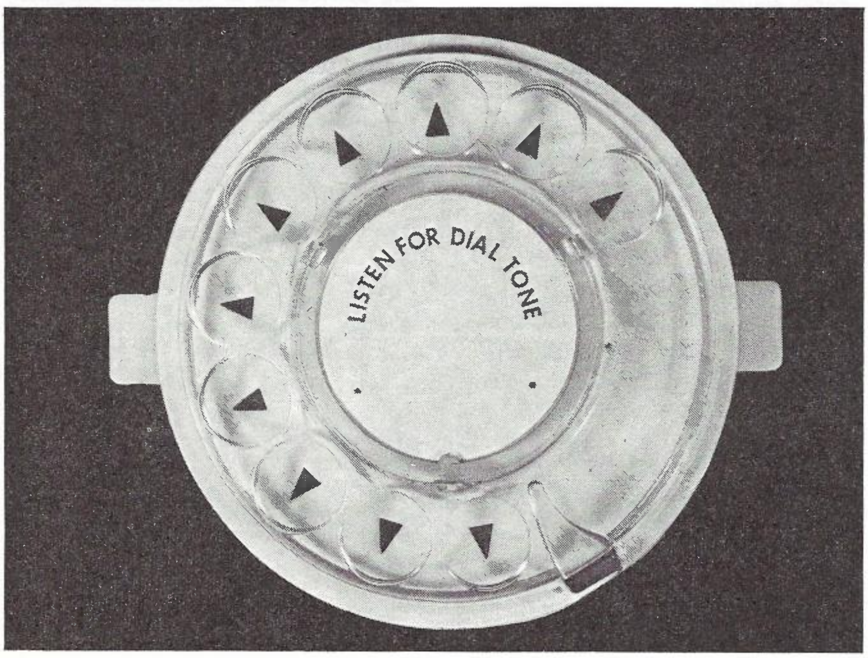


Fig. 1.

DIAL PARTS (FIG. 2)

The largest moulding in the dial is the body which has two lateral extensions for mounting in the telephone. The finger plate is fixed to the main spindle and has at its centre the label protected by a plastic cover — the dial label holder. The clutch is fixed to the spindle between the finger plate and the body. The chaplet or number ring is separate but locked into the dial body. The finger stop enters the body at the rim, through a hole in the chaplet ring and around the chaplet ring and the finger stop there is a P.V.C. gasket to cushion the dial in the telephone case.

The main gear is part of the outside of the clutch and it meshes with the pinion of the intermediate gear which protrudes through a hole in the body and runs in an outrigger bearing moulded onto the body. In turn, the intermediate gear drives the governor which has a nickel bronze cup fixed into the body.

The main spring is fixed to the main spindle by means of a spider and is isolated by a cage of polypropylene; the small end of the spring is hooked in a hole in the body. Also fixed to the spindle are the toothed pulse, or cam wheel and the off-normal actuator. In a later design the spider, the pulse wheel and the spring cage are one polycarbonate moulding.

The trigger pivots on a spindle fixed in the body and is moved by the pulse wheel, this in turn acts on the pulse springs opening and closing them with every lobe of the pulse wheel as the spindle returns to normal under spring torque. The pulse springs are part of

COMPANEZ — New Australian Dial

a spring assembly which also contains two off-normal spring sets all moulded in a plastic supporting block.

A bridge mounted between two pillars on the body and the spring assembly supporting block provides bearings for the intermediate, governor and main spindles.

The pulsing mechanism comprises a ten lobed cam, a trigger and a pair of pulsing springs. (See Fig. 3.) The pulse wheel has ten teeth on 27° centres. The Delrin trigger pivots on a stainless steel spindle fitted into a moulded recess in the body, it has on its cam follower three flat faces and a curved one which contact the pulse wheel. The curved face contacts the teeth when the dial is wound up, two other faces control the pulsing of the trigger, the last one determines the length of the break period percentage or ratio. In consequence, it is possible to use the same pulse wheel for different ratios by just changing the trigger.

The pulse springs can be adjusted with the aid of an adjusting screw which moves the position of the stationary spring, thus changing the amount of travel of the moving spring, consequently the pulse ratio.

The trigger is free on its spindle but is kept captive by the trigger spring which acts with a force of 20-25 grammes on the trigger, keeping it in one of two positions; these being either in the working position on dial return, when it can ride over the teeth and influence the pulse springs or in a position at 72° to this one in which it rides over the teeth but is away from the pulse springs.

On the opposite side of the pulse wheel are the two off-normal spring sets. An off-normal metal actuator fits into a recess in the pulse wheel and pushes the off-normal buffer on the springs. The actuator allows the buffer to move at the moment the finger plate is rotated from its rest position and the two contacts are made all the time the dial is away from the rest position.

The contacts of both pulse springs and off-normal springs are made of fine silver which proved to be more reliable than other precious metal contact materials although softer. The back of the dial is provided with a tight fitting dust cover.

Original Governor

The dial governor (Fig. 4) which determines the dialling speed, consists of a moulded body and gear, a spindle, two springs, two weights with brake shoes and a cup on which the brake shoes run. The governor only works during the return of the dial while the pulses are being sent out. The balance between the spring's position, the speed and the friction of the pads determines the speed at which the governor will run under the torque of the main spring.

The stainless steel governor spindle is moulded in the Delrin body. An aluminium or polycarbonate nut runs on the threaded body and by moving two sliders in contact with the springs sets the speed of the governor by varying the length of the springs. The nickel-silver springs are tapered to allow for almost linear adjustment of speed from 9 to 22 pps.

The weights are of sintered brass and the brake shoes moulded in Polyethylene Terephthalate (mylor, terylene). The governor cup is turned in Ni-Bronze and is pushed into the body while the moulding is still hot.

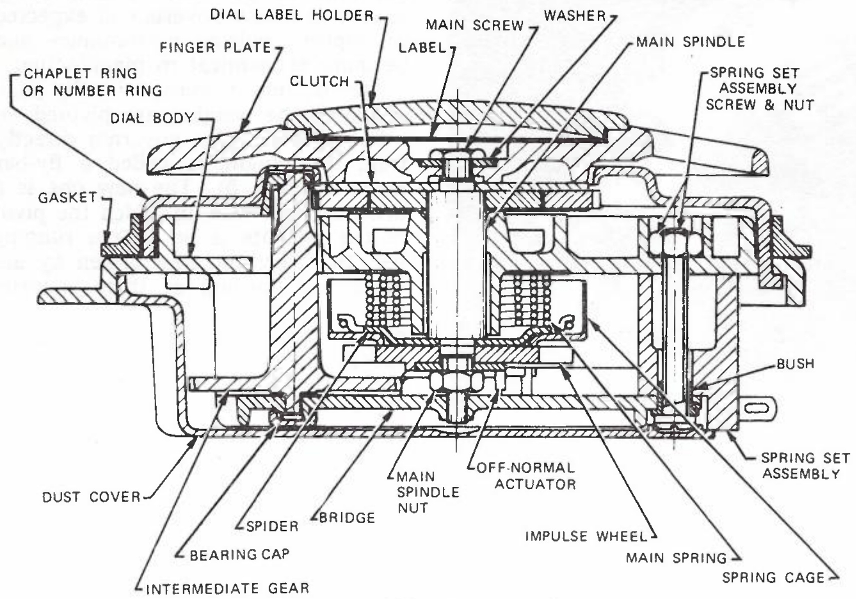


Fig. 2. — Dial Cross Sectoin.

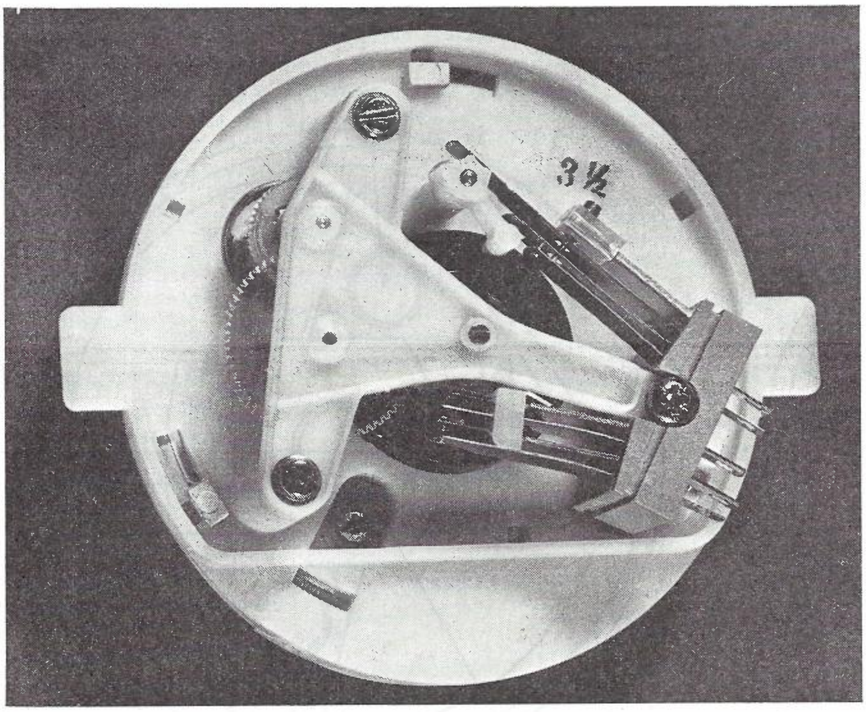


Fig. 3. — Dial Back without Dust Cover.

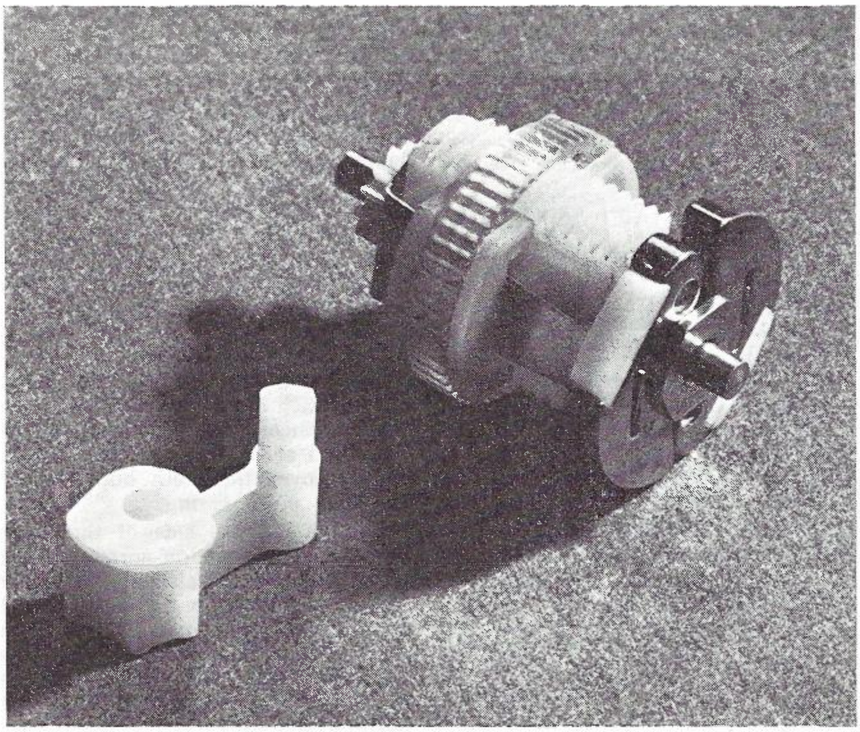


Fig. 4. — Governor and Trigger.

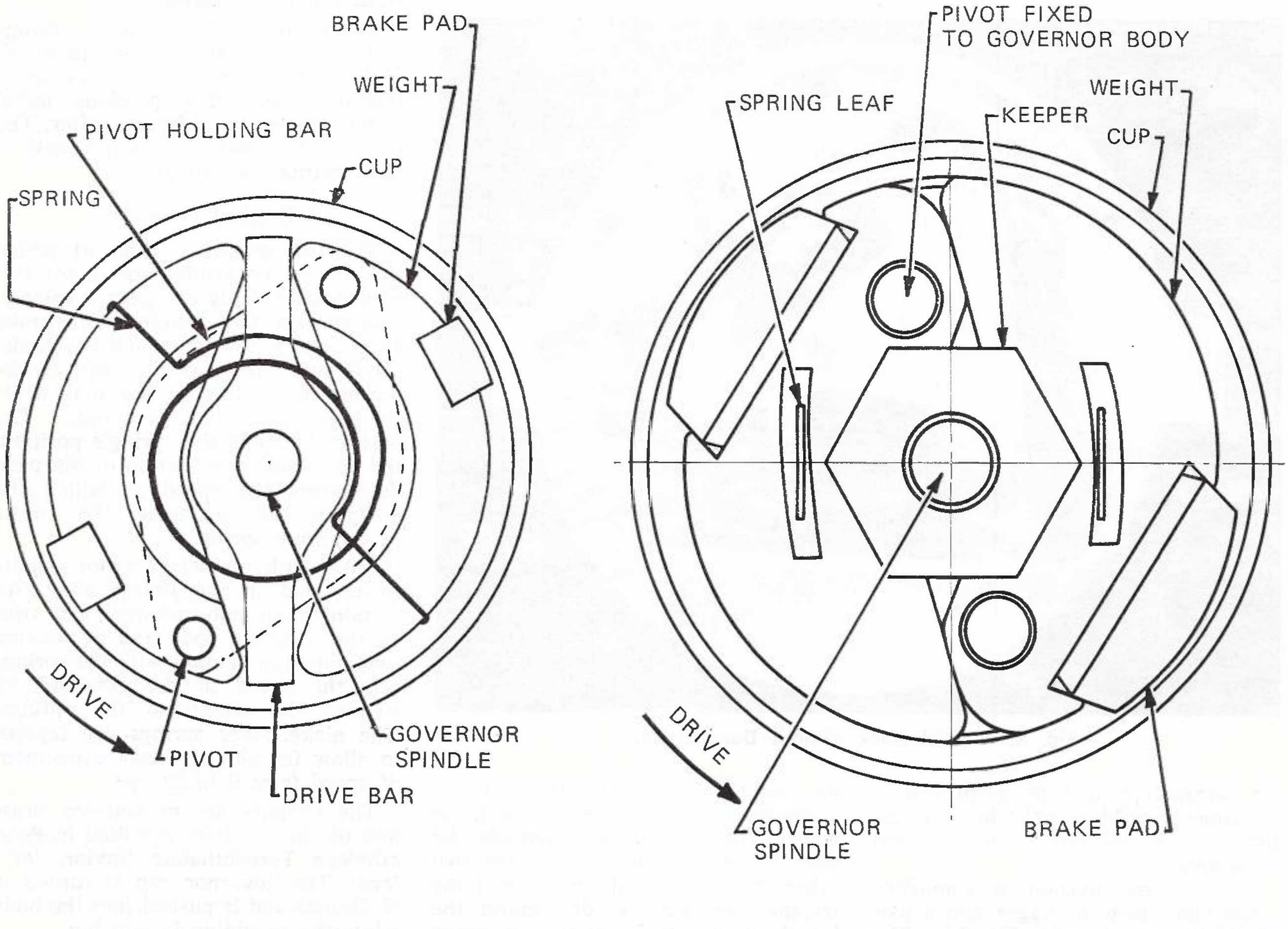
Drive Bar Governor

Recent research has shown that the wide speed range of the original governor is not necessary, and a different kind of governor is now being tested; this new governor is expected to improve pulsing performance and be more economical to manufacture.

The present governor in the dial, in which the weights are pivoted on a bar driven by the governor directly from the pinion, is called a fly-bar governor (Fig. 5). The new one is a drive-bar governor in which the pivot of the weights is on a free running bar, the weights being driven by another bar pushing at their opposite end. A single spring applies equal restraint to both weights. Different speeds can be achieved by changing the spring. This type of governor gives even better performance by maintaining narrower speed limits than the fly-bar governor.

Gears

The materials of the gears are varied; the main gear and clutch drum is made out of Rilsan (Nylon 11) with graphite, the intermediate gear comprising a 12 tooth pinion and a 67



DRIVE BAR GOVERNOR **Fig. 5.** FLY BAR GOVERNOR

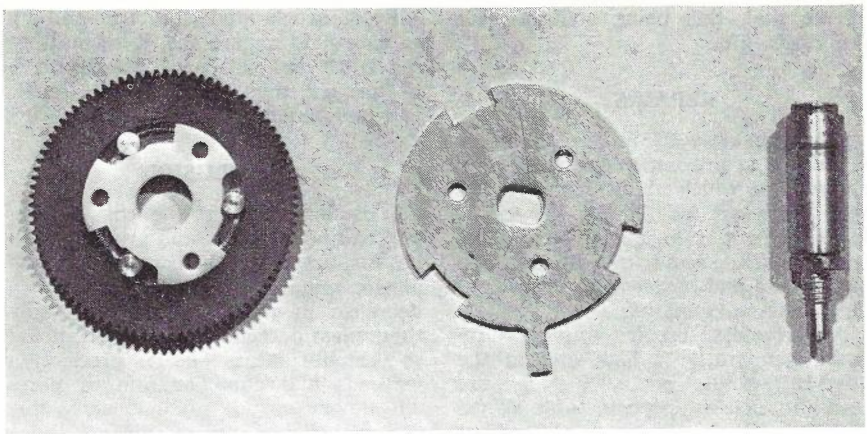


Fig. 6. — Dismantled Clutch.

tooth gear including the spindles is made in one moulding of polycarbonate. The last gear on the governor, a 12 tooth pinion, is moulded in one with the governor body in Delrin. The gear ratios are 91:12 and 67:12 giving a total ratio of 42.34 to 1.

The small 64 DP pitch of the gears is necessary because the small gears have only 12 teeth to obtain the reduction without more gears in the train.

Clutch

The clutch in this dial is of the spragg type with stainless steel springs pushing stainless steel rollers and riding on a Delrin cam (Fig. 6). The drum of the clutch is the inside of the main gear which is moulded in Rilsan and the rollers jam between the clutch drum and the cam to engage the clutch.

The clutch is fixed onto the main spindle by splines. The main qualities of the clutch are; it is corrosion resistant, it readily releases in the reverse direction, has good gripping in the engaged position and is easy to manufacture.

Main Spring

The main spring is a coiled wire 48 in. long in three helixes, the middle layer being back wound. It is pretensioned 3½ to 4 rotations which supply a substantially constant torque for the return of the dial, which needs about 300 gfcm torque for proper working. The stainless steel spring is corrosionproof, but it is dry lubricated with a fluoroplastic. This is applied as a suspension in Freon, and allows the spring to work for one million operations or more without any troublesome wear products.

The spring cage was included to prevent the small quantity of wear products from the spring — usually iron and ironoxide dust — from spreading and interfering with the contacts.

The main spring has a spider or tensioning frame on which the start of the spring is fixed and which in turn is fixed to the main spindle by means of a spline. The other end of the spring is fixed by slipping its hooked end in a hole in the body of the dial.

Plastic Structural Parts

Both the body and the bridge are moulded in Delrin 500 and the body has radial ribs and circular rims for reinforcing. The circular rim on the outside of the body is only for reinforcing purposes but the inner rim about an inch in diameter also keeps the finger plate from over-straining near the main spindle when pushed eccentrically.

The Delrin bridge on the back of the dial supports three bearings: the main spindle, the intermediate and the governor bearing. The outrigger in the body front has two stiffeners to strengthen it because it acts as a stop for the clutch. The outrigger makes room for the intermediate pinion and bearing.

The body pillars supporting the bridge have the same general thickness as the body but are hollow and are sufficiently strong to provide a stable positioning of the bearings in the bridge in relation to the body, keeping the spindles in correct positions against each other.

The finger plate is made out of acrylic in order to get good transparency. It could be made in polycarbonate for special dials to be used in Public Telephones where the increased strength of this material makes the finger plate more vandalproof.

The size and taper of the holes had to be very carefully designed to allow the average finger to get a good grip, without allowing too much scratching of the chaplet or number ring.

The centre of the finger plate mounts the label which is covered by a dial label holder made in polycarbonate and retained by three lugs which fit into the finger plate. The dial label holder can be released either with a suction cup or by inserting a pin in a small hole in the finger plate.

Originally the finger stop was fixed to the body with a screw and nut but is now positioned with a plastic snap closure — a pin on the body and a hole in the finger stop. The positioning of the finger stop into the dial fixes the chaplet or number ring, stopping it from rotating, and when the dial is installed, the finger stop cannot be removed so that the whole dial is vandal resistant.

TESTING

Because of the new performance requirements specified for this dial, the testing is now accomplished on a new set of electronic instruments, which measure ratio, speed and pulse length. There are two instruments in the set.

The Adjustment Set is mostly used to set the dial into its proper speed and ratio; it displays by means of two meters the average speed and the ratio at which the dial runs. They are averaged over nine complete pulses.

The Pulse Length Monitor shows whether all the pulses are within set limits — these limits can be set on the instrument by means of tumbler switches. It shows if the pulses are shorter, longer or within the limits set.

Two other instruments were built by A.W.A. during the development of the dial to allow the dial performance to be analysed in greater detail during life tests.

The Pulse Length Analyser shows whether each pulse is within limits, shorter or longer.

The Pulse Deviation Meter is a digital indicator device on which the longest and the shortest break period, the longest and the shortest make period and their differences and the duration of nine complete pulses is displayed.

LUBRICATION

The dial is one of the major sources of faults in subscribers equipment and experience shows that while most new dials, if properly adjusted, have a relatively low fault incidence for a period of up to five years, dial faults rise after that. An explanation may be found in the fact that the ingress of dust and contaminating substances to the oil lubricated parts of the dial, and the oxidation of the lubricating oils, produces thickening and loss of the lubricating properties and excessive friction which adversely affects the operation of the dial.

Some lubricants containing silicones can produce very high incidence of microphonic pulsing contacts and open circuits due to the formation of an insulating layer on the contacts. As silicones are very difficult to remove, they must not be used in the manufacture of or in the lubricating oils for the dial.

In the DMS dial the spindles are in stainless steel or polycarbonate and the bearings in Delrin; these combinations require a minimum of lubrication. The lubricant used is dioctyl sebacate and only a very small amount is necessary at the assembly of the dial, this being sufficient for the dial's life.

REPAIRS

Approximately 3½ million dials are in service at present in the Australian network of which about 55% are less than five years old. This is due to the large growth rate sustained in the last few years and to the replacement of obsolete and obsolescent telephones with new instruments.

Nevertheless repair activities remain comparatively high and in the year 1970 a total of 72,000 dials were reconditioned at Departmental Workshops in various States, the direct cost being about $108,000. To this must be added considerable amounts representing the cost of recovery from subscribers' premises, handling and administrative charges.

From accelerated life tests and up to date field experience, it seems that the DMS dial will have a longer life in the field; thus decreasing the repair and maintenance costs.

CONCLUSION

It is believed that the cost of this dial can be kept low and probably will be further lowered in time because plastic materials have a tendency to decrease in price and at the same time plastic technology is advancing so rapidly that better production methods and amalgamation of parts will lower costs. In conclusion, this dial is believed, for a time of about fifteen years to be the answer to the Australian requirement for a mechanical dial, a very good dial, reliable and cheaper than similar performance dials available overseas.

TECHNICAL NEWS ITEM

MULTIPATH DISTORTION IN HIGH-CAPACITY MICROWAVE SYSTEMS

When signals from a distant transmitted reach a radio received by several paths, their interference causes distortion and noise.

The maximum bandwidth which an optical tropospheric path can support is determined by the effects of such multipath propagation — an increase in noise in F.M./F.D.M. systems, or an increase in error rate in digital systems.

To probe this problem further, a current project in the A.P.O. Research Laboratories aims to represent multipath propagation through the troposphere in a general statistical model. It is hoped that the model will provide data for assessing the effects of this type of propagation and for predicting situations where distortion may reach unacceptable levels.

The model is based on the incidence in the atmosphere of layers of finite thickness, each an aggregate of uniformly distributed scatterers. These layers are Poisson distributed with height. Their distribution in time delay with respect to the direct path is therefore a Poisson distribution with variable density.

A similar model, incorporating the effects of Doppler shift, may also be developed for mobile radio systems. The common method of analysis has however, even more general applications — in the fields of equalisation and of the design of phased-array antennae to achieve a given polar pattern.

The method is based on the approximation of a given function by a finite sum of exponentials; the required minimisation techniques are being developed by a consultant at Monash University. A computer program is now working and gives good resolution.

In F.M./F.D.M. microwave systems of 600 and 960 channel capacity, as currently employed, significant increases in total system noise due to multipath propagation have been observed only rarely (and then primarily on "freak" paths as when a fortuitiously oriented building reflected a delayed signal).

However, as system capacities increase to 1800 and 2700 channels, so do intermodulation effects (for a given multipath situation). Under bad multipath conditions, intermodulation noise might then exceed thermal noise, and further degrade system performance.

Experimental work will be carried out on commercial 1800 and 2700 channel bearer systems to evaluate this phenomenon. Microwave Link Analysers will be employed on these bearers, and instrumentation is being designed to digitise and tape-record their output data.

Adjusting the parameters of the mathematical model from such field data, it is hoped that the model can then be employed to reduce subsequent work in determining paths likely to show severe multipath distortion. A sufficiently comprehensive model, so validated, in effect defines the propagation mechanisms operative.

Preliminary measurements are currently proceeding, at Julia Creek, Qld., using white-noise tests to establish simply if, under the severe fading experienced there, "path-intermodulation" noise ever reaches thermal-noise level for a loading equivalent to a 1260 channel system.

THE EVALUATION OF TELEPHONE DIAL PERFORMANCE

A. H. BADDELEY, B.Mech.E., B.E.E., M.I.E. Aust. and G. W. G. GOODE, B.Sc.***

INTRODUCTION

The advent of crossbar switching into the Australian telephone network has prompted the development of dials capable of operating at higher pulsing rates, viz. 20 pulses per second, than the older 10 pulses per second standard. Concurrently with consideration of higher dialling speeds, the Australian Post Office (A.P.O.) has sought to establish designs for dials which are locally produced, less expensive and less demanding of maintenance than those it has employed in the past. (Ref. 1).

The purpose of the present article is to describe the manner in which prototypes of the new Australian dial were subjected to performance trials in the Postmaster-General's Research Laboratories, the types of testing machines and measuring instruments which are used in the monitoring of dial performance and typical results of tests. The tests conducted up to the time of writing have been restricted to dial speeds of nominally 10 pulses per second. This article makes reference to certain design features of the new dial which were under examination during the dial development period but does not aim to describe all the features eventually incorporated in the final design.

Performance Requirements

The performance required by the A.P.O. for multispeed dials has been the subject of various interim technical stipulations. To some extent these have been modified in the light of discoveries made about the performance of the dials during evaluation studies. Certain values typical of those at present stipulated are shown in Table 1 alongside values observed in dials tested.

Dials Evaluated

Groups of dials were tested at various stages of their development. Modifications, which were seen to be desirable as a result of testing of each batch, were often incorporated in the succeeding batch. Early groups, for instance, had governor bearings comprising stainless steel balls located in conical cups in the shaft ends and governor brake shoes of a phenolic plastic material.

These groups performed unsatisfactorily. Improved performance was obtained from the succeeding groups which had stainless steel governor spindles with plastic journal bearings, a few drops of lubricant being added. The governor brake shoe material was changed to a thermoplastic material.

One design of dial was entirely abandoned owing to a major design weakness which led to frequent generation of an extra digit in the pulse train.

IMPULSING TEST METHODS

During the dial evaluation tests, three main methods of measurement were used. In the first method, a cathode ray oscilloscope (C.R.O.), with suitable trigger and pulse selection circuits, was used to display selected single pulses within a train on the screen of the C.R.O., making use of the C.R.O. time base. The pulse was photographed by a camera with a continuously open shutter during the period of the train. The beam intensity of the C.R.O. was strongly modulated at 2 kHz and a timer was used as an extra check. When the resulting negative was projected onto a screen, pulse length could be measured to ±0.5 ms, and contact bounce, where it existed, could be measured.

In the second method, a double-beam C.R.O. with a short-persistence screen was used. The signals were applied to the horizontal inputs, but no time base was applied to the vertical inputs. The dial pulse train was applied to one horizontal input and a 4 kHz marker with a superimposed 200 Hz of greater amplitude was applied to the other input. The traces were photographed by a moving film (as opposed to cine) camera with a continuously open shutter during the duration of the train. This method permits the whole pulse train to be photographed. Both pulse length and contact bounce can be measured. The measuring accuracy is about ±0.25 ms.

In the third method, a 14-channel electro-mechanical oscillograph using ultra-violet light recording on a photosensitive, high speed recording paper was used. The galvanometers had a flat response (±5%) to 2 kHz and the paper speed used was 1.06 m/s (42in/s). The attainable measuring accuracy, obtained by comparison with simultaneously recorded 1 kHz and 100 Hz timing traces, was at least ±0.5 ms. The great advantage of this method is that up to 12 dials can be measured simultaneously. Contact bounce is recognizable by this method, but cannot be measured with useful accuracy.

Ref. 1 describes electronic methods of measuring impulsing performance which are used in production testing.

ENDURANCE TESTING MACHINES

The A.P.O. cannot justifiably accept a new type of dial unless many samples are able to produce stable impulse times throughout a life of some half million dial operations. Verification of this ability demands that the A.P.O. have the means to test many dials to half a million operations within a reasonably short time. Manual dialling would be tedious and costly.

As dial development had not previously been undertaken in Australia, it was necessary to develop new testing machines for the purpose of carrying out endurance trials.

Basically, all that was required was a machine which would be capable of dialling '8' or '9' and releasing the dial finger plate. The choice of dialling 8 or 9 digits instead of '0' (10 digits) was made because of the type of pulsing mechanism used in some of the dials. This comprised a ten-lobed cam with a pivoted follower. It was considered that, if one or two of the cam lobes remained unworn during the endurance testing, they would serve as suitable reference surfaces for measuring the wear of the other lobes. The machine would have to keep dialling continually until the dial failed or until the stipulated dial testing period was completed. The means adopted for winding up the dial were quite simple and, in fact, had been used in earlier designs. A recirculating steel ball engages the dial finger plate intermittently with the continuously-running drive spindle of the testing machine; the period when the finger plate is not engaged by the ball is used to permit the dial to run down. The ball is picked up from its 'loading position' on every alternate revolution of the drive spindle of the testing machine and, after it pulls the dial finger plate around through the appropriate arc, the ball escapes and falls down to the loading position again. The passage of the ball from its escape position to the loading position must be delayed in order to avert the possibility of seizing the

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finger plate before the dial has run back. In previous machines, this delay was induced by having the ball bounce repeatedly on a hardened steel plate before it could roll to its loading position. However, in these new testing machines, the ball was made to run around a path in a casting. This resulted in a quieter machine. This particular machine dials '8' continuously.

One of the essential requirements of the testing machine was that it should not be capable of causing additional damage to the dial, even when the dial mechanism has failed. This safety feature was ensured in two ways. Firstly, the drive to the testing machine spindle from the electric motor was effected by means of a slack roller chain with a spring-loaded jockey sprocket in the tension side, so that excessive chain tension would cause the jockey sprocket mounting to move enough to operate a trip switch to shut down the testing machine. Secondly, the rotating plate, which engages the recirculating ball with the finger plate of the dial, was driven via a dry cork-pad torque-limiting clutch.

Fig. 1 shows the general appearance of one of these endurance testing machines.

An electromechanical counter was used for the purpose of counting the number of dialling operations. Equipment for monitoring dial pulse trains containing too many or too few pulses is under development.

GOVERNOR TEST RIG

In connection with the development of the dials, experiments were carried out to determine the braking torques of governors of various types as functions of their speeds of rotation. A special test rig was built for this purpose.

When mounted in the test rig, a governor rotor is carried in bearings identical with those in the dial. It is driven by a spur gear which, for this purpose, duplicates the function of the intermediate gear wheel of the dial. This spur gear is belt-driven from a small a.c. squirrel cage motor, speed control being obtained by varying the frequency of the supply by means of a variable frequency power oscillator.

In order that the torque developed by the braking action of the governor may be measured, the governor brake drum in the test rig is carried in its own pair of miniature ball bearings and is equipped with a spiral wire control spring and a pointer. The pointer scale was calibrated by reference to the deflections produced

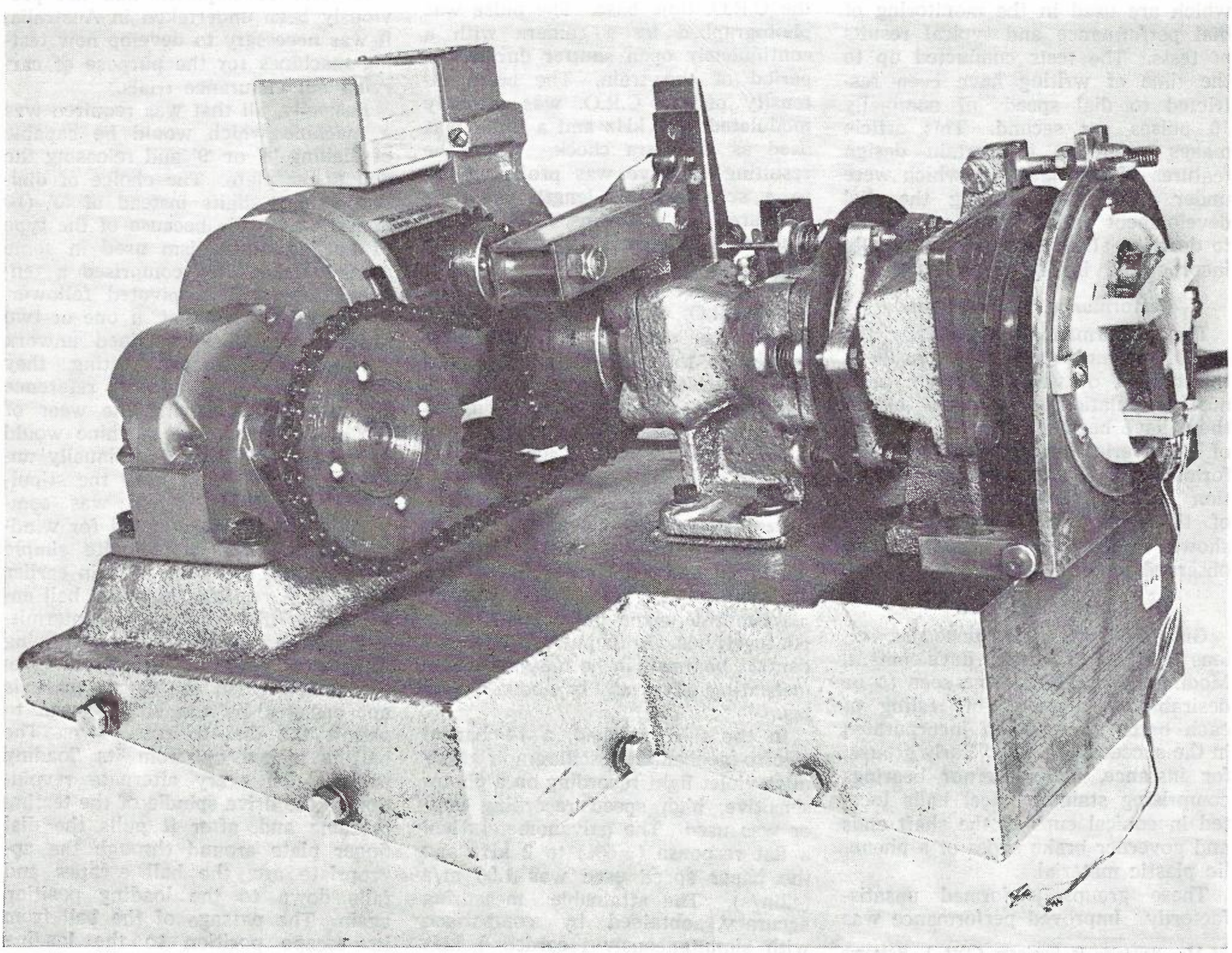

Fig. 1 — Telephone Dial Endurance-Testing Machine (Dust covers removed from machine and dial. The rear of the dial can be seen at the right-hand end of the machine).

by deadweight loads applied at a known moment arm.

This governor testing machine was used to demonstrate the relationship between speed and torque for leading-shoe and trailing-shoe governors and for brake shoes of various materials. The effects of temperature rise on governor performance were investigated by running the machine first continuously and then intermittently (under the control of a cycle timer).

BEARING CHATTER RIG

The occurrence of bearing chatter in the governor assembly is described in detail in later paragraphs. During its investigation, the chatter proved to be elusive and it was not until one particular dial was found which exhibited chatter almost continuously that it became possible to construct a visible demonstration of the phenomenon.

This dial was modified, by removal of its finger stop, mainspring and off-normal cam, and was mounted in a demonstration rig. A groove was machined in the rim of the finger plate so that the dial could be continuously driven in the pulsing direction by means of a rubber-band belt.

With the aid of a stereo microscope, the location of the chatter was easily traced to the governor spindle bearings. As the governor was accelerated to its operating speed, the sudden transition from smooth rotation to the chatter condition could be seen quite dramatically.

MAINSPRING DYNAMOMETER

The design of the mainspring of a dial constitutes a fundamental factor in the control of speed variation. A relatively stiff mainspring, which has a wide variation in wind-up torque over the working range of angular displacement, will lead to greater variation in dialling speed than would occur with a mainspring possessing a flatter load-displacement characteristic.

Thus, it is important to be able to measure the load-displacement relationship for prototype mainsprings during dial development. A torque balance was built, in which a torque load could be applied to one end of the spring by means of a pivoted arm and weights. The other end of the spring could then be wound up through a measured angle in order to produce a condition of balance with the gravity loading. From a series of measurements for each spring at varying torques, the torque-displacement curves were readily plotted.

LIFE TESTING

Each group of dials was tested on the life testing machines described above for up to 1,000,000 operations, this being above the expected number of operations of the great majority of dials. The number of operations was recorded by a 5 digit subscribers' register operated by the off-normal contacts of the dial. Each operation dialled the digit '8' at the rate of 1,680 operations per hour. The pulse lengths of sample pulse trains measured at various stages in the test are shown in Table 1. This shows the results of pulse length measurements of a typical dial from the seventh development group. Certain other properties (e.g. contact bounce, spring force, contact resistance) were measured. Fig. 2 shows the variation in break pulse lengths versus number of operations for a sample dial from each of the three groups tested.

TABLE 1: TYPICAL PULSE LENGTH MEASUREMENTS DURING LIFE TEST.

Quantity	Interval (No. of Operations	Observed Values
Range of MAKE pulses (ms), measured in interval (cf. specified 29-40ms)	$0\text{-}10^4$ $10^4\text{-}10^5$ $10^5\text{-}5\times10^5$ $5\times10^5\text{-}10^6$	33-37 34-37 31-34 29-42
Range of BREAK pulses (ms) measured in interval (cf. specified 60-76ms)	$0\text{-}10^4$ $10^4\text{-}10^5$ $10^5\text{-}5\times10^5$ $5\times10^5\text{-}10^6$	65-70 66-69 59-64 55-77
% of BREAK pulses outside specified limits in interval (+ for above limit, — for below limit).	$0\text{-}10^4$ $10^4\text{-}10^5$ $10^5\text{-}5\times10^5$ $5\times10^5\text{-}10^6$	0 0 —3 —60, +1
Maximum BREAK pulse specified limits in interval pulse train in interval (ms).	$0\text{-}10^4$ $10^4\text{-}10^5$ $10^5\text{-}5\times10^5$ $5\times10^5\text{-}10^6$	3.0 2.5 2.0 21.0
Number of pulse trains measured in each interval.	$0\text{-}10^4$ $10^4\text{-}10^5$ $10^5\text{-}5\times10^5$ $5\times10^5\text{-}10^6$	15 9 15 12
Total number of pulse trains measured.	$0\text{-}10^6$	51

Fig. 3 shows a pulse target diagram of the sample dial from the last group. This diagram comprises a set of points, each of which represents complementary make and break pulse durations at some stage of a dial's life. If many such measurements are made throughout the life test of one particular dial, a pattern of dots, as shown in Fig. 3, is obtained. The rectangle in Fig. 3 represents the tolerance area of the specification.

ENVIRONMENTAL TESTS

Early technical stipulations did not specify environmental tests for dials and none was performed until the fifth group tested. Such tests are necessary in order to check on the ability of dials to perform satisfactorily under extreme conditions, e.g. in public telephones and some subscribers' telephones in southern mountain areas of Australia the temperature of the dial could often be below 0°C and in hot, tropical areas the temperature of dials might exceed 50°C. Only a small proportion of dials in use would be subjected to such extremes, but environmental testing can exaggerate weaknesses that exist under normal conditions and which could ultimately be a problem. This testing thus enables such possible weaknesses to be relatively easily detected.

Environmental test results for the last three groups tested are shown in Table 2. Samples of the fifth group can be clearly seen to have failed catastrophically at 0°C. Some attempts at obtaining pulse trains ended

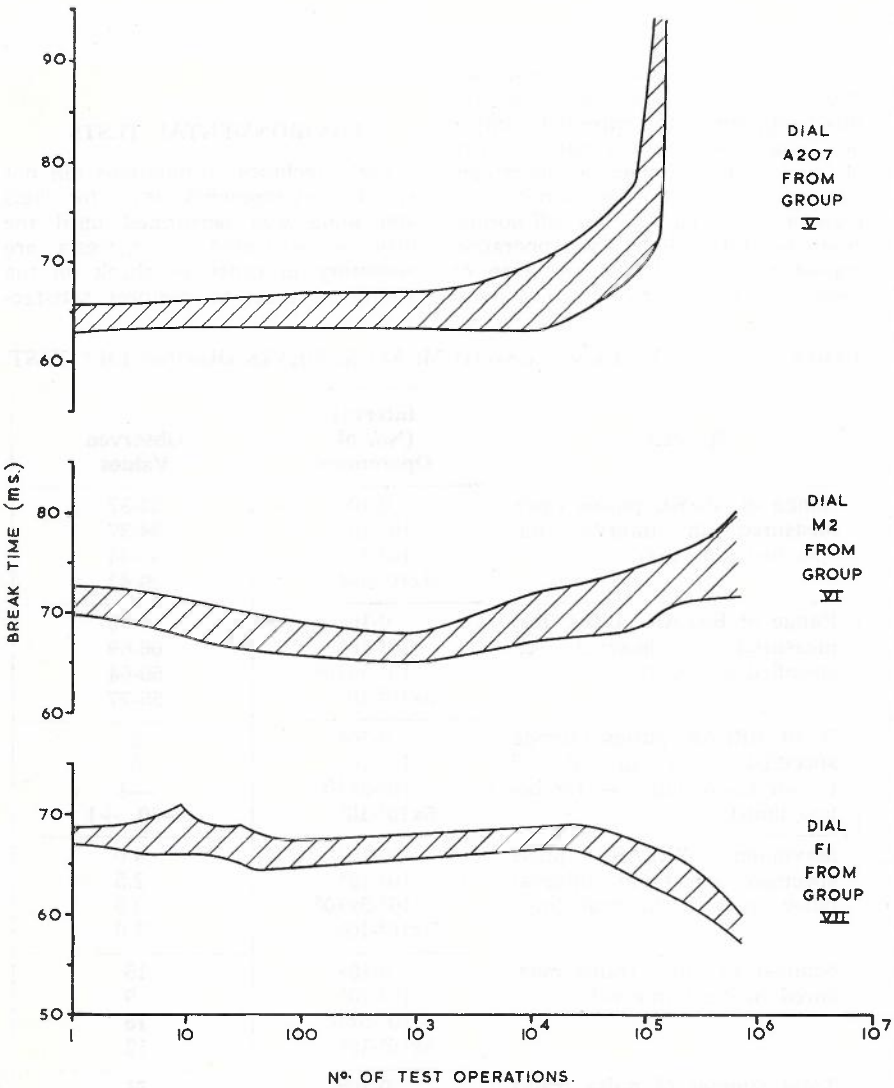

Fig. 2 — Break Times of Sample Dials from Groups V to VII During Life Test. (Cross-hatched areas indicate the range of break pulse durations).

in seizure of the dial mechanism. Excessively slow pulses occurred at all temperatures below 10°C. Although the dial was initially within the stipulated pulse length limits, and recovered after being held at ambient temperature for 2h after the 0°C test, Table 2 shows that a subsequent 2h at 50°C caused the dial again to exceed the stipulated limits.

These faults were attributed to:

(i) Misalignment of intermediate gear and governor spindle bearings.

(ii) Insufficient manufacturing control of centre distances between gears.

(iii) Insufficient bearing clearances.

(iv) Changes in the coefficient of friction of the governor brake shoe material over the required temperature range.

The sixth and seventh groups of dials incorporated changes designed to overcome the above deficiencies. The brake shoe material was changed as indicated earlier, and a damping pad and thrust spring in the governor bearing were eliminated. Table 2 shows that these changes were effective in that the environmental tests were passed.

CONTACT EXAMINATION

From time to time investigations of the life and efficiency of contact materials and spark quench circuits are carried out in connection with studies of dial performance. For example comparative tests were conducted on a silver-nickel alloy and a silver/cadmium-oxide alloy as contacting materials (in conjunction with two different spark quench circuits) as part of the investigations of the design of the new dial. (The silver-nickel alloy was found to be superior in this application.) Pure silver is used for the contacting material in production versions of the dial.

Observations are made of contact pressure and electrical contact resistance; tarnish film development and erosion of the contacting surface are observed by microscopic inspection. These observations are made before, during, and after a programme of repeated dialling under circuit conditions simulating the exchange and line circuits met with in the field.

GOVERNOR BEARING CHATTER

With the third group of dials tested, an intermittent chattering noise, coinciding with severe, visibly apparent slowing of the dial, occurred on all dials in the group, the earliest occurrence being after 100,000 operations. There was complete correlation between the slowing down and the chatter. Thus, when chattering was heard, the mean break pulse was about 95 ms whereas otherwise it was about 60 ms.

The construction of a special rig to demonstrate the presence of chatter has been described previously in this article. When a frequency spectrum analysis of the chatter noise was made, no predominant frequencies were revealed. Therefore, the noise could not be traced to the influence of gear profile irregularities or resonance effects.

The chatter phenomenon is thought to be due primarily to the disparity between the static and dynamic coefficient of friction of steel on the moulded plastic bearings. A probable explanation of the behaviour of the governor spindle, when chatter is present, is as follows:

The spindle, coming in contact with one part of the bearing, begins to rotate about the point of contact. Because there is radial clearance in the bearing, the axis of the spindle begins a translatory motion. At the same time, the spindle rebounds from the point of contact with the bearing. The spindle thus moves away from its first contact point and also across the bearing space until it again contacts the bearing some finite chordal distance away from its first point of contact. The same thing happens at the second point of contact. Continuing on, the spindle progresses around the bearing in a series of leaps, the centre of the spindle tracing out a path resembling a hypotrochoid.

It was demonstrated, during the development of the dials, that there is a fairly close correlation between

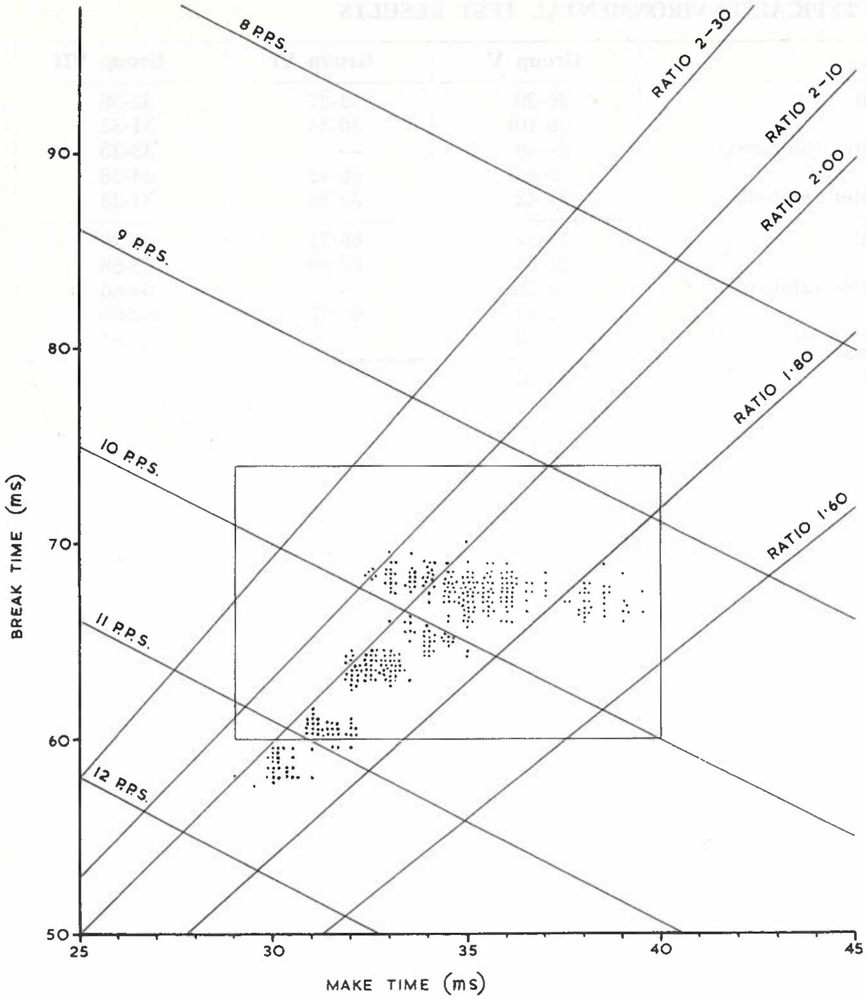

Fig. 3 — Pulse Measurements Made During a Life Test. (A dot represents a pair of adjacent makes and breaks. The rectangle shows the permissible limits).

the amount of radial clearance in the governor bearings and the tendency to exhibit bearing chatter. If the bearing clearance can be kept small, the possibility of encountering bearing chatter is lessened but, of course, such a requirement makes the solution of the problem the responsibility of the production engineer.

On several mornings, when the dials had not been operated during the previous night, it was noticed that, when testing was begun next day, the chatter took much longer to develop than if the dials had not had such a long rest period. It is thought that an increase in bearing clearance due to thermal expansion and to temporary deformation of the bearing surfaces after long running promotes chatter. Modifications which succeeded in overcoming the chatter were made, but these modifications were superseded in later designs.

BROWN POWDER

In laboratory testing, a brown powder was found to have accumulated over the body of most dials underneath the back cover after about 200,000 operations. Chemical analysis of the powder showed that 80% of its mass was dust which could not have come from the dial. The main constituents of the remainder were iron, chromium and nickel with smaller quantities of copper and zinc in the powder of certain dials.

Analysis of the main-spring material showed it to consist of iron, chromium and nickel. The trigger spring consisted of copper, zinc and nickel. The governor brake drum was made from Austral alloy 907 which contains copper, zinc, nickel and lead.

As iron was found only in the main-spring, wear of the main-spring must have contributed to the brown powder. As the main-spring contained no copper or zinc, part of the powder must have come from components other than the main-spring, probably the governor brake drum or the trigger spring or both. The powder was probably an abrasion or possibly fretting corrosion product. The 80% of dust was due to the dusty room in which testing took place.

The powder cannot fall into the spring contacts and therefore is not considered hazardous in a subscriber's telephone under normal use, but because it is electrically conducting it could cause bridging of contacts if allowed to fall under gravity during movement of the dial in a portable telephone or 'Buttinski'.

BODY MOULDING

The body is an acetal injection moulding. The stiffness of the dial body moulding must be adequate to prevent undue deflection under the loads applied during dialling. Tests were carried out to specify a figure for stiffness of the moulding which could be reasonably achieved with the types of resin commercially available.

Further tests at extremes of temperature were made to ensure that mouldings conforming to the above specification would be satisfactory in service in severe conditions.

GOVERNOR SPINDLE LUBRICANT

In the sixth group of dials tested, a lubricant, di-octyl sebacate (D.O.S.) was used in the governor bearing to prevent chatter. One of these dials became moderately noisy after about 450,000 pulse trains. This chatter was cured by the application of a few drops of D.O.S. to the governor spindle bearings. This showed that the lubricant had become ineffective, possibly as a result of chemical change, dust accumulation, creep, evaporation or other cause. The failure of the lubricant could have been a function of time or of the large number of operations. In these accelerated tests, it was not possible to obtain a clear indication of the relative contribution of these causes, but in view of the known low volatility of D.O.S. and the short time elapsed, an operation-dependent phenomenon is suspected.

Tests showed that D.O.S. is not likely to form disruptive surface films on the impulsing contacts, nor to cause accelerated erosion by contact activation. Immersion of acetal body mouldings in D.O.S. for 150h at 50°C produced no significant dimensional or hardness change in the plastic moulding.

TABLE 2: TYPICAL ENVIRONMENTAL TEST RESULTS

		Group V	Group VI	Group VII
Range of MAKE pulses measured (ms)	Initial	36-39	33-37	32-36
	0°C	38-108	30-34	31-33
	2h later (ambient)	34-38	—	33-35
	50°C	36-44	36-42	34-38
	2h later (ambient)	37-42	33-36	31-33
Range of BREAK pulses measured (ms)	Initial	73-81	66-71	67-70
	0°C	83-259	62-69	65-68
	2h later (ambient)	68-78	—	64-66
	50°C	68-81	66-75	62-65
	2h later (ambient)	71-80	63-68	62-65
% of BREAK pulses outside specified environmental test limits (+ above, — below)	Initial	+100	+6	0
	0°C	+100	0	0
	2h later (ambient)	+ 3	—	0
	50°C	+ 30	0	0
	2h later (ambient)	+ 30	0	0
Maximum BREAK Pulse Spread (ms) observed in a single pulse train	Initial	7.0	4.0	3.0
	0°C	126.0	4.0	2.5
	2h later (ambient)	4.0	—	2.0
	50°C	5.5	4.0	2.5
	2h later (ambient)	4.0	5.0	2.5
Number of pulse trains measured	Initial	4	4	5
	0°C	12	4	5
	2h later (ambient)	4	—	5
	50°C	4	4	4
	2h later (ambient)	4	4	5
Total number of pulse trains		28	16	24

CONCLUSION

This article has been restricted to describing the work performed by the A.P.O. in the evaluation of new telephone dials for its use. This work included the design and construction of various mechanical testing machines and dynamometers, the most important of which was an endurance testing machine using a recirculating ball to engage the dial's finger-plate. Although the recirculating ball principle had been used previously in a known commercial machine, it had been the practice to use a single machine for testing several dials. Each of the machines developed by the A.P.O. was designed to operate one dial only. This principle enables the testing of other dials to continue if one dial fails. It also permits the incorporation of more effective overload trips to protect a seized dial from mechanical damage.

It must be emphasized that the results quoted are based on small samples made from production-type tools but not under full scale production conditions. For this reason, similar tests to those described in this article will be conducted on samples drawn from time to time from full-scale production to obtain an audit of their quality. Another aspect of this dial which has not yet been explored is its performance at 20 pulses per second.

The testing programme employed in these tests largely involved continuous operation to obtain results of a large number of operations quickly although on some occasions the dials were not operated during the night so that their recovery behaviour could be examined.

It is realized that such a continuous testing programme might not accurately simulate the behaviour of dials in service as time-dependent effects could have been masked. Information from actual service is required to confirm the findings made in this investigation.

Possible alternative programmes which could be used in future dial testing would include regular and frequent recovery periods. Such testing would have the disadvantage that it would take considerably longer to complete.

As a result of experience gained during the testing period of the dials, the A.P.O. established specifications for equipment for measuring the pulsing performance of dials. New testing equipment built to these specifications has been developed by an Australian manufacturer and is used in dial manufacturing and reconditioning workshops, acceptance laboratories and performance trials.

REFERENCE:

1. J. Companez, 'The Australian Dial'; Telecom. Journal of Aust., June 1971, Vol. 21 No. 2, Page 120.

THE APPLICATION OF PERT TO A MULTI-DISCIPLINE PROJECT

*S. A. HOWARD, A.M.I.E.E.**

INTRODUCTION

The development of two new coal mining centres and a new township in Central Queensland has involved the Department in a major project to provide telephone services to the mining complex and township. The mines, one at Goonyella due to start production in 1971 and the other at Peak Downs due to start production in 1972, will be served by a new township being constructed at Moranbah to accommodate from 2,000 to 3,000 people with a permanent population of 2,000 in 1972. Engineering planning had to consider not only the present project but also requirements for the development of two additional mines farther south and also growth in the Brigalow area.

The use of Programme Evaluation and Review Technique (PERT) has spread throughout many sectors of industrial and government organisations since its introduction into Australia some 10 years ago. This paper discusses the application of PERT to the activities associated with the complex engineering and management task of planning and providing the telephone services. Manual processing methods have been used throughout because they offered a faster and more economical result than computer processing for this particular project. The use of a computer for network analysis and resource scheduling was outlined in a previous paper entitled 'PERT In the Light Engineering Field' (Ref. 1).

THE PROJECT

At the time of writing this paper the project had been in progress for two weeks in the Mackay engineering division. A plan of the project indicating distances and locations where work was required along with the main activities associated with each location is shown in Fig. 1. Work could proceed in a number of areas simultaneously, requiring a high degree of co-ordination by the project manager to ensure smooth operation and optimum utilisation of men and machinery.

The work of a variety of specialist personnel had to be considered and co-ordinated as the project involved aerial line construction, installation of underground cable, ARK equipment installation and carrier equipment installation by departmental staff and the installation of a PABX, road clearing, building erection and conduit laying, by outside organisations. The PERT technique was selected as the means of analysis and scheduling because it had been well established as a sound management and decision making aid in the equipment installation field and offered a superior method of project analysis to other available techniques. The project in this exercise comprises 200 activities with 16 different types of resources requiring consideration.

THE BROAD STEPS

The following steps which represent the systematic PERT method of project planning were employed:—

(i) Preparation of a network showing the inter-relationships of all activities to be performed.

(ii) Allocation of an activity time and resources to each activity in the network.

(iii) Performance of network calculations, selection of the critical path and analysis of the project in the light of calculated information.

(iv) Preparation of a time scaled schedule from the information on the network.

(v) Calculation of resource requirements for each day of the project.

(vi) Levelling of resource requirements for the project to ensure that the schedule could be achieved with available resources.

To provide an indication of the planning effort and personnel involved the following details are offered:

The exercise was undertaken as a team effort with the team comprising the Divisional Engineer and Engineer Class 2 of the Mackay Division and a Senior Technical Officer Grade 2 (the author). Two line inspectors were also involved part time. Network preparation required six hours elapsed time for the three team members. Allocation of activity times required three and a half hours for the team members in conjunction with the line inspectors.

Network calculations were performed by the senior technical officer in one and a half hours. He also prepared the time scaled schedule in five hours. Three hours were then utilised by the team in discussing and levelling resources, allocating and calculating the resource 'engineer time' and obtaining prints of the schedule.

NETWORK PREPARATION

This was a crucial stage of the planning because at this point the project was dissected and analysed to enable the team to commit to paper the intended method of working, the decisions made and the relationship between various parts of the project. The network is shown in Fig. 2. Considerable care was exercised during this stage because all further calculations, and decisions were to be based on the network. Conventional symbols were used in network preparation i.e. an event represented by a circle, an activity or definable piece of work represented by an arrow and a dummy activity used to show a restriction or relationship represented by a dotted arrow. (Ref. 2.)

Before commencing the network the Divisional Engineer outlined the work to be undertaken and stated his requirements. This information along with discussion arising from questions regarding the number of work locations, the type of work in each and the technical relationship between these localities enabled the networker to broadly visualise how he would lay the network out. The type of information in question has been entered on the plan in Fig. 1. As work could commence immediately in a number of locations it has been possible to present the network roughly in geographic areas although there was unavoidable overlap with some activities. All arrows do not necessarily move in a direction from left to right but this does not affect the logic of the diagram. The important aspect is the relationship of one arrow to the other arrows in the network.

In selecting appropriate activity definitions, consideration was given to the degree of detail necessary to ensure adequate project analysis and the requirements of the project manager in the ensuing period from the

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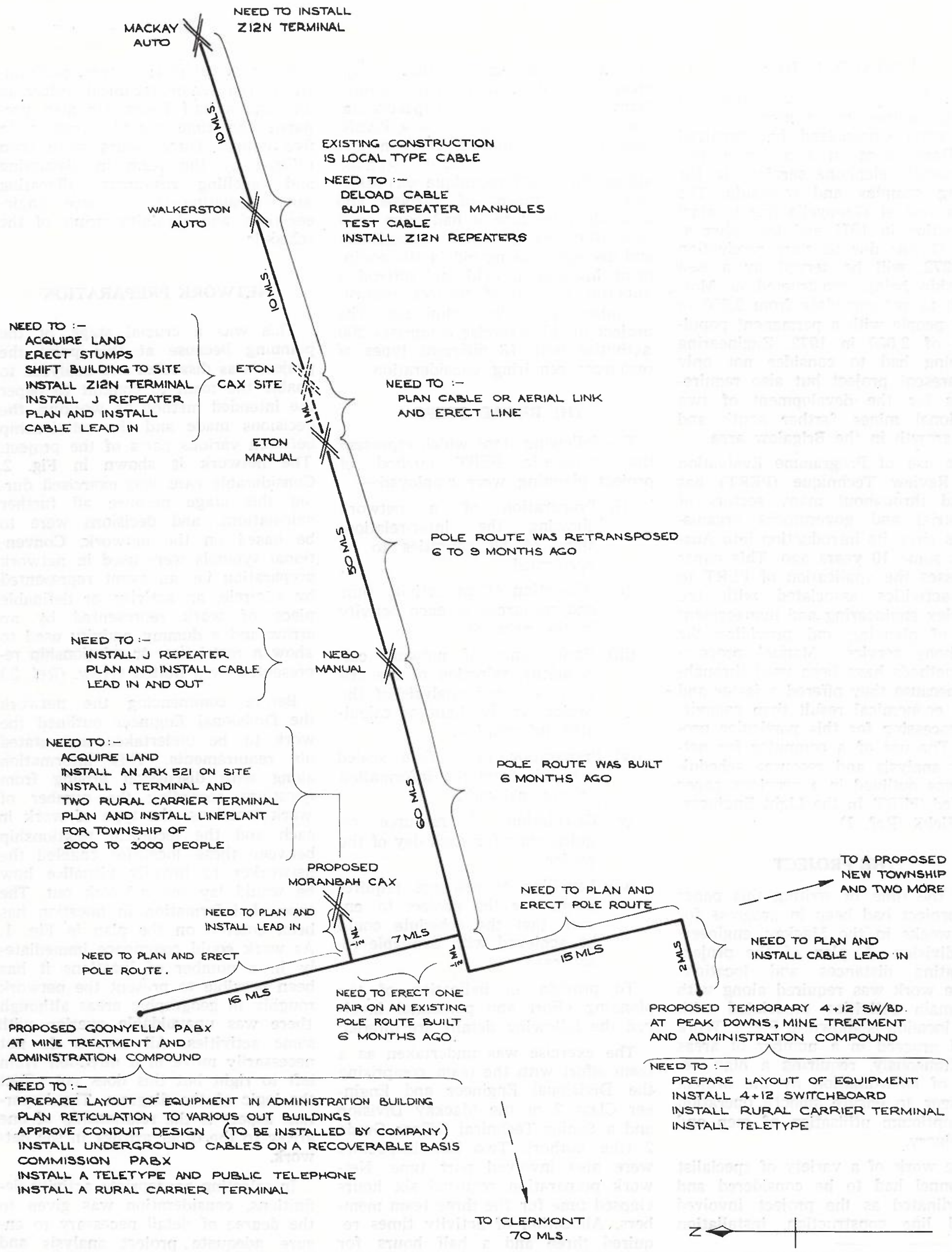

Fig. 1. — Project Plan.

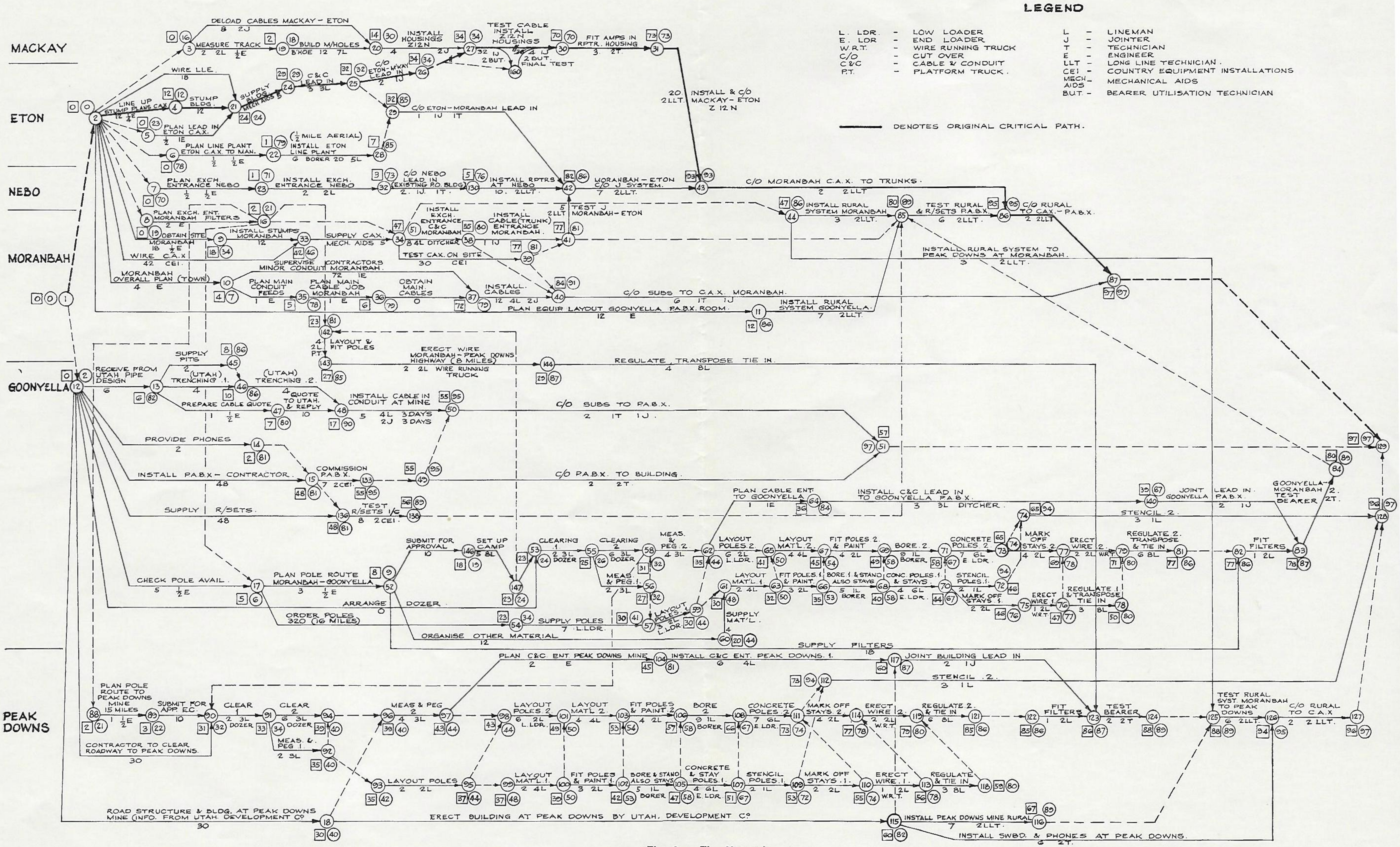

Fig. 2. — The Network.

point of view of project control. Activities outside the control of the local division, such as 'wire CAX' were considered only in broad terms while activities within the division's control were subject to more detailed discussion and definition. Activities for the pole route construction Moranbah-Goonyella and Peak Downs mine have been sub-divided into two parts to enable practical presentation of the performance of this work in network form. Having decided the activity definition requirements, the network was built up piece by piece. This meant planning all the moves and making decisions to enable the team to display the entire project on paper.

It was not certain at the networking stage whether the link between the Eton CAX site and Eton manual exchange would be provided in underground cable or by aerial construction. Activity 22-28 'Install Eton line plant' shows the assumption that aerial construction would be used. The project manager was aware of the implications of this assumption and it was a better course of action to follow than to leave the planning incomplete because of the absence of a small percentage of the total information.

Upon completion of the network drawing, multiple start events and multiple finish events were extended out to single start and finish events by dummy activities. A check was made to ensure that the logic was true and that technical considerations were not overlooked.

NETWORK NUMBERING

To assist in identifying any activity in the network, all events were numbered commencing with number 1 for the start event and continuing through to number 129 for the finish event. To identify an activity by event numbers, the activity 'test rural system Moranbah to Peak Downs' would be seen as activity 125-126. Event numbers higher than 129 were introduced as a result of network modifications being made after allocating the original event numbers. The networker could have altered the original numbers to ensure sequential numbering throughout but no advantage could be gained from the extra time and effort which would have been expended so the higher numbers were used where convenient ensuring that event numbers were not duplicated.

ACTIVITY TIMES

It was necessary when entering activity times on the network to select a suitable unit of elapsed time and enter all activity times as a multiple of this unit. The selected time unit was one working day. This could mean seven men for one day or one man for one day or simply a delay of one day waiting for the supply of material. Having decided on the unit, each activity was taken as a separate identity and a time to perform the work allocated. The times were generally derived through discussion and agreement concerning the method to be used, the team size for that particular activity and the amount of time most likely to be required. To illustrate how this information was entered on the network, activity 53-55 from the Moranbah-Goonyella pole route is shown in Fig. 3.

Thus for each activity the time and resources were assessed and shown on the network. The total level of resources which may be available was not considered at that stage because an attempt to build restrictions into the network because of total resource availability would have prevented a thorough analysis of the alternatives and probably concealed valuable information from the project manager. However, one resource and timing restriction was included by the use of dummy activity 58-90 to ensure that work on the Peak Downs route would follow work on the Goonyella-Moranbah route. It was important that the level of resources allocated to any single activity did not exceed the total resources available

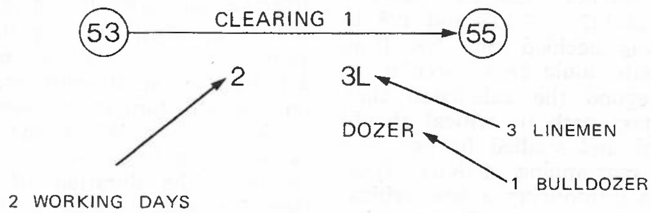

Fig. 3.

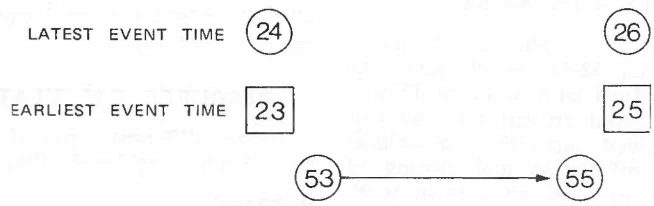

Fig. 4.

NETWORK CALCULATIONS AND ANALYSIS

Network calculations were carried out using the conventional forward pass and backward pass method. The forward pass calculation which nominates the earliest time an event can be achieved is shown on the network as a figure in a square symbol adjacent to the event concerned. The backward pass calculation giving the latest time any event can be achieved and still complete the project in the calculated time is shown in a circle adjacent to the event concerned. Activity 53-55 is again used to illustrate these calculations in Fig. 4.

This information says that event 53 could commence on day 23 but must commence no later than day 24 if the calculated completion time of 97 days as shown on event 129 is to be achieved. Activity 53-55 has one day slack or free time.

An inspection of the network in Fig. 2 will show that the earliest time in which this project could be completed is 97 days — according to the method shown in the network. By studying the earliest and latest event times for each event it was found that events numbered 1, 2, 4, 21, 24, 25, 26, 27, 30, 31, 43, 86, 87, and 129 were critical, i.e. they had no slack or free time. By selecting the activities that linked these critical events, the critical path was located. This placed the critical path through activities 1-2, 2-4, 4-21, 21-24, 24-25, 25-26, 26-27, 27-30, 30-31, 31-43, 43-86, 86-87 and 87-129. After further analysis of the activities along this path it was decided that activity 27-30 'test cable, install Z12N housings' could be subdivided into two parts, 27-160 'test cables, install, Z12N housings' taking 32 days and 160-30 'final test' taking four days with activity 25-26 'cutover Eton-Mackay lead in' being required for the start of activity 160-30.

Earliest and latest event times were not recalculated after this alteration as the effects could easily be seen from the existing figures. This introduced a new critical path through portion of the Moranbah-Goonyella pole route and the Peak Downs mine pole route. This path which previously had one day slack time involves activities 1-12, 12-17, 17-52, 52-146, 146-147, 147-53, 53-55, 55-58, 58-90, 90-91, 91-94, 94-96, 96-97, 97-98, 98-101, 101-103, 103-106, 106-108, 108-111, 111-114, 114-119, 119-121, 121-122, 122-123, 123-124, 124-125, 125-126, 126-127, 127-128 and 128 to 129. It was decided that the Peak Downs route could be allowed to go slightly beyond the calculated time and the next path to critical should be selected and studied further. The effect of rearranging activity 27-30 apart from introducing a new critical path through the Peak Downs mine pole route has been to reduce the amount of slack time available to other events in the network

The path 1-2, 2-33, 33-34, 34-39, 39-41, 41-42, 42-43, which joins the original critical path at event 43 was then considered critical also. As this path involved activities associated with the installation and testing of the Moranbah CAX, an area of work outside the control of the Mackay Division, the path which had to be considered critical as far as divisional resources were concerned was also selected. This path passed along activities 1-12, 12-17, 17-52, 52-146, 146-147, 147-53, 53-55, 55-58, (these activities were also critical as far as the peak Downs route was concerned) 58-62, 62-65, 65-67, 67-69, 69-71, 71-73, 73-77, 77-79, 79-81, 81-82, 82-83, 83-84, 84-85, 85-86 which joins the original critical path at event 86. This path from event 58 to event 86 had a slack time of the nine days shown on the network less four days which is the reduction caused by the modification to activity 27-30.

The slack or free time available to all other events in the network can be read directly from the diagram by comparison of the earliest and latest event times for each event, remembering that the latest event time for many of the events has been reduced by four days. When satisfied that the project had been adequately presented and analysed, the information was transcribed onto a time scaled drawing.

TIME SCALING

While the network was the main document in that it illustrated the decisions made during the disciplined and systematic planning and calculations, it was considered a difficult document to use for project control and was not suitable for resource levelling as it was not drawn to a time scale. To prepare a project schedule which would be easier to read and use for control purposes the activities, whose earliest start and and latest finish times had been determined by network calculations, were transferred onto a standard PERT pro formae QG.3155, Sheet 77 (tracing paper) as shown in Fig. 5.

This involved drawing the critical path activities and all non-critical activities to scale with one division on the pro formae representing one working day. When the activities were drawn to scale it was possible to show the duration of the float time for each activity by the length of a dotted line. It was important to see this float time so that resource levelling could be undertaken. Initially all activities were drawn at their earliest start time.

RESOURCE CALCULATIONS

Sixteen different types of resources have been considered, they are:—

Personnel

Engineer manhours

Linemen not in the camping party

Linemen in the camping party

Jointers

Technicians from the local division and three other specialist divisions

Mechanical Aids

Bulldozer

Ditcher

Low Loader

Wire running truck

End Loader

Borer

Platform truck

Backhoe

After the time scaled schedule was drawn the quantity of each type of resource for each day of the project was assessed by totalling the requirements for the activities being worked on during that day. The totals for each day appear at the foot of the schedule

RESOURCE LEVELLING

The earliest start schedule produced irregular profiles of daily demands on resources and moves were made to eliminate the peaks and valleys in the requirements by altering the start time of activities within the range of their float time. Fig. 5 shows the completion of testing and cutting over the Moranbah-Peak Downs rural system to the CAX on day 103. A study of the schedule will show that spare time has been introduced into the critical path through the Peak Downs work on days 32, 33, 34, 35, 62, 63 and 86. The extra time was incorporated to facilitate resource scheduling Utilisation of an additional borer could result in a rearrangement of work eliminating six of the spare days and bringing the completion time back to day 97. The seventh day could also be eliminated by rearrangement of activity timing but the method shown provides continuity in activities such as 'regulate, transpose the tie in'.

The resource 'linemen' has been considered as two groups i.e. linemen not in the camping party and linemen in the camping party. This was necessary because the camping party was to be established as one group and the non-camping men were to be provided from the Mackay line depot. The schedule has not produced a particularly even profile for the camping party but based on this information the project manager can make the necessary day to day adjustments to ensure a uniform and continuous work load e.g. 21 camp linemen are shown to be required on day 55 because of an overlap of one day of activities 68-70 requiring 6 linemen and activity 104-117 requiring 4 linemen. A few alternatives could be adopted to reduce this level, they are:—

(a) Relocate the activities within their float time.

(b) Split one or both of the activities causing the peak.

(c) Vary an activity time and its resources.

In an attempt to predict the extent of engineering effort required to plan and control the project, the resource 'engineer time' has been included. The method of calculating this resource was possibly a little unorthodox but resulted in an indication of the volume and distribution of engineering effort to be provided throughout the project. The method employed was simply to estimate the man hours of engineers time for each

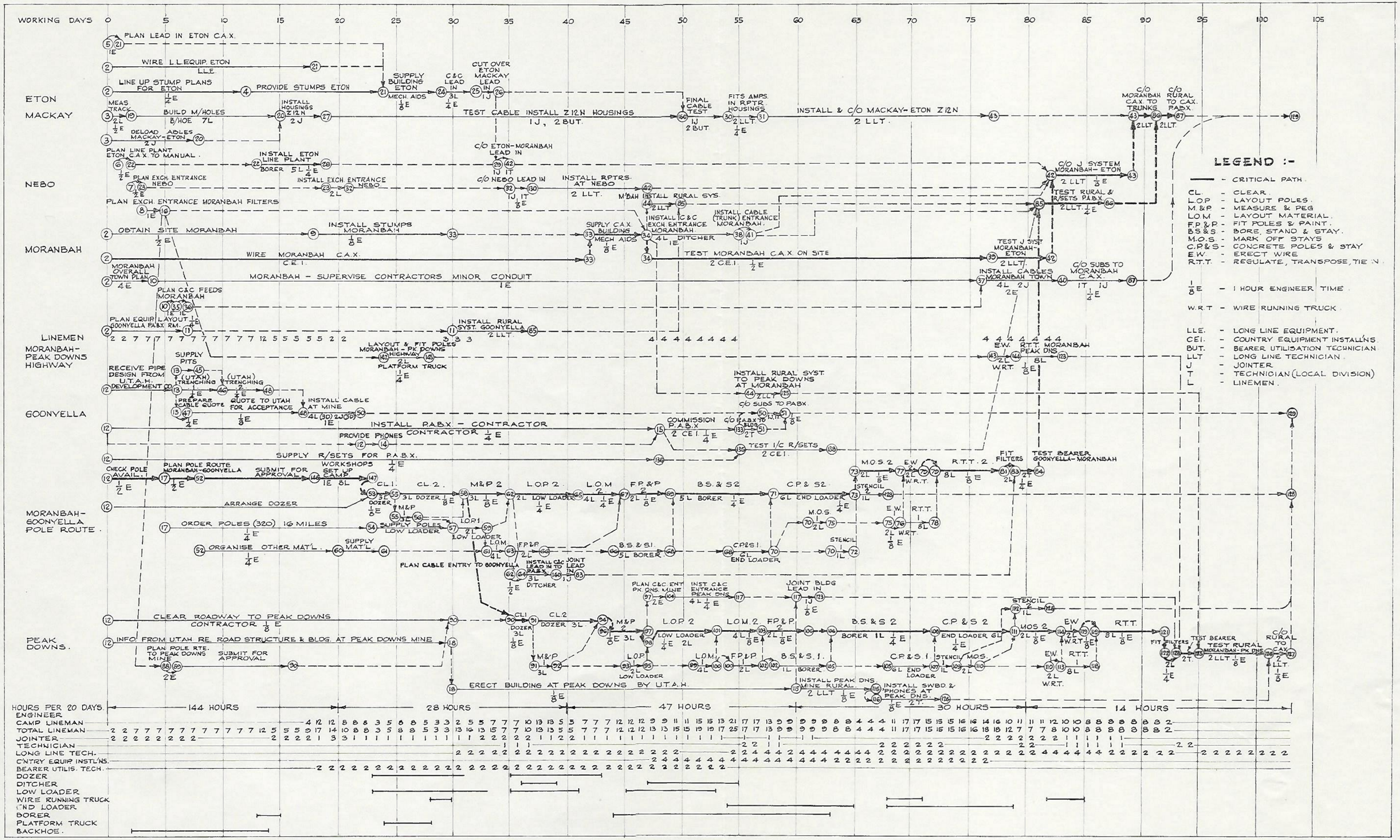

Fig. 5. — Time Scale Scheduled.

activity and enter the figure as a fraction of a day below its activity on the schedule. The schedule was subdivided into units of 20 working days and all entries within each period totalled to produce a man hour requirement for each of the periods. The times were not intended as standards but assessed by the division to be a reasonable representation of the time and effort to be allocated to this particular project. The levels of each resource for each day of the project can be taken directly from the figures at the foot of the schedule in Fig. 5.

While it was anticipated that wet weather would interfere with progress it has not been accounted for either in the activity times or the schedule although the seven spare days could be useful in the event of unforeseen circumstances. When weather conditions affect the project, it will be necessary to decide whether to extend the final date to take account of the delay or to reschedule the remainder of the project in an attempt to achieve the original completion date. In the latter case an increased number of resources will almost certainly be required if, on further analysis of the remainder of the project, activities could be shortened or rearranged to produce a new critical path which confirmed that the original completion date was still a realistic target.

INFORMATION GAINED BY THE EXERCISE

From the schedule in Fig. 5 the following information was available:

A clear presentation of all necessary activities.

Logical relationship of all activities.

Completion times of phases of the project and of the whole project. From this target dates could be given to other divisions and organisations.

Latest allowable dates for the receipt of planning and design information.

Latest allowable dates for the delivery of material and equipment to the work site.

Required time for the delivery of buildings to their site.

Critical activities.

The priority to be given to non-critical activities.

The range of times between which any activity must be undertaken and the resources for each activity.

The level of each type of resource required for each day of the project.

A mechanical aids programme for the project.

The schedule provides an excellent aid to project control and can be revised quickly in the light of changed conditions or variations in the rate of progress. Variations are expected to occur because the times used were mainly estimated and changes in the plans of any of the other divisions or outside organisations could affect this project. The project has, however, been carefully analysed and laid out so that the effect of changed conditions can quickly be assessed by the project manager and the wisest decision made regarding future action.

PROGRESS REPORT

This paper would not be complete without a progress report. The objective of the exercise was to co-ordinate the resources of several departmental specialist divisions and outside contractors to provide a communication service to the new mining area early in 1971. After the first two weeks of operation the Divisional Engineer, Mackay, has offered the following facts which have emerged to highlight the value of the PERT method of project planning:—

(a) The network and schedule clearly presented the project manager's thoughts and project complexity thereby enabling him to evaluate his plans and extract from the schedule essential data to ensure adequate co-ordination. He is confident at this stage that the completion target will be achieved.

(b) Copies of the schedule (Fig. 5) have been forwarded with a covering memorandum to each of the three specialist divisions. namely Long Line Equipment Installation, Bearer Utilisation No. 2, and Country Equipment Installation No. 2 showing their involvement and requesting confirmation of the target dates associated with their work. Confirmation has been given and the divisions expressed pleasure at receiving information in this form.

(c) Written advice has been forwarded to Utah Development Company stating acceptable dates for commissioning and cutover of the PABX and construction of the road to Peak Downs and erection of the Peak Downs Building. If the Company fails to meet the specified dates the project completion will be delayed.

(d) The Lands Department surveyor at Moranbah did not have the CAX site on his list. As the CAX was on the critical path, pressure has been exerted to quickly rectify this omission.

(e) Arrangements have been made with the Regional Electricity Board to ensure a co-ordinated effort.

(f) Utah have been given dates for the completion of the trenching and conduit installation at Goonyella.

(g) Difficulty was experienced in procuring poles but this has been overcome. The latest allowable supply date was known from the schedule.

(h) The supply of caravans has been arranged with units being made available by two other divisions and local hiring. The latest allowable supply date was shown on the schedule.

(i) Limited staff availability presented a problem at the time required for activities 27-160 'test cable, install Z12N housings' and 160-30 'final test'. With the knowledge that work could not be allowed to slip behind on this path, alternative arrangements were made.

The amount of time allocated to the resource 'engineer time' was proving to be inadequate as 117 hours were required during the initial two weeks compared with 144 hours anticipated for the first 20 working days.

It is emphasised that having prepared a network and schedule for a project, it cannot be accepted as final. It represents a plan of action influenced by known circumstances at the time of planning. To gain most from a schedule, the project manager uses it as a starting point and makes modifications where and when he sees that it is advantageous to do so. Numerous minor changes can be incorporated without the necessity of redrawing the schedule but in the event of a major setback, redrawing may be necessary.

CONCLUSIONS

The value of PERT has been proved beyond any doubt in fields such as equipment installations but very limited use has been made of the technique as an aid in the external plant field as a co-ordinating aid where the activities of several divisions and possibly outside organisations are involved. This paper demonstrates the application of PERT to a project requiring both external plant work and co-ordination of the activities of other divisions and organisations to meet a common objective.

It is not suggested that the break-up of activities or the times used are appropriate to other projects but the technique and this method of analysis and presentation are applicable and provide project management personnel with better information regarding their project and potential trouble areas than any other technique available at this time.

ACKNOWLEDGEMENTS

The author wishes to thank the members of the Country Branch staff for their assistance and co-operation with particular thanks to Mr. J. Alcorn, Divisional Engineer Mackay.

REFERENCES

1. S. A. Howard 'PERT in the Light Engineering Field'; The Telecom Journal of Aust., June, 1969, Vol. 19, No. 2, p. 114.
2. Industrial Engineering Information Bulletin No. 1, PERT Handbook.

TECHNICAL NEWS ITEM

TROPOSPHERIC SCATTER RADIO SYSTEM

The first Tropospheric Scatter Radio Relay System to be employed by the A.P.O. is currently being installed between Darwin and Gove in the Northern Territory by the contractors, N.E.C. Australia Pty. Ltd., to provide access to the A.P.O. trunk network for the Nabalco township at Gove.

The system, providing an ultimate capacity of 120 voice channels, will have an installed cost of approximately $1.2M and is anticipated to be fully commissioned during December, 1971.

A three-hop configuration has been chosen for the 650 kilometer path between Darwin and Gove, with repeater stations located at the Munmalary Homestead and Millingimbi Island. The system parameters are as follows:—

(a) Frequency Band 2.5 GHz
(b) Transmitter Power Output 1 kilowatt
(c) Free Space Antenna gains are 45.7 dBi for 10 metre dishes and 47.2 dBi for 12 metre dishes (the latter located at Munmalary); these figures being reduced by 5 to 8 dBi per hop due to the "antenna to medium" coupling loss associated with tropospheric scatter propagation
(d) Path attenuations (for 50% of time) vary from 213dB (183 km hop) to 221 dB (259 km hop)
(e) Frequency and space diversity are used, requiring four 12 metre and eight 10 metre dishes
(f) Receivers employ low noise (better than 2.5 dB noise figure) parametric amplifiers and will operate down to an input level of -110 dBm for a signal to noise ratio of 25 dB. The S/N ratio for the overall system will be better than 39.8 dB for 99.99% of the time.

The system will operate to C.C.I.R. Recommendations and is thus suitable for operation into the A.P.O. and international networks.

Due to the difficulties anticipated in gaining regular site access to the repeater stations, special arrangements regarding supervisory, control and maintenance are being implemented. Power supplies present a difficult problem and the solution adopted is to provide three diesel alternator sets (each 35 kVA) at Munmalary with 6 months fuel supply, two similar sets at Millingimbi backing up the Mission power station, and electric motor alternators at Gove to stabilise line fluctuations on the available mains supply.

Supervisory and control is carried out via sub-baseband channels from the control centre located at the Darwin Troposcatter Terminal. Arrangements have been made with N.E.C. to provide "plug-in" maintenance units in specially designed transit cases, each coded in accordance with the supervisory indication, so that only minimum time delays will be incurred in transporting (by light aircraft if possible) the spare units to site in the event of equipment failure. The use of quadruple diversity provides a substantial advantage from the maintenance viewpoint. It will require a catastrophic failure of working equipment to render the system unuseable for traffic.

THE APPLICATION AND METHOD OF MEASURING GROUP DELAY

*G. B. Read, B.E., Grad.I.E. Aust.**

INTRODUCTION

Until the last few years the demand on the Australian Post Office telecommunications network has been for telephone, telegraph and television services. At the present time a projection of trends indicates that within ten years possibly 50% of the network will be used for the transmission of digital signals. Because of the high percentage of the band-width which ultimately will be occupied by such signals the overall loading of broadband systems must be taken into account, and consequently the level of the data signal. In order to maintain a satisfactory margin between the data signal and both impulse noise and basic noise, the linear distortion of a data link must be tightly controlled. Group delay distortion is measured and, if necessary, equalised to ensure that the existing transmission equipment and physical lines will efficiently handle digital signals. (Ref. 1). Generally the individual group delay characteristic from filters, transformers, amplifiers, loading coils and line capacitance add systematically in a link. At present on the longer more complex links group delay distortion is measured so that the data link may be equalised to obtain a flat group delay response over the required bandwidth. These measurements which require expensive instruments and skilled operators are at present justified by the inherent flexibility of the telecommunications network to provide service to customers in almost any location. As the present transmission equipment was developed mainly for telephony there may be advantage in developing a completely separate transmission network in the future to carry the major part of the digital traffic. (Ref. 2). Group delay equalisation is used for data speeds greater than 600 bauds on voice band links, for 40.8 kilobits/sec data on a 48 kHz link, and for newspaper facsimile transmission on a 240 kHz link.

CARRIER FACILITIES

Broadband line links (coaxial cable and radio) were introduced into the Australian network in 1959 and will soon connect all of the large population centres. The terminals of these broadband line links are connected to several stages of multiplexing equipment which assembles voice bands in the frequency range of 300 to 3400 Hz in blocks of twelve to form one basic group in the range 60 to 108 kHz; five of these groups are then assembled to form one basic supergroup in the range 312 to 552 kHz. Depending on the type of line link a total of 2 to 45 supergroups can be transmitted, equivalent to 120 to 2700 voice channels. The single sideband multiplexing equipment produces a line signal comprising a large number of voice band channels spaced at 4 kHz intervals. Data modems have been designed to operate on 2.4, 48 and 240 kHz bandwidth links which utilize the present facilities and avoid most problems of compatibility with other services on the telecommunications network.

Generally the group and supergroup modems are so designed that a band-pass filter must be used when through connecting a basic group or basic supergroup between two separate line links; otherwise energy at the frequencies of the adjacent groups or supergroups can leak between the two line links via the through connecting point. The filter in a voice band modem has a sharp attenuation 'cut-off' characteristic and an additional band pass filter is not required when through connecting these modems. The group and supergroup modems produce negligible group delay distortion while voice band modems have significant group delay distortion in the passband.

It can be seen from the above that if all voice band modems, and through group filters, and through supergroup filters had a standard group delay characteristic the need for field measurements of overall delay distortion would be reduced considerably. Planners would probably avoid allocating edge of band positions in certain instances; i.e., channels 1 and 12 when a steep sided through group filter (T.G.F.) is used, or groups 1 and 5 when a through supergroup filter (T.S.G.F.) is used, or supergroups situated near the lower and upper frequency edges of the broadband line link, as these may have excessive delay distortion. There are two types of T.G.F.'s. A steep sided type for through group connection between group modems on broadband line links and a simplified filter used for through group connection of balanced cable or open wire carrier equipment to a broadband line link.

If it is required to transmit at an information rate of 40.8 kilobits/sec from Melbourne to Sydney a 48 kHz data link would consist of frequency translating equipment on balanced cable pairs in Melbourne and Sydney, group connected at each end to a broadband system. In the link may be one steep-sided T.G.F. at the receiving terminal and at least one T.S.G.F. By using either group 2, 3 or 4, delay distortion from the T.S.G.F. would be small and the overall delay distortion results from the T.G.F. and two group band translating terminals.

SUBSCRIBERS CABLE CIRCUITS

The balanced cable pair which connects the subscriber to the carrier equipment must be properly engineered to ensure a satisfactory link between the subscriber's transmit and receive modems. The cable pairs are prone to crosstalk and impulse noise, and co-ordination of levels and carrier equipment on the same cable is necessary to avoid excessive interference; e.g., interference from a teleprinter service into a low level data link. Split pairs, bad jointing, incorrect lumped loading and poor terminations all contribute to the overall distortion and error rate. The first two affect the noise on a cable pair, and the others distort the frequency response producing unwanted echoes of the data signal.

MEASUREMENT OF GROUP DELAY

Although the time delay between the input and output waveform may be important when considering error detection and correction, it is the difference in delay between the frequency components of a modulated signal which causes intersymbol interference and pulse distortion. This implies that it is only necessary for the phase shift characteristic to be linear in that part of the frequency spectrum containing the carrier frequency and its significant sidebands. If there is no phase distortion, all the sidebands have zero delay with reference to the carrier frequency and the group delay frequency response will be flat.

The terms used are explained below with reference to Fig. 1.

Phase delay (absolute time delay of a single frequency) is given by Øc/fc, where Ø is the phase shift in cycles and f the frequency in hertz.

If the angle of intercept (A) is neither zero nor a multiple of $\pm 180^0$, or the phase response is not linear (as shown) a baseband signal (unmodulated components from d.c. upwards) will be distorted. By using a modulated signal the zero reference is shifted to the carrier frequency (f_c) and the

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problem of zero intercept is removed.

The delay of a sideband of a modulater signal with reference to the carrier frequency is called—

Sideband Delay $= (\emptyset_s - \emptyset_c)/(f_s - f_c)$

Generally this is not measured but is deduced from measurements of envelope delay which gives an average measurement of delay over a frequency bandwidth equivalent to twice the modulating frequency.

Envelope Delay $= (\emptyset_1 - \emptyset_2)/(f_1 - f_2)$

In the limiting case when the frequency increment f is much smaller than f_c ($\triangle f \rightarrow O$) envelope delay is termed group delay.

Group Delay $= d\emptyset/df = \tau$

The difference in phase delay between two frequencies (usually called sideband delay) can be found by integrating the group delay frequency response between those two frequencies.

$\emptyset = \int \tau df + A$ (Angle of intercept)

The value of A is lost in the process of measuring (differentiating) the slope of the phase response. Fortunately this is only of concern when using a baseband system.

It is not possible to measure the phase response of a data link in Australia as the carrier frequency supplies are not phase locked and are usually not frequency synchronised. For this reason group delay is measured and it also has the advantage of being able to be measured between remote locations. Group delay is thus a derived term used by sheer necessity for the measurement of a particular link characteristic to design and adjust delay (phase) equalisers.

When measuring group delay between remote localities only the distortion can be measured; i.e., group delay is measured with reference to that existing at a particular frequency in the band:

$\tau_{rel} = (\triangle\emptyset_m - \triangle\emptyset_{ref})/\triangle f$

Where τ_{rel} is the group delay distortion and $\emptyset m$ and $\emptyset_{ref}$ are the phase increments over a frequency increment $\triangle f$ at the measuring frequency and the reference frequency, respectively.

This means that besides losing the angle of intercept, also a measure of absolute delay is lost which is usually of no consequence. When the transmitter and receiver are located together $\triangle\emptyset$ ref can in effect be made equal to zero and thus enable absolute group delay to be measured.

Group delay is normally measured by using a narrow band amplitude modulated carrier signal and measuring the delay of its envelope relative to the envelope of a reference carrier frequency. For measuring purposes envelope and group delay are synonymous when the modulating frequency is much smaller than the carrier frequency. Under these conditions

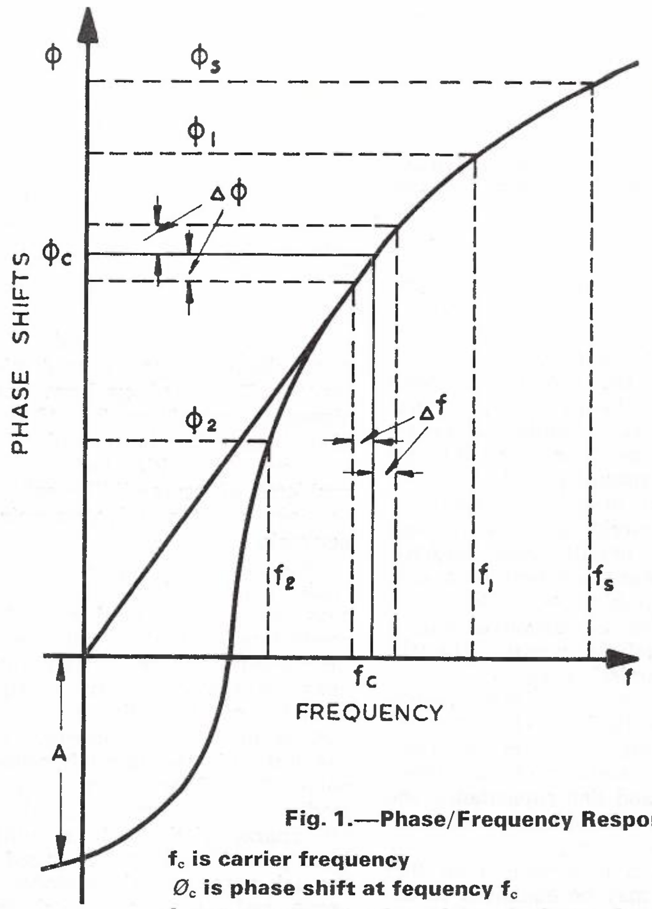


Fig. 1.—Phase/Frequency Response

f_c is carrier frequency

$\emptyset_c$ is phase shift at fequency f_c

f_s and $\emptyset_s$ relate to the sideband of a modulated signal

f_1 and f_2 are the line frequencies of the modulated signal used to measure envelope delay

A is the angle of intercept

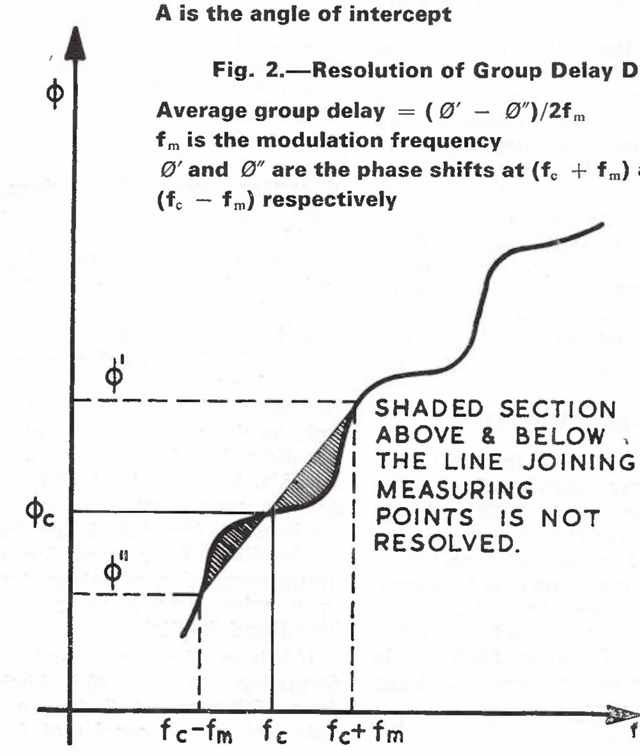


Fig. 2.—Resolution of Group Delay Distortion

Average group delay $= (\emptyset' - \emptyset'')/2f_m$

f_m is the modulation frequency

$\emptyset'$ and $\emptyset''$ are the phase shifts at $(f_c + f_m)$ and $(f_c - f_m)$ respectively

the delays of the upper and lower sidebands relative to the carrier are almost equal; i.e., the phase frequency response over a sufficiently small frequency increment is linear.

There are two practical methods of synchronising the send and receive units for measuring group delay between two remote locations. The first is to use two highly stable oscillators and synchronise them prior to carrying out measurements; and secondly to add extra information to the test signal which will synchronise the two oscillators at regular intervals.

Group delay is actually measured over a finite bandwidth bringing in the further factor of frequency resolution which is directly determined by the modulating frequency. The larger the modulating frequency the more accurate the resolution of delay distortion but with a decreased frequency resolution. The only way to overcome this difficulty is to use a different modulating frequency for the various frequency ranges to obtain the required resolution for both delay distortion and frequency.

Fig. 2 shows a modulating frequency with an increment in the frequency band greater than the fine structure of the phase response. Consequently the measuring set only measures the average group delay over that frequency band and the actual phase ripple is not resolved.

The accuracy of the measurement is also dependent on the sensitivity of the instrument to interference. The larger the modulating frequency the less sensitive the measurement is to interference from noise, spurious tones, phase jitter and hum modulation, which is a further reason for not using a lower frequency than is necessary to obtain the required frequency resolution in the range being measured.

rier frequency as measurements at all other frequencies are referred to it. For very accurate measurements occasional checks at the reference frequency should be made and any drift in the reading corrected. The measuring frequency is demodulated in the receiver and the phase shift encountered by the envelope with respect to the reference carrier frequency is measured by a zero crossing detector.

In the other method a combination of signals conveys information to synchronise the receive oscillator to the transmit oscillator at regular intervals. In the recommended set the transmitter generates a reference frequency and a measuring frequency, and switches from one to the other at 4 Hz. This alternating signal is amplitude modulated at 40 Hz and for one cycle of the 40 Hz modulating frequency, during the transmission of the reference frequency, a 160 Hz marker is added. The latter sets timing circuits in the receiver and switches through the measuring frequency for determining its frequency and group delay. Now a phase difference will be due to either drift between the transmit and receive oscillators or a frequency dependent phase variation of the link. By switching from reference frequency to measuring frequency at a 4 Hz rate there will be two distinct components at the output of the phase meter: a slow change due to drift between the oscillators and a faster change due to phase delay between the reference and measuring frequencies of the link. The slow phase change is separated from the output of the phase meter and used to phase lock the receive oscillator; i.e., the receive oscillator is continuously adjusted to reduce any slow phase variation to zero. The output of the phase meter contains essentially the faster

TABLE 1 : ACCURACY REQUIREMENTS

Frequency range (kHz)	Accuracy (μ secs)	Modulating Frequency (Hz)
0.2 to 20	10	41.66
20 to 600	1	416.6
100 to 1400	0.01	20,000

Table 1 shows the order of accuracy required for various frequency ranges and suggested modulating frequencies.

In the method of long term synchronisation a reference carrier frequency in the middle of the passband is transmitted and the modulating signal is used to synchronise the receive oscillator to the transmit oscillator by tuning the receive oscillator for a steady group delay reading at that frequency. This is the reference car-

(4 Hz switched) phase changes which are further processed to give a measurement of the group delay of the link.

DIFFICULTIES IN MEASURING GROUP DELAY

Difficulties have been encountered in measuring group delay due to actual transmission impairments of the link being measured, and problems of the measuring technique.

Transmission Impairments

Noise, spurious signals, phase jitter, hum modulation, mismatch, incorrect termination and crosstalk can degrade the accuracy of the measurement. Although these same impairments similarly effect a data signal they are nevertheless a handicap when dealing with group delay distortion on its own. Noise, spurious signals, phase jitter and hum modulation cause random fluctuation in the group delay reading as the phase meter cannot determine whether it is measuring a phase change or interference.

The interference from regular inband noise and spurious signals can generally be allowed for. Noise causes fluctuations across the whole band while a spurious signal will only cause interference when its frequency is less than 12 Hz different from the carrier frequency of the measuring signal. The measuring set used by the Department has a receiver bandwidth of 12 Hz and for a test signal level of 0 dBmO and weighted noise level of — 60 dBmOp the group delay reading fluctuates by approximately 4 microseconds peak to peak (4μs p-p) in a voice band and by 60 μs p-p in a basic supergroup band. A spurious signal 60 dB below the level of the carrier frequency used by the measuring set will cause fluctuations of 30 μs p-p. For every increase in noise or spurious signal level by 20 dB the amplitude of the fluctuation increases by a factor of 10 times.

Hum modulation has been found to originate on some old carrier supplies, thus causing phase modulation on a signal transmitted through the link with 50 Hz components less than 60 dB below the signal level. This interference could result in a random fluctuation across the band with an amplitude of up to 20 μs p-p. Depending on the type of modulation used, hum modulation may or may nòt degrade the data signal even though it affects the measurement of group delay.

Many reports have been received of large fluctuations (from 100 μs to 1 ms) occurring during group delay measurements. This has not been fully explained but phase hits of the order of 20^0 peak to peak can occur due to irregular phase changes of the system's carrier supplies which produce low frequency sidebands of magnitude approximately 22 dB below the transmitted signal. Phase jitter of this order could cause fluctuations of about 1 ms p-p if one of the spurious components has the same frequency as the modulating frequency used in the measuring set.

Additional paths to the main signal resulting from mismatch, an incorrect termination or crosstalk can cause fluctuations with a magnitude in milliseconds and must be eliminated before any meaningful measurements can be made. In the case of a mismatch in the link or incorrect termination at the transmitter or receiver the group delay frequency response may have a regular ripple. The frequency of the ripple is dependent on the location of the mismatches, and the amplitude of the ripple depends on their severity. In the case of crosstalk, the difference in time delay and frequency shift of the main and crosstalk paths, and the level of the crosstalk signal, will determine the type of interference.

Measurement Technique

A difficulty most probably common to all group delay measuring instruments is intermodulation within the receiver. Referring back to the section on carrier facilities a voice band link has very little interference from frequencies of the adjacent modems. In contrast the group and supergroup modems do not suppress the frequencies from the adjacent modems as much and this has led to serious problems when measuring the group delay of these links.

Measurements with white noise loading have shown that intermodulation products corresponding to a level of aproximately 63 dB below the input wideband noise level affect the measuring set receiver. The wideband energy (mostly out-of-band) intermodulates in the demodulator of the receiver and some of these products then randomly fall within the passband of the following stages in the receiver causing interference.

Without a receive band pass filter noise levels in excess of O dBmO can occur producing random fluctuations greater than 10 μs p-p. This can be overcome by using a T.G.F. or T.S.G.F. and making allowance for the filter's group delay distortion, or by clearing traffic off the adjacent group or supergroup bands, or by doing the measurements when the traffic load is light. In the case of a voice band link a high pass filter to eliminate low frequency components below 200 Hz and a low pass filter to block carrier leaks from the modems should be used.

CHOICE OF SYNCHRONISATION METHOD

For measurements on voice band links the synchronising of oscillators prior to measurement and automatic synchronisation, are both satisfactory. The technique used must take account of frequency resolution, group delay resolution and sensitivity to interference. The overall accuracy under realistic field conditions is the sum of these parameters which will dictate the synchronisation method and the modulating frequency. By using a modulating frequency as large as allowable the problem of detecting a very small angular difference in phase shift in the presence of noise and other unwanted products is reduced. Generally it may be easier to achieve all these requirements in the voice and possibly the group band ranges by the manual synchronisation method prior to and during measurement. But for the supergroup and high frequency bands the need for absolute stability between the send and receive modulating frequency oscillators would almost certainly demand synchronisation at quite frequent intervals. Any instability between the oscillators during a measuring period is interpreted as group delay. This can be eliminated by automatic continuous synchronisation or when doing discrete measurements, manually alternating between measuring and reference frequencies and checking that the latter has not varied. On some links it is possible to maintain the group delay response by doing a loop measurement of the two directions of transmission and obviate the problem of stability.

HIGH SPEED NEWSPAPER FACSIMILE SYSTEMS

At present in Australia there are three links with a bandwidth of 240 kHz over which newspapers are transmitted at a very high speed. Nationwide News transmit the "Australian" from Sydney to both Brisbane and Melbourne, and John Fairfax transmit the "Financial Review" from Sydney to Melbourne.

The facsimile equipment makes use of the basic supergroup band, 312 to 552 kHz. It has a carrier frequency of 500 kHz and uses vestigial sideband modulation with two levels to convey information that the spot being scanned is either black or white.

There are no greys and the facsimile system can be likened to a binary non-synchronous data set. A non-synchronous detection gives it the freedom to send transitions at any arbitrary time which are not necessarily spaced at multiples of a uniform time interval. It is vital that the rotating transmit and receive drums are locked together in speed and position. Because of their mechanical inertia they are locked in speed by synchronising a transmit and receive 9.6 kHz oscillator with a 600 Hz signal transmitted by amplitude modulating a 320 kHz pilot, and locked in position by comparing phasing pulses generated by each drum. The pilot, 10 dB below the carrier level, is also used to regulate the level of the received signal.

The facsimile system can resolve fine grained dots and transmit the equivalent of 330 kilobits per second over a delay equalized supergroup link with linear distortion less than 2 dB and 8 μs from 328 to 532 kHz. These limits control the tolerance margin the signal has to impulse and basic noise, and spurious signals. It also determines the distortion observed on a pulse transmitted through the system.

False triggering produced by noise, interference between pulses and pulse shape distortion will cause 'errors' at the facsimile receiver. These 'errors' are generally only noticeable on half tone pictures where regular errors can produce moire patterns. Waveform distortion may alter the size of the pulses and change the ratio of the lengths of a series of alternate black and white dots which has the effect of making a page appear to have its highlights either darkened or subdued depending on the black/white ratio and the modulation polarity.

By making very efficient use of the 240 kHz bandwidth with a VSB signal the facsimile equipment can transmit a copy of one page to a distant city in three minutes. It has a fine resolution to cater for high quality half tone pictures having elements of external dimensions 3 thousandths of an inch (i.e., 9 μs at a drum speed of 3000 r.p.m.) which can be transmitted with little distortion. Although smaller elements can be transmitted pulse distortion starts to be significant due to band limiting of the facsimile equipment and the supergroup link.

For the initial facsimile links high quality measuring equipment was necessary to measure the group delay distortion of the link and components. From these measurements delay equalisers were designed and built which are now standard. All that is required is that a check be made of the delay distortion of the link after the equalisers have been installed. An eight section equaliser is used for one T.S.G.F. and a 12 section equaliser for each pair of tandem T.S.G.F.'s (See Fig. 3). It has been found that generally broadband line links, supergroup modems and coaxial cable end sections (operating at 312 to 552 kHz) contribute negligible group delay distortion. The most important factor in facsimile transmission is the group delay (coming from the T.S.G.F.'s) of the lower frequency components; i.e., equalisation of the band 500 $\pm$ 30 kHz to a limit of 3μs. Although this limit was generally obtained for a larger

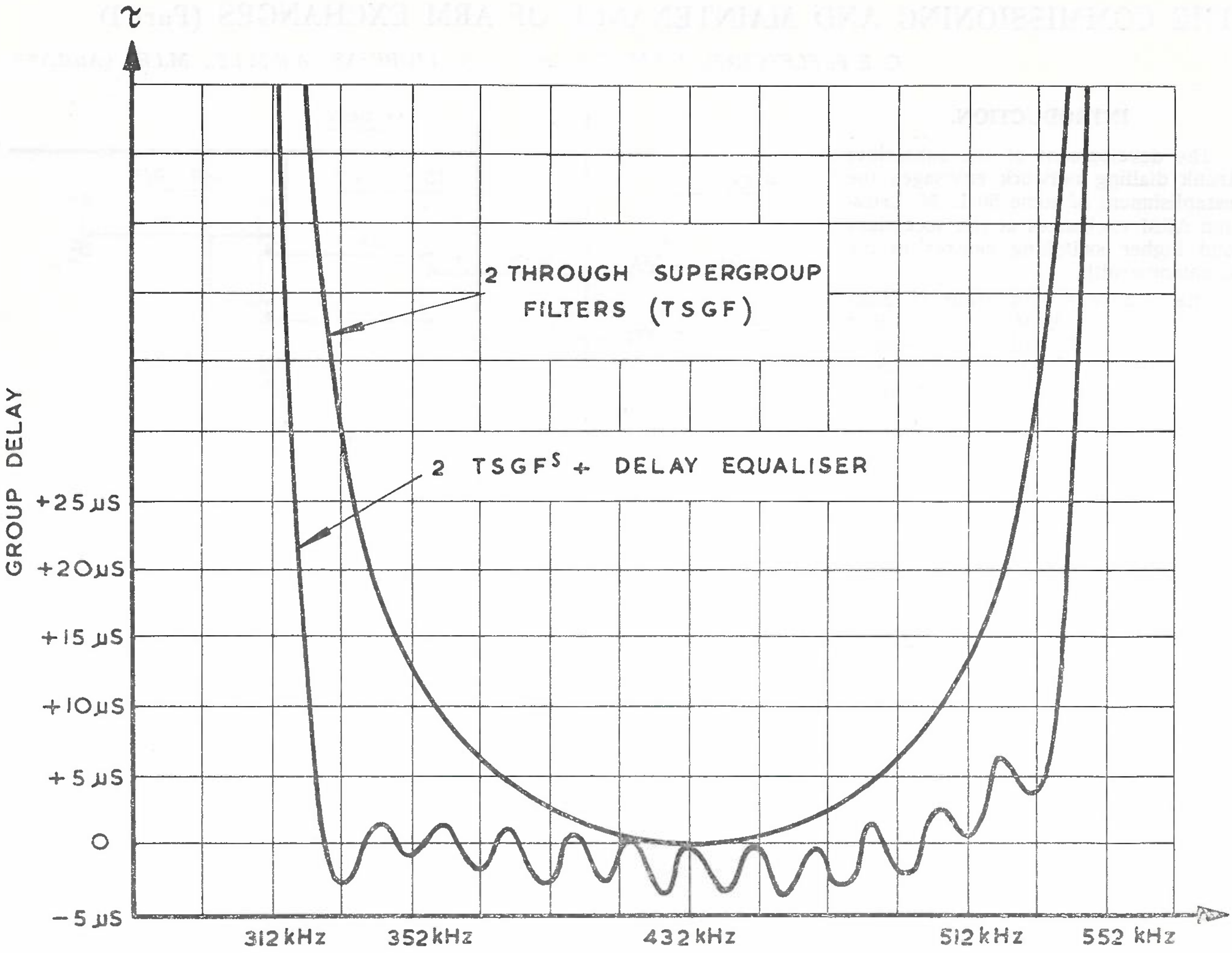


Fig. 3.—Equalisation of Group Delay Distortion

range (328 to 532 kHz) subsequent tests showed that it is not as critical below 470 kHz and the limit could in fact be allowed to gradually widen over the frequency range 470 to 328 kHz with only a small increase in the distortion of the finer elements.

FUTURE DIGITAL NETWORKS

For a digital system comprising a transmission line and a modem to operate successfully the interface between the two must be compatible.

One of the more important criteria is the group delay distortion of the data link which may have to be measured, equalised and maintained under field conditions. For the sake of expediency it would be desirable if objectives for group delay distortion were set, such that, say, 90% of all data links could be provided without the need for special delay equalisation and delay distortion measurements. With carrier systems properly planned and specified it should be possible to provide standard links suitable for digital transmission. Even so, delay equalisation of special quality links could be quite elaborate and for this reason alone the development of suitable measuring equipment tailored for the various frequency ranges and field conditions is a definite requirement for the communications industry.

REFERENCES

1. Coenning, F., 'Progress in the Technique of Group Delay Measurements'; NTZ-CJ, 1966, No. 6.
2. Mahoney, J., 'Transmission Plant for General Purpose Wideband Services'; I.E.E.E. Transactions on Communication Technology, Vol, COM-14, No. 5, October, 1966.

THE COMMISSIONING AND MAINTENANCE OF ARM EXCHANGES (Part 1)

C. E F. FLETCHER, A.R.M.I.T. and E. A. LIUBINAS, A.R.M.I.T., M.I.E. (Aust.)***

INTRODUCTION.

The development of the subscriber trunk dialling network envisages the establishment of some 50 L. M. Ericsson ARM exchanges at the secondary and higher switching centres in the Commonwealth.

The relatively high order of complexity of the ARM system makes fault location difficult under service conditions. It is, therefore, desirable that the installation testing prior to the commissioning of the ARM be integrated with the maintenance testing to follow, so that no areas remain untested and there is a minimum overlap of effort.

This article shows the boundaries between the testing efforts of the installation and maintenance groups based on the experience gained at the North Melbourne ARM. New test sets, test aids and testing methods are discussed under the following headings:—

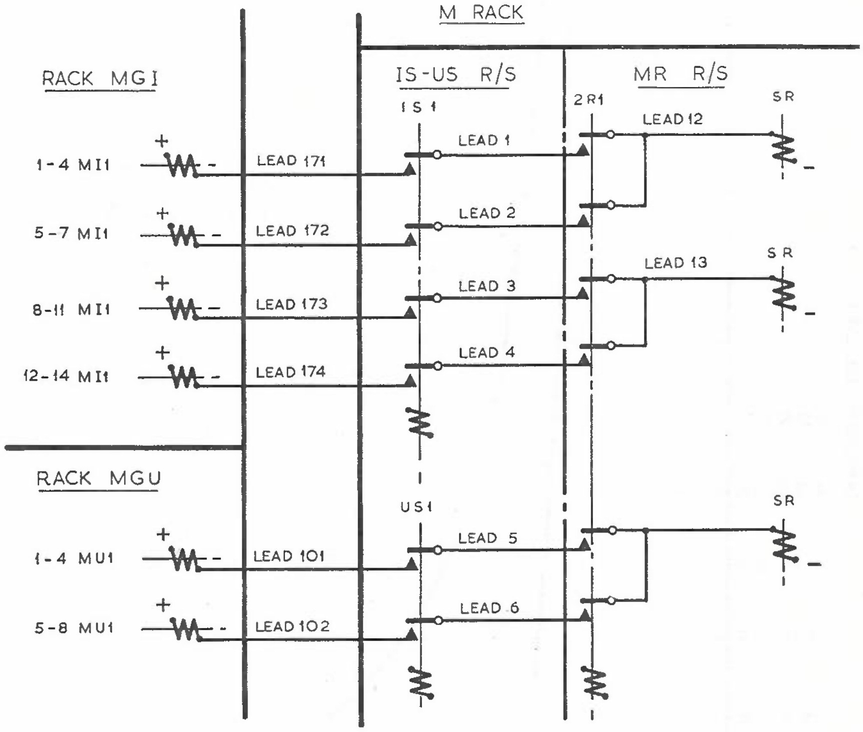
PART 1:
- Common Control Equipment and Switching Stages.
- Registers and Analysers.

PART 2:
- Incoming Circuits and Tariff Equipment.
- Outgoing Circuits.

PART 3:
- A Maintenance Plan for ARM Exchanges.
- Summary of Maintenance Experience at North Melbourne ARM.

The complete article wlll appear in three parts as shown in this and two subsequent issues of the journal.

The discussion of the testing methods does not deal with the early stages of the installation testing as prescribed in the ARM installation test instructions issued by Headquarters. This area covers wire testing, electrical push-up tests, etc., an example of which is shown in Fig. 1, and precedes the functional testing discussed in this article.



Test Out — Program

1. Operate manually relays IS1 and US1 in marker 1. Relays 1-14 MI1 and 1-8 MU1 in the MGI, MGU racks corresponding to the marker and 200 group should operate as soon as R1 in marker is operated.
2. Check all IS-US combinations (IS1 with all US relays etc.) and observe that corresponding MI and MU relays operate.
3. Repeat tests 1 and 2 from all markers.

Marker 1 operates MI1 and MU1
Marker 2 operates MI2 and MU2
Marker 3 operates MI3 and MU3
Marker 4 operates MI4 and MU4
Marker 5 operates MI5 and MU5
Marker 6 operates MI6 and MU6
Marker 7 operates MI7 and MU7
Marker 8 operates MI8 and MU8
Marker 9 operates MI9 and MU9
Marker 10 operates MI10 and MU10.

Fig. 1. — Operation of MI and MU Relays.

THE COMMON CONTROL EQUIPMENT AND SWITCHING STAGES.

As can be seen from Fig. 2, the internal switching machine of an ARM 20 comprises the switching stages (GI, GU) organised in 200 line groups, Route marker connectors (RM), Route Markers (VM), Markers (M), Test Blocks (TB) and free line indicating equipment (VL).

Fig. 2 also shows the various strapping and jumpering areas in the common equipment, together with the various tests performed at installation. It is important that before any functional tests are carried out on the Common Control Equipment, the Centralograph (Cph) equipment should be fully operational, with typical tests described later.

Link Tester.

The most important installation testing aid for the ARM switching stages is the link tester. This device was initially designed by the staff of L.M. Ericsson Pty. Ltd. and was further developed by installation staffs in South Australia and Victoria. The tester can set up and hold up to 20 simultaneous calls from FIR rack positions to FUR rack positions with the aid of the common control equipment.

Fig. 3 shows the connection of the link tester and the strapping and jumpering required for the link test.

The Link Test. — The prime purpose of the link test is to set up a call via each GIB to GUB link and to test these for continuity and absence of foreign potentials or transpositions.

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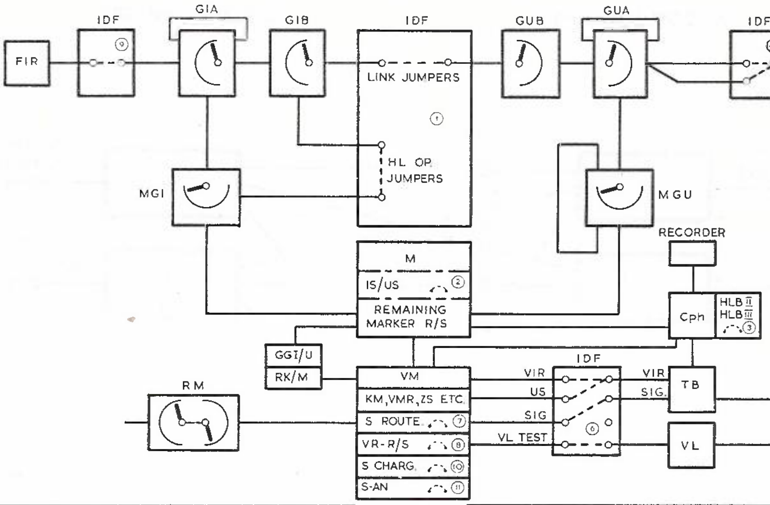


STRAPPING OR JUMPERING AREA	FUNCTION	INSTALLATION TESTS	REFERENCE
①	LINK JUMPERS AND HL OPERATION LEADS	LINK TEST WITH AUTO LINK TESTER	ARM 20 TEST INSTRUCTIONS SECTION 12
②	IS/US R/S STRAPPINGS CONTROLLING LINK SELECTION	" " " "	" " "
③	HLB R/S STRAPPINGS CONTROLLING RECORD'G OF GIB DETAILS	FUNCTIONAL TESTS OF Cph.	TEST SECTION 7·6 C.I.D. 174
④	GUA-FUR JUMPERING	ROUTE TEST WITH AUTO LINK TESTER	———
⑤	TB, VL-FUR JUMPERING	" " " "	———
⑥	VM-TB, VL JUMPERING	" " " "	———

STRAPPING OR JUMPERING AREA	FUNCTION	INSTALLATION TESTS	REFERENCE
⑦ ⑧	'S'-R/S FOR ROUTING VR-R/S (I RELAYS) ETC. STRAPPINGS	ROUTING, CHARGING ETC. STRAPPING TESTER	VICTORIAN CIRCUIT REPORT V124
⑨	FIR-GIA JUMPERS	FUNCTIONAL TESTS ON FIR'S WITH TARIFF TESTER	TEST SECTION 9
⑩ ⑪	'S'-R/S FOR CHARGING AND S-AN R/S STRAPPINGS	ROUTING, CHARGING ETC. STRAPPING TESTER	VICTORIAN CIRCUIT REPORT V124

Fig. 2. — ARM Common Control Equipment.

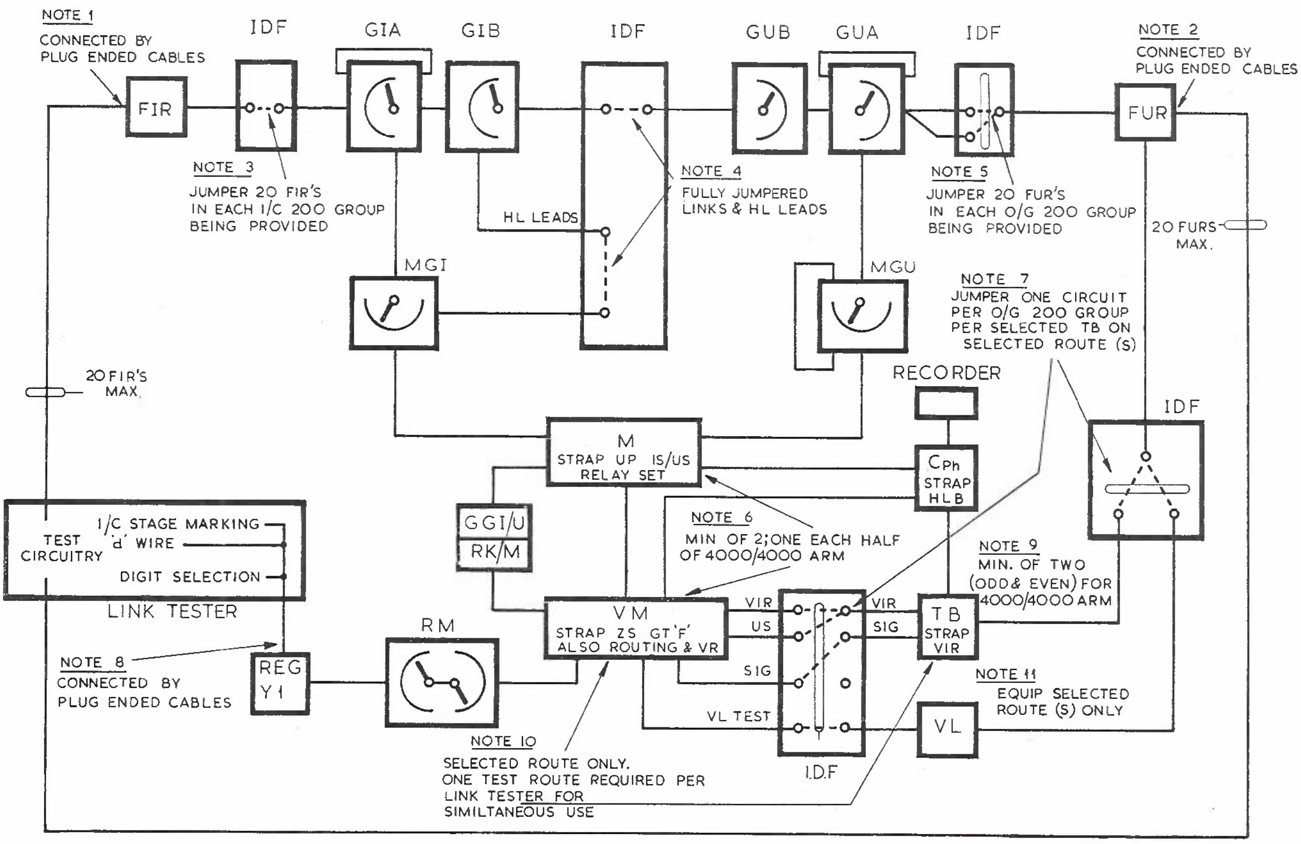


Fig. 3. — Connection of Link Tester.

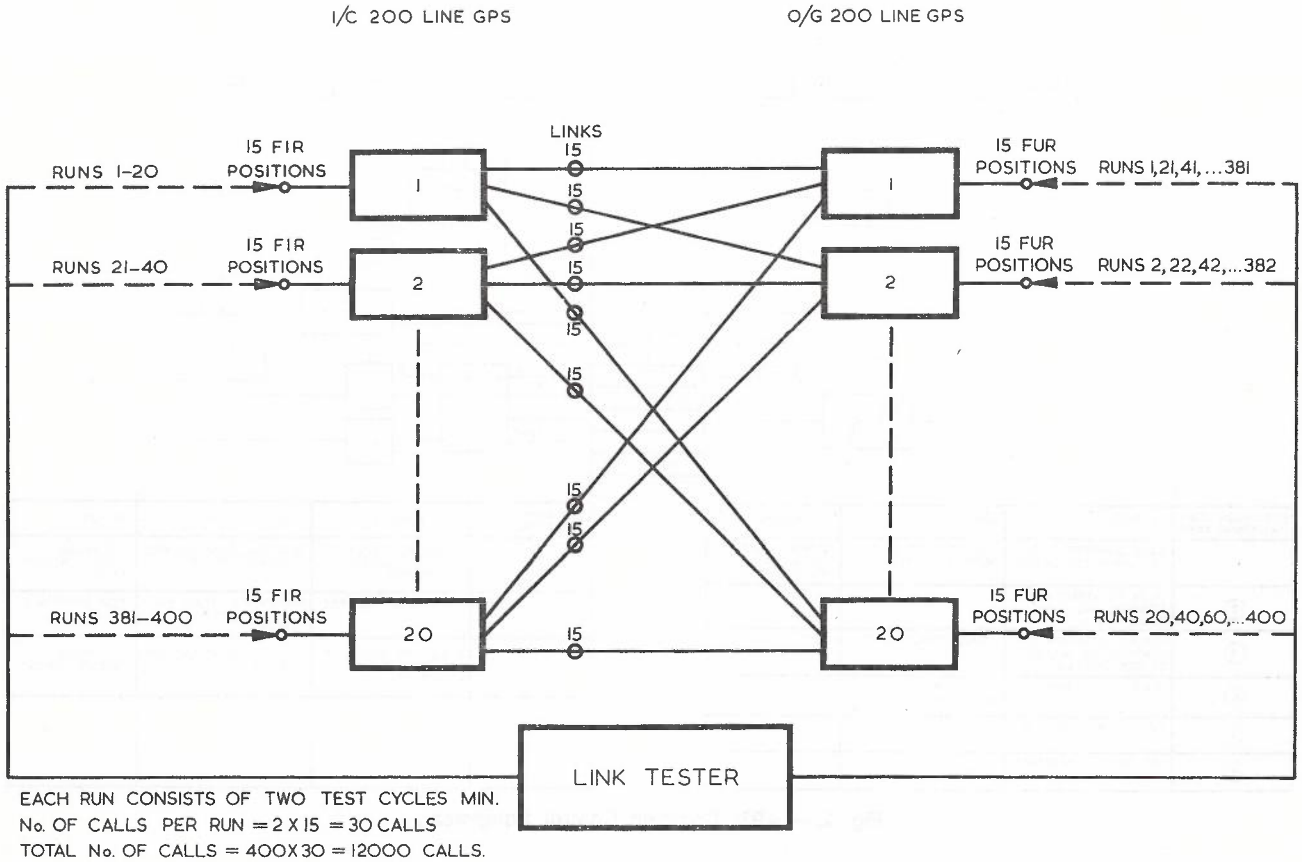


Fig. 4. — Link Testing.

The FIR to GIA links are adequately tested by functional tests performed on FIR's, as will be seen later. The GIA to GIB, and GUB to GUA, links are all tested with 95 per cent. certainty, as approximately 600 calls are set up via each 200-line group and there are only 200 GIA to GIB and GUB to GUA links per 200 group.

Fig. 4 shows the test runs (400) required to completely test the links between each of 200 i/c and o/g 200 groups, with 15 links in each case. The total number of calls involved is 12,000 and the only links not adequately tested are the GUA to FUR connections. These will be tested in the following series of runs, i.e., the route test programme. As can be seen from Fig. 4, the connections between two particular 200-line groups are tested during each run. As the outgoing stage number is transferred to the marker from the test block (VIR relay), it is only necessary to fully strap and jumper one outgoing route with one circuit per selected test block per outgoing 200-line group.

For additional links only FUR to GUA jumpering is required in each o/g 200-line group, as each connection in this 200 group is set up utilising the path of FUR 21 built into the link tester.

The Route Test. — For this test all jumpering and strapping except FIR-GIA connections and charging must be completed.

Fig. 5 shows the method of calling from 20 FIR positions to every outlet on all available routes. In our example, if their are 200 routes and 4 test cycles are carried out in each run. some 16,000 calls are put through the exchange during this programme. This to FUR connections, the functions of VM, M, TB, and VL. To adequately test all common control devices a per- test checks, in addition to all GUA centage of all calls should be forced via each VM-M pair. During the course of this test as the fault incidence diminishes, all M's and VM's are let in and the statistical meters are read to check the correct functioning of allotters and distributors. The few remaining common equipment faults are traced using Cph printouts.

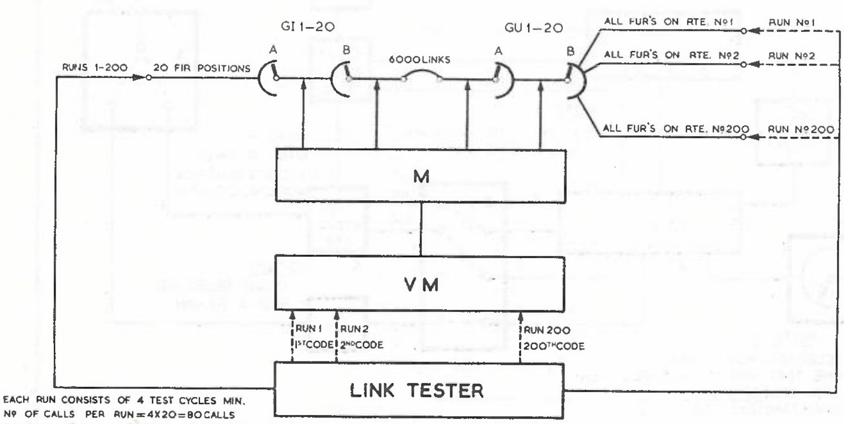


Fig. 5. — Route Test with Link Tester.

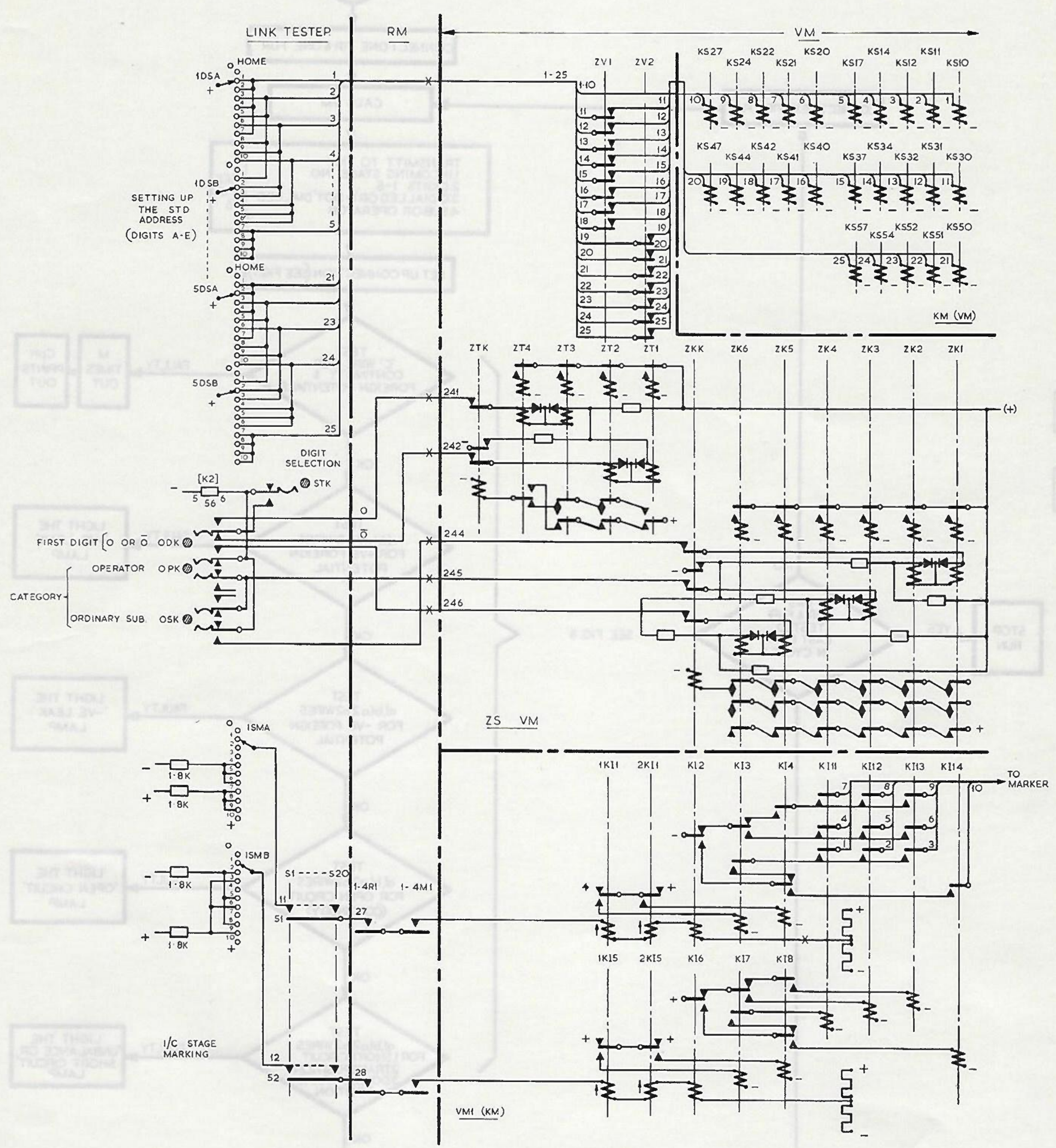


Fig. 6. — Link Tester — Setting up.

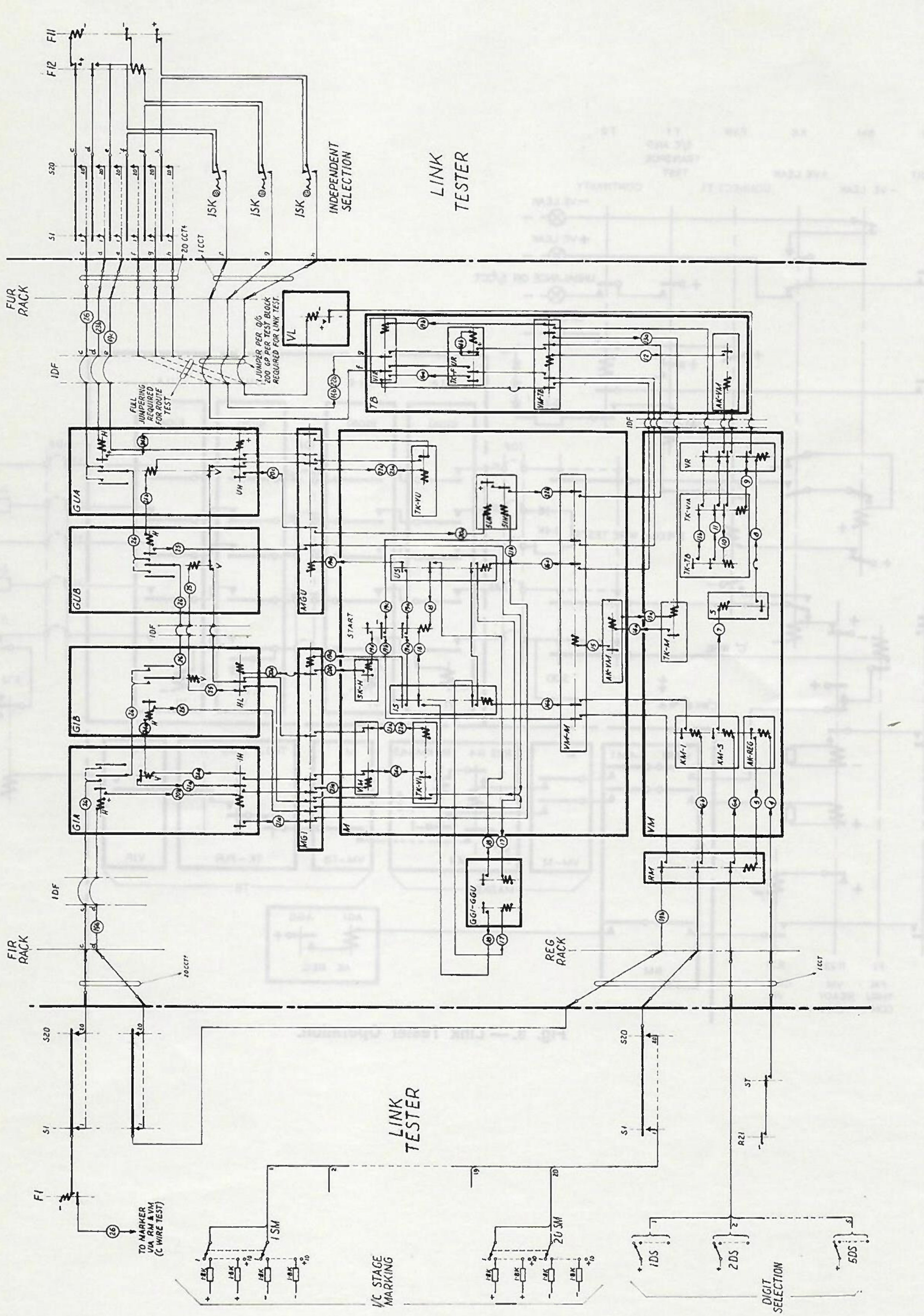


Fig. 7. — Link Tester — Setting up Connection Through ARM.

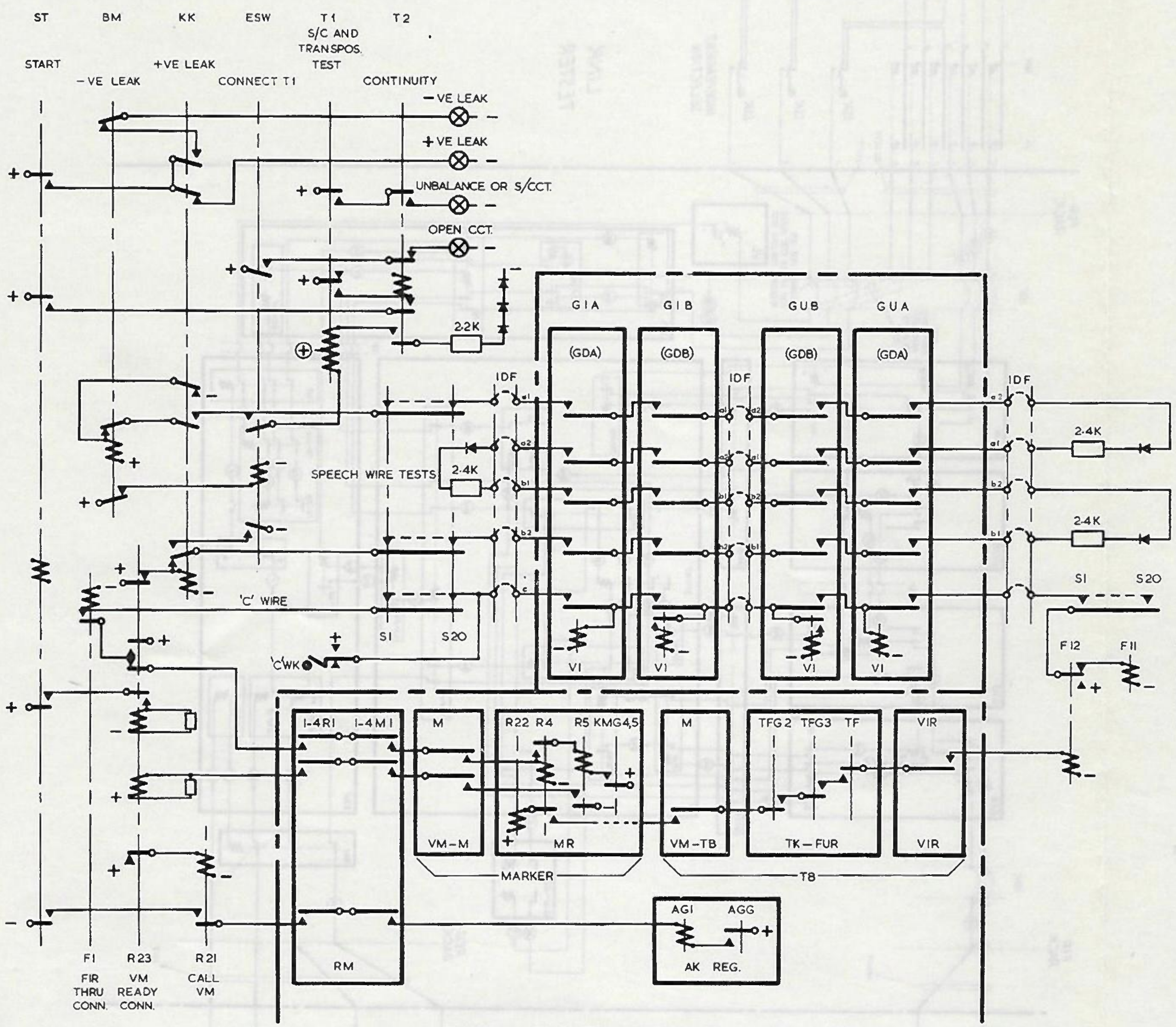


Fig. 8. — Link Tester Operation.

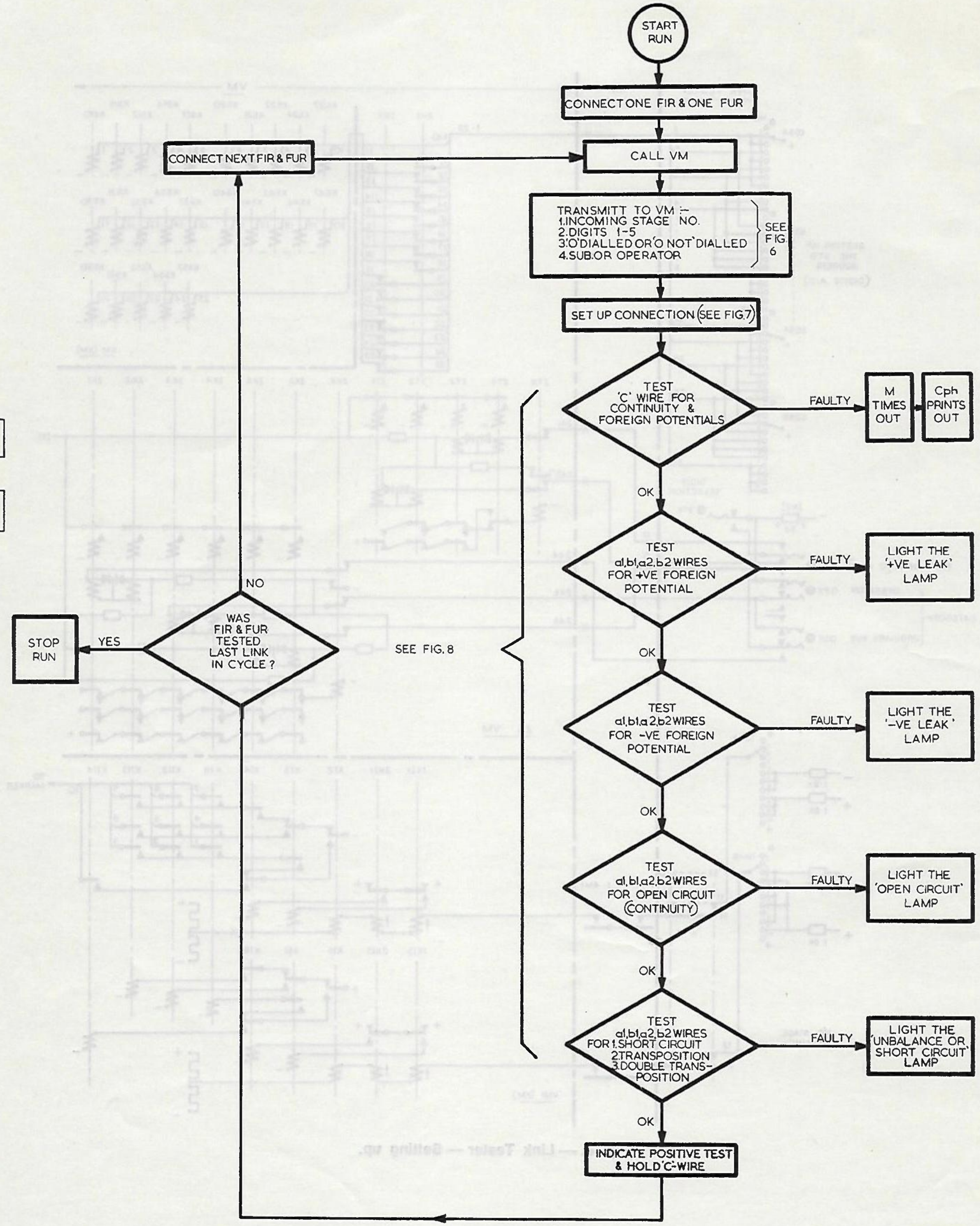


Fig. 9. — Flow Diagram of Link Tester Operation.

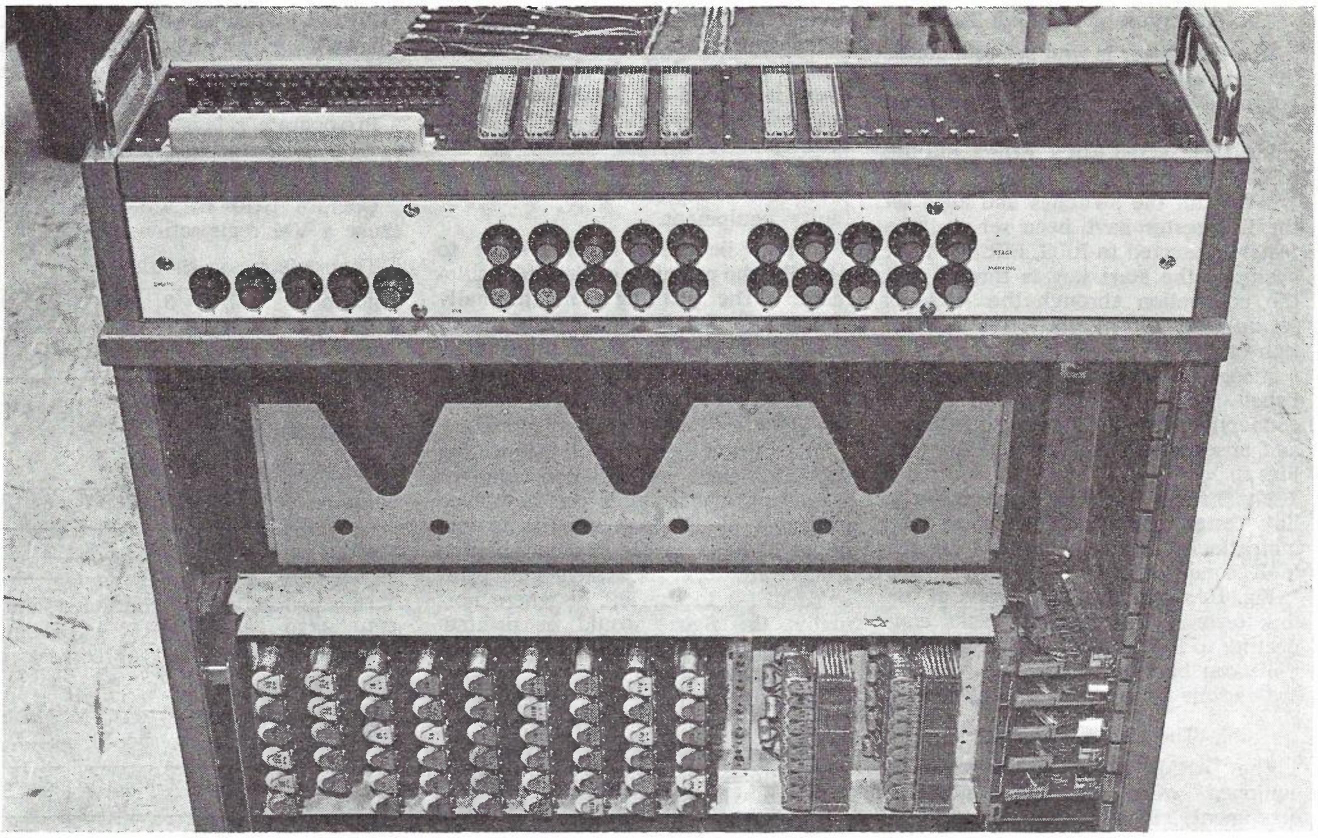


Fig. 10. — ARM Link Tester.

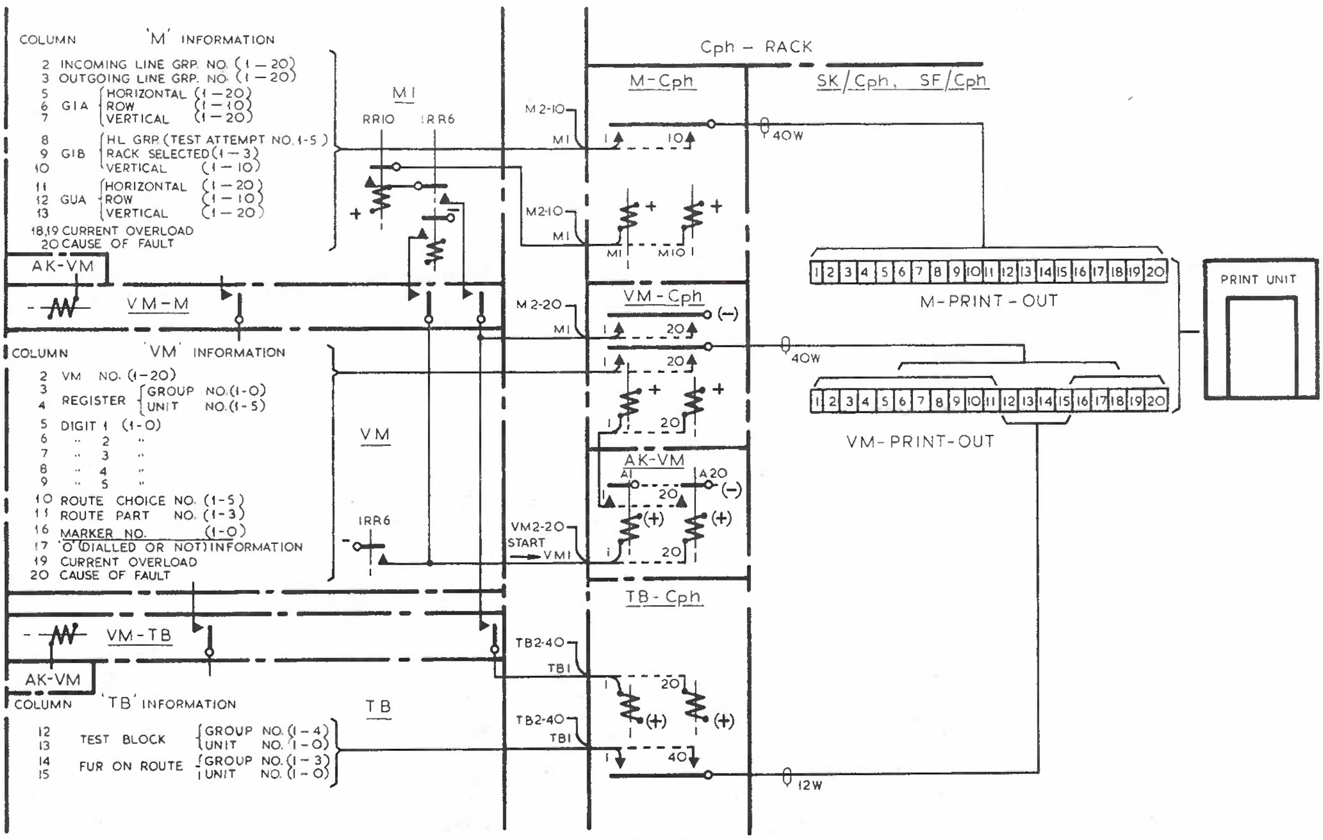


Fig. 11. — Connection of Cph.

The Operation of the Link Tester.

The link tester is first set to indicate 'B' subs digits, 'A Subscribers' category and incoming stage number, and is then connected up by plug-ended cables to selected FIR's, FUR's and the REG-Y1 as shown in Fig. 6.

When all the switches and keys on the link tester have been set and the tester connected to REG, FIR and FUR positions the start key is thrown and the connection through the ARM is set up as shown in Fig. 7 (for description of Fig. 7 see Ref. 1).

After the connection has been established, the a1, b1, a2, b2 and c wire connections are tested for continuity and absence of foreign potentials (see Fig. 8).

Fig. 9 shows the flow diagram of the link tester operation and also the indications received under various fault conditions.

Fig. 10 shows the photograph of the link tester. The 80-point jacks connecting to FIR, FUR and REG connections can be clearly seen, as well as the various keys and rotary switches.

The Centralograph.

The ARM switching system is equipped with automatic print-out equipment, which will provide a printed record of the equipment involved in an unsuccessful attempt to set up a connection. This equipment is known as the Centralograph and is connected to route markers, markers and test blocks.

The Centralograph (Cph) is always called from the route marker if time supervision occurs there, or from the marker via the route marker if the failure is recognised in M. Fig. 11 shows how 1RR6 relays in each of these devices originate the call to the Cph equipment.

One Cph rack will serve 20 VM's so that a 4000/4000 exchange requires two Cph installations. The call to the Cph is identified in the relay set AK-VM, and the operation of one of the relays A1-A20 operates the connecting relays in VM-Cph. If the connection did not proceed further than the VM then only one line of information, namely the VM print-out, is recorded. If, however, the marker was called in, the Cph equipment forwards a negative to the VM which is transferred via the VM-M relay set, with relays 1RR6 and RR10 in the marker operated, to the M-Cph relay set to effect a connection between M and Cph. Similarly, a relay in the TB-Cph relay set is operated via the VM and VM-TB connection. Fig. 11 also shows the information printed out for M and VM in the 20 columns of each line. A study of these will reveal that all relevant details of the failed connection are recorded, making fault location relatively simple. However, it should be understood that one individual print-out seldom leads to a particular fault condition, but rather that an analysis of a number of print-outs is necessary to locate the faulty equipment.

It may be useful at this stage to describe the principle of the Cph equipment. The printing unit (normally situated in the service control room) is associated with rack-mounted interrogating equipment and prints lines of 20 digits where each digit can take on the value 1-20 (1 to 0 and –1 to –0).

The printer consists of 20 printing sub-units, each sub-unit consisting of a printing wheel which can be turned into one of 11 positions (home and digits 1 - 0). In the "home' position a separate lever is attached to print a 'dash' (–) to the left of where normally the figure would be printed. The digit wheel is stepped on by successive energisation of the 'F' magnet connected to one of the wires 41-50. When the printing of the figure to which the wheel has been turned is required, the 'S' magnet is energised and the wheel is pressed against a typing ribbon and the paper. After this action, the wheel flicks back to the home position.

If the 'S' magnet is energised with the wheel in the home position a 'dash' is printed. The survey in Fig. 12 shows in principle how the following is printed:—

Digit 1 on wheel No. 1.
Digit 5 on wheel No. 2.
Digit –2(12) on wheel No. 19.
Digit 5 on wheel No. 20.

These figures were chosen for simplicity and do not necessarily form part of a normal VM print-out. For the same reason TB and M information has been omitted.

In the VM, as well as in M and TB, there are certain relays provided with contacts specifically for the Cph. When a time-out occurs, these relays will either be operated or will have failed to operate, depending on which function was disturbed, causing the 'time out.'

These special contacts connect the pulse leads 41-50 to leads 21-40 (F magnets) as required. Other contacts may connect +ve to leads 1-20 to effect a 'dash' print if the digit lies in the range 11-20. The reliability of Cph print-outs is of great importance to both installation and service staffs. To ensure this, functional tests on Cph connections should be carried out at a very early stage of the installation (see Ref. 2).

Fig. 13 illustrates how routing digits 1-5 are displayed on columns 5-9 in the VM line. To test this function one should proceed as follows:—

Pre-operate relays S111, S121, etc., to S151 by operating appropriate relays in the KM R/S in VM No. 1.

Operate 1RR6 in VMR, which will cause a VM registration on the Cph.

The registration should be:—

Column	2	5	6	7	8	9
Reg'n	1	1	1	1	1	1

Pre-operate relays S112, S122, etc., to S152 and repeat (b).

Registration should be:—

Column	2	5	6	7	8	9
Reg'n	1	2	2	2	2	2

This procedure is continued until S110, S120, etc., to S150 have been operated and checked for correct registration.

Repeat steps (a)–(f) on VM No. 2. The first registration should be:—

Column	2	5	6	7	8	9
Reg'n	2	1	1	1	1	1

The procedure is continued until all digit registrations in all VM's have been tested.

As mentioned earlier, a single Cph print-out rarely leads directly to the cause of the fault. A number of prints, when analysed, combine to form a pattern showing the faulty piece of equipment by repetition of certain figures. An example of such an analysis is given below. Position No. 20 in both lines reveals the particular disturbed function by means of an appropriate code, while all the other positions detail the equipment involved. It is, therefore, reasonable to group together prints containing the same fault code, i.e., the same figure in position 20. Maintenance staff at Haymarket ARM in Sydney developed an analysis pro forma which is now generally used. One such pro forma is made out for each fault code and prints are entered thereon as they occur.

The sample analysis given below concerns the M 9 print, which is the most frequently encountered type of print. The M-9 print is given when the final act in establishing the connection between FIR and FUR, i.e., the 'C' wire control test, is not successful. The 'C' wire control test is carried out as follows: see Fig. 14.

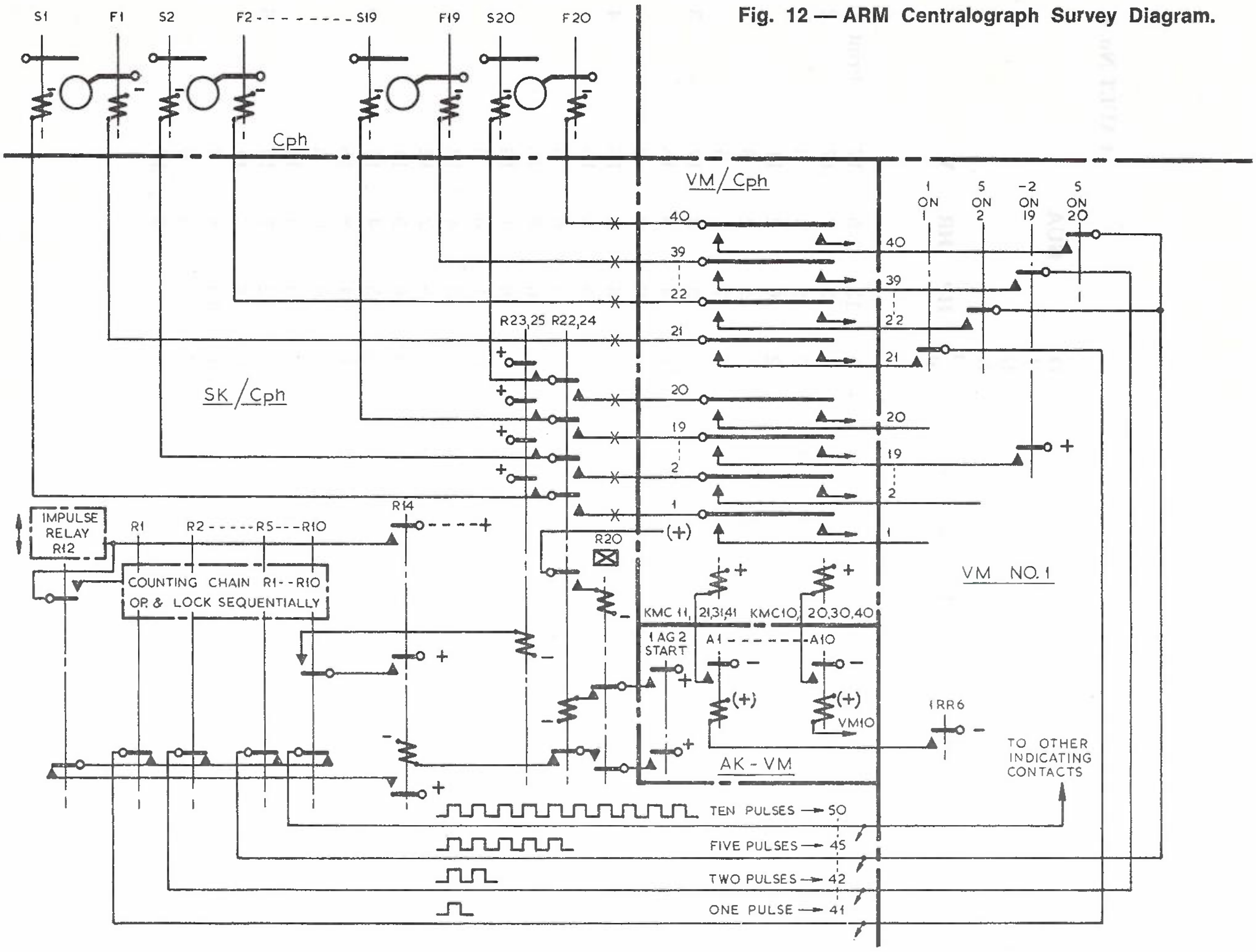


Fig. 12 — ARM Centralograph Survey Diagram.

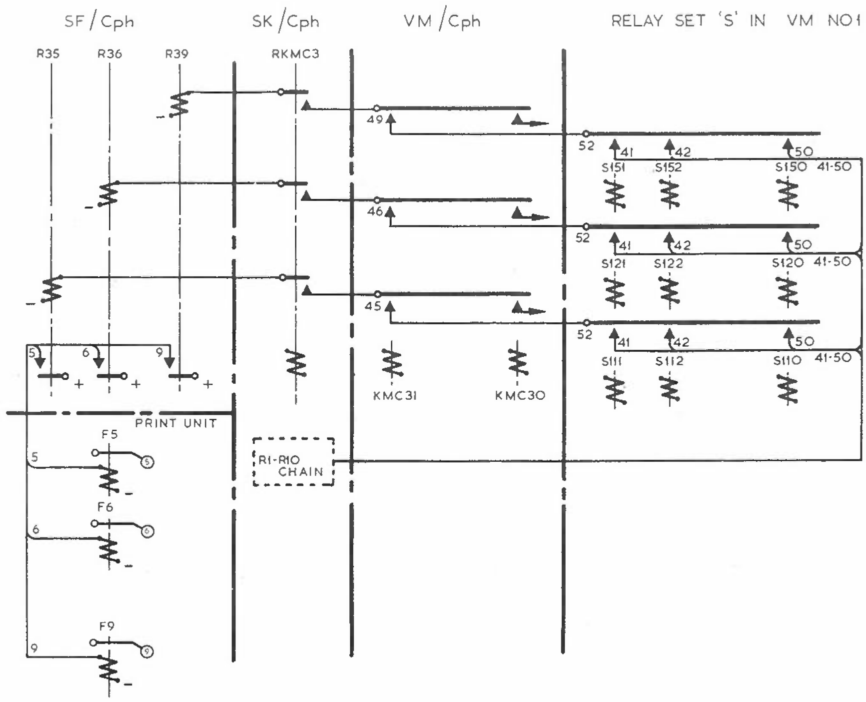


Fig. 13. — Testing of Cph.

TABLE 1 — SAMPLE Cph. ANALYSIS SHEET.

STAGE 1/2 **Cph. WORKSHEET.** **FAULT No. 9.**

Date	Route M	REG Type	REG No.	Called No. (Inc. Cph. 17)	RTE Choice	RTE Part	T.B. No.	T.B. T.F.	Marker	I/C Grp	GIA HP	GIA HR	GIA V	GIB HL	GIB RK	GIB V	O/G Grp	GUA HP	GUA HR	GUA V	
5/5	1	H2	70	05955	1	2	8	18	2	1	16	7	8	1	1	3	5	13	5	17	Print 1
	21	H1	43	059689	1	3	3	16	4	1	14	6	8	1	1	3	5	3	7	17	2
	12	H1	28	0626	2	3	11	8	1	4	—	6	12	2	3	4	7	5	3	5	
	2	H2	52	054234	1	1	3	4	5	5	6	9	1	2	2	5	2	16	2	11	
	12	H1	34	0284	1	2	7	10	3	6	13	9	16	12	2	6	5	15	2	9	
	13	Y1	110	05141	1	3	9	7	2	4	11	5	12	2	3	4	7	7	5	5	
6/5	23	H1	40	00221	2	3	10	20	4	1	3	8	7	1	1	3	5	5	3	17	3
	2	H2	52	06005	2	1	5	3	7	5	—	3	8	1	1	1	1	4	8	18	
	3	H1	20	052921	3	2	5	4	6	1	14	1	—	2	2	5	4	16	0	8	
	23	H1	7	052214	1	2	14	22	6	1	14	1	7	1	1	3	5	16	5	18	4
	22	H1	31	00241	2	3	10	13	7	2	13	2	6	12	1	9	6	5	6	15	
	13	H2	76	00251	2	2	11	20	5	4	15	9	12	11	3	7	3	5	6	5	
	21	H2	67	054237	1	1	3	2	7	5	6	9	8	1	1	1	1	6	8	18	
	13	H2	79	054230	1	3	1	4	2	4	16	2	—	12	1	9	6	16	1	19	
	1	Y1	104	66043	1	2	11	11	5	1	4	4	16	11	2	9	6	1	0	5	
	13	H2	76	05945	1	3	1	5	2	5	7	1	—	11	2	9	6	13	4	13	
	22	H2	68	07268	2	2	12	7	7	7	7	2	8	11	3	9	3	5	2	12	
7/5	4	H1	13	054235	1	1	3	4	7	5	4	5	8	12	3	7	2	16	2	11	
	3	H1	23	0231	1	3	6	2	7	1	13	5	8	1	1	3	5	15	4	17	5
	13	H2	77	06021	2	1	5	3	3	5	—	9	7	1	1	1	1	4	8	18	
	13	H2	82	054201	1	3	1	1	1	7	6	0	10	12	2	6	5	6	0	3	
	22	H1	44	053220	1	2	13	8	1	5	4	9	1	2	3	3	5	6	4	11	
	11	Y1	115	35902	2	2	5	5	1	1	1	2	8	1	1	3	5	12	7	17	6
	12	H1	25	00222	2	3	10	22	2	2	15	8	2	1	2	3	6	5	5	11	
	11	H1	32	0626	3	1	11	6	1	3	17	2	18	1	1	1	1	15	8	7	
	22	H1	37	0234	1	3	6	6	5	3	14	1	16	1	2	4	6	15	5	0	
	13	H2	76	053225	1	2	13	3	3	5	6	5	7	1	1	2	3	6	9	17	

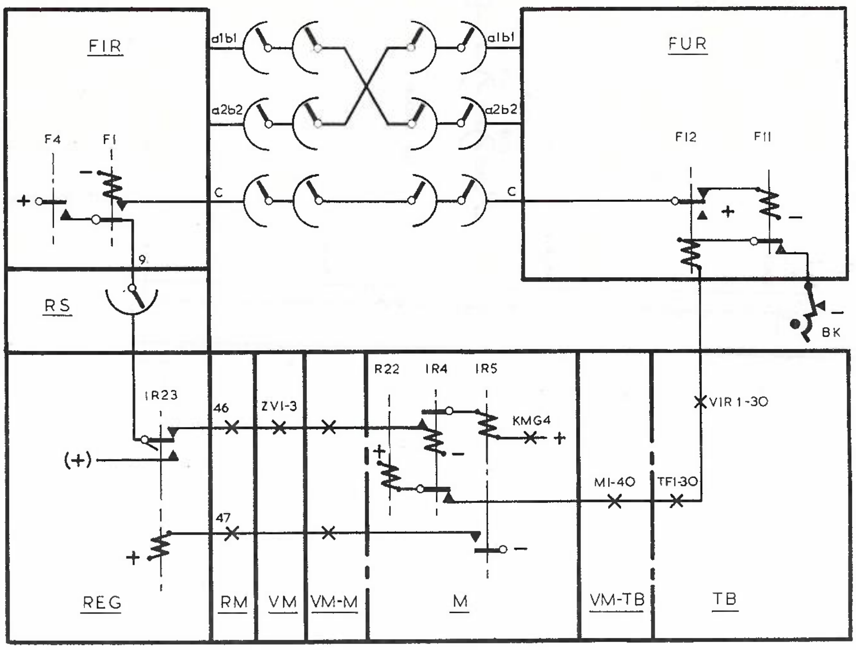


Fig. 14. — C-Wire Control Test.

When all the relevant verticals in the switching stages have operated, the marker connects R22 in series with F12 in the FUR. F12 and R22 operate and F12 connects positive to the 'C' wire in the FUR. This potential should hold the switching stages, operate F1 in the FIR and be extended via the register and VM to operate 1R4 in the marker. 1R4 releases F12 in the FUR and connects the low resistance winding of 1R5 in series with 1R4. F12 disconnects the positive from the 'C' wire but 1R5 will hold the switching stages and operate in series with the vertical magnets. The operation of 1R5 signals a successful connection to the register via wire 47, which in turn releases the common equipment (VM, M and TB) and holds the connection via 1R23 operated. Two conditions are thus checked:

An open 'C' wire prevents 1R4 from operating, and

A permanent positive potential on the 'C' wire prevents 1R5 from operating.

Failure of either or both of these relays to operate causes the M-9 print

Table I contains some Cph prints (M fault code No. 9) spread over three days. The sheet contains six prints identified as prints 1-6, which form a pattern.

Fig. 15 shows the grouping plan of the incoming and outgoing stage in which the particular failures are occurring. The verticals, as far as they are identifiable, are also marked. The analysis is carried out in steps as follows:—

Step 1. — Attention is first brought to the fault by the repetition of 9 prints from I/C group 1 to O/G group 5.

Step 2. — An obvious pattern is that I/C group 1 GIB RK1 Vertical 3 is used on each call to O/G group 5 (prints 1 to 6).

Step 3. — A general look at these 6 prints reveals:

A different FIR used on each call.

A different FUR used during each call.

Either GIA, RK1 or RK2 are used and always an odd switch using Verticals 7 and 8.
(Vert. 7 prints 3 and 4.)
(Vert. 8 prints 1, 2, 5 and 6.)
This indicates that the GIB RK1, Vertical 3, is in Switch 4.

The GUB rack, Switch and Vertical can now be found from the 'Link' charts.

The fault occurred when either HA or HB was used from this GIB vertical, and also occurred when any H1 to H10 was switched on it.

Similar analysis is used for the GUB Vertical.

Step 4. — Fault is centred on the GIB and GUB Verticals themselves.

Electrical test should be carried out to prove the GIB and GUB verticals will operate in parallel, and will hold to a +ve on the 'c' wire.

Check spring-lift by operating the verticals with—

(i) HA-H1 op.
(ii) HB-H1 op.
(iii) HA-H10 op.
(iv) HB-H10 op.

Step 5. — The fault was GUB Verticals HA/HB operating finger jammed and therefore inoperative.

The Centralograph is one of the most effective and important service and installation aids in the ARM system. However, its effectiveness is seriously impaired if the exchange is operating at too high a fault level, because analysis becomes extremely difficult as different faults may cause similar patterns, and efficient testing at the installation stage is therefore essential to prevent such a disastrous condition from arising.

Strapping Testers.

As indicated in Fig. 2, the route marker contains two important and complex strapping areas:

Routing analysis in 'S' relay sets, together with signalling mode and starting point strappings in the VR relay sets.

Charging analysis in the 'S' (charging) and the SAN relay sets.

Installation staff at Haymarket ARM developed strapping testers for these strappings, which were further improved by installation staff in Melbourne.

Fig. 16 shows, in principle, how the routing strappings in a new VM rack are tested. The principle of all strapping testers is the same, i.e., digit and other information is transmitted to the analysis relay sets and the resultant signals are observed and checked for correctness. On the VM rack spare jack places 30 and 53 are specially wired to accommodate this tester. After connection to the VM rack the testing officer sets the digit switches 1-5 and the 'O' - 'not O switch to the code to be tested, the route choice switch to the appropriate route choice number and operates KTT. The 'S' relays will now be operated from negative potential behind KTT and the VR relays of the various choices will operate. The testing officer checks by observation that the correct VR relays operate. Depending on the route choice a particular I relay operates which signals to the ZN relays in the tester, the signalling mode, starting point and amplifier information. The ZN relays de-code this information and display it on lamps. Comparison between the lit lamps and the information contained in the routing chart can now be made to verify the correctness of strappings. To check charge strappings the process is similar, except that the 'O' - 'Not O' switch is set to contacts 3 or 4 and not

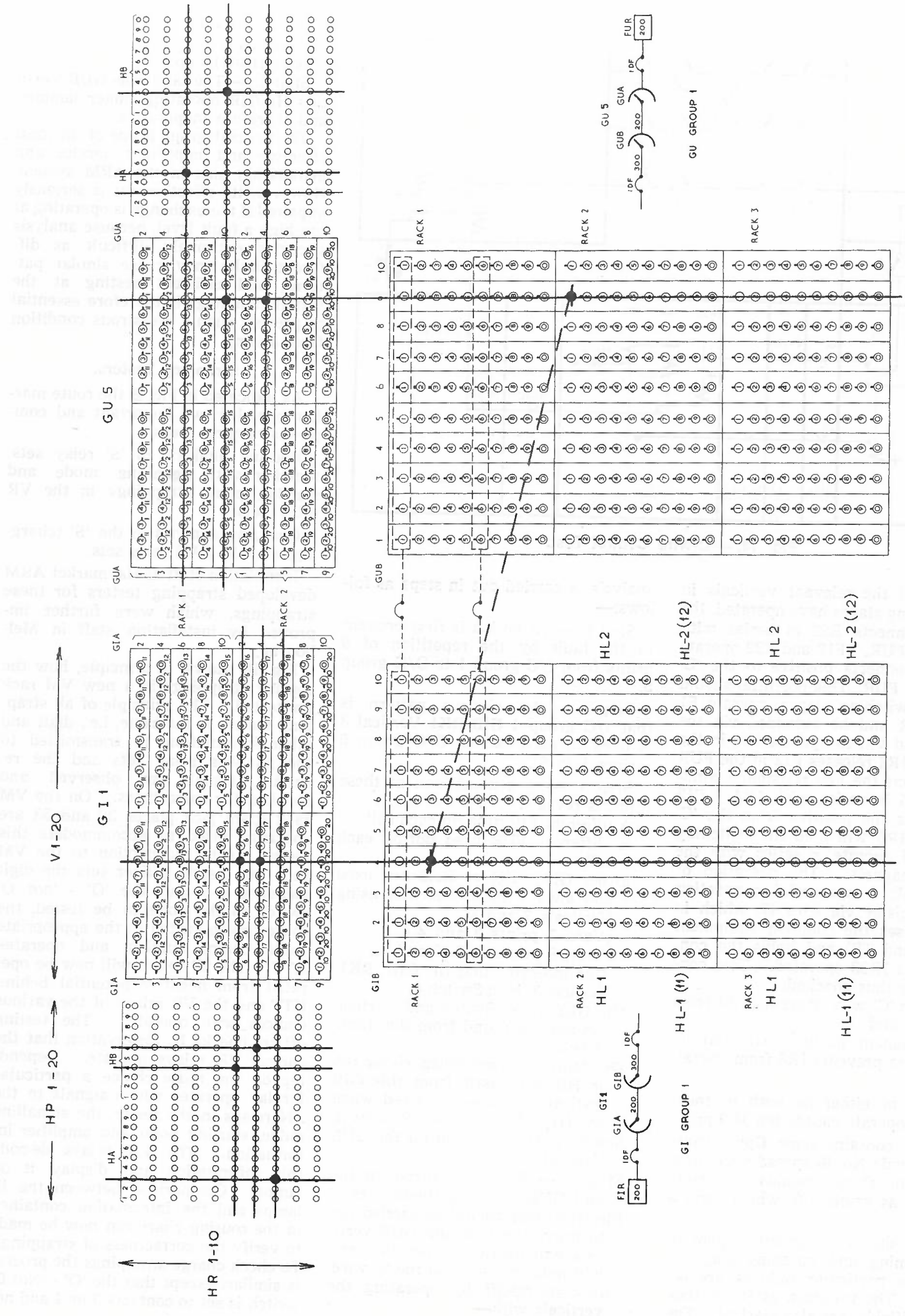


Fig. 15. — Grouping Plan for Sample Cph Analysis.

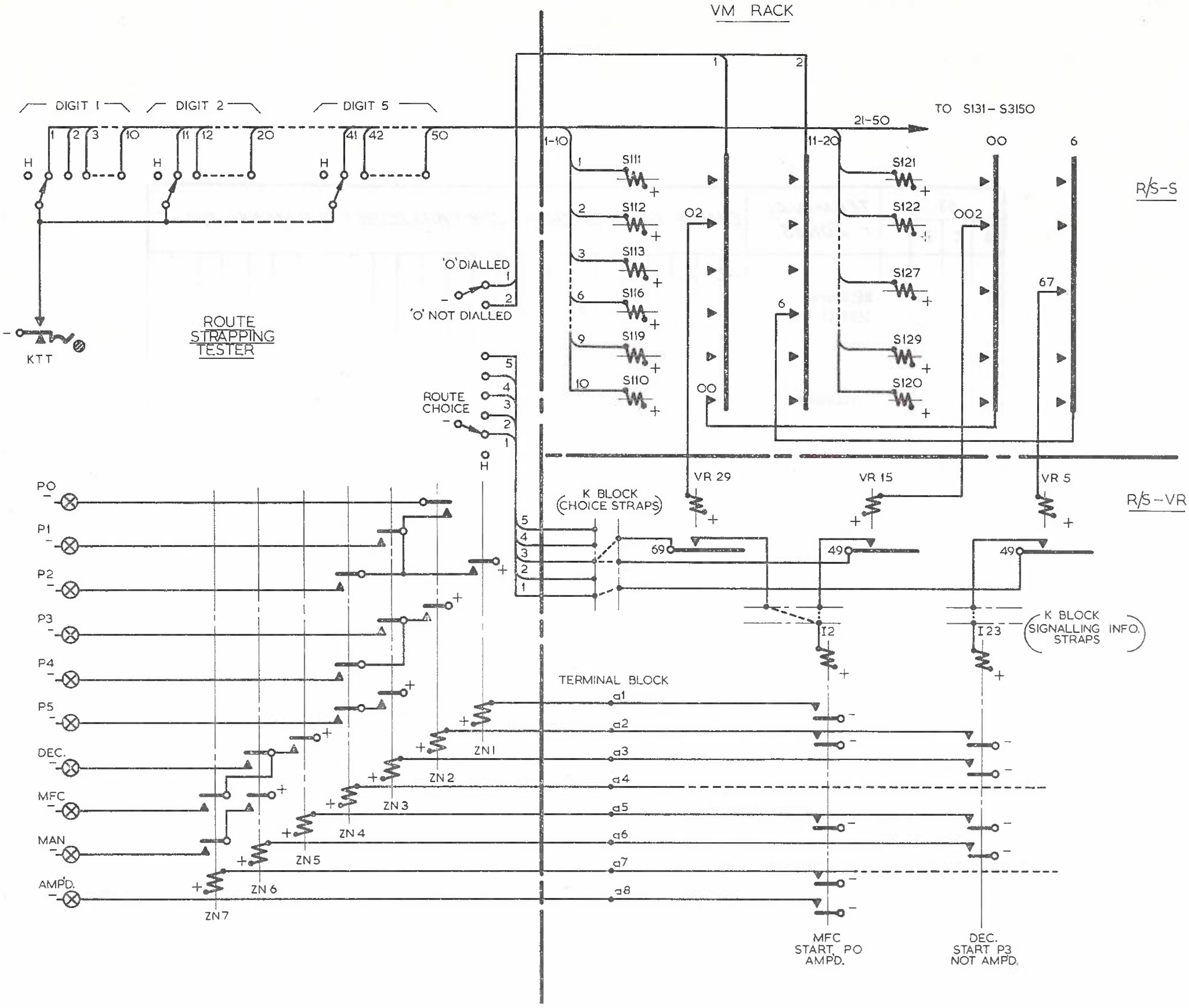


Fig. 16. — Checking of Routing Strappings in VM.

contacts 1 or 2 as previously. The 'Zone of Origin' switches must also be set to the appropriate Z00 marking. The charge rate, appropriate to the code and Z00 set, appears on lamps A-N and can be compared with the charge analysis sheets.

Fig. 17 shows a typical charge analysis sheet for the Lonsdale ARM. These sheets are produced as a joint effort between the Engineering and Telecommunications Divisions, and are individual to each exchange. Checking of the charge strappings by means of the tester against these sheets is facilitated by testing each particular code against all Z00's starting from 1 to 24 in one code setting, which corresponds with the layout of the charging information sheet.

Fig. 18 shows such a strapping tester in use on a VM rack.

Maintenance of Common Control Equipment.

There are no specific routine tests performed on common control equipment. Service staff rely here on the automatic surveillance of live traffic provided by the Cph Service Alarms and Statistical Meters as an efficient analysis of these indicators will reveal any plant fault very quickly.

REGISTER AND ANALYSER EQUIPMENT.

Fig. 19 shows a block schematic of the register complex and its associated equipment. Its functions are briefly:

To store details of the wanted 'B' number, together with the 'Zone of Origin' number for charge analysis.

To initiate the setting up of the connection through the exchange, and

To forward signals to the next traffic point as and if required.

The Crossbar Switch (REG-KV).

ARM registers are at times required to perform the 'Waiting place' function, i.e., to delay seizure forward until sufficient digits have been received if the call is to be routed to a X-bar terminal. If this rule is not adhered to, time-outs will occur in the terminal GV marker should the 'A' subscriber delay dialling the complete 'B' number. To carry out the 'waiting place' function the ARM register must be informed of the length of the B number (NL) and the type of terminating exchange (T.O.T.E.), which it obtains from the analyser. Due to limited analysing capacity of the REG-KV, the register calls for an analyser at the reception of 5 digits at the latest, if required. Use is made of REG-KV

03				TERMINAL ZONES	CHARGE RATES OF ORIGIN ZONES WITH RESPECT TO TERMINAL ZONES																							
B	C	D																										
1				MELBOURNE SERVICE CODE	L	L	L				M										F	A		F	A		A	F
2				)																								
3				)																								
4				) MELBOURNE	L	L	L				M										F	A		F	A		A	F
5				)																								
6				)																								
7	1	1		WERRIBEE	L	F	F				M										F	F		M	F		F	M
7	1	2		WHITTLESEA	L	A	L				F										F	F		A	A		L	A
7	1	3		SUNBURY	L	F	F				M										F	F		M	F		F	M
7	1	4		WHITTLESEA	L	A	L				F										F	F		A	A		L	A
7	1	5		KALKALLO	L	F	A				F										F	F		F	F		A	F
7	1	6		)																								
7	1	7		)																								
7	1	8		) WHITTLESEA	L	A	L		SEE LONSDALE ELSA TENDER EXCHANGE CHARGING ANALYSIS		F	SEE LONSDALE ELSA TENDER EXCHANGE CHARGING ANALYSIS									F	F		A	A		L	A
7	1	9		)																								
7	1	0		)																								
7	2			)																								
7	3			) CROYDON	L	L	L				M										A	F		A	L		L	A
7	4	1		)																								
7	4	2		) WERRIBEE	L	F	F				M										F	F		M	F		F	M
7	4	3		)																								
7	4	4		)																								
7	4	5		) SUNBURY	L	F	F				M										F	F		M	F		F	M
7	4	6		)																								
7	4	7		)																								
7	4	8		)																								
7	4	9		) WERRIBEE	L	F	F				M										F	F		M	F		F	M
7	4	0		SUNBURY	L	F	F				M										F	F		M	F		F	M
ZONE No					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

ORIGIN ZONES: MELBOURNE, DANDENONG, CROYDON, WHITTLESEA, KALKALLO, SUNBURY, SEYMOUR, WERRIBEE, CRANBOURNE, MORNINGTON, WARBURTON, EMERALD, HEALESVILLE, MARYSVILLE

Fig. 17. — Typical Charge Analysis Sheet.

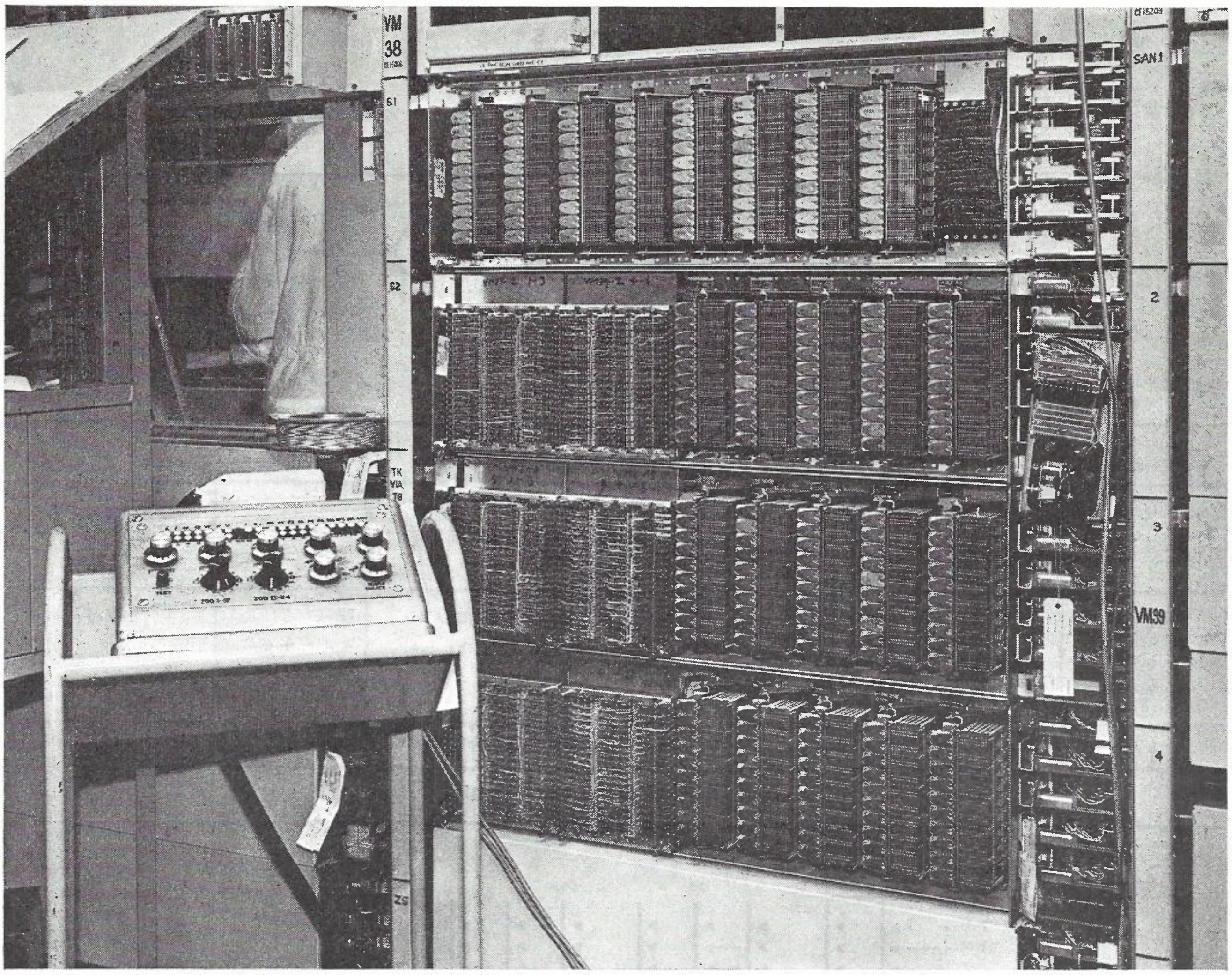


Fig. 18. — Strapping Tester.

vertical slave relays to provide this waiting place function as shown in Fig. 20.

Fig. 20 shows haw the route marker is called if REG-KV strappings are made to one of tags 1h1-1h7. 1R21 is operated via these straps and relays 2V2 - 2V8 operated. If the analyser is required, strappings are made to tags 1h11 - 1h15. Relay 1AN1 is ope rated via relays 2V2-2V5 operated, and the analyser will analyse 'B' digits and will indicate T.O.T.E. and NL by operating one of relays MFC or SBS and two of relays NL1-NL5. Fig. 20 shows that if SBS was operated, the route marker is called as soon as the analyser has restored (1AN1 released). If MFC was operated, then the VM is only called when the full B number has been received in the register.

A REG-KV strapping tester is shown in Fig. 21. The tester is mounted on a 'Rotissery' trolley and the REG-KV relay set under test is plugged in below.

Fig. 22 shows how the digits are stored in the crossbar switch. The digit switches 1 - 8 are set to the appropriate values, and by stepping the uniselector by means of the stepping key over contacts 1-15, multi-coil relays V1-V8 are operated in turn Whenever a coil is operated the appropriate horizontal in REG-KV operates. The horizontal off normal via an arc of the uniselector, operates the appropriate vertical, which locks to its off normal springset via relay RV.

Once the digits are stored, lamps on the tester will display (see Fig. 23)—
What digit the VM or AN is called.
The number lengths of the distant closed numbering area if the call is to be routed to a foreign ter minal.

By rotating the digit display switch and appropriately operating the MFC-decadic key, the digits stored in each vertical will be displayed in '2 out of 5' or '1 out of 10' code. The tester thus not only checks the correctness of the strappings, but also the wiring of REG-KV for any possible fault conditions.

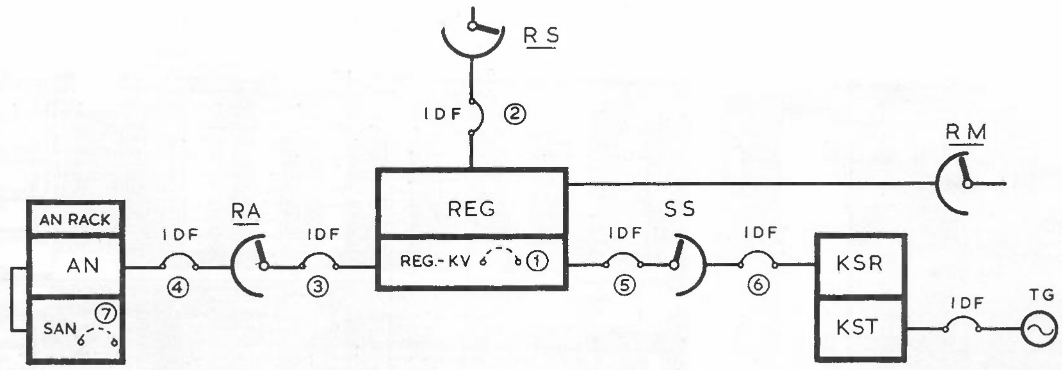
The Analyser.

The VM strapping tester can also be used to test the analyser strappings. With the AN relay set removed, the tester is plugged into places 25 and 27 if AN1 is to be tested, and places 34 and 36 for AN2.

As previously described the 'B' code to be tested is set, and on operation of KTT a number length lamp, together with a T.O.T.E. lamp should light as shown in the survey diagram (Fig. 25). Each analyser code is set up in turn and the correctness of the strappings is verified by comparing the lamps alight with the analyser strapping chart.

The Register Test Rack.

During the installation of the North



JUMPER OR STRAPPING AREA	FUNCTIONS	INSTALLATION TESTS	REFERENCE	SERVICE TESTS
①	a. DIGIT TO CALL V.M. b. " " " A.N. c. NUMBER LENGTH OF FOREIGN A.R.F. AREA d. ECHO SUPPRESSOR ANALYSIS	KV STRAPPING TESTER	—	SERVICE REG. TESTS VIA FIR-P'S
② ③ ④ ⑤ ⑥	RS REG GRADING REG-RA CONNECTION RA-AN GRADING REG.-SS CONNECTION SS-KSR GRADING	"PUSH UP" TESTS AND WIRE TESTS	TEST SECTIONS 4·4 – 4·6 6·1-6·2, 6·6	" " " " "
⑦	N.L.& T.O.T.E. STRAPPINGS	V.M. AN. STRAPPING TESTER	—	" " " " "

Fig. 19. — ARM Register Complex.

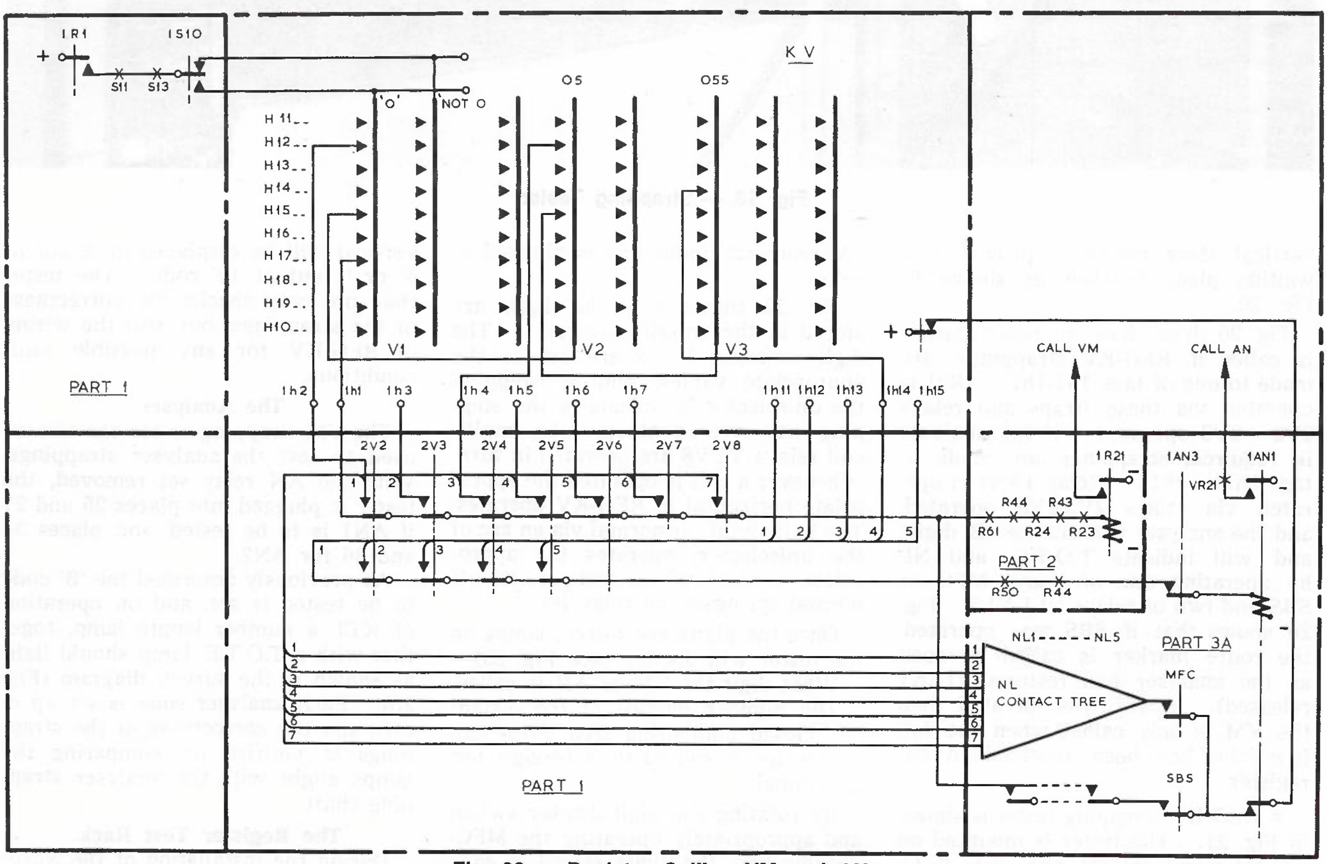


Fig. 20. — Register Calling VM and AN.

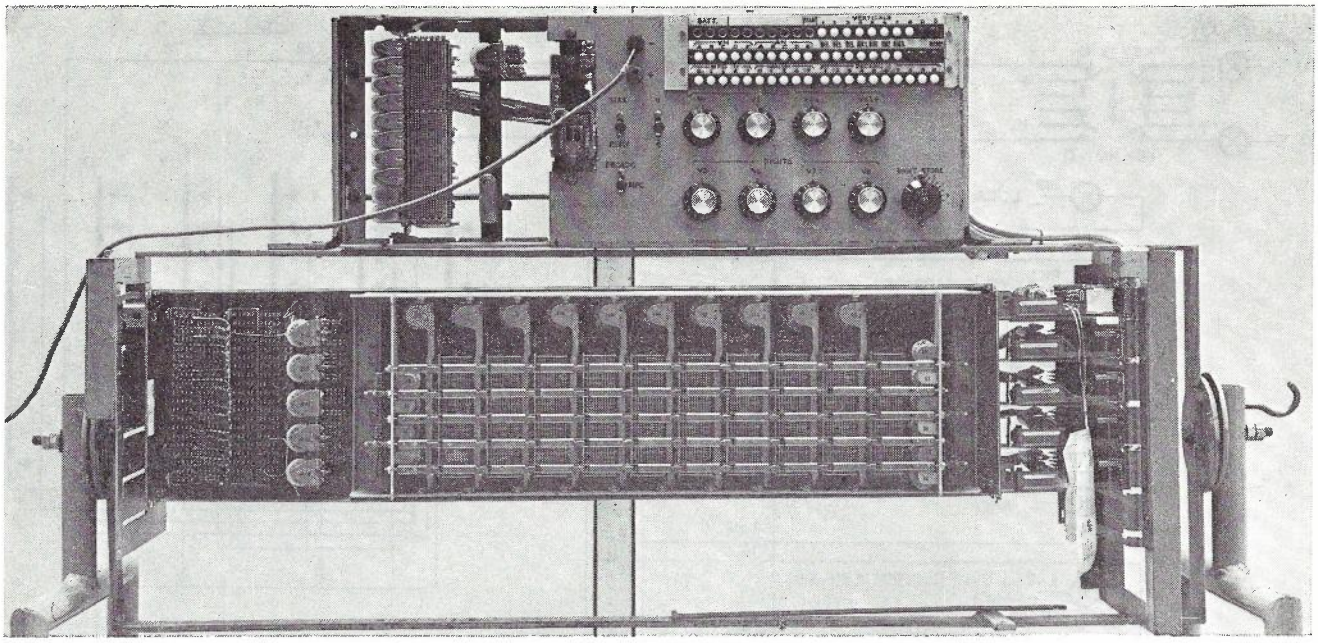


Fig. 21 — REG-KV Tester.

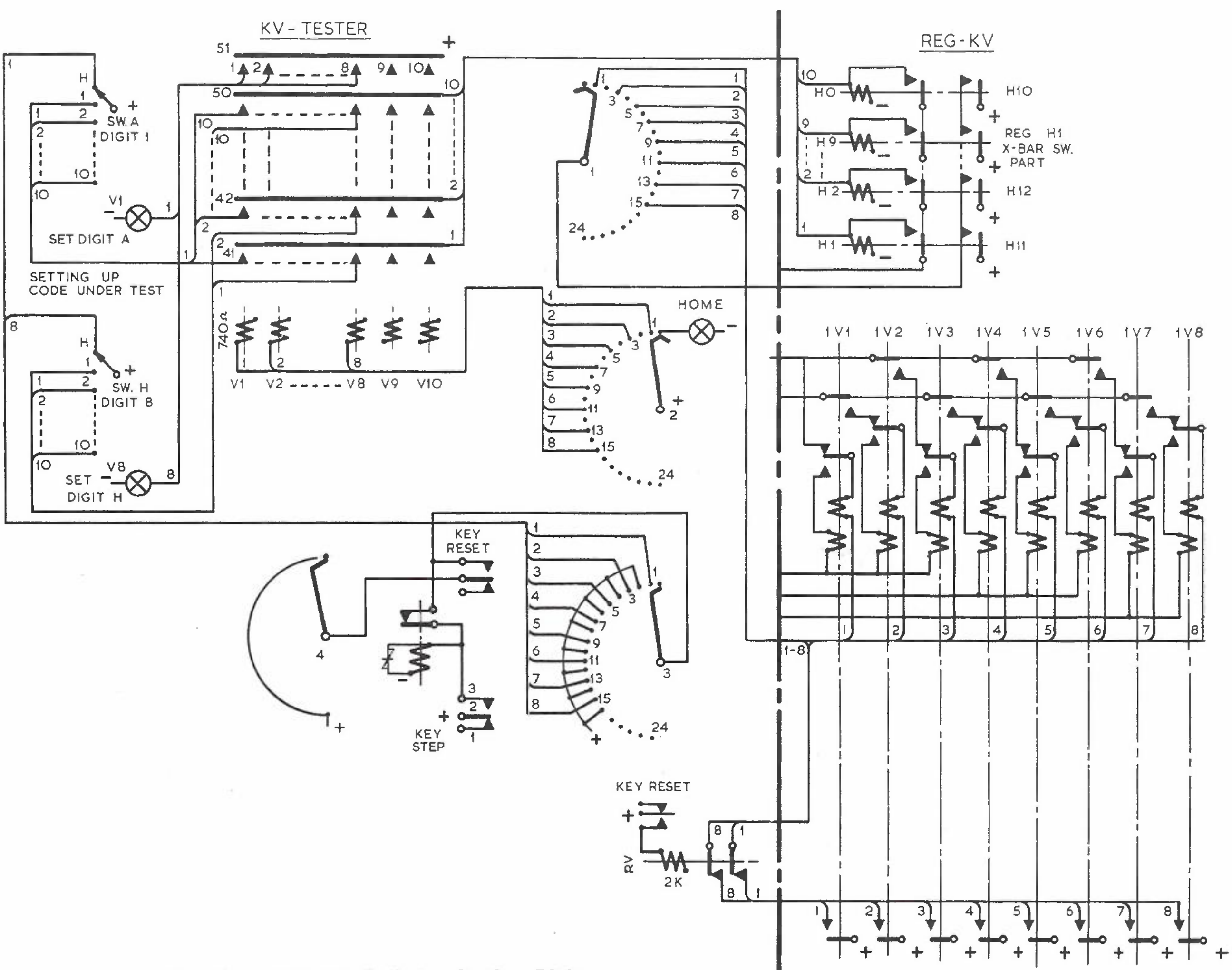


Fig. 22. — REG-KV Tester — Storing Digits.

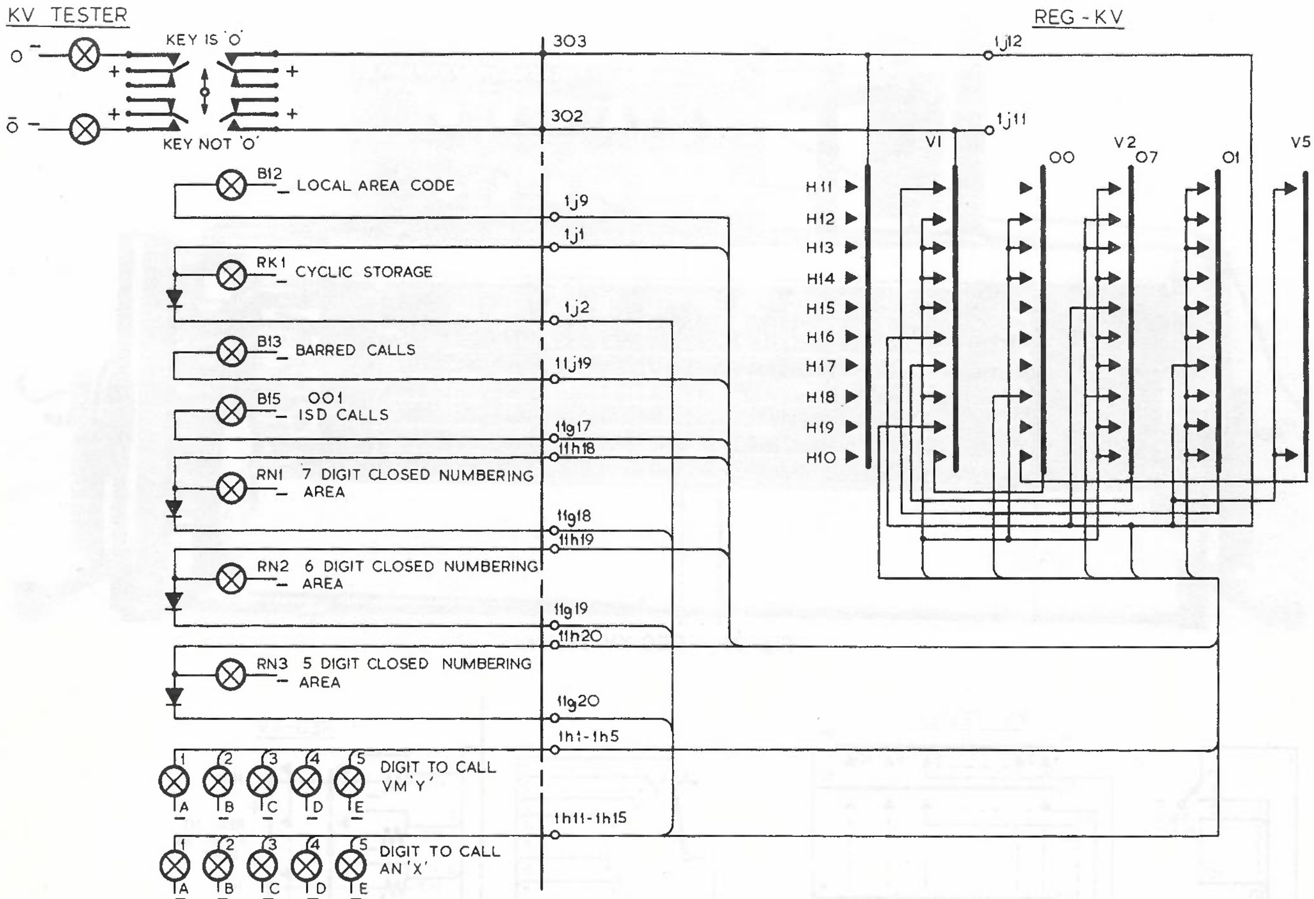


Fig. 23. — REG-KV Tester — Output Indication.

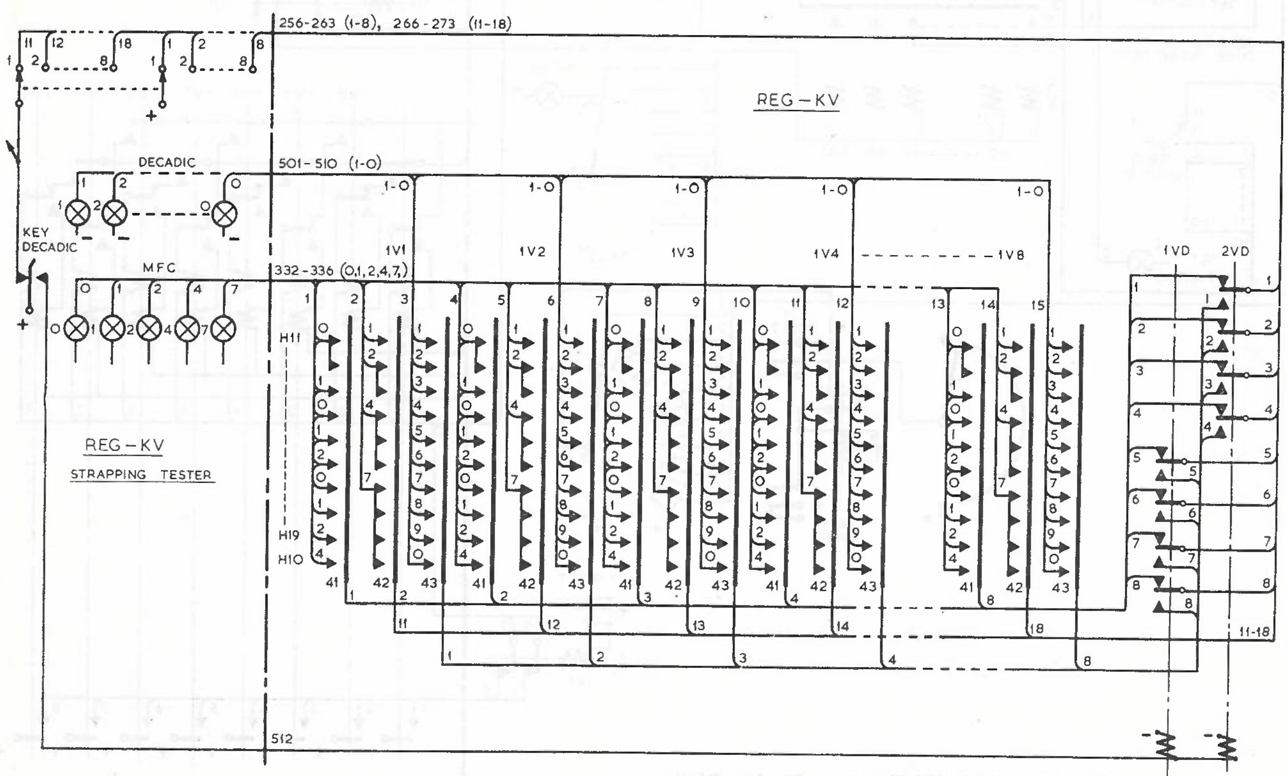


Fig. 24(a). — REG-KV Tester — Display of Stored Digits.

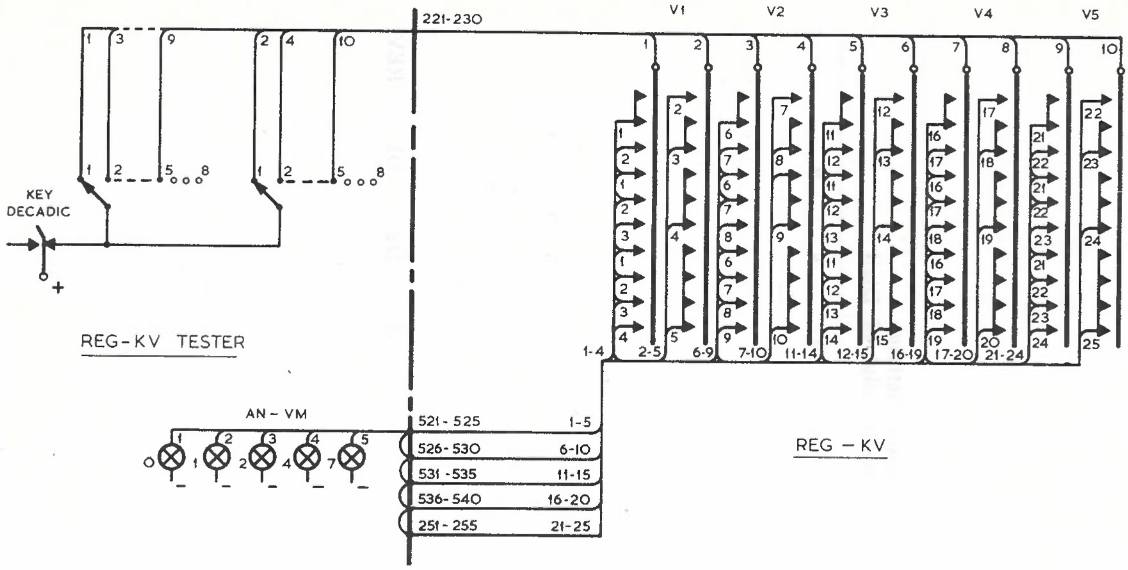


Fig. 24(b). — REG-KV Tester — Display of Digits to be Transferred to AN/VM.

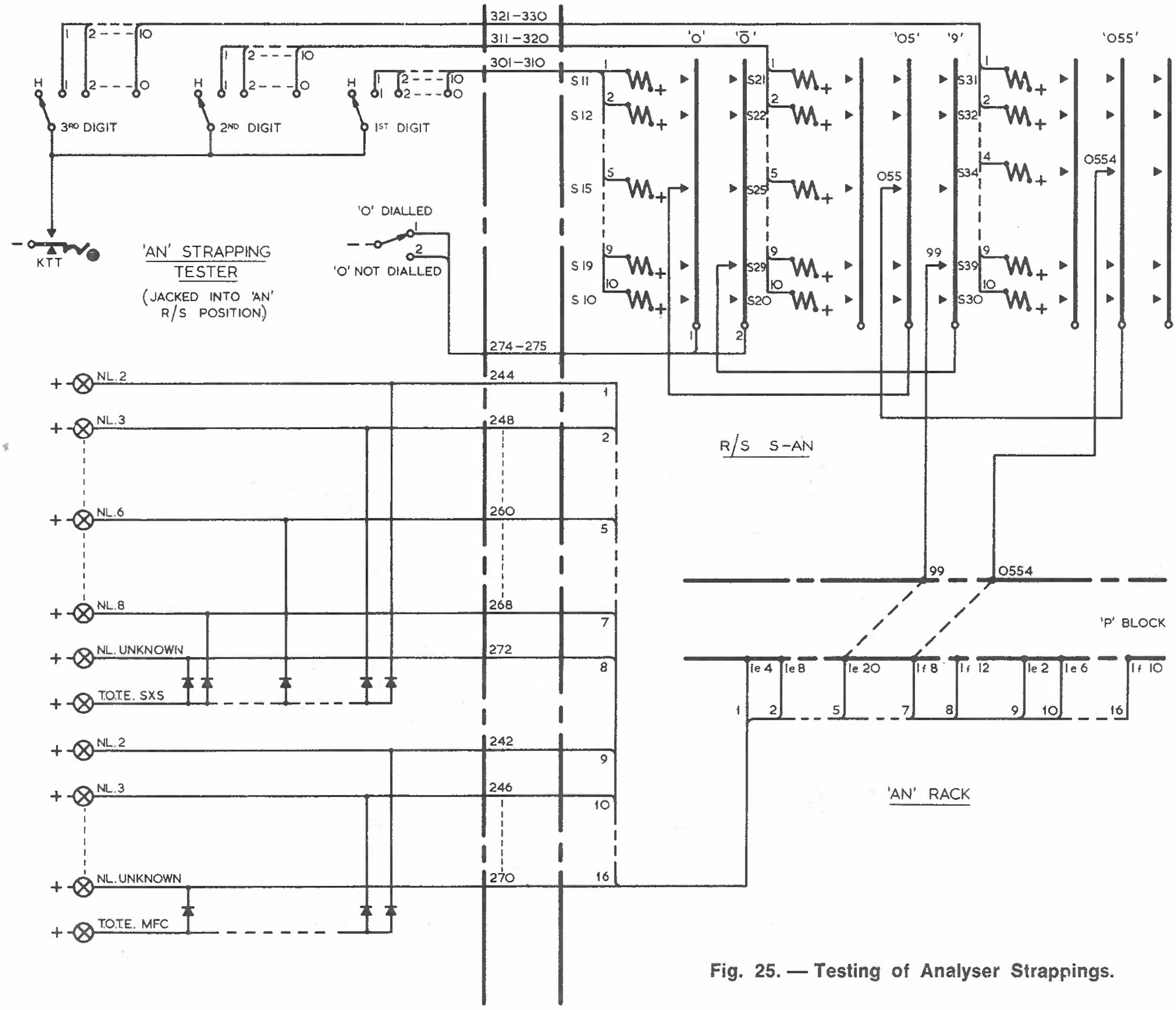


Fig. 25. — Testing of Analyser Strappings.

TABLE 2. — REGISTER TEST RACK — TEST CODES

Input to AET	Analyser		Reg.	VM		Network Simulator Setting. Control Signals after Receipt of Digit									
Numerical Value	Tote	NL	KV	P Start	I Relay	1	2	3	4	5	6	7	8	9	
1 1 3 2	NT		A4	PSO	2	3A1	3A1	3A1	3A1	3A3	B1				
1 1 3 3 3	MFC	5	A4	P1	3	3A1	3A1	3A1	3A1	3A3	B1				
1 1 3 4 3 2	MFC	6	A4	P2	3	3A1	3A1	3A1	3A1	3A3	B1				
1 1 3 5 3 2 1	MFC	7	A4	P3	7	3A1	3A1	3A1	3A1	3A3	B1				
1 1 3 6 3 2 1 0	MFC	8	A4	P4	9	3A1	3A1	3A1	3A1	3A3	B1				
1 1 3 7 3 2 1	MFC	0	A4	P5	11	3A10	3A1	3A1	3A1	3A3	B2				
1 1 4 1	S x S	3	A4	M A N	30	—									
1 1 4 2	S x S	4	A4	M A N		—									
1 1 4 3 4	S x S	5	A4	M A N		—									
1 1 4 4 4 3	S x S	6	A4	M A N		—									
1 1 4 5 4 3 2	S x S	7	A4	M A N		—									
1 1 4 6 4 3 2 1	S x S	8	A4	M A N	30	—									
1 1 4 7 1 3 2 1	S x S	0	A4	P5	26	3A4	D1	D1	D4	D7	D1	D3	D2	D1	REV
1 1 4 7 2 3 2 1	S x S	0	A4	P3	22	3A8	D2	D3	REV						
1 1 4 7 3 2 3	S x S	0	A4	P2	20	3A9	D2	D3	REV						
1 1 4 7 4 2 3	S x S	0	A4	P1	18	3A9	D2	D3	REV						
1 1 4 8 8	S x S	5	R1	P4	9	3A7	D8								
1 1 4 9 8	S x S	5	R2	P4	9	3A6	D8								
1 1 4 0 8	S x S	5	R3	P4	9	3A5	D8								

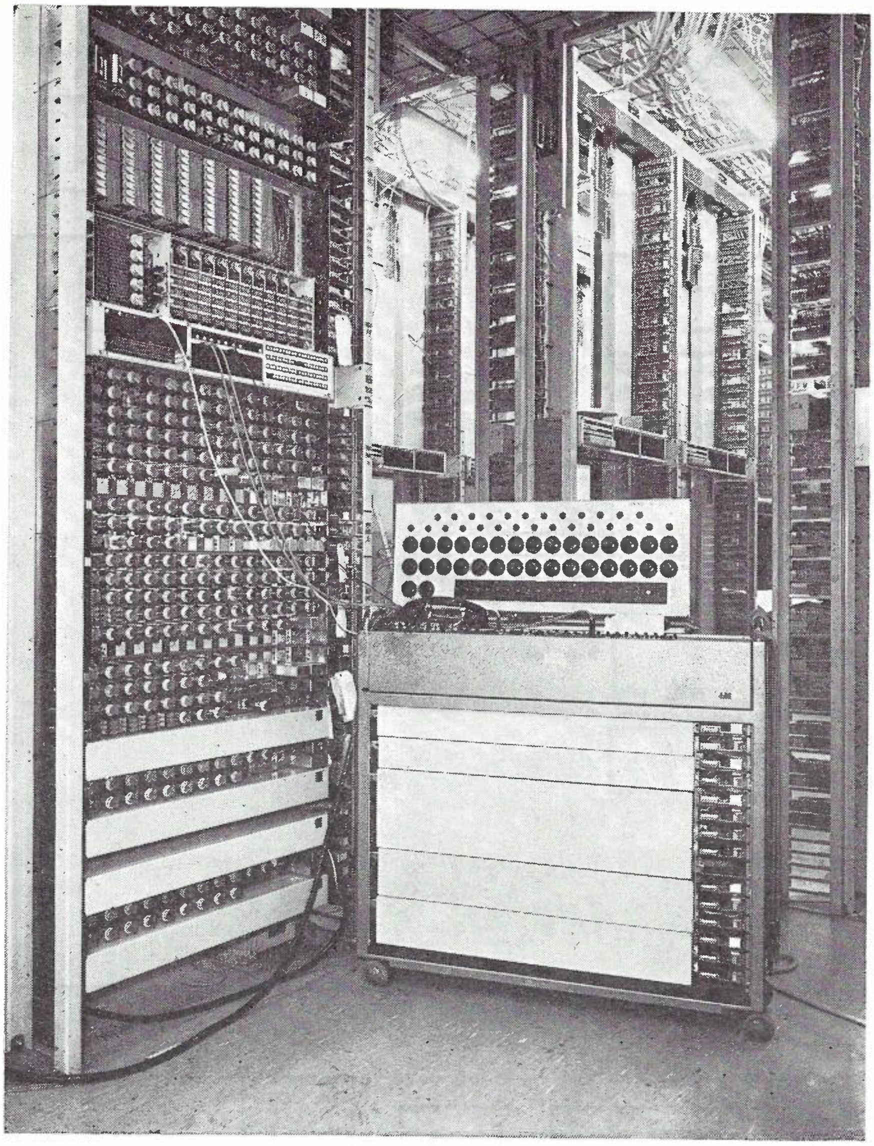


Fig. 26. — Register Test Rack.

Melbourne ARM many faults were found in the various register parts and their location with the relay sets mounted in their rack positions proved inefficient and time consuming. For this reason the installation staff at Lonsdale ARM developed a register test rack, a photograph of which is shown in Fig. 26. The rack contains a specially strapped up 'Test REG KV' as well as equipment that simulates the peripheral conditions surrounding the register complex.

Table 2 shows the B numbers used on the register test rack, together with analyser, REG-KV, and VM strappings. Each test consists of transmitting the particular test code to the register under test from a tariff tester causing the register to re-transmit the digits to a network simulator. The tariff tester is used in the role of an exchange tester to simulate the originating exchange. The network simulator is the exact inverse of a tester in that it is pre-set to receive particular digits either in MFC or decadic pulses.

If the received digits agree with those pre-set, the network simulator signals success by a number of 'Answer' conditions.

Fig. 27 shows a block schematic survey of the test rack as well as the flow of one call through the equipment as follows:—

(1) The tariff tester seizes the FIR.
(2) The FIR causes the RS simulator to connect it to the register under test.
(3) The first digit is transmitted and stored in the test REG-KV.
(4) If MFC signalling is employed the REG under test will call for Z00 or further digits as required.
(5) and (6). When sufficient digits are stored in KV, the analyser or VM is called. We assume in this case that AN is called.
(7) The REG under test causes the RA simulator to connect it to an AN relay set, and the analysis simulator.
(8) AN returns the appropriate NL and T.O.T.E. signals as shown in Table 2.
(9) The register under test now calls for the VM simulator, to which it connects via the RM simulator.
(10) Digits and other information are transferred to the VM.
(11) & (12) The digits are analysed and converted to the appropriate 'P Chain' information.
(13) The 'P Chain' information is returned to the register under test.
(14) At the same time signals are transmitted via the REG under test to establish a connection through the GI/GU simulator.
(15) The FUR-L1M-C is seized and a 'C'-wire test is carried out. The VM simulator and associated equipment are now released.
(16) The register under test now couples to a KSR/KST via the SS simulator.
(17) The digits are forwarded in MFC to the network simulator, where they are checked for correctness.

In this way the functions for each type of call can be checked in the register under test. The only faults that should be encountered after a register has been put through the register test rack are rack wiring faults. Although the relay sets under test are plugged directly into the rack, they could be mounted on 'Rotisseries' and extended by 80 wire cords to the appropriate places on the test rack. The fault-finding process is very efficient as all the interworking equipment is concentrated on one rack.

Service Testing of Registers. — Faults occur more frequently in the registers and associated equipment than in the other ARM equipments. (It has been found in practice at the North Melbourne ARM that approximately 13 faults occur in 100 registers every month). The register and associated peripheral equipment comprises many racks of relays and switches embodying quite complex circuitry. In the normal lifetime of an exchange, changes have to be made to register strappings quite frequently to meet growth and changes in the network. Because of this, it was necessary to develop routining methods for testing ARM registers and associated equipment under actual call conditions.

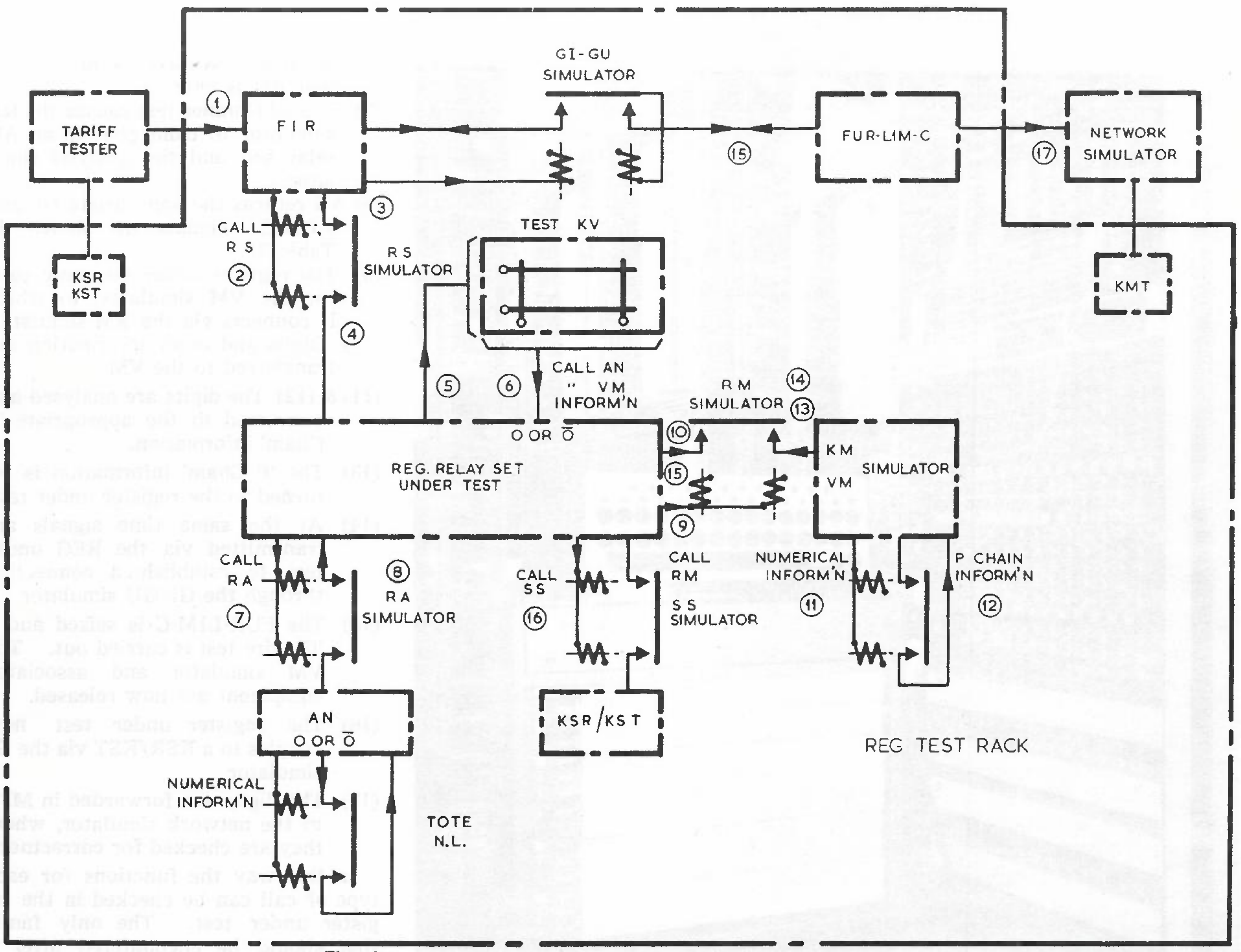


Fig. 27. — Register Test Rack — Block Schematic Survey.

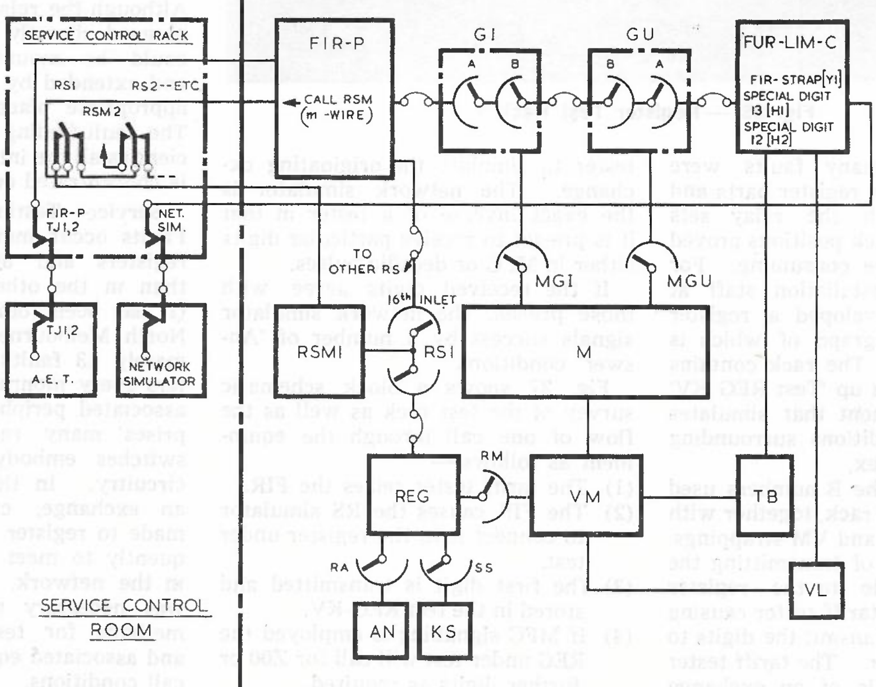


Fig. 28. — Service Testing of Register — Block Schematic.

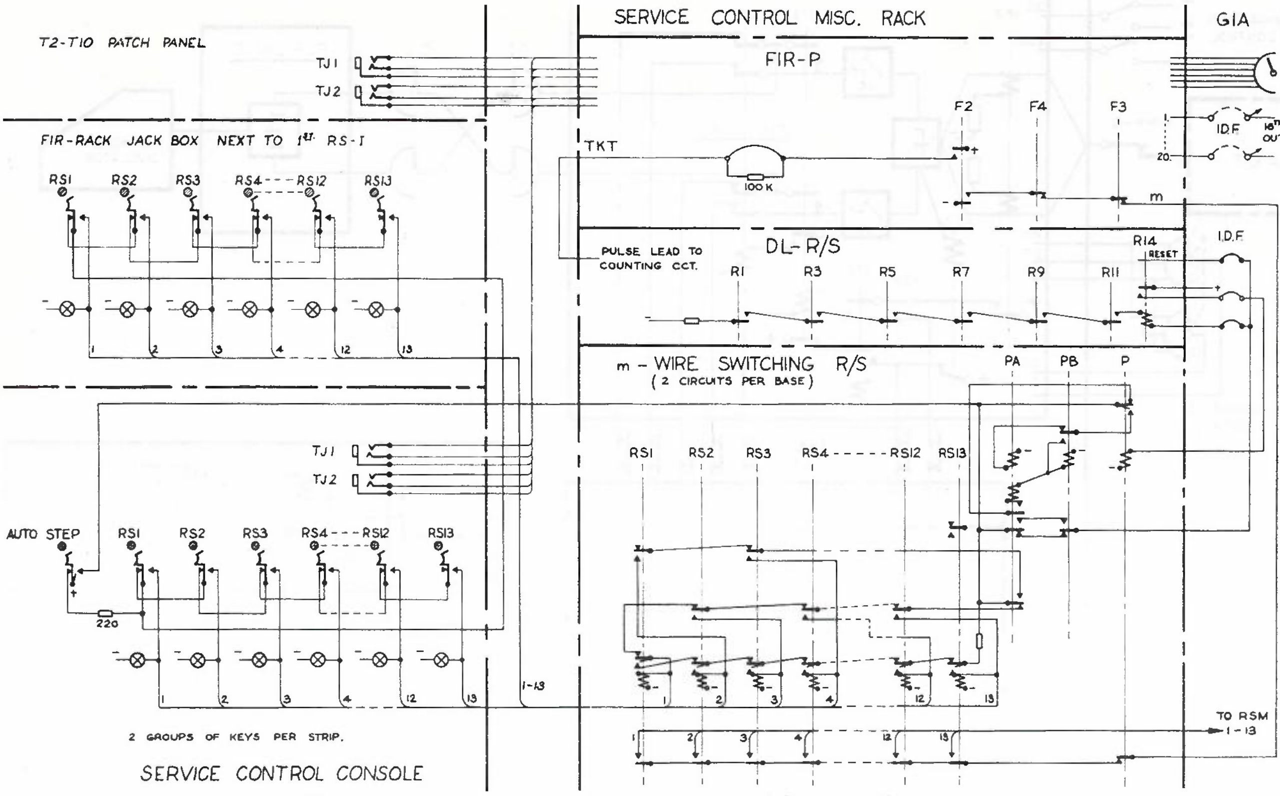


Fig. 29. — Automatic Sequential Access to Different RS Groups.

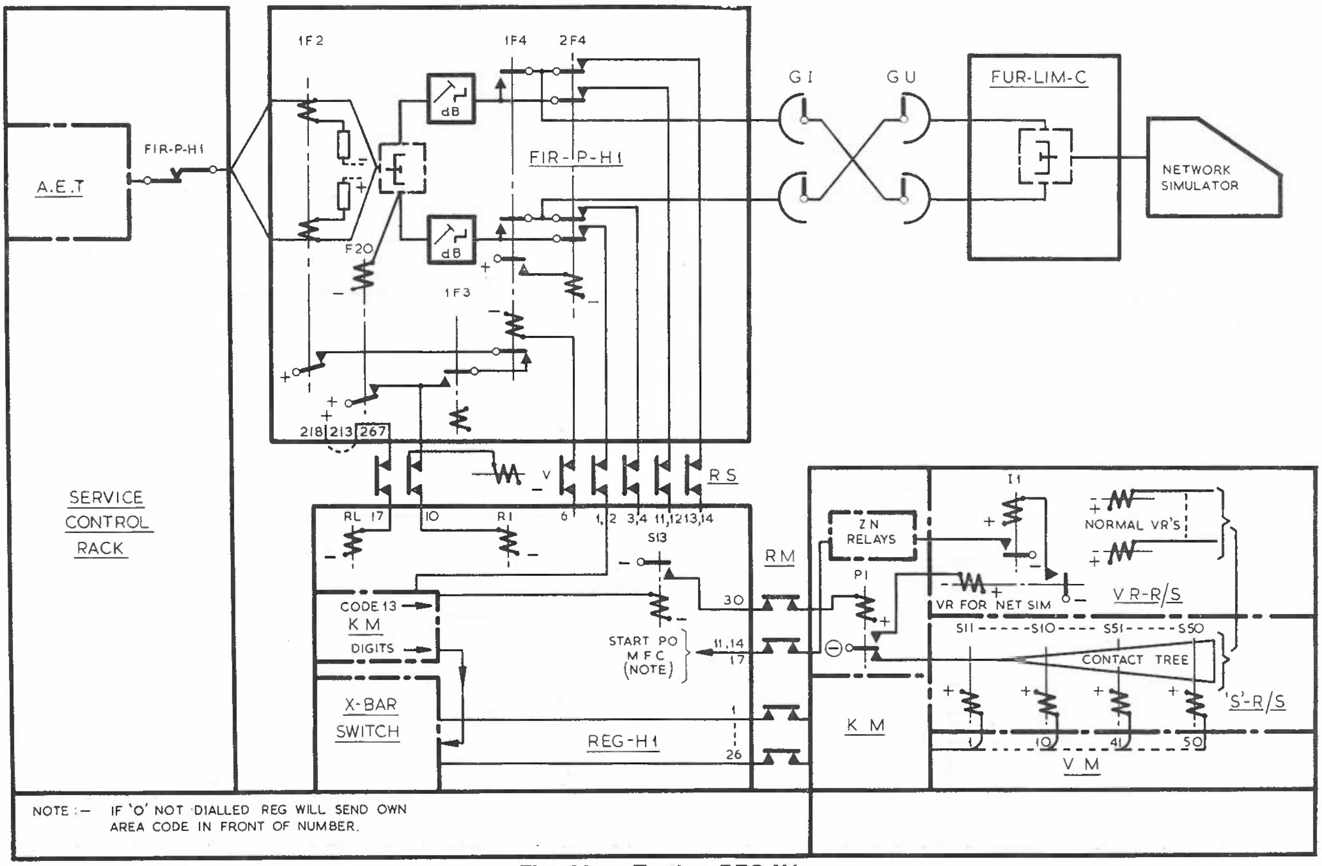


Fig. 30. — Testing REG-H1.

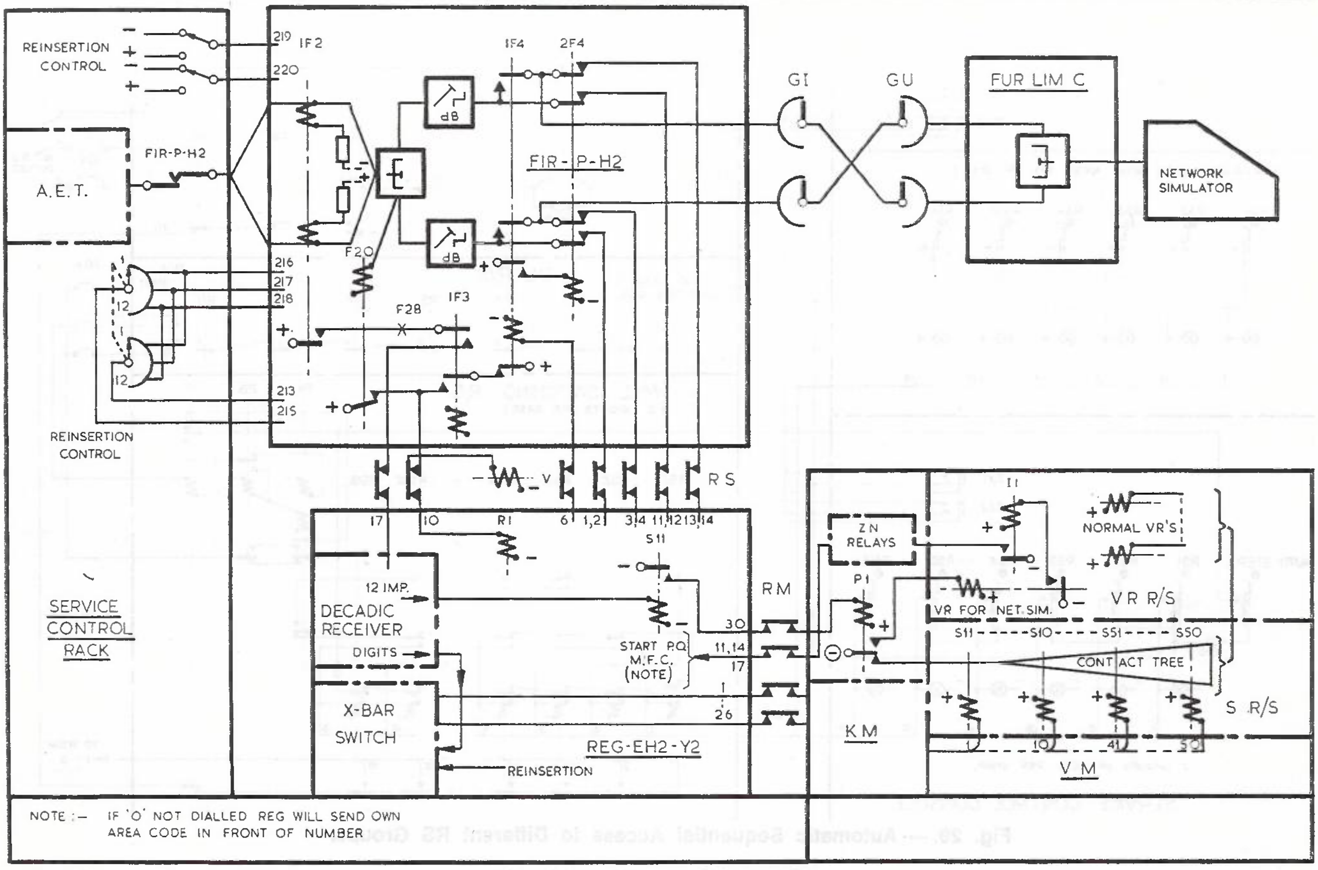


Fig. 31. — Testing REG-EH2Y2.

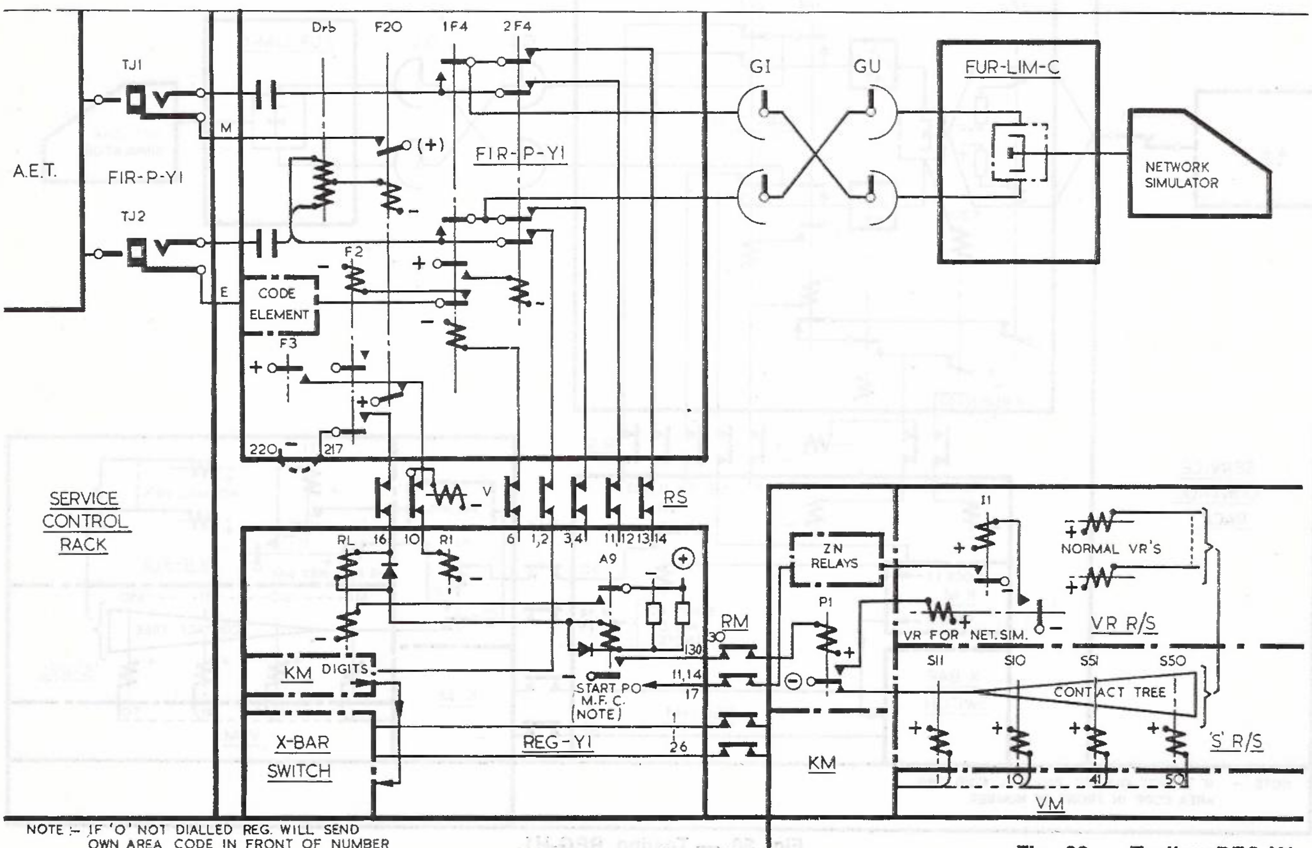


Fig. 32. — Testing REG-Y1.

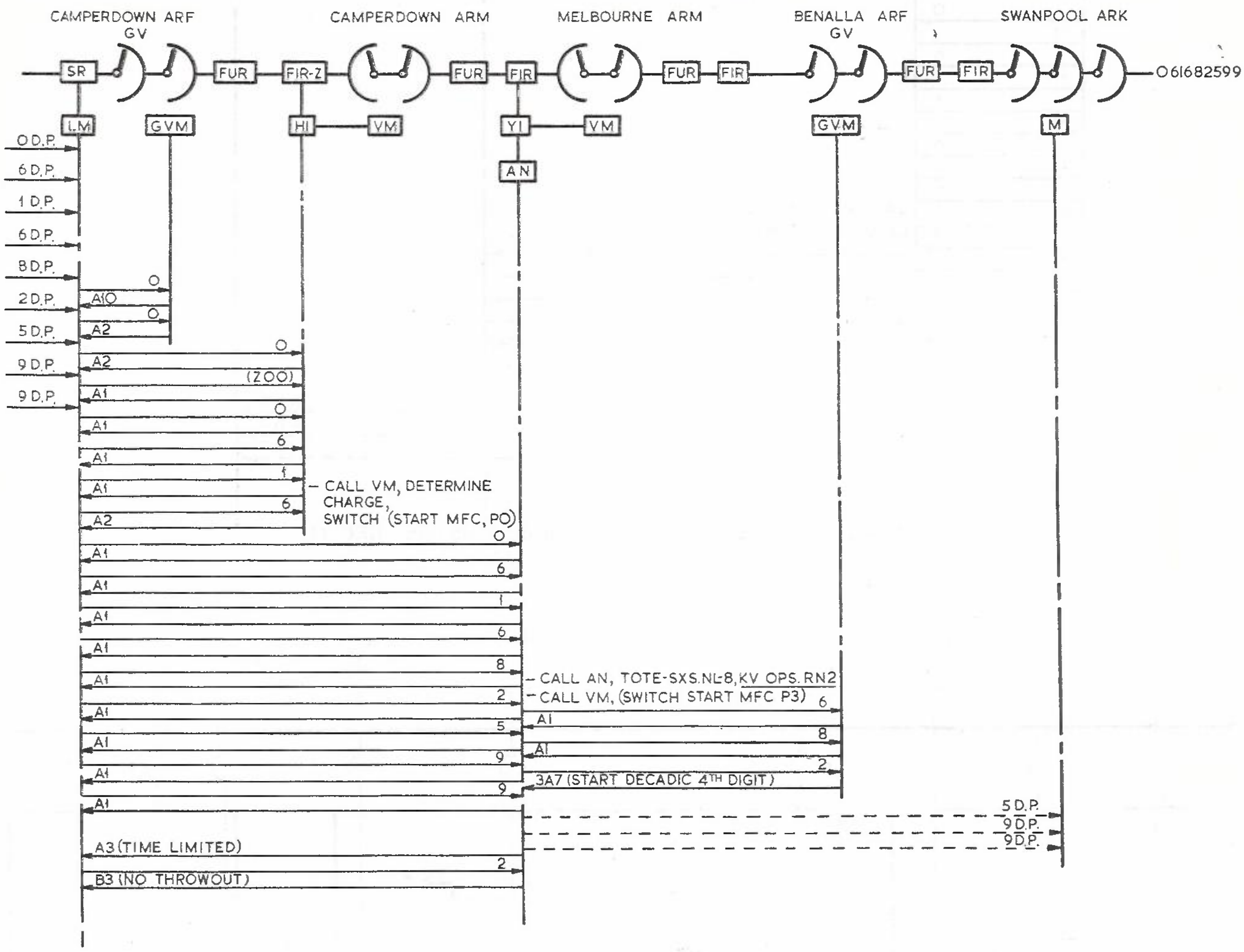


Fig. 33. — MFC Signalling During Set up of an Actual Call.

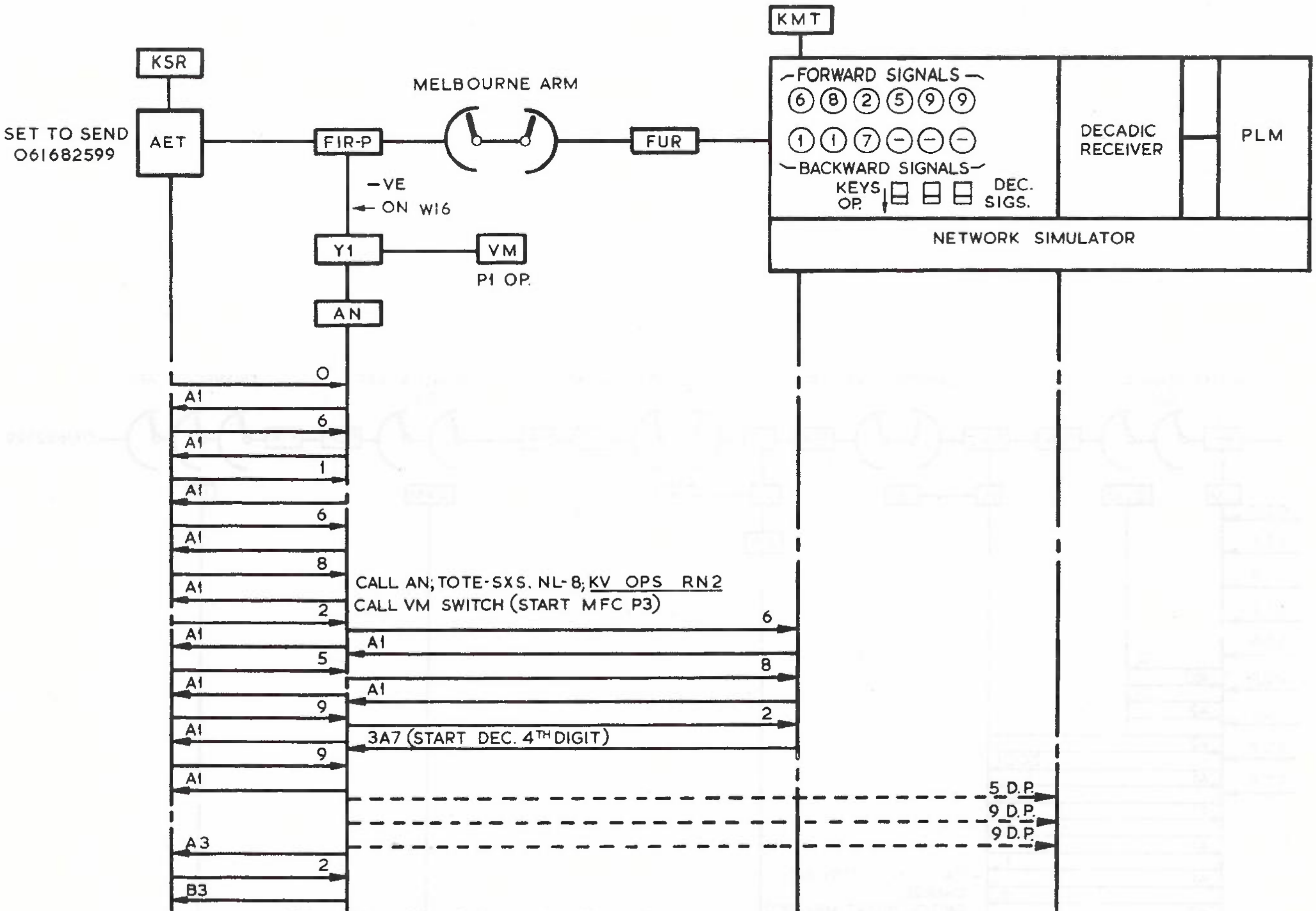


Fig. 34 — Simulation of Call to Swanpool on Melbourne REG-Y1.

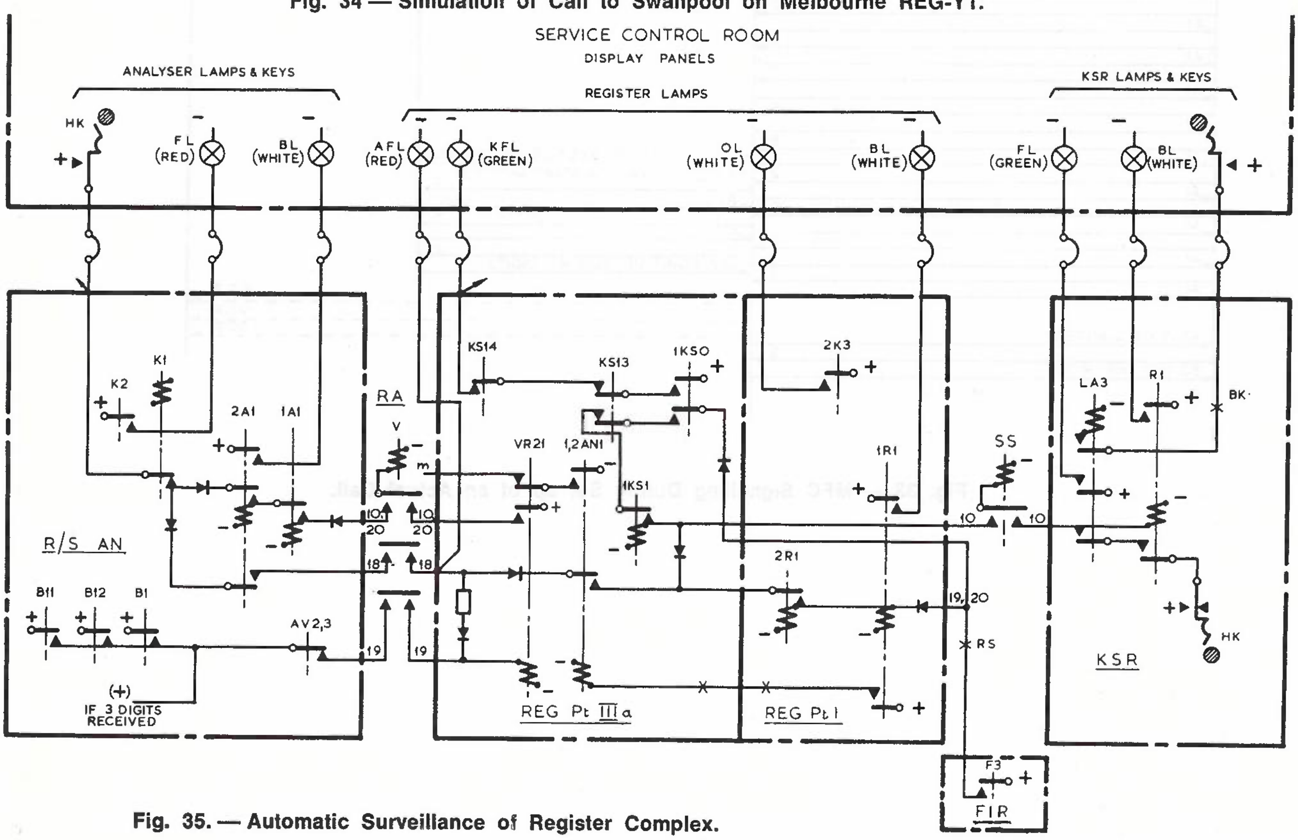


Fig. 35. — Automatic Surveillance of Register Complex.

FIR-P's — Modified FIR's for each type of register (see Fig. 28) accessible via test jacks on the service control rack are provided as FIR-P's. The modifications are concerned mainly with giving the FIR the ability to hold the register until the call is successful ('answer' received). The FIR-P connects to the 16th inlet of each RS stage associated with the particular type of register. The call RSM lead from the FIR-P is switched by means of keys on the service control rack to call only the RSM of the wanted RS stage. In this way, test calls may be directed into any wanted group of 20 registers. In large ARM exchanges it is desirable to test all registers automatically without human intervention, and an automatic changeover to the next RS group after completion of 63 test calls in each, has been developed (see Fig. 29).

One FIR-P is provided for every one of 13 RS stages. The 'call RSM' lead (m wire) from the FIR-P is switched by the m-wire switching relay set to call the RSM of the wanted stage.

During each call, relay 1F2 in the FIR-P operates, and the operations of 1F2 are counted in a DL relay set. When 63 calls have been made R14 is operated. The reason for 63 calls is that as there are 20 registers in each RS group, approximately 60 calls must be originated to ensure, with 95 per cent. certainty, that each device is tested at least once. The operation of R14 operates relay P in the 'm wire' switching relay set. RS1 was operated originally when the auto step key on the service control rack was pressed. When P operates, PA is operated and resets the DL circuit by removing positive from the reset lead. This, in turn, causes R14 and P to release and PB is now operated in series with PA. PB restores the holding circuit for the DL and PA operates RS2 via RS1 contact made. RS2 in operating releases RS1, and the m wire of the FIR-P is now extended to call the RSM of the second RS stage. The process is repeated every 63 calls, and continues until all 13 RS stages have been test-called. The keys on the service control rack also allow direct access to any wanted RS stage, and with the auto step key released no 'Step on' in the 'm' wire switching relay set will occur.

Register Tests. — Network simulators have already been mentioned as part of the register test rack. Their facilities have been further increased for service requirements by the addition of a pulse length monitor circuit. The simulator will now not only check the received digits for correct value but also each decadic pulse length to be within specified limits. It is possible to test registers by means of Auto Exchange Tester runs into self-answering bases located at distant exchanges. However, fault location is difficult and time-consuming due to the amount of extraneous equipment, e.g., carrier circuits, distant switching stages, etc., included in the test. The aim should therefore be to test ARM registers by originating normal test calls to any 'B' number, with the path of the call involving as little equipment, other than the register complex, as possible.

This can be achieved by utilising the original tariff test facility built into the ARM exchange (see Figs. 30, 31, 32). To this end REG-H1 and REG-H2 are made to extend a negative on wire 30 towards VM, by sending code 13, or 12 impulses, to them respectively.

Register Y1 has to be modified to include a new relay (A9) operated from the FIR-P as shown in Fig. 30. Operation of A9 again places negative onto wire 30, resulting in the operation of relay P1 in the route marker. To achieve different starting points with a single VR relay in VM, relays R41-45 are utilised in a particular VR relay set, and are operated by keys on the service control rack depending on which particular route should be simulated. If these relay contacts cannot be made available for this purpose, the alternative mentioned in the note on the surveys should be followed.

Fig. 33 shows the information signalling that takes place as a call proceeds from Camperdown ARF via the ARM grid to Swanpool ARK. Fig. 34 shows how the same call is simulated in Melbourne to test register type Y1. It is proposed to test one working routing code in the VM per test run, and this will ensure that even in a large ARM such as 'Lonsdale A' all registers are tested against all codes approximately once every six months. To override the disconnection of REG-H1 or Y1 whenever signal 'start PO MFC' is received all FIR-P's are marked as long i/c line (operation of relay RL).

Automatic Call Surveillance in the Register Complex.

In large ARM exchanges, some 400 registers may interwork with approximately 15 analysers or 70 KSR's and under these conditions back tracing to the register is extremely difficult. With the provision of the HK keys, holding potentials can be fed back to the register under time out conditions, thus holding the register with all stored information intact. Fig. 35 shows how the analyser can hold the register via wire 18 and how the KSR holds via wire 10.

Relays 1R1 and 2R1 in REG Part 1 are held operated and the register only needs to be traced in order to obtain the information about the fault condition. Fig. 35 shows how lamp leads can be extended into the service control room to aid in the tracing operation. If, for example, a particular analyser times out, relay K2 lights the red FL lamp appropriate to the analyser in the service control room. The holding positive from the same analyser via wire 18 also lights a red AFL lamp associated with the particular register. If only one time-out has occurred at any one time (the usual condition), both register and analyser are immediately identified. Similar facilities have been provided for the KSR's.

At North Melbourne ARM a field trial was conducted to indicate 'No Progress' calls to MFC destinations. With the addition of a small electronic timing circuit, selected KSR's can be caused to 'time-out' in 6 sec. and hold the REG if no revertive signals are received. Normally the register times out under these conditions and returns 'Congestion.' The trial was successful and helped to locate some faults.

Acknowledgement.

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REFERENCES.

1. A.P.O. Planning Letter No. 1, 'Planning of ARM Trunk Exchanges. (An internal A.P.O. document.)

2. J. Mapleston, 'Functional Tests of Centralograph; CID174. (An internal A.P.O. document).

PATENTS AND THE AUSTRALIAN POST OFFICE

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INTRODUCTION

A major review of Post Office policy on the protection of its interests in inventions, designs, developments and development contracts was concluded in 1968. The main decision taken as a result of this review was that there should be a greater emphasis on the use of patents to cover inventions made within the Post Office and on the acquisition by the Post Office of rights in inventions and new equipment designs resulting from its own financial and technical contribution to developments made by contractors. The aim is for the Post Office to acquire sufficient rights in inventions and know-how to give it both royalty free usage for its own purposes and the right to charge royalties for the use of the inventions and know-how to supply non-Commonwealth customers.

The new policy can only be effective if information about inventions and new developments is brought to attention early enough to allow appropriate patent protection to be obtained before the information becomes public knowledge. The aim of this article is therefore to give a brief outline of the Australian patents system, as a guide to what may be patentable, and how it can be used to the advantage of the Post Office.

THE BASIS OF THE AUSTRALIAN PATENTS SYSTEM

Patent law in Australia was of course taken directly from the British law by the separate States individually before federation. At federation, responsibility for the patents system was transferred to the Commonwealth. The Australian Patents Act is still very similar to the British equivalent in most of its provisions. British court cases are therefore relevant to the interpretation of the law in Australia as well as forming part of the history of its development (Refs. 1 and 2).

Letters Patent, literally "open letters", refers generally to letters issued by a sovereign addressed openly to all his or her subjects. The purpose of the open letters is usually to make known the granting by the sovereign of some favour or appointment. In the case of letters patent for inventions the favour granted is a limited monopoly to the use of an invention in return for its disclosure to the public. The monopoly is in one sense a reward for the Inventor's ingenuity but it is conditional upon disclosure of the idea and may be taken away if abused. It is normally limited to a period of 16 years in Australia with provision for extension in certain exceptional circumstances.

The origins of the modern patent system can be traced back at least to mediaeval England where the earliest grants of monopolies by letters patent appear to be to foreigners, in return for introducing certain industrial arts into England. These early monopolies were for 14 years, two periods of apprenticeship, and it was expected that the introducers would train native citizens in their crafts during the period of monopoly. Early 14th Century grants related to weaving, dyeing, clock making and salt manufacture. By the 16th Century the system had become the subject of abuse by the Crown. It was being used as a method of rewarding court favourites or enriching the privy purse. Existing craftsmen were being prevented from working by unjustifiably wide monopolies. By the time of James I, however, Parliament had become powerful enough to do something about such abuses and the ability of the Crown to grant monopolies was sharply curtailed by the Statute of Monopolies of 1624. This permitted the granting of monopolies only to the 'true and first inventor' of 'any manner of new manufacture'. These words appear in Section 6 of the Statute which is still referred to in the present Australian Patents Act as the basis for defining an invention.

Originally there was no requirement that the inventor should describe his invention in writing but conditions written into the grant required that demonstrations of the invention were to be made, apprentices and the public were to be instructed, facilities for witnessing manufacture were to be provided and the invention or a model were to be set up within a definite time. The equivalent conditions today involve the lodging of a detailed specification which fully describes the invention and the best method known to the inventor of performing it. The specification must also end with a set of claims clearly delimiting what is claimed as the invention. If the inventor himself does not work the invention in a reasonable time there is provision for the grant of compulsory licences so that others may do so.

WHAT IS PATENTABLE?

The basis for deciding what is patentable in both British law and Australian law, which is derived from the British, lies in Section 6 of the 1624 Statute of Monopolies referred to above. To be eligible for grant of monopoly an invention must fit within the words 'any manner of new manufacture'. It must be 'new' and it must be a 'manufacture', both words requiring careful definition because of their legal significance in this context.

The requirement of newness or novelty involves something more than just a difference over what was known before. There must be an inventive difference, something more than would normally be expected of a skilled man in the particular field. Thus, by way of example, a 'new' sausage making machine which was simply a combination of a known mincing machine and a known filling machine driven on the same shaft was held not to be patentable and a 'new' application of fish plates for joining rails was held to be too closely analogous to earlier use for joining bridge girders to be 'new' in the patent sense. Nevertheless a novel invention may be extremely simple in its final embodiment without detracting from the ingenuity of the inventor, witness the hairpin and the zip fastener.

The interpretation of what is a 'manufacture' is a question which has often exercised the courts when deciding questions of patentability. It is interesting to see how the definitions given in succeeding court decisions have gradually changed in line with changes in the character of industry and the needs of society.

Clearly there is no difficulty in accepting something tangible, which has been made, as a manufacture, but it will be seen that this is insufficient if patents are to serve a real purpose. As early as 1790 the courts decided that a process of manufacture came within the definition. They have had some difficulty since in trying to decide whether a process which does not result in some tangible product may be included within the definition. For some time Australia followed the English Courts in holding that unless some saleable end product could be identified there was no 'manufacture'.

By 1957 the definition had been widened sufficiently to allow a method of dispersing fog to be patented on the grounds that the production of a fog free atmosphere could be a factor in the site value of the land where the process was applied. This English Court decision was followed soon afterwards by an important Australian case in which the National Research

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and Development Corporation sought to have a process for the selective destruction of weeds growing in a lucerne crop declared patentable. The High Court of Australia held the process patentable and in doing so established new guidelines for deciding the patentability of a process. It now seems that as long as some artificially created object, or state of affairs, which has economic value can be identified then the process involved may be patentable.

Certain things, however, remain not patentable. For instance it would appear that processes for the treatment of the human body cannot be patented. The same processes applied to animals may be patentable, presumably because they can have an assessable economic value in terms of the saleability of the animal or animal product. Business schemes are not patentable nor are mathematical methods as such, though apparatus which enables them to be carried out or relies on their validity may be patentable.

Of particular note is the fact that computer programs are not yet patentable in Australia and it is of some concern to those who are in the software business that the copyright laws are not adequate to protect their product either (Ref. 3). Perhaps there is some logic in this situation in the sense that a modern computer is approaching the infinitely adaptable machine and having invented this there is no patentable merit in finding a new adaptation. It is certainly the case that the courts have refused patents which amount to no more than sets of instructions for operating existing machinery; a new takeoff procedure for an existing aircraft was held not patentable, for example. On the other hand patents are granted when new applications are found for known chemicals. By analogy it might be argued that patentable inventivity is involved in finding a new application for a known computer. The more ingenious programs would then merit patents. There is some indication from the latest English court cases that in some circumstances 'processes for the conditioning of' computers and ancillary equipment to achieve certain results can be patented.

As a final requirement to sustain a patent it is of course necessary that the invention should be useful. If it has no purpose or does not work in the way the inventor says it should when his instructions, as set out in the specification, are carefully followed then the patent will fail for 'inutility'.

THE PATENT SPECIFICATION

The document which serves to define for the patents office (acting for the Crown) and the public, what it is that the inventor claims to have invented, is the patent specification.

The patent application may be accompanied by either a provisional specification or a complete specification. The only requirement of a provisional specification is that it should describe the invention. A complete specification is required to describe the invention, give details of the best method of performing it known to the inventor and include a set of claims, specifying exactly what the inventor believes he is entitled to monopolise as his invention.

The provisional specification is filed at the Patent Office as a record of the fact that the inventor had thought of his idea at least by the date when he lodged his application. It establishes his priority to claim the invention as his own. If he is to take advantage of the priority date established he must follow up with a complete specification within 12 months of the application date. Anything he claims which is fairly based on the disclosure in the provisional specification will then be accorded a priority date corresponding with that first disclosure.

In effect this gives the inventor 12 months in which to consider all the possibilities of his invention, develop it further if necessary and take initial steps to find out whether there is sufficient chance of commercial exploitation to justify the extra expense of lodging a complete specification and going ahead with the application. If the application is not completed the provisional specification remains confidential within the Patent Office and as long as the invention has not been published in the meantime a new application could be started at some later date.

The complete specification and particularly the claims it contains have to be very carefully prepared if the applicant for a patent is to obtain worthwhile protection for his patent. It is usual to hire the services of a skilled patent attorney to prepare and lodge the specification. He must ensure that the description of the invention is complete and unambiguous and is so worded as to include, without necessarily describing them in detail, all possible variations of the invention as a basis for the claims. The method of performance must be described in sufficient detail for persons skilled in the appropriate arts to follow without difficulty. This does not necessarily mean that sizes, materials, times and temperatures etc. must be specified exactly. It is permissible to leave the skilled person to experiment to some extent to achieve the specified results but he must not be left completely in the dark over some aspect or faced with a choice of possibilities, some of which will not work.

In the final analysis it is the claims appended to the specification which determine how good the patent is in protecting the invention. They must of course be fairly based on the description of the invention and they must be drawn wide enough to protect the invention in all its variations without being so wide as to include any of the prior art. If the claims are not wide enough it will be too easy for somebody to use the essence of the invention without infringing the patent. If they are too wide the patent will not be granted or will be held invalid because it includes something which is already known.

Because of the difficulty of being sure of what is already known it is permissible, and usual, to include a series of graded claims starting with a wide general claim and proceeding to narrower claims in which various features of the invention are specified in more detail. If the wider claims are disallowed because they include some of the prior art then narrower claims, including, hopefully, the preferred form of the invention, may still be available to give the inventor some protection.

APPLYING FOR A PATENT

The process of obtaining a patent involves a series of steps which may take place over a period of several years. For an inventor resident in Australia the process will usually start with the lodging of an application accompanied by a provisional specification, followed 12 months later by a complete specification if the inventor is still convinced that he has something good. In fact nearly two thirds of applications started with a provisional specification are allowed to lapse or are withdrawn before a complete specification is lodged.

Once a complete specification has been lodged at the Patent Office the next step is examination. Previously, every complete specification would be examined in its turn unless it had been positively withdrawn. Changes made in the Patents Act which came into force in January 1970 provide that an application is only examined on the request of the applicant. This change was aimed at reducing the examination load on the Patent Office, which now only examines applications which are still of interest. Examination may not be deferred indefinitely of course. If some other party has an interest in the fate of an application he may, for a fee, ask the Commissioner of Patents to direct the applicant to request examination. The Commissioner may on his own discretion also direct a request for examination at any time up to five years from the lodging date. If a request is not made within the time allowed the application lapses.

The examination of a patent is carried out in the Patents Office by an examiner specialising in the subject field of the patent. He checks whether the application and specification complies with the Patents Act and whether the invention is in fact novel. This means in particular that he must report whether the description of the invention is sufficient, so that the public will be able to use the invention when it becomes public property at the end of the monopoly period and whether the claims are fairly based on what is described as the invention. The novelty check is limited to a search of the patents office records of published patent specifications lodged in Australia within fifty years before the date of the patent under examination. However, other information of which the examiner has knowledge may be taken into account in certain circumstances. A new clause inserted into the Act in 1969 provides that after a patent specification has been made open to public inspection any person may submit to the Commissioner published documents which he feels would affect the validity of a patent if granted.

If the examiner is satisfied, the patent specification will be accepted. If his report is adverse then the applicant will be given the opportunity to amend his specification to meet the examiner's objections. If he disagrees with the validity of objections he may be heard by the Commissioner who, after hearing both sides of the argument, may allow or refuse the case. An appeal against a refusal may be made to the Patents Appeal Tribunal, from there to the full High Court and finally to the Privy Council.

If the application is accepted this fact is advertised in the Australian Official Journal of Patents. Any person who can show that he would be affected in some way by the grant of the patent then has six months in which to lodge an opposition to the grant on various grounds including alleged lack of novelty of the invention or lack of 'invention'. The opposition, if any, is heard by the Commissioner with the possibility of appeals as above.

Assuming the application survives any opposition, it then becomes eligible for sealing, on payment of the appropriate fee which then keeps it alive for 4 years. Further fees are payable annually thereafter to renew the patent up to a total of 16 years from the date of lodgement of the complete specification. These fees rise from $12 for the fifth year to $50 for the sixteenth year. Extension beyond 16 years is only possible in special circumstances if the patentee can show he has suffered loss due to war or that he has been inadequately remunerated for a meritorious patent which was difficult to exploit. Such extensions are relatively rare.

The sealing of a patent gives the patentee the right to sue infringers of his monopoly which is the right to make, use, exercise and vend his invention. However, it does not make his patent immune from attack. A patent may be revoked at any time on application by the Attorney-General or any other person to the High Court.

The grounds for revocation include all of those grounds of lack of novelty, incompleteness of description and lack of invention on which the examiner must report or which an opponent may raise. There are also some additional grounds such as that the alleged invention was not an invention within the meaning of the Act, it was not useful, the patent was obtained on a false suggestion or that it has been used secretly in Australia before the priority date of the claim. An application for revocation will most often appear as a counter claim from a defendant being sued by the patentee for infringement of the patent. A long and expensive legal battle may then ensue as by the time such actions occur both sides may well have large financial investments at stake.

INTERNATIONAL ARRANGEMENTS

So far, only Australian patents have been discussed. The grant of an Australian patent gives the inventor, or his assignee, protection in Australia only. If he wishes to protect his idea in other countries he must apply individually to the patents offices in all the countries concerned. There is no such thing as a world patent.

However, there is an International Convention for the Protection of Industrial Property which at least makes sure that the foreign applicant is not at a disadvantage relative to the native inventor. The main provision of importance to the applicant for a patent is that, if an application for a patent is made in any of the countries subscribing to the Convention, priority is then assured for a period of 12 months in all the other countries as though an application had been lodged in each. In order to maintain the priority date of the first lodged application, individual applications must be made in each country within the 12 months period of grace.

It is interesting to note that the Soviet Union is a subscriber to the International Convention as are some other Communist countries. They seem willing to pay royalties on their use of foreign inventions on the basis that by doing so they can expect a return when their inventions are used by other countries. It would seem that an inventor within one of these countries is bound to assign his invention to the State, but in return he receives at least a "Certificate of Authorship" and usually a direct financial reward calculated in terms of the value of his invention to the State.

An inventor will need to be fairly confident of the value of his invention before he embarks on a major world-wide patenting programme. He will almost certainly require the services of patent attorneys and will therefore be involved in costs averaging $500 or more per country to have his applications lodged for him. The best use the private inventor can make of his 12 months period of protection under the International Convention is therefore to find a commercial enterprise which is interested in taking up his idea and making the most of its exploitability.

Whilst there is at present no 'World Patent,' international discussions are currently working towards some simplification of the process for obtaining protection in several countries (Ref. 4). Present suggestions are for a system which would reduce the duplication of searching effort which at present takes place as each country's patent office tries to determine the novelty of an invention separately according to its own rules. The proposed system would involve the designation of two or three major countries as search centres and novelty searches done by these centres would be accepted by other countries. There are also proposals for simplifying the method of lodging applications in selected countries after a basic application has been made in one country.

Australia has gone some way towards accepting the fact that it is most probably duplicating work by doing a novelty search on patent applications where a patent has already been granted in another country.

Under amendments to the Patents Act made in 1969, an applicant for an Australian patent under the International Convention may request an abbreviated examination of his patent application if he has already been granted a patent in another country. The other country must be one which has done a novelty search and the Australian specification must be the same, apart from matters of form, as that lodged overseas.

OWNERSHIP

An invention is a piece of property which may be owned, sold, transferred, left in a will or otherwise dealt with in much the same way as a piece of real estate. It starts life as a product of the intellect, 'intellectual property', in much the same way as a work of literary, dramatic or musical art. In common with such works it is recognised that the first owner is the person who conceives the idea. However, whereas the author of a literary, dramatic or musical work is automatically protected by the Copyright Act, without having to register his work in any way, the inventor is required to peg out his claim and obtain title to his property by way of an application for a patent. If he simply publishes his idea it is tacitly assumed that he is giving it to the public.

There are some special exceptions to this assumption. For example, if the publication is by way of an exhibition recognised by the Attorney-General or by way of a paper read to or published by a learned society, a patent may still be obtained if application is made within a specified limited period after such publication and the other conditions laid down by the Patents Act have been met. Great care needs to be taken in interpreting these conditions and it is as well to avoid any publication, if possible, before a provisional patent specification has been lodged. It is quite possible, for example, that the publication somewhere else of an abstract of the learned society paper could constitute publication of the invention which would invalidate any claim to a patent.

Whilst the first owner of an invention is of course the inventor he may, if he is an employee who is expected to produce inventions as part of his duties and the invention is in the field of operations of his employer, be required to assign ownership of the invention to the employer. This requirement may be spelled out in a contract of employment. If it is not it applies as a common law right which derives from long established legal precedent resulting from court examinations of the master/servant relationship in numerous cases, over hundreds of years.

Since there is no written contract of employment in the Commonwealth Public Service it is the common law principle which applies to any inventions made by Australian Post Office staff. It is difficult to generalise to give any satisfactory indication of what the position would be in a given set of circumstances because this will depend very much on the nature of the invention, the area of employment and instructions or requests which may have been given to the employee concerned. However, it can be expected that the Commonwealth of Australia will be entitled to the assignment of most inventions made by Engineers and other professional staff if they are at all related to the areas in which the inventors are working. In the case of inventions by technical staff, ownership may depend on whether they have been made on the inventors' own initiative or have resulted from work which the inventors have been asked to carry out. Other staff are unlikely to be expected to invent and would normally be entitled to retain ownership of inventions they make even if they relate directly to Post Office activities.

Where an invention is made in the course of normal duties there is no provision in the C.P.S. for any special reward to the inventor. Where an inventor has gone beyond what is expected of him in the position in which he is employed then he may be entitled to an award under the Post Office Suggestions Scheme (Ref. 5). This is similar to the practice in most large commercial organisations both in Australia and overseas, though in some places token awards may be made as an incentive, even to those who are employed in a situation where they are expected to invent. It differs from the position in academic institutions where a staff member will usually be permitted to retain his invention, share in its ownership, or at least receive a share in any profits from its exploitation by the institution.

EXPLOITING INVENTIONS

The hopes of a patentee are, naturally, that he will gain in some way from his patent, preferably financially. It is of course a main purpose of the patents system that the inventor should be given the opportunity to benefit from his ingenuity as long as the public also benefits. However, there is no guarantee in the system that there will be any reward for every invention. It will not matter how much ingenuity has gone into the invention, if it is not something the public wants there will be no reward. In fact, only a very small proportion of inventions make money for their inventors.

By way of example the experience of the National Research and Development Corporation in Britain may be quoted (Ref. 6). N.R.D.C. was established for the specific purpose of ensuring that worthwhile inventions should not be lost to the nation for want of some initial interest by industry or because of lack of funds for development. In 19 years, from 1949 to 1968, N.R.D.C. was offered some 8800 inventions resulting from Government financed research.

Just under half of these were accepted for further development and exploration of licensing possibilities but only 350 marketable industrial products have resulted. Thus less than one in twenty inventions resulting from professional research work was commercially successful and the figure for private inventions will be much lower.

The major benefits of N.R.D.C.'s activities appear to accrue not always to N.R.D.C. and the inventors but to the users of the inventions who find they can operate more cheaply and efficiently by having access to the new inventions. Thus the farsightedness of the thinking behind the introduction of the patent system ' . . . . that our realm may subsist more of itself; that idleness be avoided, and the drawing out of our treasure for foreign manufacture be stopped' (Chancellor Moreton, in the time of Henry VII, Ref. 1) seems to be vindicated. The nation benefits in the long run by protecting the ingenuity of the inventor and allowing (and even assisting) him to collect some reward for his ingenuity during a limited period of monopoly.

The words of Chancellor Moreton might well be applied to Post Office policy in relation to the encouragement of Australian manufacture of its needs. Its aim is to see that Australia contributes at least a proportionate share of new developments in the telecommunications field. It is expected that some of the developments will result in products for which there is a market overseas or in other fields in Australia. Present Post Office policy is therefore to cover inventions arising from developments it carries out or finances by patent applications where appropriate. As well as the possibility of direct earnings in the form of royalties a favourable bargaining position is created for the exchange of know-how with overseas administrations and manufacturers.

The Post Office has in fact recently concluded an agreement with the Western Electric Company, U.S.A. for a royalty-free exchange of rights in each others' inventions. Western Electric handles all patents for the Bell Telephone System in U.S.A. and the agreement therefore relates to inventions of all A.T. and T. companies including Bell Telephone Laboratories. It covers all fields of telecommunications but excludes inventions related solely to mail-handling. The Post Office gains free use only of Western Electric's 'systems' patents which apply to systems as they are installed and operated by an administration. The agreement does not disturb the Post Office's relationship with Australian manufacturers who are normally required to negotiate appropriate rights to patents involved in equipment being supplied to the Post Office. Its main effect is to facilitate the flow of information between the two organisations. Inventions arising from the interchange of ideas will be freely available to both parties under the agreement.

In the field of telecommunications, where operations are carried out in most countries by government departments or government controlled administrations, and much of the research and development work is carried out under government sponsorship, it may well be that the arrangement of royalty-free exchange agreements would largely obviate the need for expensive patenting action. It would be necessary to accept that all administrations tend to produce new ideas at a rate proportional to their size and therefore also to the value they obtain from new ideas arising in the field. If this were in fact the case then the necessity for patenting of inventions with application only in the field of telecommunications would disappear. The incentive to finance research and development would lie in the need to establish acceptability as a member of the circle exchanging ideas and information. In the meantime international patenting of its own ideas is the only way an administration can hope to offset the payments it or its contractors have to make for the use of ideas conceived elsewhere.

POST OFFICE INVENTIONS

With this in mind the Post Office is now being much more protective of its own ideas and inventions. Formerly the results of research and development work carried out or financed by the Post Office were made freely available to Australian industry in the interests of establishing a healthy local telecommunications manufacturing capacity. The position has now been reached where local industry is well established and is beginning to compete on world markets. It is therefore considered that the Post Office may expect some return for its technical and financial contribution to new developments in its fields of interest. Greater emphasis is therefore being placed on the use of patents to protect the possibility of earning royalties or entering into exchange licensing agreements.

Responsibility for examining new Post Office developments for possible patentability, and initiating the necessary action where appropriate, rests with the Post Office Patents Officer located in the Research Laboratories. This includes a general oversight of the industrial property aspects of research and development contracts proposed anywhere within the Post Office and the protection of Post Office industrial property involved in other contracts. The majority of new Post Office inventions arise from work carried out within the Research Laboratories. The table shows the subjects and inventors of 12 new inventions for which patent applications have been started in the two years following the change of policy. Prior to this only seven inventions in the previous 18 years had been followed up with patent applications and until patents are granted on some of the current applications the Post Office has only five valid patents and a registered design. These relate to a cable jointing technique (U.S.A.), a subscriber instrument tester (U.S.A. and Australia), telephone dials (2 Australian patents) and the 800 series wall telephone case design (Australia and New Zealand).

In addition the Post Office has acquired an interest in patent applications originating with the University of N.S.W., for a novel form of cable with built in amplification, and with Monash University, for a novel form of self adapting hybrid circuit. It also

TABLE 1: CURRENT A.P.O. PATENT APPLICATIONS

Subject	Inventor(s)	Countries
Vandal Proof Public Telephone	K. B. Smith and A. A. Rendle	Australia, Britain, Japan
Dual Vibrating Tine Cable Plough	E. W. Corless	Australia, South Africa, U.S.A.
Tip Welding Tool for Cable Jointing	E. Bondarenko	Australia, Britain, U.S.A.
Analogue Multiplier	H. Bruggemann	Australia, Britain, Germany, Japan, U.S.A.
Semiconductor Light and Magnetic Field Detector	N. F. Teede	Australia, Britain, Germany, Japan, U.S.A.
Improved Trunking Method (For Integrated Switching and Transmission)	A. Domjan	Australia, Belgium, Sweden, Holland, France, Britain, Germany, Japan.
Self Adaptive Filter and Control Circuit (Echo Cancellation)	L. K. Mackechnie	Australia, U.S.A., Britain Germany, Japan, Italy, Sweden, France, Holland
Reduction of Error Noise in P.C.M.	P. Glick	Australia (Provisional)
Digitally Tuned Detector	J. Lewis	Australia (Provisional)
Fluidic Detector and Double Letter Separator	R. Kilby	Australia (Provisional)
Pulse Generator and Flip-Flop	I. Macfarlane	Australia (Provisional)
Faulty Circuit Detector	N. McLeod	Australia (Provisional)

has rights in mail-handling equipment developed under contract by Plessey Pacific Pty. Ltd.

PATENTS AS INFORMATION

Patent specifications are of course a valuable source of information giving details of new developments which have taken place. They become open to public inspection 18 months after the application has been completed and at this stage the Patents Office publishes abstracts sheets usually giving the first claim of each specification. These abstract sheets are used to provide a patent watching service for the information of the Post Office Research Laboratories and other Central Office staff. Abstracts of patents which appear likely to be of some interest to the Post Office are circulated to appropriate officers in a form of SDI (Selective Dissemination of Information) service. Copies of the abstract are also filed to provide a retrospective searching facility. Where further information is required copies of complete patent specifications are obtained from the Patent Office in Canberra.

A watch is also kept on patent applications accepted for grant of a patent as advertised in the Australian Official Journal of Patents. If necessary, action can then be taken to oppose the grant of a patent where there is a conflict with Post Office interests and suitable grounds for opposition appear to exist.

For example the grant of a patent for a Mylar electret, the electrical analogue of a magnet, was recently successfully opposed. Post Office interests arose because of the possible application of electrets in telephone transmitters. It was shown that papers describing Mylar electrets, written by Bell Telephone Laboratories authors, had been published in Australia before the priority date of the patent applications.

CONCLUSION

The Australian patents system with its origins in mediaeval England still serves as the best available protection for the individual inventor. The system has developed and been refined, particularly in respect of the definition of what may be patented, but it is inevitably a step or two behind the needs of developing industry.

On a world-wide basis the protection of an invention by patenting is a cumbersome and expensive process. Patenting may not necessarily be the most appropriate way of protecting the exchange of know-how in the telecommunications field where governments hold a monopoly of operations in most countries. However, until there are improvements in international arrangements for patenting, or perhaps agreement on mutual sharing of know-how between administrations, the available system is the only way of protecting Post Office industrial property which may then be leased or exchanged for know-how originating overseas. Post office activity in this field is in fact increasing following a change of policy in 1968 which recognized the advanced stage of development reached by the Australian telecommunications industry.

REFERENCES

1. Patent Office, Australia, 'Notes on the history of the British and Commonwealth Patents Acts and the law relating to letters patent for inventions in Australia'; 4th Edition, 1969.
2. K. B. Petersson, 'The Inventor and the Patent Law'; Proc. I.R.E.E. (Aust.) May, 1966, Vol. 27, No. 5, pp. 113-121.
3. R. Malik, 'Who Owns Software? The Chaos Continues'; New Scientist 20th Nov., 1969, pp. 406.
4. E. Gelles, 'Towards the World Patent'; New Scientist, 3rd April, 1969, pp. 15-17.
5. R. C. M. Melgaard, M. S. Finlay, 'Suggestions Schemes — an Aid to Management'; Telecom. Journal of Aust., Feb. 1959, Vol. 11, No. 6, pp. 191-196.
6. K. Grossfield, 'The Role of N.R.D.C.'; Physics Bulletin, May, 1969, Vol. 20, pp. 69-172.

FURTHER READING
(For the budding inventor)

1. C. Lees, 'Patent Protection, the Inventor and his Patent'; Business Publications, London, 1965.
2. Patent Office, Australia, 'Guide for Applicants for Patents'; Govt. Printer, Canberra.
3. P. Fairley, 'Project X — The Exciting Story of British Invention'; Mayflower, 1970.

MELBOURNE TEST AND FAULT DESPATCH CENTRES

*R. G. NELSON, M.I.E. Aust., M.I.E.E., Assoc. M.C.T.**

Editorial Note: This article describes the Fault Despatch Centre at Brunswick, Melbourne and illustrates the basic approach of the Victorian Administration to the initial fault testing and to the despatch of a faultman on subscriber complaints in the Melbourne network. In the next issue of the Journal will be a description of the development of Fault Despatch Centres in the Brisbane network. Whilst these centres have a common purpose, there are some variations in the basic organisation and procedures employed, and these are described in the two articles.

INTRODUCTION

This article describes the facilities and operation of a typical Fault Despatch Centre (F.D.C.) in the Melbourne metropolitan area. Some information on the evolution of these centres and possible future trends has been included.

Bulte (Ref. 1) summarised briefly the initial steps of the establishment of F.D.C. in Melbourne and listed the main advantages of centralising the control of substation equipment maintenance.

During the six years which have elapsed since then, 1964, further centres of varying size, complexity, and functions, have been established, but all the advantages then listed are still being obtained. For convenience they are repeated here:—

(a) An overall greater manhour efficiency due to the operation of a large group as against several smaller, independent groups.
(b) Better field supervision of work.
(c) More specialised attention can be given to faults.
(d) A closer control over the handling of urgent faults.
(e) More economical stores handling.

Centres have since been established at Footscray, Malvern, South Yarra, Brunswick, Russell and Ivanhoe and all except the Brunswick Centre are located at telephone exchanges; Brunswick F.D.C. is in leased premises very close to Brunswick telephone exchange. The original centre, Collingwood, was replaced by Ivanhoe F.D.C. because the available space at Collingwood was insufficient to accommodate all the staff and facilities required. Centres first established at North Melbourne and Hawthorn were replaced by centres at Brunswick and Footscray and South Yarra.

Also, since 1964, the F.D.C.s have taken over the testing of telephone services and the maintenance of P.A. B.X. equipment. On absorption of the testing function, the name was changed to Test and Fault Despatch Centre (T.&F.D.C.)

SIZE AND LOCATION OF CENTRES

Some of the factors governing the size of a centre are:—

(a) Each T.&F.D.C. should have sufficient work to justify the employment of a reasonably large number of people.
(b) The number of persons employed at a centre should not be so large that control by a Senior Telecommunications Technical Officer is not practicable.
(c) The centre should have an easily identifiable geographical area consisting of a number of complete telephone exchange areas.
(d) The related Line Fault Despatch organisation should be in the same room as the T.&F.D.C. because close co-operation between the two is essential. This means that T.&F.D.C. boundaries should coincide with Metropolitan District Works boundaries.

Some factors which influence the location of a T.&F.D.C. are:—

(a) A site large enough to accommodate a building having on one floor an area of about 4000-5000 square feet, and able to cater for the parking of about 25 vehicles is needed.
(b) The exchange to which the centre is to be connected should have ready access by cable to all the exchanges in the centre's area.
(c) The centre should be close to the "work centre" of its area and it should have ready access to public transport.

Consideration of these factors has led to the conclusion that, for the time being, the locations and areas for the T.&F.D.Cs. should be as shown in Fig. 1 and steps are being taken to implement this. The establishment of the centres at Brighton and Blackburn is well under way, the existing centres at Footscray, South Yarra, Brunswick and Russell will remain, and the Ivanhoe and Malvern T.&F.D.C.s will eventually close down. Later, the centre at Russell will move to Lonsdale Exchange and the centre at Brunswick will move to a site at Preston. At a much later stage a centre will be established at Oakleigh.

The boundaries of all T.&F.D.Cs. except Russell will coincide with Metropolitan District Works boundaries. The Russell Centre controls the city area, in which there is enough maintenance work to occupy fully the staff of a large T.&F.D.C., but there is little line maintenance work. The number of staff working at the centres will vary from about 45 to 85.

GENERATION OF WORK

Wth the exception of older types of P.A.B.Xs., corrective maintenance only is applied to subscriber's plant. Plant reliability is increasing with modern technology and further the subscriber can give prompt advice when performance is not satisfactory. A subscriber experiencing trouble with his service will dial 1100 and be answered by one of the three Service Centres — Russell (24 operators' positions), Hawthorn and Windsor (14 operators' positions each).

Consequently, almost all suburban maintenance activity is initiated by reports from the Service Centres. Reports from exchanges account for only a small percentage and are mainly reports of external plant faults detected by permanent ground alarms (PGs). Trouble Recording Registers in ARF exchanges (R.K.R.) and Automatic Line Insulation Routiners. A few exchanges are equipped with devices to monitor public telephone services and some reports are originated by these devices.

A great deal of clerical work is generated by the need to keep records up to date. For instance, cable transfers alone cause several hundred manhours per year to be expended in each centre on amending cable information on master cards.

BRUNSWICK TEST AND FAULT DESPATCH CENTRE

Although all T.&F.D.Cs. perform essentially the same functions, the procedures in all centres are not identical. This is because of variations in size, the type of work load and geographical area, and differences in the stage of evolution.

To simplify presentation, Brunswick T.&F.D.C. will be described. This is the longest established centre using the layout and equipment recommended by the Centralised Testing Working Party (Ref. 2) and its procedures are

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Fig. 1. — Test and Fault Despatch Centres — Locations and Areas.

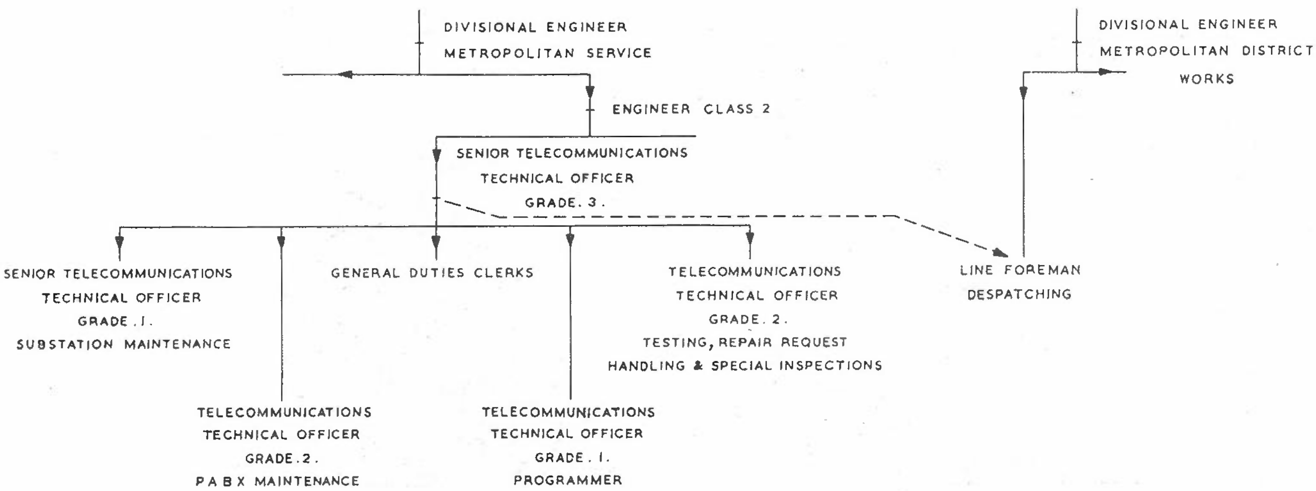

Fig. 2. — Organisation Chart — Test aud Fault Despatch Centre.

fairly typical of those at the other centres.

The apparatus maintained by Brunswick T.&F.D.C. includes 100,000 telephones and 150 P.A.B.Xs to which 2,500 exchange lines and 15,000 extensions and tie-lines are connected. Just under 4,000 repair requests per week are processed there.

Activities

The activities carried out by the Brunswick T.&F.D.C. can be divided into seven main components which are:—

1. The maintenance of public telephones and subscribers' equipment.
2. The maintenance of P.A.B.X. switching equipment.
3. The handling of repair requests and the testing of services.
4. The despatching of technical staff to faulty services.
5. The despatching of line faultmen to faulty external plant.
6. General clerical duties (working reports, petty cash, vehicle returns, updating master cards, sorting and counting of fault dockets and compilation of repair statistics, handling of telephone orders).
7. Miscellaneous duties such as the handling of stores, special inspections, discussions with subscribers, handling letters of complaint, etc.

Organisation and Hours of Staffing

The organisation established to carry out the work of a particular body is determined to a great extent by the importance and demands of the individual activities carried out, and the experience and ability of the individuals attached to that body. The organisation of the Brunswick T.& F.D.C. is shown on the chart, Fig. 2.

A Senior Telecommunications Technical Officer Grade 3 (S.T.T.O.3) is in charge of the centre and subordinate staff are functionally grouped.

Activity 1 is carried out by a team of Telecommunications Technical Officers Grade 1 (T.T.O1s) and technicians for which a Senior Telecommunications Technical Officer Grade 1 (S.T.T.O.1) is responsible. A typical team is two T.T.O.1s, 18 technicians engaged on fault clearance work and a re-wire team.

A Telecommunications Technical Officer Grade 2 (T.T.O.2) having a group of 11 T.T.O.1s and lower grade staff carries out Activity 2.

A T.T.O.2 is in charge of Activity 3. His teams consists of two T.T.O.1.s, three technicians engaged on test desk work and two clerical assistants handling teleprinter slips, fault dockets and master cards.

A T.T.O.1 who is denoted programmer in the text and a clerical assistant handle work at the technicians' despatch console, while a Line Foreman Grade 2 and a Lineman Grade 2 man the linemen's despatch console.

General clerical duties are the responsibility of five clerical assistants under the control of the S.T.T.O.3 or the T.T.O.2 in charge of Activity 3.

Activity 7, miscellaneous duties is spread over the six functional departments.

The hours of staffing and the number of men required at a particular time are influenced by:—

(a) The rate of arrival of repair requests.
(b) The average time allowed between the receipt of a repair request and the repair of the faulty service.
(c) The number of faulty services awaiting attention.
(d) The need to visit exchanges after normal working hours to deal with exchange alarms, the reconnection of services, the release of held services, etc.

The hours of staffing and the number of men on duty vary from the ideal requirements because it is desirable to have as many as possible of the persons attached to the centre working normal working hours, 8.00 a.m. to 5.00 p.m. weekdays; split shifts and six-day weeks are avoided, and although the work load varies from hour to hour and day to day, the number of men on duty is arranged well in advance. The staffing outside normal working hours is as follows:—

From 7.00 a.m. to 8.00 a.m. a T.T.O.1. only is in attendance and is stationed in the centre. From 5.00 p.m. to 10.00 p.m. on normal week days a

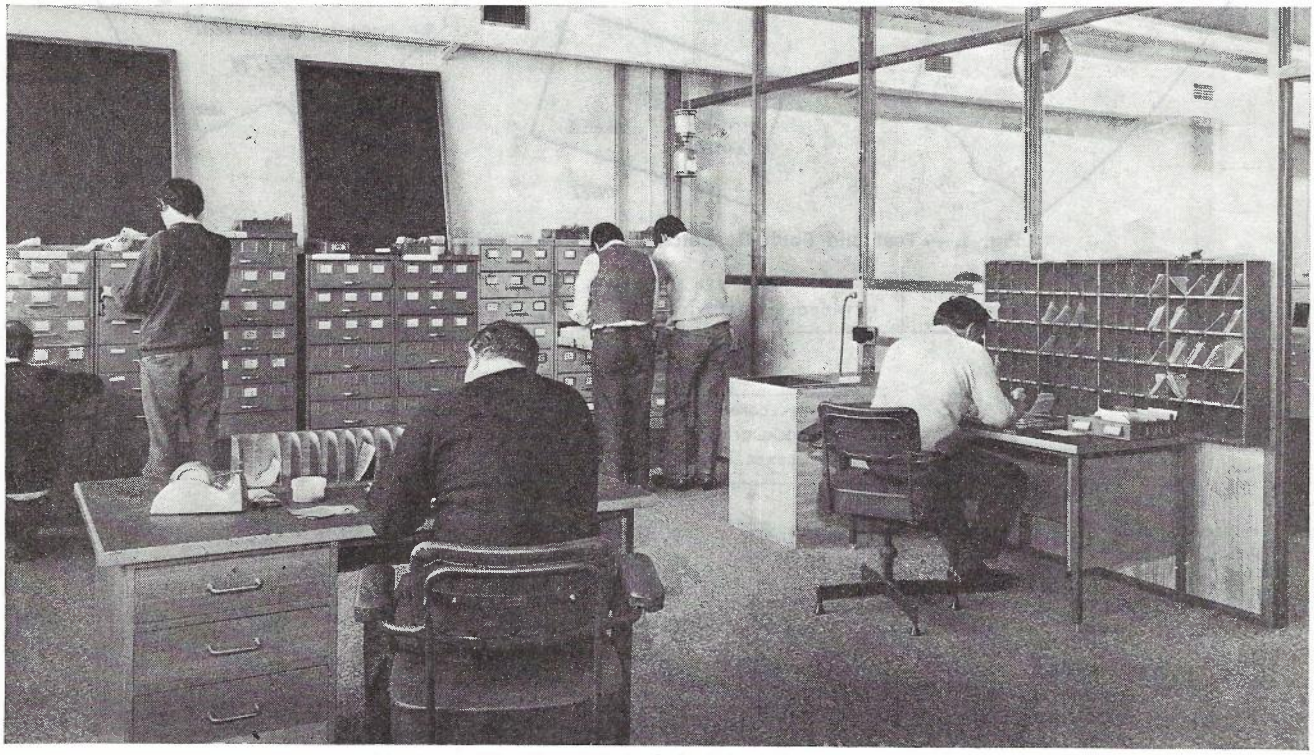

Fig. 3. — Clerical Assistant Area.

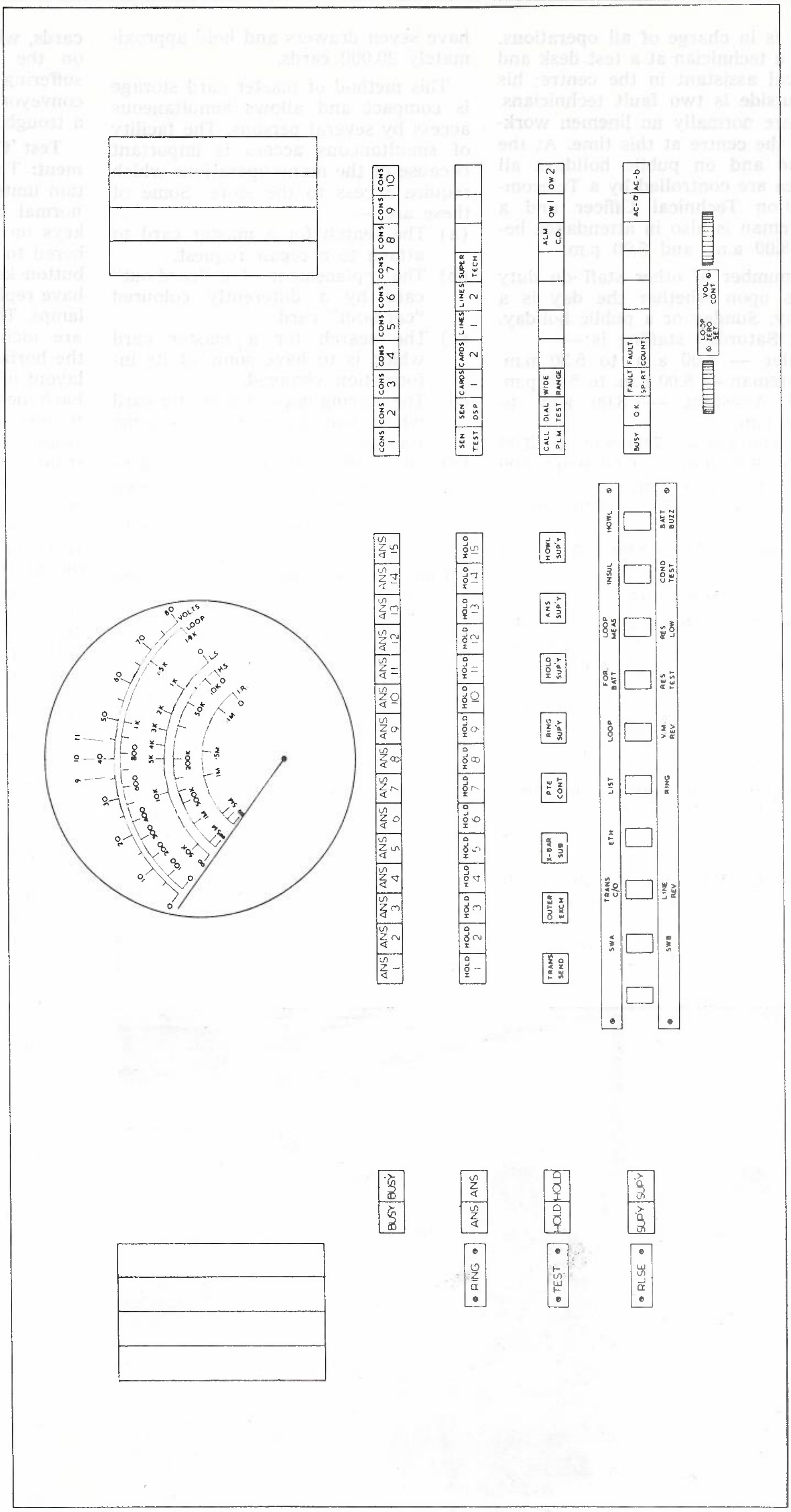

Fig. 4. — Layout of Test Console Panel.

T.T.O.1 is in charge of all operations. He has a technician at a test desk and a clerical assistant in the centre; his staff outside is two fault technicians. There are normally no linemen working for the centre at this time. At the weekend and on public holidays all activities are controlled by a Telecommunication Technical Officer and a line foreman is also in attendance between 8.00 a.m. and 5.00 p.m.

The number of other staff on duty depends upon whether the day is a Saturday, Sunday or a public holiday. Typical Saturday staffing is:—

Controller — 8.00 a.m. to 5.30 p.m.
Line Foreman — 8.00 a.m. to 5.00 p.m.
Clerical Assistant — 8.00 a.m. to 5.00 p.m.
Testing Officers — 7.00 a.m. to 3.00 p.m.; 9.00 a.m. to 6.00 p.m.; 3.00 p.m. to 10.00 p.m.
Fault Technicians (3) — 8.30 a.m. to 5.30 p.m.
Fault Linemen (4) — 8.00 a.m. to 5.00 p.m.

Apparatus

Teleprinters: There are four teleprinters in the centre. Two, connected as a rotary group, receive repair requests from the Service Centres; one is used for the receipt of information from the Finance and Accounting Branch, such as advice about disconnection and reconnection of services following delay in settling accounts; and one is used for the receipt of telephone orders from the local Sales Office.

Master Card Storage: Master cards are stored in specially designed filing cabinets with free running drawers. Most cabinets have six drawers, each with 3,000 cards, but later cabinets have seven drawers and hold approximately 20,000 cards.

This method of master card storage is compact and allows simultaneous access by several persons. The facility of simultaneous access is important because of the many operations which require access to the store. Some of these are:—

(a) The search for a master card to attach to a repair request.
(b) The replacement of a "card-out" card by a differently coloured "card-out" card.
(c) The search for a master card which is to have some of its information changed.
(d) The placing back of a master card which was taken out for some reason.
(e) The marking of a master card to indicate that the service has been disconnected.

The store can be seen in the background of Fig. 3.

Conveyor System: Cards, etc., are carried between the operating units by a ten track, straightline, flat belt conveyor system which has eight forward and two reverse tracks. It stretches from the clerical area to the technicians' despatch console and on the way feeds the test desks and the linemen's despatch console.

The conveyor system has been designed in modules to give flexibility in layout and to facilitate removal, if necessary. The modules, except for the end modules, are six feet in length.

Cards are placed on edge in the track to be carried to the required destination. At each test console and the linemen's despatch console a small wedge is inserted into a track and cards, when stopped by a wedge, ride on the belt at that point without suffering damage. At each end of the conveyor system the cards drop into a trough.

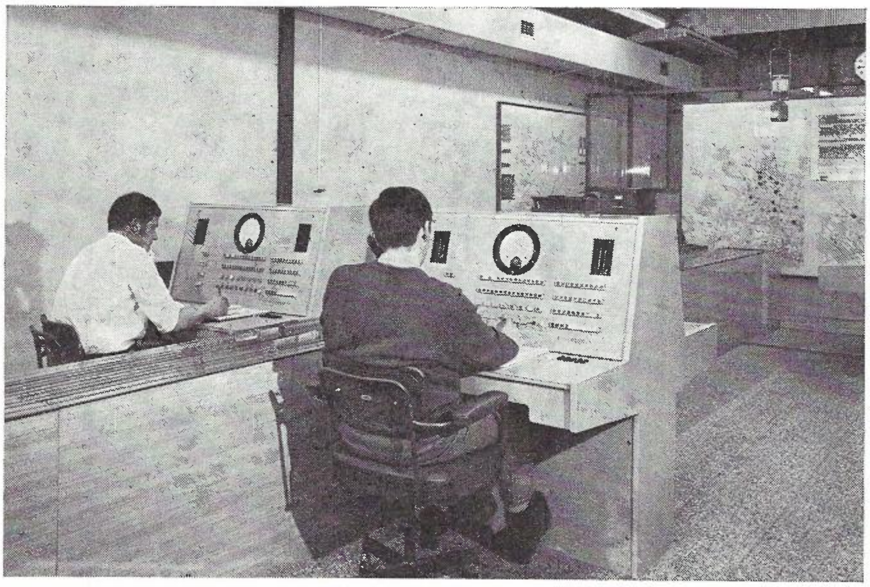

Fig. 5. — Test Consoles.

Test Console and Auxiliary Equipment: The test console are two position units to economise on space. The normal layout and positioning of test keys on the face panel has been adhered to wherever possible, but pushbutton keys and miniature lever keys have replaced the older lever keys and lamps. The face panels of the consoles are inclined at an angle of 75^0 to the horizontal. Figs. 4 and 5 show the layout of the equipment on the panels. Each desk has two individual trunks to test distributor selectors and provision has been made for 15 incoming trunks. Some changes from normal have been made and these will now be described.

Avoidance of Correction Factors. Test pairs between the test centre and the local exchanges vary in capacitance and resistance. While the differences can be taken into account by the use of correction factors for each exchange, it is far more convenient to make tests which do not need this.

Insulation testing and the detection of foreign battery are virtually uninfluenced by the cables which connect the test centre to the local exchanges; dial testing, loop resistance measurements and the location of ' open circuits" are severly affected.

Correction factors have been avoided by:—

(a) The use of pulse length monitors preceded by Dial Testing Impulse Repeaters to reshape the incoming distorted impulses for dial testing.
(b) All test pairs have resistors inserted at the local exchanges so that the test pair loop resistance is two thousand ohms. A "floating" 24 volt supply is provided so that the loop resistance of lines can be read directly. Fig. 6 shows the relevant circuits.
(c) Test pairs have capacitors placed across them at local and intermediate exchanges and are combined into capacitance groups. All members of a group have the same total capacitance. A multivibrator which automatically applies constant frequency line reversal conditions to the test pair is brought into circuit when the Condensor Key is operated. This allows the meter deflections to be read accurately and gives greater precision in the location of open circuit faults.

Digit Translation. For simplicity, a testing officer should need only dial

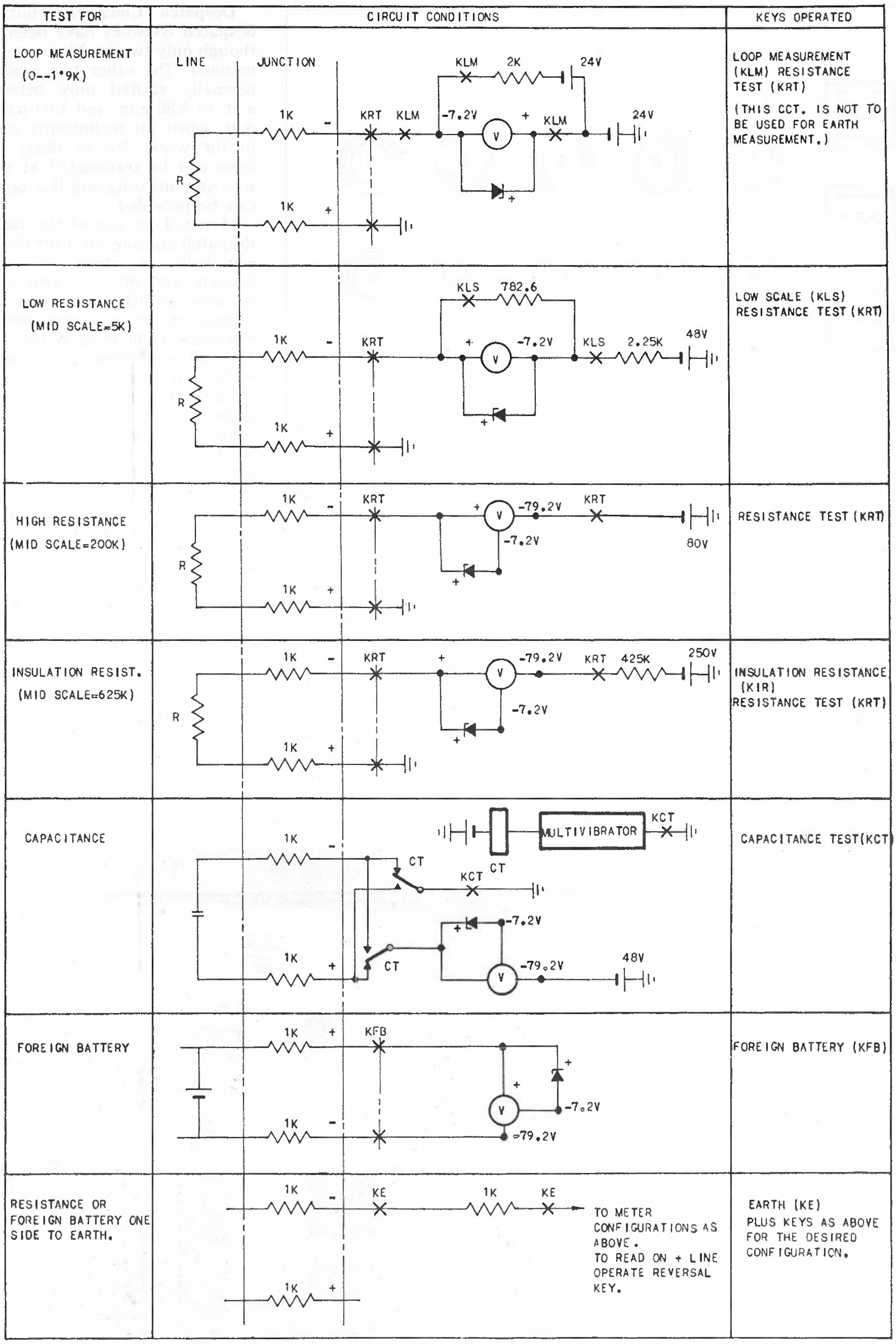

Fig. 6. — Test Desk — Testing Circuit.

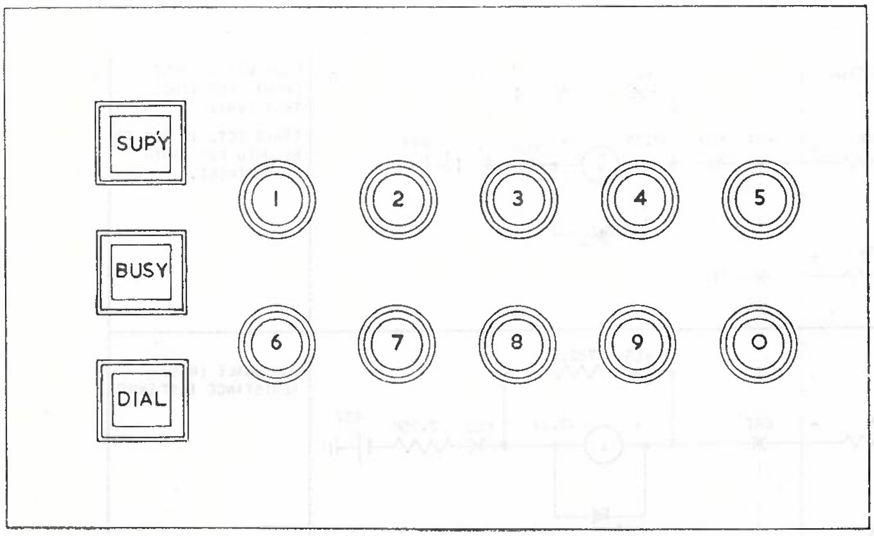

Fig. 7. — Keysender Panel.

a subscriber's directory number to gain access to his service. Digit translators have been provided which store the digits sent from a key-sender, change the directory number to the code required to gain access to the required exchange, and send out all necessary digits.

A translator also informs the testing officer of the type of equipment at the remote exchange and the capacitance group. Equipment is split into three types—step bp step, crossbar and SR-B, and in practice, it has been found convenient to divide the exchanges into three capacitance groups.

The crossbar sub lamp shows to the test desk operator the type of exchange equipment. This lamp glows permanently when the called number is connected to crossbar equipment, it flashes for a line connected to SR-B equipment, and it remains extinguished for a step by step number.

The "Outer Exchange" lamp indicates in which capacitance group the exchange to which the operator is connected lies. Depending upon the capacitance group the lamp will glow permanently, flash or remain extinguished.

Keysender Key Panel. No dial is provided on the test console; instead a keyboard mounted on the writing table section of each console is used to insert digit information into the translater.

Fig. 7 shows the keyboard. The 'dial' key is pressed to seize a translator and the supervisory lamp glows when the translator is transmitting digit information.

Selector Release. A selector release key is not needed. Circuits at the local exchanges have been provided which apply the selector release condition on the application of ringing current. The ring key therefore, performs the function of selector release key.

Orderwire. An orderwire circuit is associated with each of the trunk to test distributor selectors. The circuit consists of a single wire earth return speech circuit utilising the sixth wire of the test circuit. The orderwire is, therefore, automatically connected to the local exchange while the test is being performed; this obviates the need for a separate orderwire network.

Detection of High Voltage A.C. Potentials on Test Pair. Two neon lamps are provided to indicate the connection of A.C. supply potential to the 'a' and 'b' wires of the test pair.

Despatch Consoles: Four position despatch consoles have been provided though only two positions are normally manned. The other two positions are normally staffed only between 8.00 a.m. to 8.30 a.m. and 1.00 p.m. to 1.30 p.m. when all technicians are calling in for work. Up to thirty incoming lines can be terminated at each console and one outgoing line per position can be provided.

Mounted on top of the technicians' despatch console are four rows of pigeon holes in which are kept fault dockets and master cards for repair requests awaiting, (i) allotment to a technician, or (ii) the advice of a clearance code from a technician, or (iii) an appointment to visit a subscriber after he has been found not-in-attendance, or (iv) the receipt of parts.

Fig. 8 shows the technicians' despatch console and the rows of pigeon holes mounted on the top. The linemen's despatch console has three rows of pigeon holes for a similar purpose.

Magnet Boards and Magnets. A magnet board consists basically of a suitably mounted sheet of mild steel on which maps and other information are mounted. To ensure a long life the whole is coated with a thin sheet of plastic.

Fig. 9 shows a close-up of the technicians' magnet board which is 6ft. x 7ft. 6in. On the left half of the board is a map of the area maintained from the centre, and on this map has been drawn the relevant section of the key map of the street directory used by the outside faultmen. The top right

Fig. 8. — Despatch Consoles.

Fig. 9. — Technicians' Magnet Board.

section of the board has the magnet store and a chart which is used to indicate the progressive total of faults cleared by the outside staff, and there is also a store for the magnets which were allocated to faults subsequently coded T99, subscriber not-in-attendance. The bottom right hand corner has a map, to a much larger scale than the main map, of the outer city area which lies in the area maintained from the centre.

An auxiliary board 2ft. 6in. x 2 ft. is used to show the location of the P.A.B.Xs outside the city area and adjacent to this board is a stack of pigeon holes in which are posted faults dockets for P.A.B.X. equipment.

On the technicians' board the magnets used to denote the location of faulty services are 3/8in. in diameter, coated with coloured plastic, and sequentially numbered, while the magnets used to denote the location of technicians are 11/16in. in diameter and painted. Different colours are used for different classifications of faulty services. Some of the colours in use at the moment and the corresponding classifications are as follows:

Red	Urgent
Red on Yellow	Prompt
Black on Yellow ...	Minor
Green	Public telephone
Red on Blue	Upgraded minor
Blue	Appointments
Green on Yellow	Awaiting parts

A similar system is used on the linemen's board.

Power and Tone Supply Requirements: The following power supplies are provided:

50 V — provides power for the equipment and transmission requirements.

50 V + combines with 50 V — to supply 100 volts transmission battery.

24 V — and 24 V "floating", for loop resistance measurement.

80 V — and 250 V — for insulation testing.

The following tones and supplies are provided:

Busy tone.
Interrupted ring tone.
Ring — continuous and interrupted.
Interrupted earth.
Howler — standard sweep-frequency.

Standby A.C. Power and Lighting: Standby A.C. power for the teleprinters is provided by an invertor operating from the 50 V-battery and standby lighting is provided by butane lamps.

LAYOUT OF CENTRE

Fig. 10 shows the layout of Brunswick T.&F.D.C. The Centre is divided into three main areas:—

(i) The teleprinter and master card area.
(ii) The testing and despatching area.
(iii) Offices, store, equipment room and amenities area.

The layout has been designed to:—

Minimise staff movement and facilitate the flow of data.

Provide for adequate supervision by the Officer-in-Charge.

Isolate from other working areas the noise generated in the teleprinter and master card area.

Provide security for the store.

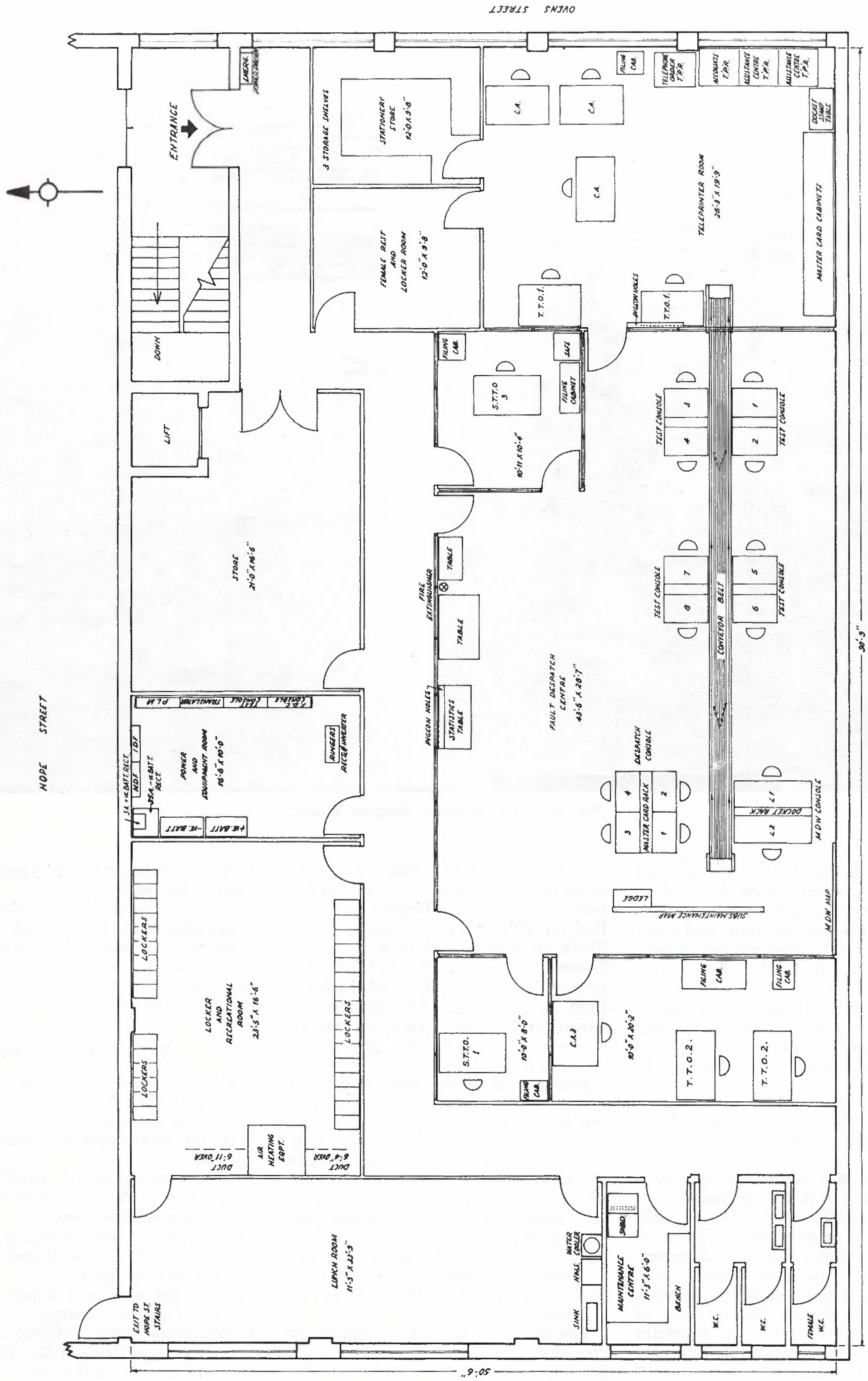

Fig. 10.—Layout of Brunswick Test and Fault Despatch Centre.

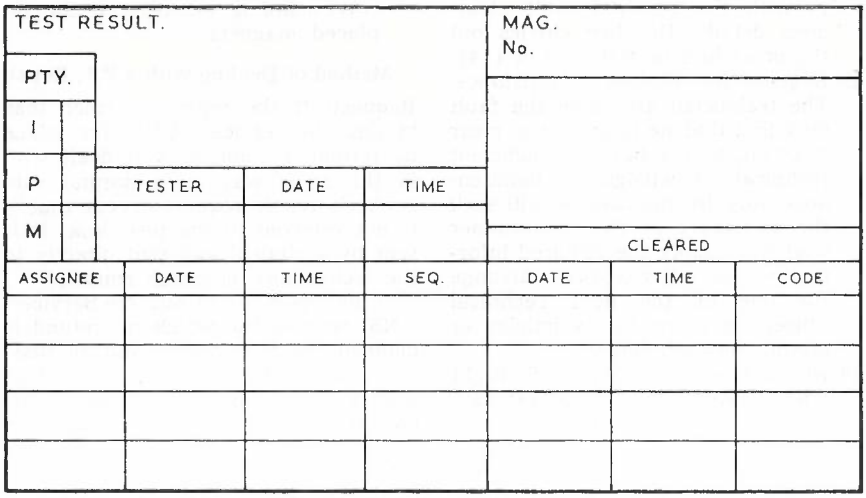

Fig. 11. — Fault Docket Stamp.

Provide separate accommodation for the batteries, power equipment and relay sets.

The movement of dockets between the operating centre is facilitated by the conveyor belt system; background noise is reduced by the carpet provided in the operating areas.

HANDLING OF REPAIR REQUESTS IN CENTRE

The handling of repair requests in the centre, while basically simple to understand, is, in fact, complicated because of the procedural changes which can occur as data about a faulty service accumulate. The following is a description of the processing procedure for a repair request on an ordinary telephone service and it also indicates how some of the required statistics are obtained.

Repair requests from the Assistance Centres arrive on a group of two teleprinters. The teleprinter stationery consists of two sheets interleaved with carbon paper so that an original and a duplicate report are available.

1. A clerical assistant tears off the teleprinter slip and stamps the top copy with a fault docket stamp (Fig. 11) This stamped slip is now a fault docket.
2. He then attaches the fault docket and the duplicate report to the relevant master card and substitutes a yellow "card-out" card for the master card.
3. The docket, the duplicate report, and the master card are then sent to the test desk.
4. A test desk operator tests the line, unless the repair requests shows obvious reason for this not being necessary, and talks to the subscriber, if possible.
5. The test desk operator writes on the fault docket:
   (a) Result of test and discussion with subscriber.
   (b) Date and time of test.
   (c) Priority allotted to fault.
   (d) His initials.
6. The test desk operator then sends the docket, the duplicate report, and the master card to the appropriate despatch console, or to the clerical area (teleprinter room) if his test indicates an exchange fault or if the service is R.W.T. (Right when Tested). Assume that the fault docket and master card are sent to the technicians despatch console.
7. *Substation Equipment Fault.* The programmer stamps the docket with a numbering machine, allots an appropriately coloured magnet to the fault, and writes the magnet's number on the fault docket. The duplicate report, together with a green "card-out" card, he sends in a plastic envelope to the clerical assistant area.
8. The duplicate docket and the green "card-out" card replace the yellow "card-out" card which replaced the master card at step 2.
9. The programmer then places the allotted magnet on his map at the point corresponding to the street directory's map and reference number shown on the master card.
10. The fault dockets and the master card to which it is attached are then placed, until required, in the pigeon hole labelled with the allotted magnet number.
11. The details of the reported fault are passed on to a fault technician as early as the work load and the priority allotted at step 5 allow. The master card and fault docket are then transferred to a pigeon hole labelled with the fault technician's number and the magnet representing the fault is placed adjacent to the technician's magnet.
12. When the fault technician rings back with the fault clear code and the time the fault was removed, the relevant information is entered on the fault docket, the allotted magnet is removed from the board, and the technician is credited with the fault clearance.
13. The despatcher then sends the docket and the master card to the clerical assistant area.
14. A clerical assistant replaces the master card in the master card file after writing on the back of it details of the fault and checking to see if a special inspection of the service is warranted. He stores the docket for subsequent sorting and counting for statistical purposes.
15. *Subscriber Not In Attendance.* If the fault technician at step (12) reports that the subscriber is not in attendance and he has left a 'not-in-attendance" card, the despatcher enters the information on the fault docket which, together with the master card, he places in a slot marked with the day of the week.
16. Two days later, if the service is without service and the subscriber has not contacted the centre to arrange a visit, the programmer arranges another visit by a fault technician.
17. *Transfer from Technicians to Lines.* If the fault technician at step (12) reports that the fault is in external plant, the despatcher places this information on the fault docket which, together with its master card, he sends to the lines despatch console.
18. It is then handled in a manner similar to that in which a fault passed directly from the test desk is treated.
19. An "ALFA" (Automatic Line Fault Analysis) fault docket is made out, and the original fault docket and the master card are sent to the clerical assistant area.
20. A clerical assistant replaces the green "card-out" card with a pink card and the docket and master card are held in suspense until an ALFA card showing fault clearance details is received from the line despatch console.
21. *Subsequent Reports.* During the time the technicians' despatch console was holding the fault docket a further repair request could have been received.
22. In this case a clerical assistant, after finding a green "card-out"

card where the master card should have been, takes the fault docket directly to the programmer after placing on it the clear code "90Z/PR".

23. The programmer places it with the original fault docket and raises the priority he has already given to the repair request. He raises the priority by placing a piece of paper under the magnet he has allotted to the fault.
24. Action as described in (11) then follows.
25. *Transfer from Technician to Exchange.* If the fault technician finds that the service is affected by a fault in the exchange, he reports this to the exchange and receives a sequence number. He then advises the despatcher that the fault is in the exchange.
26. The despatcher enters the necessary information on the fault docket and sends it and the master card to the clerical assistant area.
27. A clerical assistant subsequently replaces the green card-out card with a white card and holds the master card and fault docket in a slot labelled with the name of the exchange until the exchange rings in with the required fault clearance details. He then carries out the procedure he followed in (14).
28. *Request for Technical Assistance.* The technician attending the fault may find that he is unable to clear it owing to his having insufficient technical knowledge or maintenance aids. In this case he will seek the assistance of the programmer who will supply the required information or, alternatively, arrange for one of the field Technical officers to assist the technician or attend the fault later.
29. *Repair Request Coded RWT* (Right when Tested). A fault docket having a RWT code written on it together with its attached master card which arrives in the clerical area after being sent by a test desk operator at step (6) is dealt with as at step (14).
30. *Raising of Priority.* At 7.30 a.m. each morning each fault docket for services reported faulty over 24 hours earlier to which a technician is to be sent has its priority increased. This is carried out by allotting to it a magnet which denotes "up-grade". A list is made out of the numbers of the magnets used for "up-grade" purposes and the corresponding numbers of the replaced magnets.

Method of Dealing with a P.T. Repair Request: If the report is other than "Coins No Service", CNS, for which no refund is claimed, it is dealt with in the same way as a normal subscriber's repair request except that it is not referred to the test desk. It is sent by a clerical assistant directly to the technicians' despatch console.

If the report is a "Coins No Service", CNS, request for which no refund is claimed, the fault docket and the master card are placed in suspense and an orange "card-out" card replaces the master card. If no further report is received within a predetermined time which depends on the calling rate and is shown on the master card, the report is coded 90P and action similar to that described in (14) of the method of dealing with a repair request on an ordinary service takes place.

If a further report is received before the predetermined time has elapsed then both reports and the master card are posted to the technicians' despatch console after the second report has been coded 90Z/PR. The procedure followed is then similar to that follow-

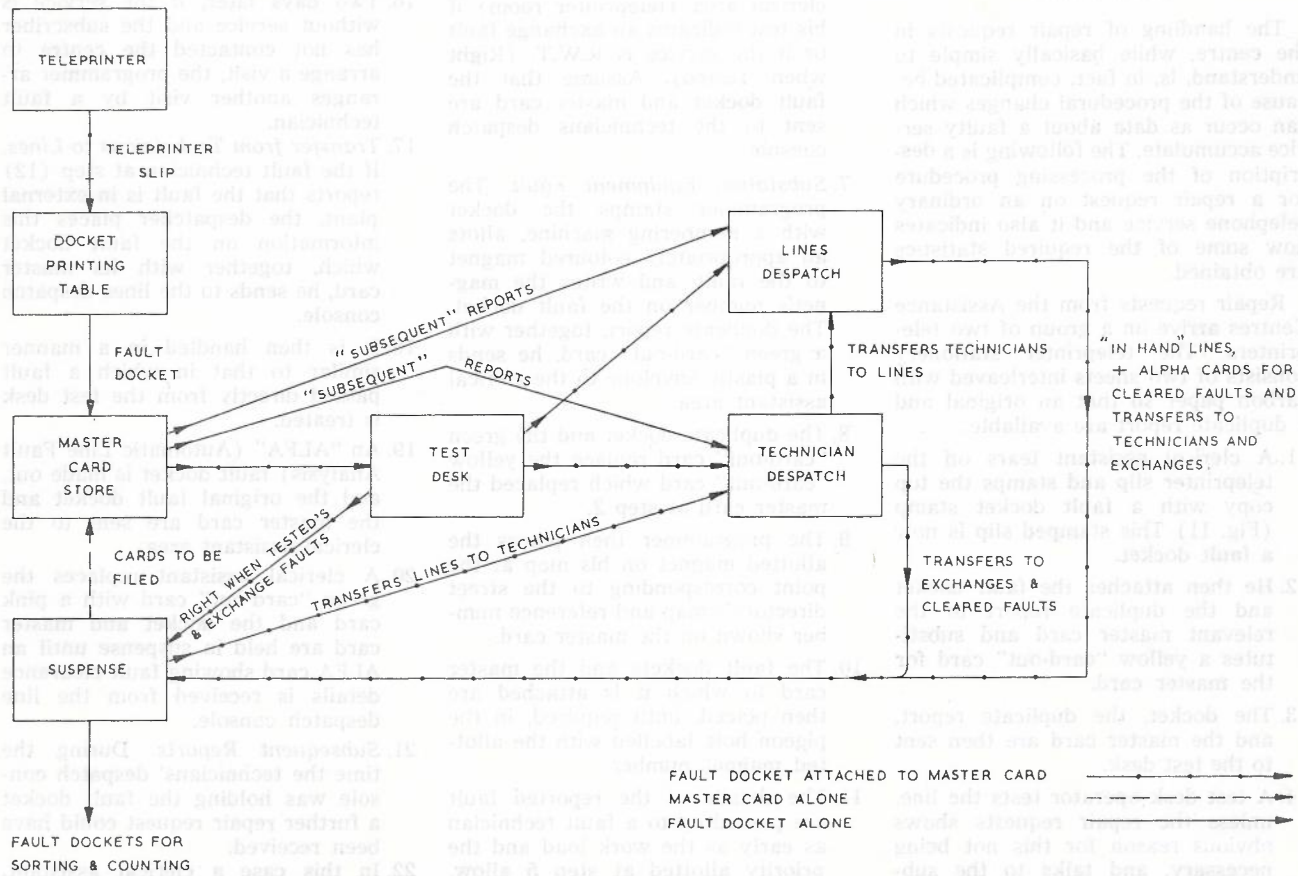

Fig. 12. — Path followed by Fault Dockets and Master Cards for Repair Requests on Ordinary Services.

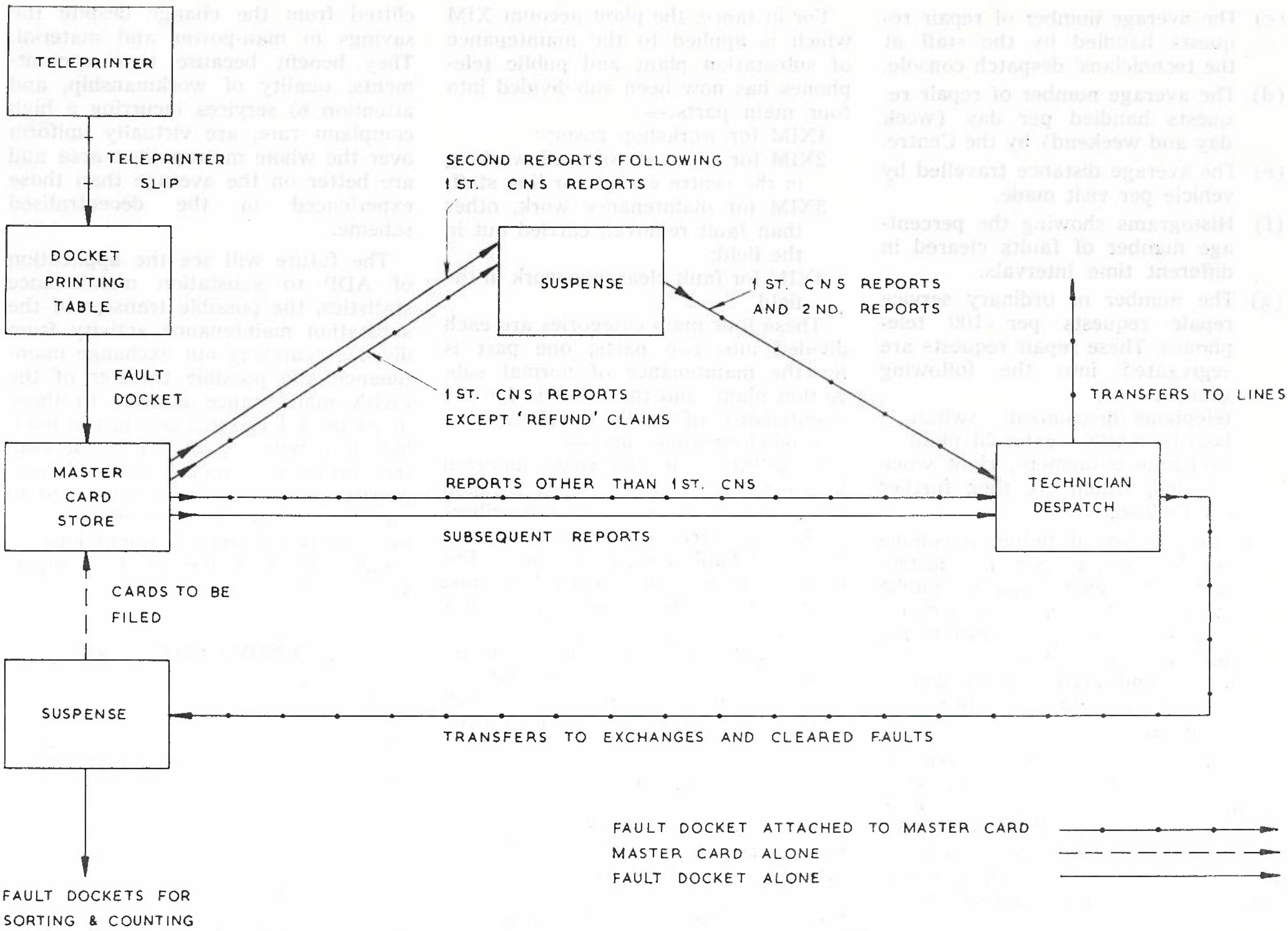

Fig. 13. — Path followed by Fault Dockets and Master Cards for Repair Requests on Public Telephones.

ed for a repair request on an ordinary service from step (7) onwards. Figs. 12 and 13 show in a simplified form the routes followed by fault dockets and master cards in the centre.

DEPLOYMENT OF FIELD STAFF

Outside fault technicians and linemen spend most of their time in one distinct geographical area. Some time is spent in areas adjacent to their home area, but it is unusual during normal working hours for a technician or a lineman to be sent a considerable distance to clear a fault.

The faultmen are divided into groups and each group is stationed at a location reasonably close to its work load centre. These locations are telephone exchange or the T.&F.D.C. for fault technicians and line yards for fault linemen. This arrangement provides simplification of supervision and material supply. An average of four fault reports are allotted to a technician at one time, but normally only one fault at a time is alloted to a lineman. All faultmen are expected to report in hourly.

The two T.T.O.1s engaged on substation maintenance:

(i) handle special inspections following the issue of special inspection dockets;
(ii) attend to faults on new equipment until the training of technicians is sufficiently advanced;
(iii) assist, at the request of the programmer, technicians experiencing difficulty in fault finding;
(iv) assist in training; and
(v) sample, at the request of the S.T.T.O.1 in charge of substation maintenance, work carried out by technicians.

The standard of workmanship of the fault linemen is checked by line inspectors attached to the District Works Division employing the line faultmen. Each inspector samples work carried out in his area only.

Each T.T.O.1 engaged on PABX maintenance is assigned a group of PABXs for which he is responsible for the maintenance. Each group of PABXs is confined to an individual geographical area or particular types of equipment. A T.T.O.1 can have subordinate staff, technicians, technician's assistants, or technicians-in-training to assist him.

MANAGEMENT CONTROL

A continuous oversight of staff and plant performance is required for the following purposes:

(a) To ensure that an adequate service is being given to subscribers.
(b) To ensure that staff are being used effectively and economically.
(c) To facilitate the estimating of future staff requirements.
(d) To determine where training of staff is needed.
(e) To pin-point plant weaknesses.

The following data for each centre is available to management as an aid to assess staff and plant performance and the quality of the service given to subscribers.

(a) The average number of visits made by each technician per day (weekday and weekend).
(b) The average number of faults carried over from one day to the next.

(c) The average number of repair requests handled by the staff at the technicians' despatch console.
(d) The average number of repair requests handled per day (week day and weekend) by the Centre.
(e) The average distance travelled by vehicle per visit made.
(f) Histograms showing the percentage number of faults cleared in different time intervals.
(g) The number of ordinary service repair requests per 100 telephones. These repair requests are segregated into the following groups:—
telephone instruments, switchboards, PABXs, external plant, exchange equipment, right when tested, which are then further sub-divided.
(h) The number of public telephone repair requests per 100 instruments for each type of public telephone. The repair requests for each type are segregated into the following groups:—
faults and FOKs, faults due to vandalism, right when tested (RWT).

Since a public telephone service is not tested from a test desk, RWT applied to a PT is a misnomer, even though a test desk RWT code, 90P, is applied. A RWT code is applied to a CNS report when no further report arrives within a predetermined time.

COST OF OPERATIONS

The cost of carrying out the activities controlled by the centre, except for activity five, are available from Costing returns, and the information is available now in far more detail than it was only a few years ago.

For instance, the plant account XIM which is applied to the maintenance of sub-station plant and public telephones has now been sub-divided into four main parts:—

1XIM for workshop costs;
2XIM for the costs of staff working in the centre except for line staff;
3XIM for maintenance work, other than fault removal, carried out in the field;
4XIM for fault clearance work in the field.

These four main categories are each divided into two parts; one part is for the maintenance of normal sub-station plant, and the other is for the maintenance of public telephones.

Typical examples are:—

8//2XIM5 indicates costs incurred by Metropolitan Service West Division for work connected with subscribers equipment carried out in the Footscray Test and Fault Despatch Centre. For instance technicians engaged on test desk work will book their time to this plant account.

11/4XIM8 indicates the plant account debited for the clearance of faults on public telephones by staff in the Metropolitan Service East Division.

CONCLUSION

The advantages which at the outset were expected to be gained by the centralisation of substation maintenance have been fully realised. Further, the administration of this activity has been greatly simplified because of its concentration to a few centres; for example, the training of staff and the carrying out of surveys to collect data is now performed much more quickly and efficiently than hitherto with minimal effort on the part of divisional office staff. Subscribers, too, have benefitted from the change despite the savings in man-power and material. They benefit because time commitments, quality of workmanship, and attention to services incurring a high complaint rate, are virtually uniform over the whole metropolitan area and are better on the average than those experienced in the decentralised scheme.

The future will see the application of ADP to substation maintenance statistics, the possible transfer of the substation maintenance activity from divisions carrying out exchange maintenance, the possible transfer of the PABX maintenance activity to these divisions, a large increase in the number of females employed in the centres, an increase in the technical complexity of substation equipment and an increase in the qualifications — not necessarily technical qualifications — required by the higher levels of supervisory staff at the centres.

ACKNOWLEDGEMENT

The author expresses his thanks for the extensive assistance provided by staff associated with the project; and in particular Mr. L. P. H. Nelson, S.T.T.O.3, who has been in charge of the Brunswick T.&F.D.C. since its establishment.

REFERENCES

(1) E. J. Bulte, 'Operating and Servicing of the Melbourne Telephone Network'; Telecomm. Journal of Aust., Vol. 14 No. 5/6 Page 390.
(2) W. Close and W. Bate, Report — 'Centralised Testing Design and Facilities.'

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R. G. NELSON

G. B. READ

L. R. A. MELTON, author of the article, 'Patents and the Post Office' graduated from Imperial College, London with a B.Sc. (Physics) in 1958. He completed a two year graduate apprenticeship with A.E.I. (Rugby) Ltd. before joining the Australian Post Office late in 1960. Initially he was Physicist Grade 1 and later Engineer Class 2 in the Information Group of the Research Laboratories and during 1965/66 studied Information Science at the City University London under a Commonwealth Public Service Board Scholarship. The formal course, which led to the granting of a Diploma of the City University, was followed by several weeks investigating information services in Britain, Europe and U.S.A. Mr. Melton was promoted Engineer Class 3 (Patents Officer) in the Research Laboratories in March 1968 and completed a 6 months training course for Patent Examiners at the Patent Office, Canberra during 1968/69. Mr. Melton is a Member of the Institute of Information Scientists (U.K.) and an Associate of the Institution of Electrical Engineers. He is on the Board of Editors of the Telecommunication Society journal, Australian Telecommunication Research.

★

R. G. NELSON, author of the article 'Melbourne Test and Fault Despatch Centres', was engaged on railway signalling and communication between 1939 and 1947, firstly, as equivalent to a technician-in-training, then technician and finally senior technician. He became qualified as an engineer in 1946 after completing a part-time course at Manchester College of Technology. In 1947 he joined the British Broadcasting Corporation as a recording engineer and until April, 1958, when he was recruited in England by the P.M.G.'s Department, he worked on studio equipment and recording equipment. Since 1958 Mr. Nelson has spent $3\frac{1}{2}$ years in Internal Planning, 2 years in District Works, and 8 years in the Metropolitan Service Section.

★

A. H. BADDELEY, co-author of the article, 'The Evaluation of Telephone Dial Performance', is Engineer Class 3, Mail Handling, in the P.M.G. Research Laboratories. He obtained a Bachelor of Mechanical Engineering Degree in the University of Melbourne in 1944 and worked as a design draftsman for a year at Industrial Service Engineers Pty. Ltd. before returning to the University to complete studies for a Bachelor of Electrical Engineering Degree in 1946. He has been employed in the P.M.G. Research Laboratories since 1947, mainly on a wide range of design projects. In 1961, he obtained six months leave from the Department to enable him to accept a French Technical Co-operation Fellowship, under which he studied electronic equipment design and construction at Le Materiel Telephonique and Etablissements M. Portenseigne in Paris. Mr. Baddeley transferred to the newly established Mail Handling Division in the Research Laboratories in 1967 after 10 years' experience as Engineer Class 3, Design (Mechanical and Electrical).

G. B. READ, author of the article 'The Application and Method of Measuring Group Delay' joined the Postmaster-General's Department as a Cadet Engineer in 1958. After graduating from the University of Western Australia in 1962 he worked for two years in Trunk Services and Primary Works in Perth. He transferred to the Research Laboratories, Melbourne, in 1965 as an Engineer Class 1. After a few months in the Multichannel Division he acted in the Information Officer position for 18 months. Since 1966 he has been an Engineer Class 2 in the Design Section of Long Line Equipment. His duties there involved high speed newspaper facsimile circuits, acceptance testing of supergroup links, field testing new broadband line links, and many aspects of digital transmission. Recently he was promoted to Engineer Class 3, Postal Engineering.

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G. W. G. GOODE

B. M. SMITH

A. E. LIUBINAS

G. W. G. GOODE, co-author of the article, 'The Evaluation of Telephone Dial Performance', is Physicist Class 3, Environmental Physics, in the P.M.G. Research Laboratories. He obtained a Bachelor of Science degree in the University of Melbourne in 1958. After some time with the Signals Branch of the Department of Defence, he joined the Physics Division of the P.M.G. Research Laboratories in 1962. When the Physics Division was separated into Material Physics and Environmental Physics Divisions in 1967, he transferred to the latter.

B. M. SMITH, author of the article 'A Brief Introduction to Digital Data Transmission Techniques', graduated from the University of Adelaide in 1964 with the Bachelor of Engineering degree and following graduation he carried out post-graduate work in the same University on various aspects of phase-locked loop behaviour. In 1969 he received the degree of Doctor of Philosophy. Since September, 1968 Dr. Smith has worked in the Pulse Systems Division of the P.M.G. Research Laboratories and been mainly concerned with data transmission.

A. E. LIUBINAS, co-author of the article 'Commissioning and Maintenance of ARM Exchanges', joined the Postmaster-General's Department as an Exempt Technician's Assistant in 1952. He became an Engineer Grade 1 in 1954, after completion of a Radio Engineering Diploma course at R.M. I.T., and was subsequently engaged on exchange maintenance, P.A.B.X. installation and exchange installation. During the latter period he was mainly concerned with the introduction of Subscriber Trunk Dialling in the Melbourne network, including the installation of ARM exchanges. Lately he has joined the Design Section of L. M. Ericsson Pty. Ltd.

TECHNICAL NEWS ITEM

WORLD ADMINISTRATIVE RADIO CONFERENCE ON SPACE TELECOMMUNICATIONS 1971

Following numerous preparatory meetings of Commonwealth Government Departments and instrumentalities concerned with the use of radio, an Australian delegation of 15 radio experts led by Mr. L. M. Harris, F.A.D.G. (Planning and Research), of the Australian Post Office is at present (June, 1971) attending the 1971 World Administrative Radio Conference on Space Telecommunications (W.A.R.C. — S.T.) in Geneva.

W.A.R.C.'s are held from time to time by the International Telecommunications Union (I.T.U.) to revise and supplement the administrative and technical provisions of the international radio regulations which determine the way in which the radio spectrum is used and which coordinate the conflicting requirements of the many radio services and scientific radio activities throughout the world.

The rapid development of space communication technology in recent years has given rise to demands for facilities for communication with space vehicles (used for meteorological purposes, earth resources surveys and spacetravel) as well as with terrestial and aeronautical mobile vehicles which so far have been provided with a very limited service from ground-based stations.

Radio astronomy and amateur radio communications are examples of non-commercial activities which will also be affected by the conference decisions.

It is anticipated that satellite broadcasting services, firstly to remote community centres and later to individual home receivers, will grow considerably during the next decade. In Australia such techniques are particularly attractive, but the frequency spectrum requirements conflict with existing terrestial services, such as those used in civil aviation. Such matters will be resolved by the Conference taking into account world-wide requirements.

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THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

VOL. 21 No. 2
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Victoria.

The TELECOMMUNICATION JOURNAL of Australia

ABSTRACTS: Vol. 21, No. 2

BADDELEY, A. H. and GOODE, G. W. G.: 'The Evaluation of Telephone Dial Performance'; Telecom. Journal of Aust., June 1971, page 125.

The advent of crossbar switching in the Australian telephone network has prompted the development of dials capable of operating at either 20 pulses per second or at 10 pulses per second as required. Concurrently, designs have been sought for dials which can be locally produced and which are cheaper and easier to maintain than older types. The equipment developed for testing prototype dials and the range of pulsing performance, operating life, environmental behaviour, and mechanical tests which may be applied are described.

COMPANEZ, J., 'The New Australian Dial (D.M.S.)'; Telecom. Journal of Aust., June 1971, page 120.

A telephone dial designed for the Australian network is described. The paper includes references to the principal design features as well as to testing and repair features.

FLETCHER, C. and LIUBINAS, A. E., 'Commissioning and Maintenance of ARM Exchanges'; Telecom. Journal of Aust., June 1971, page 146.

In a series of three articles the authors describe testing procedures developed for the commissioning of ARM exchanges. The emphasis is on those tests which ensure satisfactory interworking of the ARM equipment with the telephone network. The principles of the maintenance of ARM equipment are also covered.

HOWARD, S. A., 'The Application of PERT to a Multi-Discipline Project'; Telecom. Journal of Aust., June 1971 page 131.

This paper describes the application of P.E.R.T. to a major project involving external plant work and the co-ordination of the activities of several departmental divisions and outside contractors to provide telephone facilities at the new township of Moranbah and two new coal mines at Goonyella and Peak Downs in the Mackay Engineering Division, Queensland. The paper lists the steps taken, the personnel and time required, and information gained from the analysis and planning. A progress report outlining how the Divisional Engineer is using the P.E.R.T. technique is also included.

MELTON, L. R. A.: 'Patents and the Australian Post Office'; Telecom., Journal of Aust., June 1971, page 172.

The history and development of the Australian patents system is outlined and some indication given of what may be patented. The process of obtaining a patent in Australia and extending protection to other countries is described. The methods of exploiting patents are discussed with particular reference to current Post Office activity in this area.

NELSON, R. G., 'Melbourne Test and Fault Despatch Centres'; Telecom. Journal of Aust., June 1971, page 178.

This article covers briefly the evolution of the Test and Fault Despatch Centres in the Melbourne Metropolitan Telephone Area, the size and location of the centres, the way in which work for the centres is generated and it describes in some detail one particular Test and Fault Despatch Centre. Items included for this centre are activities, organisation and hours of staffing, apparatus, method of dealing with fault dockets, deployment of field staff, management control, and cost of operations.

READ, G. B.: 'The Application and Method of Measuring Group Delay'; Telecom. Journal of Aust., June 1971, page 141.

The volume of digital signals transmitted through the trunk network is increasing. Projection of trends indicates that within ten years 50 per cent of the capacity of the broadband line links which are used to provide voice band links for the trunk telephone network will be used for other services than telephony. Until it is found expedient to control the phase characteristic of carrier modems (channel, group and supergroup) and through connecting filters within specified limits and thus be able to utilise standard equaliser networks, it will be necessary to measure group delay distortion before and after delay equalisation.

A description is given of three high speed newspaper facsimile services in Australia, two between Sydney and Melbourne and one from Sydney to Brisbane.

SMITH, B. M.: 'A Brief Introduction to Digital Data Transmission Techniques'; Telecom. Journal of Aust., June 1971, page 111.

This paper provides a brief introduction to the principles of digital data transmission systems, with particular reference to transmission on the telephone network. The paper has a short section on bits, bauds and the effect of a limited bandwidth transmission channel, and then it discusses the characteristics of the more common modulation techniques used in data transmission as well as the effects of various channel impairments.

ERRATA

In the previous issue, the ABSTRACTS page was incorrectly headed as Vol. 21, No. 3 instead of Vol. 21, No. 1.

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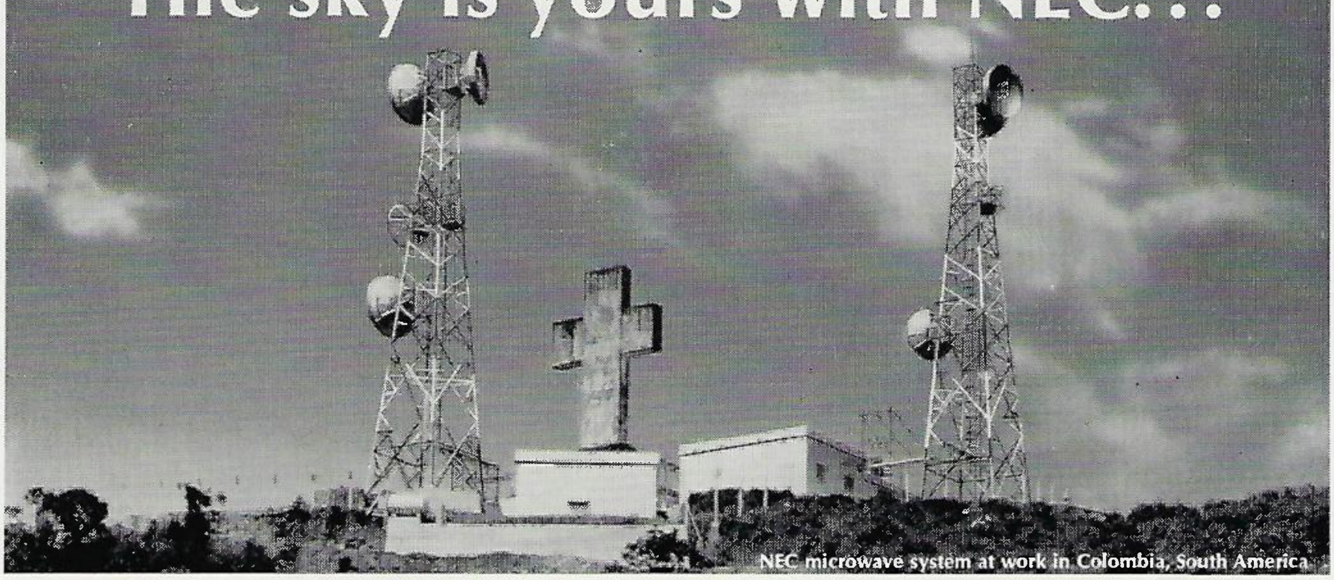

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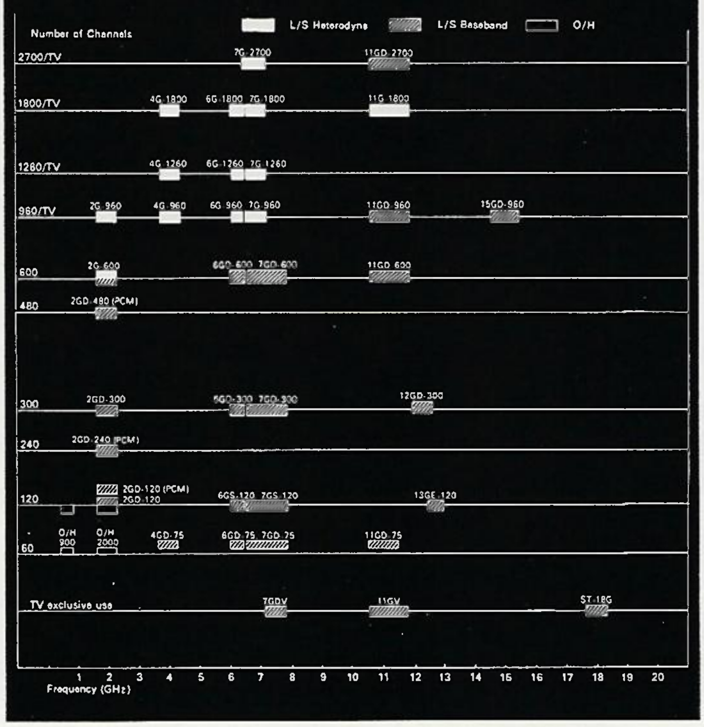

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