The

Telecommunication Journal of Australia

VOL. 10, No. 5 | Registered at the General Post Office, Melbourne, for transmission by post as a periodical. | OCTOBER, 1956

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OBITUARY — MR. W. ENGEMAN

The Engineering Division in particular and the P.M.G. department as a whole, suffered a severe and sad loss by the sudden death, at the age of 60 years, of Mr. W. (Bill) Engeman, Deputy Engineer-in-Chief, on Sunday, August 26, 1956.

During his distinguished career of some 44 years in the Engineering Division in four States and at Central Office, Mr. Engeman contributed very substantially, both technically and in the high level administrative sphere, toward the remarkable progress which has been made over this period in the field of departmental telecommunication engineering.

Mr. Engeman originally entered the department as a clerk in the Accounts Branch, Queensland, in October, 1912, when he was just over 17 years of age; however, he was advanced as Junior Assistant Engineer in that State a few months later. He was subsequently promoted as Assistant Engineer in Queensland in 1917, and as Engineer in June 1918, when he was not quite 23 years of age. Later appointments in his notable career included those of Divisional Engineer, Townsville; Divisional Engineer, Newcastle; Metropolitan Engineer, Queensland; Supervising Engineer, Equipment, Brisbane; Supervising Engineer, Lines, Melbourne; Assistant Superintending Engineer, Victoria; Supervising Engineer, Lines, Central Office and, in January, 1952, Deputy Engineer-in-Chief. Additionally, Mr. Engeman had, on several occasions, acted as Engineer-in-Chief.

Perhaps the two largest and most important engineering projects with which Mr. Engeman was intimately associated were the laying of the Sydney-Newcastle-Maitland trunk cable, which was the first of our long distance carrier cable projects in Australia, and on which several articles by Mr. Engeman were published in this Journal, and the erection of some 2000 miles of copper circuits on the Adelaide-Darwin telegraph route.

Mr. Engeman was made personally responsible for the Adelaide-Darwin project, which was undertaken during the early stages of the second World War. The project was of tremendous national importance and, from an engineering viewpoint, a work of considerable magnitude. In addition to duplicating the copper circuits throughout, which traverse some of the worst type of country in Australia, some hundreds of miles of the pole route required extensive reconstruction; furthermore, a large number of special prefabricated steel structures embedded in concrete had to be engineered and erected at many creek crossings between Maree and Alice Springs. It is a tribute to the standard of Mr. Engeman's planning, organising and engineering abilities that this undertaking was completed well within the scheduled time and that the special structures on the route have

withstood severe floods since their erection, thereby minimising the possibility of serious interruptions to these important channels of communication. The completion of this work brought both Alice Springs and Darwin for the first time into telephone communication with the Australian trunk line system, in addition to providing all of the extra telegraph channels required for military purposes.

As the Liaison Officer in Queensland between this department and all branches of the Allied Services, from 1942 to 1944, Mr. Engeman was actively engaged in the organisation of material supplies and the detailed work of construction, etc., associated with the provision of the many telecommunication services required throughout Queensland at that time for military purposes.

In his capacity as Supervising Engineer, Lines, and Assistant Superintending Engineer, Victoria, from 1944 to 1951, Mr. Engeman was in the spearhead in that State of the constantly and rapidly growing and remarkably successful engineering effort which was necessary to meet the unprecedented post-war demands for the provision of telephone services.

It was therefore with a particularly sound and most comprehensive background of practical knowledge and engineering experience that Mr. Engeman took up duty at Central Office in June, 1951. As Deputy Engineer-in-Chief and, for several periods, as acting Engineer-in-Chief, he did not spare himself in applying the wealth of his technical knowledge and practical experience, in close and harmonious co-operation with his Chiefs, for the benefit of the department throughout the Commonwealth and, in this field, he displayed outstanding administrative capacity and ability.

In his diversified activities on the Central Staff, Mr. Engeman was a regular member of the Departmental Headquarters Advisory Council, the Departmental Policy Planning Board, Chairman of the Headquarters Training Committee, and Chairman of the Headquarters Telecommunications Planning Committee, in addition to being a member of special committees convened from time to time to undertake important nationwide investigations into various aspects of departmental management.

Quite apart from the high standard of his acknowledged capabilities, however, Mr. Engeman was in every sense a loyal and zealous officer of the Post Office, with a most pleasing personality; his main objective was at all times to get on with the job and have it done promptly and successfully. Notwithstanding the heavy demands on his time and his far-reaching and onerous responsibilities, Mr. Engeman was imbued with a deep sense of human understanding and in his associations with all staffs, he maintained an easy, reassuring and approachable manner, which never failed to inspire the greatest confidence. He displayed a keen interest in the development of the Engineering Division staffing organisation and in matters of staff welfare generally.

The death of Mr. Engeman robs the Post Office of one of its most valued and esteemed engineers and executive officers and it leaves his many colleagues throughout the various divisions and branches of the postal organisation with a sincere feeling of personal loss and regret.

23-CHANNEL P.T.M. RADIO TELEPHONE SYSTEM

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INTRODUCTION

During the past two years, 23-channel radio telephone systems, designed and manufactured in Australia by Standard Telephones and Cables Pty. Ltd., have been placed in service between Sydney and Wollongong, Melbourne and Warragul, Melbourne and Sorrento and Brisbane and Southport. This article describes the main features of these systems and reviews the general principles of pulse time modulation which is used in the equipment.

The use of pulses for communication is not an entirely modern conception, although it is only in recent years that the technique has been applied to the transmission of speech. Heising, in 1924, described pulse length modulation for speech, and Kell, in 1935, and Deloraine and Reeves, in 1937, made important contributions towards applying the technique to telephony. Since 1937 several practical pulse communication systems have been developed, one such system being the Wireless Set No. 10, which played an important role in World War II.

Multi-channel operation of pulse communication systems is obtained by the use of Time Division Multiplex, a technique first used in the Baudot system of multiplex telegraphy in 1874 and still employed today in the Murray Multiplex system. The fundamental difference between Frequency Division systems, as used in open wire and cable carrier telephone systems and Time Division systems lies in the fact that the signals of all channels of the former systems are present simultaneously whereas, in the latter case, only one channel has use of the transmitting medium at any one instant. From the viewpoint of interchannel crosstalk, non-linear distortion in the transmission circuit is therefore unimportant in a system using Time Division. This easing of the transmission circuit requirement is of major importance when the bearer circuit is a radio link.

Transmission of modulated pulses by cable, although possible, is not used, chiefly because the additional frequency bandwidth required makes its use uneconomical, at least at the present time. However, this limitation does not apply to radio systems using microwave frequencies, and in this frequency range, advantage may be taken of the ease with which radio transmitters can be amplitude or frequency keyed by the pulse train. Wartime developments in radar demonstrated the use of pulsed transmitters at microwave frequencies and these techniques were soon applied to pulse communication systems. At microwave frequencies radio waves behave in a similar manner to light and for this reason the most suitable paths for microwave transmission are "line of sight" paths. With "line of sight" transmission, it is possible with transmitter power of a few watts to direct the radio beam to a remote receiving or repeating station.

Within the last few years, however, experiments have indicated that the received fields, far beyond the horizon, were much greater than would be expected on the smooth earth diffraction theory. This "over-the-horizon" radio transmission is still in the development stage, but present results indicate that transmission for distances up to 250 miles without intermediate amplification in the frequency range 40 to 4000 Mc/s is feasible. Systems of this type are based on the use of high-power transmitters and large antennae to force signals of useful intensity beyond the horizon. Propagation of this type may make possible the use of microwave frequencies for long distances over water or flat country where it is not possible to provide the intermediate stations required for "line-of-sight" transmission.

PULSE MODULATION

Modulation of continuous waves is inherently restricted to amplitude and angular variations, but a series of pulses recurring at a constant rate also allows variations in shape of pulse to be effected and this extra degree of freedom coupled with the discrete nature of pulses makes possible a variety of types of modulation. The basic types of pulse modulation are as follows:

Pulse Amplitude Modulation	P.A.M.
Pulse Length Modulation	P.L.M.
Pulse Frequency Modulation	P.F.M.
Pulse Time Modulation	P.T.M.
Pulse Code Modulation	P.C.M.

It is not possible, in a paper of this length, to discuss the relative merits of the various forms of modulation. The discussion will therefore be limited to Pulse Time Modulation, which is used in the equipment described in this paper. P.T.M. has been titled by various authors Pulse Phase Modulation, Pulse Position Modulation and Pulse Displacement Modulation. In this case the carrier is a train of pulses T secs. apart and modulation is performed by advancing or retarding the time of occurrence of each pulse by an amount proportional to the instantaneous amplitude of the signal at sampled instants T secs. apart.

Selection of the Pulse Sampling Rate

Since a system using pulse modulation depends for its operation on the sampling of the speech signal, it is necessary to know what this sampling rate should be and what effect the sampling will have on the quality of the speech when the samples are reconstructed back into speech (demodulated) at the receiving end.

To determine the amount of distortion introduced by the modulation and demodulation process it is necessary to determine what frequency components can be expected to lie in the audio band at the demodulator output. To do this it is necessary to determine the frequency spectrum of the modulated pulses. Various mathematical treatments may be found in the literature so it will suffice to mention the results obtained. The mathematical treatments are usually applied to ideal pulses and ideal modulators and demodulators, and the results obtained can only be used as a guide in the design of any pulse communication system.

Frequency Spectrum of Unmodulated Pulses

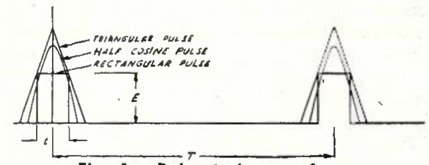

Fig. 1.—Pulse train waveforms.

The Fourier analysis of the waveforms of Fig. 1 gives a frequency spectrum as shown in Fig. 2. The envelope to the frequency components takes the following form for the three pulse shapes shown:

Pulse Shape	Frequency Spectrum Envelope
Rectangular	$(2E.\text{Sin } \omega t/2)/ (\omega t/2)$.
Half Cosine	$(4E.\text{Cos } \omega t/2)/ \pi.(1 - \omega^2t^2/\pi^2)$.
Triangular	$8E.(1 - \text{Cos } \omega t/2)/ \omega^2t^2$.

The components in the spectrum are spaced N cycles per second apart, where $N = 1/T$ is the pulse repetition frequency.

The frequency spectrum of the pulse waveforms shown therefore extends to infinity with "nulls" occurring at intervals of $1/t$, where t is the pulse width

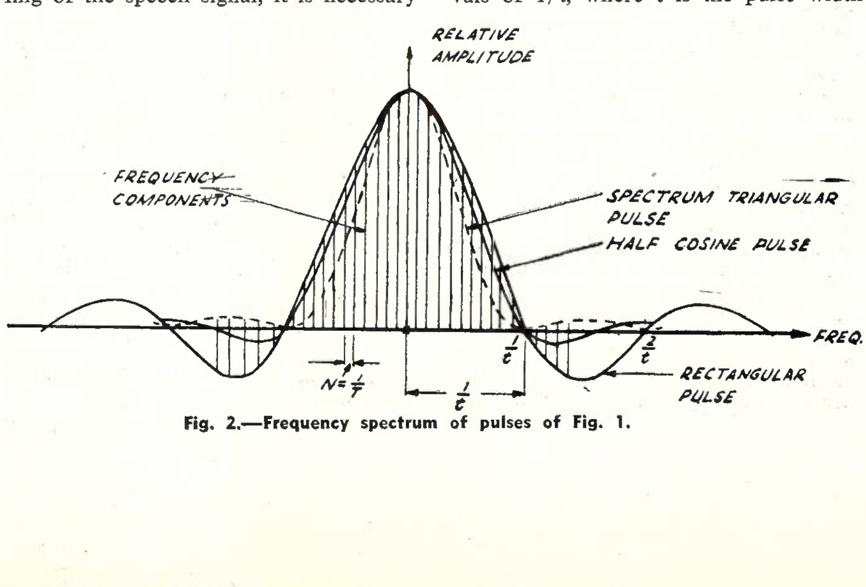

Fig. 2.—Frequency spectrum of pulses of Fig. 1.

* Standard Telephones and Cables Pty. Ltd. Sydney, N.S.W.

at half amplitude. These null intervals are independent of the pulse repetition frequency. The frequency components beyond the first interval 1/t are small.

Spectrum of Modulated Pulses

The spectrum of modulated pulses is similar to that of Fig. 2 excepting that each harmonic of the pulse repetition frequency N has sidebands corresponding to the signal spectrum being transmitted.

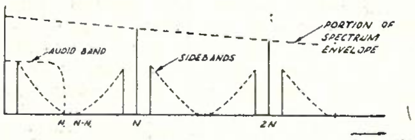

Fig. 3.—Frequency spectrum of modulated pulses.

From Fig. 3 it is evident that the sideband at frequency $N-N_1$ will enter the audio band and cause distortion if N is less than $2N_1$. It may be concluded then that the pulse repetition frequency should be greater than twice the highest modulating frequency. Tests in England revealed that a pulse repetition frequency of 1.4 times the highest frequency could be used where the amount of distortion is not important. For good quality circuits it is found in practice that a sampling frequency of 2.3 to 2.6 times the highest frequency should be used. This extra margin is necessary to allow some margin for the operation of filters and also because the channel frequency response characteristic becomes non-linear in the region of half the sampling frequency. For a telephone channel having an upper frequency of 3,400 c/s, then the pulse repetition frequency should be 8,000 to 9,000 c/s. A repetition frequency of 9,000 c/s is used in the system described in this paper.

Multiplex Operation

Having fixed the pulse repetition rate at 9,000 c/s, the sampling intervals are then $1/(9 \times 10^3) = 111$ micro-seconds apart. Thus if we use pulses of 0.1 or even 0.5 micro-second duration and limit the pulse displacement during modulation to ± 1 micro-second, the total space occupied by one channel is 2.5 micro-second. The large interval remaining between the sampling pulses makes possible time division multiplex in which pulses from other channels can be made to occupy the remaining interval. Various systems have been used to provide the sequential sampling of the multi-channel speech inputs in order that the modulated pulses for each channel may be interleaved without interference. One such method using a polyphase transformer will be described in a later section.

Bandwidth Requirements

A fundamental problem in the design of a pulse communication system is the determination of the bandwidth required to transmit the pulses in both the radio frequency and video frequency circuits. The spectrum analysis of the pulse shape has shown that the frequency components for a rectangular pulse extend to infinity, and if perfect reproduction of the pulse were essential the receiving circuits would have to pass all the pulse component frequencies with negligible amplitude and phase distortion. However a practical system differs in that the transmitted pulse is not rectangular and since pulse time modulation is used, it is not necessary to restore the transmitted pulse shape. Distortion of the pulse may produce ringing of the pulse which will cause crosstalk with the neighbouring channel. A compromise has to be made between the transmission bandwidth required and the allowable inter-channel crosstalk. The effect of the bandwidth on signal-to-noise ratio will be discussed later. The effect of the transmission bandwidth on the pulse shape will now be discussed in detail.

The envelope frequency spectrums of Fig. 2 are obtained by using the Fourier Integral which has the important property that time and frequency variables are interchangeable providing the functions are symmetrical about the vertical axis. Thus frequency functions of the shape shown in Fig. 1 will have time functions as shown by the envelope curves of Fig. 2. Thus for an ideal transmission system with a frequency characteristic with constant amplitude and delay in the transmission band together with an abrupt cut off, the received pulse has the shape shown in Fig. 2. This type of transmission characteristic cannot be physically realised since it will have phase distortion and infinite transmission delay.

Video Bandwidth

In a pulse time modulation system the shape of the pulse does not have to be retained to preserve the modulation as it does for example for pulse width or pulse amplitude modulation. With P.T.M. it is only necessary to preserve the timing of the leading edge of the pulse. The effect of reducing the video bandwidth on the shape of the pulse is shown in Fig. 4.

In most examples of Fig. 4, the responses are non-physical since they show infinite amplitude before t = O. For a practical filter there will be suffi-

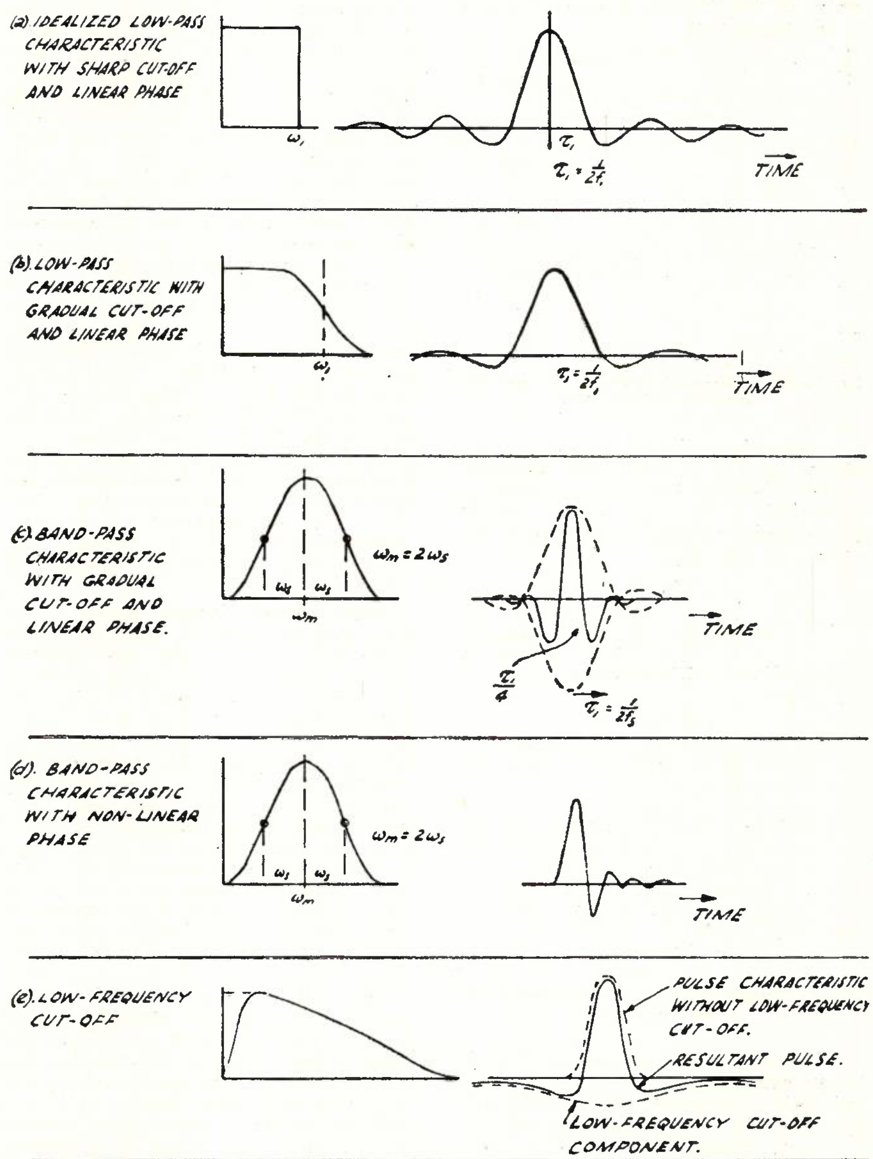

Fig. 4.—Some video frequency response characteristics and corresponding pulse distortion.

cient phase distortion and delay introduced to remove all traces of signal before the time of receipt of the pulse. The effect is shown in Fig. 4d, and this type of characteristic is used in the video circuits of a P.T.M. system. The ringing of the pulse which occurs may be reduced by the use of a diode to limit the negative overshoot of the pulse and damp out subsequent ringing. In all cases shown, limiting the video bandwidth gives rise to tailing of the pulse which will cause interference with neighbouring channel pulses. In the design of the system a compromise is made between video bandwidth and crosstalk requirements. By reducing the video bandwidth required a simplification is obtained in the video amplifiers and pulse transformers used throughout the system.

Radio Frequency Bandwidth

The effect of the bandwidth of the radio frequency circuits is shown in Fig. 5 where ω_m is the carrier frequency (radio or intermediate frequency) and ω_s is the bandwidth.

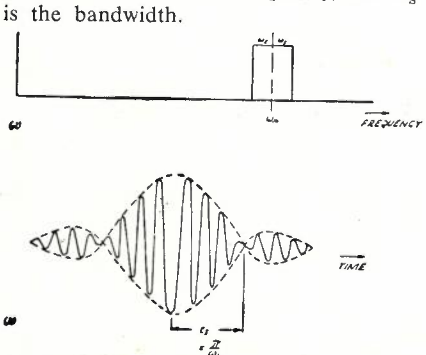

Fig. 5.—R.F. frequency response (a) and time function output (b).

The received radio frequency pulse is shown in Fig. 5 (b). The frequency characteristic of Fig. 5 (a) cannot be realised in a practical system and the characteristic is likely to approach that shown in Fig. 6.

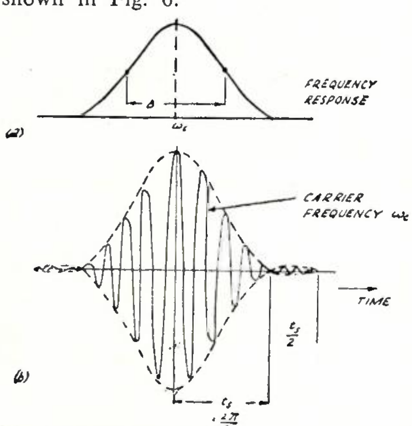

Fig. 6.—Practical R.F. frequency response and time response.

Thus an amplifier of bandwidth B with linear phase characteristic will pass a pulse of the envelope of Fig. 5 (b) without distortion. Phase distortion will have the same effect as that shown in Fig. 4. It will be noticed from Fig. 6 that ringing of the pulse is reduced by using the frequency response curve of Fig. 6 (a).

Signal-to-Noise Ratio

Like frequency modulation, all forms of pulse modulation provide an improvement in signal-to-noise ratio by using an increased transmitter bandwidth. In the case of P.T.M., noise can only affect the leading edge of the pulse which carries the information. If the build up time were zero, the signal-to-noise ratio would be infinite but so would be the transmission bandwidth required.

The noise level in a telephone channel at the end of a P.T.M. radio link is made up of two components, namely multiplex equipment noise and radio circuit noise.

Multiplex Equipment Noise: The multiplex equipment noise is due to imperfections in the multiplex equipment and is independent of the radio path attenuation. The noise from the multiplex equipment arises mainly from the low level audio amplifiers and the pulse timing circuits. For example, if a pulse is generated the instant a sine wave passes through the zero axis, any noise added to this sine wave will cause a displacement of the zero point of the sine wave along the time axis. Thus the noise on the sine wave will cause modulation of the pulse. If, for example, the peak displacement of the pulse in a 23 channel P.T.M. system for 100% modulation is 1.1 microseconds (corresponding to 3.6° at 9 kc/s) then for a signal-to-noise ratio of 70 db on the modulated pulse, the displacement of the pulse due to the noise is 3.5 x 10^{-4} microseconds (corresponding to 4.2 seconds of arc at 9 kc/s). The corresponding amplitude signal-to-noise ratio of the 9 kc/s timing sine-wave is therefore Sin 3.6°/Sin 4.2″ = 1.71 x 10^5, or 105 db. It is evident therefore that noise from power supplies and the low level circuits of the 9 kc/s oscillator can contribute to the multiplex noise. Likewise at the demodulating end the same degree of stability in the timing of the demodulating reference voltage is required.

Radio Circuit Noise: Radio circuit noise may be separated into two distinct components, namely the noise due to thermal agitation in the input circuit of the receiver, and the noise produced by imperfections in the high level circuits in the receiver and in the transmitter circuits. The first of the components is amplified by an intermediate frequency amplifier to an extent which depends on the strength of the incoming signal and hence on the attenuation in the path between transmitter and receiver. For this reason it is sometimes called the "radio path noise." The second is designated "radio equipment noise" and is independent of the radio path attenuation.

The radio path noise has been described as that due to normal agitation in the receiver input circuits. The signal-to-noise ratio at the receiver output depends upon the received signal and hence the radio path length. It is possible to remove a considerable amount of the radio path noise by a process known as "slicing." This process is analogous to limiting in C-W frequency modulation. The amount of improvement in signal-to-noise ratio is sometimes referred to as the P.T.M. improvement factor. The action of the "slicer" is as follows. The radio frequency pulses coming from the receiver are held at constant amplitude by the receiver A.G.C. These pulses are then detected and applied to the "slicer" which removes the upper and lower portions of the rectified pulses and accepts only those sections of the pulses lying within a narrow voltage range near the centre of the pulses. The pulse slice is then amplified and the only noise remaining is on the rise and decay portions of the pulse. Thus if a zero rise time pulse is used the improvement obtained is infinite. However, as shown earlier an infinite bandwidth would be required for the transmission of such a pulse. The radio equipment for a pulse system should be designed so that the contribution to the channel noise from the radio equipment is negligible for normal working paths with a suitable margin for fading of the radio frequency signal.

As far as radio equipment noise is concerned, once the pulses have been generated, noise in the high level circuits can only introduce modulation of the pulse by causing a displacement of the rise time of the pulse. If the pulses have a very small rise time, the amount of interference introduced by the high level circuits of the transmitter and receiver is very small and can usually be neglected in a pulse communication link.

23 CHANNEL P.T.M. RADIO TELEPHONE EQUIPMENT

Principal Features

The Pulse Modulated U.H.F. Radio Telephone Equipment type 386-SU-1A provides up to 23 high grade trunk-line telephone circuits, together with an independent service order-wire channel which is also available at repeating stations. The channels are provided between voice-frequency terminations without the need for carrier telephone terminal apparatus. In addition means are provided for setting up and supervising telephone calls so that the system will operate in conjunction with existing equipment. This is achieved by assigning two mean positions to each channel pulse and arranging the circuits so that the voice-frequency signal may modulate the pulse about either of its mean positions. These mean positions can be regarded as two D.C. conditions which can be used to cause the operation or release of a relay. It is possible, therefore, to transmit C.B., dialling, 17 c/s ringing and telegraph signals without the need for V.F. signalling equipment and, at the same time, to handle supervisory tones and non-reversal telephone calls if required. The equipment has been designed for spur-line and minor-trunk applications ranging in length from 10 to 150 miles, but it may be used to give good quality circuits for distances in excess of 1000 miles with suitable arrangement of terminal and repeater stations.

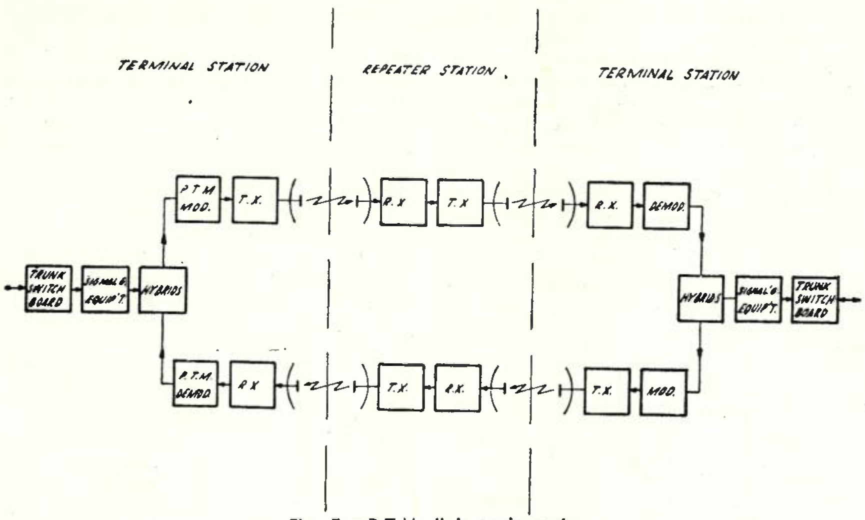

Fig. 7.—P.T.M. link equipment.

Each system comprises terminal stations and repeater stations, spaced at intervals of approximately 30 miles, as required to suit the distances and terrain of each particular case. The telephone circuits are provided by suitable interconnections of various equipment bays, enabling some degree of flexibility in the disposition of the apparatus to suit particular field applications. Channel input and output levels are consistent with normal values in line communication technique, making possible the use of P.T.M. links in line networks. Conventional hybrid circuits are used to convert from 2-wire to 4-wire working. Each hybrid is fitted with a peak limiter which operates at a level corresponding to the peak of a steady tone of +8 dbm (6 mW) at the transmitting trunk switchboard. Conventional automatic telephone-type relay sets are used to pass switching and supervisory signals into the multiplex terminal equipment.

The Terminating Bay type 102-SU-2 and Multiplex Bay type 707-SU-1A may be separated by several miles, depending on the transmission characteristics of the drop cable used. The multiplex equipment bay may be separated from the radio equipment bay by distances up to 1000 yards provided suitable coaxial cable is used. The radio equipment and the aerial system should be kept as close as practicable but may be up to 100 yards apart if suitable waveguide feeder is used.

Built-in monitoring is provided for the speech circuits and two cathode ray oscilloscope units are built in to monitor the pulses and circuit waveforms. No external equipment is required to line up the voice frequency channels, an oscillator and T.M.S. being built into the V.F. monitor. The C.R.O. unit is used to measure the pulse displacement of ±1.1 microsecond for 100 per cent modulation. A power meter and wavemeter are provided to measure the radio transmitter power output and frequency respectively. Alarm facilities are provided to indicate the failure of tubes operating under steady conditions and the failure of signals at important points of the network. D.C. test points are provided throughout the circuits to indicate abnormal conditions.

Channel units and equipment common to all channels, excluding the power supplies, are made in small units which plug into the rack and can be readily replaced by spare units in the advent of a failure. Facilities are available to "busy out" automatic circuits during a changeover. All voltages above 200 volts are protected with covers or mechanical interlocks. Test frames are provided to facilitate the maintenance of plug-in units under operating conditions. Forced air cooling is supplied by means of blower units located at the bottom of the racks, the intake being carried through air filters to ensure dust free cooling air. The complete construction is consistent with the Australian Post Office double sided rack design.

The parabolic aerial reflectors are provided with mounting plates and turnbuckles, the latter allowing a movement of alignment of $\pm 22\frac{1}{2}$ degrees in the horizontal plane and ±5 degrees in the vertical plane.

All connections for power and speech circuits are made at the top of the racks. The equipment operates from a 50 c/s 240 volt single-phase supply. An external 50 volt D.C. supply is required for the operation of the signalling relays of the multiplex equipment.

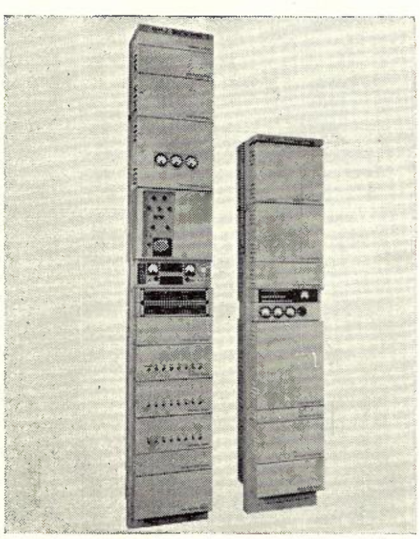

Fig. 8.—Terminal equipment.

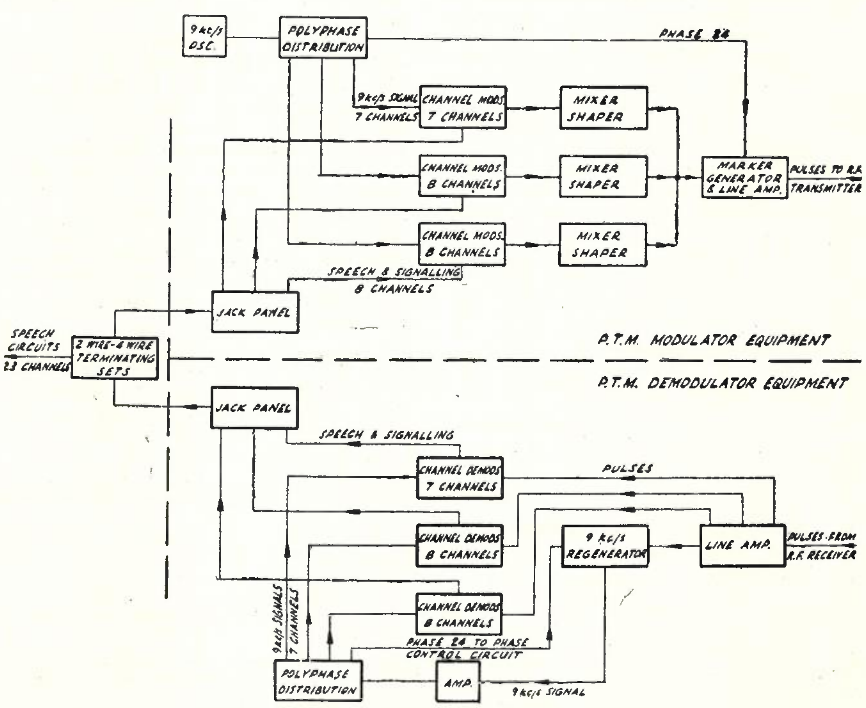

Fig. 9—P.T.M. multiplex equipment.

Multiplex Equipment

The multiplex equipment bay may be considered as performing three main functions, namely that of time multiplexing the 23 channels, pulse modulating, and pulse demodulating. These three functions are described in the following sub-paragraphs together with sections on synchronising and signalling.

Multiplexing: As described earlier each channel is represented by a train of pulses with a repetition rate of 9 kc/s and in order to perform the multiplexing of the channels each train of pulses must be displaced in time with respect to the other channel pulses. In this equipment the time relationship of the 23 channel pulses and a marker or synchronising pulse is established by the 24 phase-shifted sine wave outputs of a polyphase transformer. The operation of the polyphase transformer is described with reference to Fig. 10.

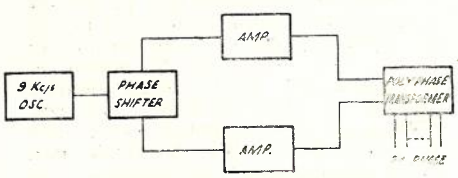

Fig. 10.—Polyphase distribution unit.

A 9 kc/s crystal oscillator, phase shifter and amplifiers supply the primary of the transformer with two voltages which have a relative phase of 90 degrees. The transformer primary windings are wound on a "rotor" similar in form to the rotor of an electric motor. The quadrature supply to the primary windings produces a rotating field in the same manner as the rotating field is produced in the two or three phase induction motor. The 24 secondary windings are arranged on a stator surrounding the primary windings. Each secondary winding therefore supplies a timing sine-wave signal, spaced 15 degrees (4.65 micro-seconds) from the neighbouring sine wave, to each of the 23 channel modulators and marker pulse generator.

Channel Modulator: The channel modulator generates a train of pulses from each 9 kc/s sine wave input. The speech or other intelligence to be transmitted is made to vary the position of the pulse in such a way that the displacement of the pulse from its mean position is proportional to the amplitude of the modulating signal.

The process of modulation is illustrated in Fig. 11. This diagram indicates that the pulse is generated as the 9 kc/s timing waveform passes through the zero axis in the negative going direction. If the zero axis of the sine wave as shown at (A) is Y_0, then the modulator output as shown at (B) will be represented by the pulses which are shown as full lines. If an alternating voltage is added to the 9 kc/s sine wave as shown in (C), the pulse will deviate from its mean position as shown by the dotted lines in (D). This represents the condition which exists when the pulse is being modulated by a voice-frequency waveform. The actual modulator circuit is illustrated in Fig. 12.

The 9 kc/s and speech inputs are added in the bridge circuit R1 R2 R3 R4 and are then amplified by the valve V1 before passing to the multiar pulse generator V2. The condenser C2 provides an adjustment for the pulse position by varying the phase of the 9 kc/s signal. The condenser C1 is switched by the relay RL1 and produces a phase shift of the 9 kc/s signal in synchronism with the incoming signalling impulses. This 9 kc/s phaseshift produces a corresponding shift in the time position of the pulse.

Pulse Demodulator: The demodulator selects the correct channel pulse from the composite pulse waveform and converts the variations in the position of the channel pulse into a replica of the original modulating voice-frequency waveform. The channel pulse selection is accomplished by the output sine wave voltages from the polyphase transformer at the demodulating end. The output from the correct phase of this transformer selects the channel pulse in a gating circuit which is then demodulated in a "box-car" circuit, the operation of

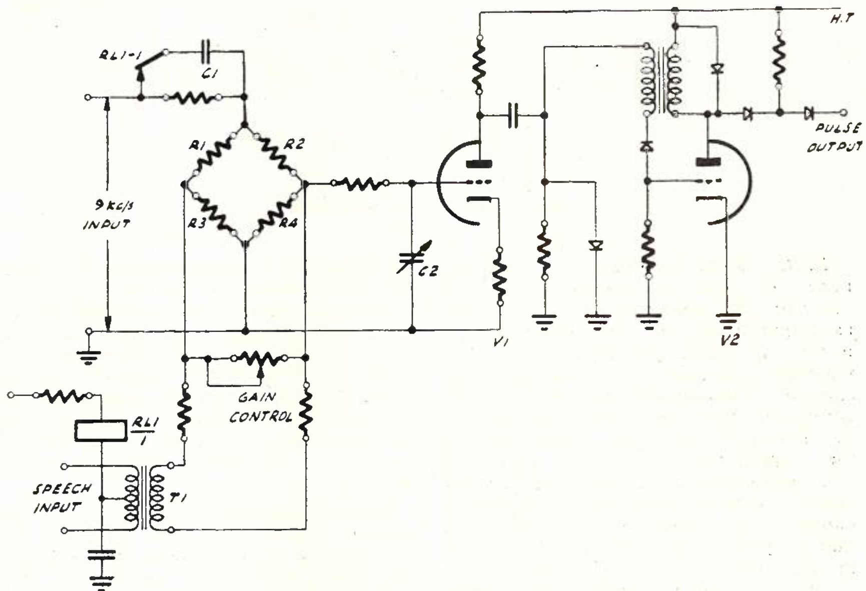

Fig. 12.—Circuit channel modulator.

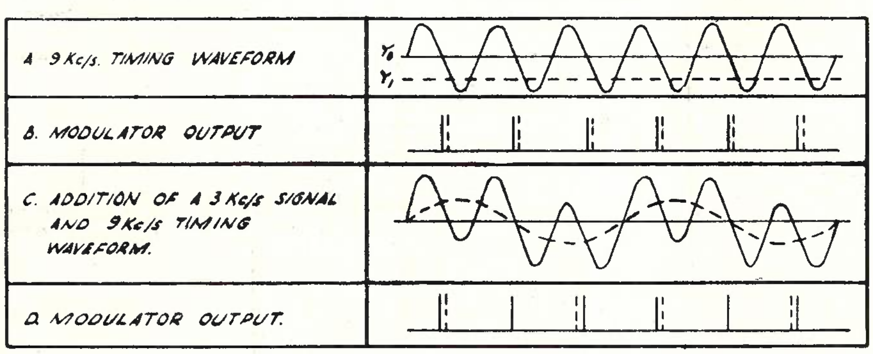

Fig. 11.—Waveforms showing modulation process.

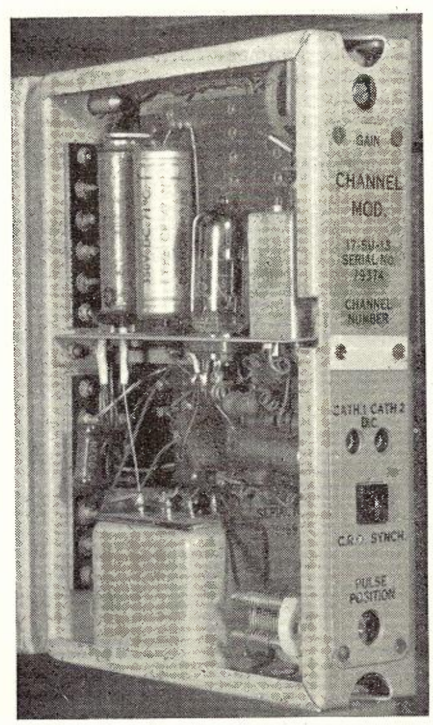

Fig. 13.—Channel modulator

which is described with reference to Fig. 14.

The channel pulse may be considered to cause a switch S (Fig. 14) to close for the duration of the pulse. The contact closes the circuit to the 9 kc/s generator which charges the condenser C through the generator internal impedance Z, the voltage on the condenser

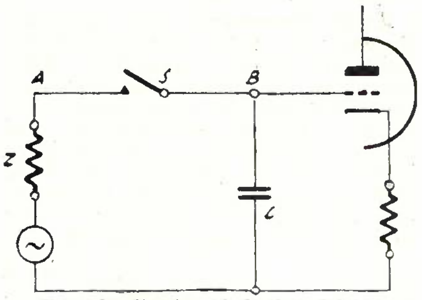

Fig. 14.—Simple switch demodulator.

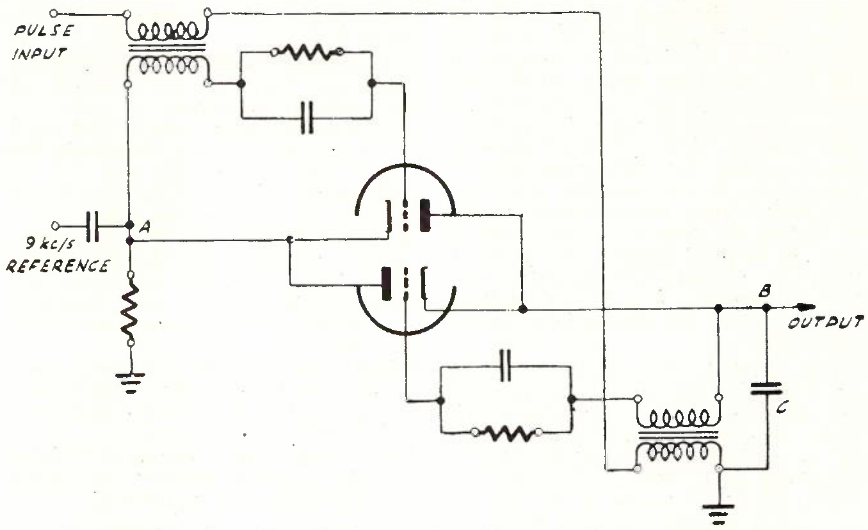

Fig. 16—Box-car demodulator circuit.

rising to a value depending upon the instantaneous voltage from the generator at the instant that the switch is closed. When the pulse is unmodulated, the value of the 9 kc/s voltage at the instant of closing of the switch will be always the same since the closing of the switch is at a 9 kc/s rate, and hence the condenser C will assume a constant charge. If however the switch is made to close earlier or later, the condenser will assume a difference charge since the closing of the switch will occur when the instantaneous value of the voltage is different. Modulation of the pulse position causes the charge on the condenser to vary in steps by amounts which are proportional to the displacement of the pulse. The output produced by the demodulator when the pulse is modulated at a 1 kc/s rate, is shown in Fig. 15. To obtain the original modulated signal from this waveform, the output from the switch tube is passed through a low pass filter network.

Fig. 15.—Switch demodulator output.

In the practical demodulator the switch S is replaced by a triode valve, the two halves being connected in opposite directions so that conduction will take place in both directions depending on whether the voltage at B is higher or lower than the voltage at A when the switch is closed. The form of this circuit is shown in Fig. 16.

Synchronising: The 9 kc/s signal used for demodulation must be synchronised accurately to the 9 kc/s signal used for modulation. Various means are available for generating and transmitting a distinctive synchronising signal which may readily be recognised by the receiver circuits and separated without ambiguity from the channel pulse. In this system the synchronising signal takes the form of two pulses, each of the same duration as the channel pulses

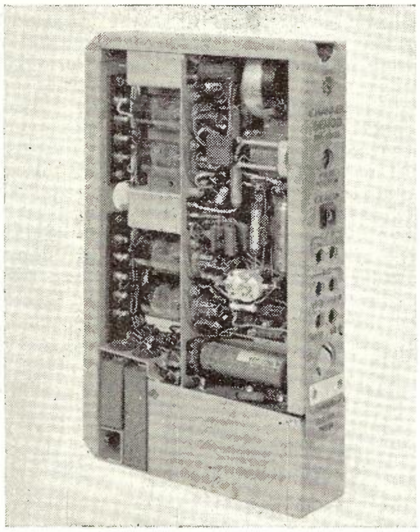

Fig. 17.—Channel demodulator.

but more closely spaced in time, both pulses occurring during a period which is less than the period assigned to each modulated channel pulse.

This synchronising signal, sometimes called the marker pulse, is separated from the composite pulse train in the synchronising separator unit where the 9 kc/s demodulator reference sine wave is generated. The Synchronising Separator consists of a delay line pulse separator, the output of which operates a ringing circuit to produce a 9 kc/s sine wave output. The 9 kc/s ringing circuit has automatic phase control applied to it in order to lock the phase of the 9 kc/s output to the incoming marker pulse. This phase control is of utmost importance in a time multiplexed system since drifts in the mean positions of the channel pulses or the phase of the demodulating reference sine waves can lead to incorrect operation of the signalling circuits. The importance of stability of the pulse positions will be evident from the description of the signalling facilities which follow.

Since it is possible for the inadvertent juxtaposition of two channel pulses to stimulate the synchronising signal and cause ambiguity of demodulation, the synchronising separator circuits are arranged so that as soon as synchronisation has been achieved, a gating circuit is introduced to reject all pulses except those of the desired synchronising signal.

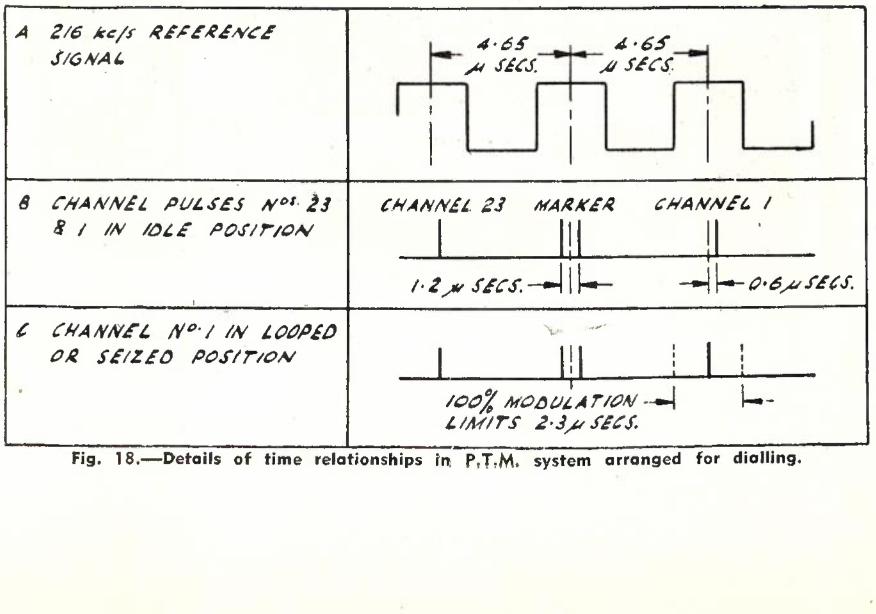

Fig. 18.—Details of time relationships in P.T.M. system arranged for dialling.

Signalling Facilities: It is possible to arrange the channel pulse in either of two positions which can be regarded as two D.C. conditions which can be used to cause the operation or release of a relay. The shift of pulse is caused by the operation of RL1 in the modulator circuit of Fig. 12. This pulse shift is demodulated at the receiving end back to a D.C. voltage change which is used to control the grid of a valve with a relay in its plate circuit. Any drift of the pulse position will therefore correspond to a change in the D.C. voltage on the grid of the demodulator signalling valve.

Fig. 18 shows the condition existing when the channels are in their released and seized conditions. Waveform (B) shows channels 23 and 1, together with the marker pulse, when idle or released conditions exist. When the channel is seized, the pulse moves to the left of its original position, the shift being 0.6 micro-seconds. The condition is illustrated in (C) where channel 1 is shown in the seized condition. The 216 kc/s reference square wave (A) which is displayed on the Cathode Ray Oscilloscope (C.R.O.) Monitor, is used as a time reference for the purpose of lining up the channels.

The equipment may be used for ring down operation as well as dialling, the changeover from dialling to ring down operation being effected by changing strappings on the back panels of the modulator and demodulator units. The effect of changing these strappings is to cause all the pulses to lie in the position as represented by the seized condition when the system is arranged for dialling. Signalling on the line causes the pulse to be retarded by an interval of 0.6 microseconds, in step with the 17 c/s ringing. The pulse may be modulated in either of its two possible positions making possible the handling of supervisory tones and non-reversal telephone calls.

Monitoring Facilities: The following monitoring facilities are available on the multiplex equipment.

(i) Monitor, speak, ring or dial on 4-wire circuits with a monitoring loss of less than 0.1 db.
(ii) Speak, ring or dial on 2-wire order-wire channel or test trunk.
(iii) V.F. Transmission Test Oscillator.
(iv) V.F. Transmission Measuring Set.
(v) Impulse Distortion Test Set.
(vi) Facilities to "busy out" automatic circuits during maintenance operations.
(vii) Monitor cathode ray oscilloscopes for setting the pulse displacement and for monitoring the waveforms throughout the system.
(viii) Voltmeter for checking D.C. levels and cathode currents of valves throughout the equipment.

Radio Frequency Equipment

The radio frequency equipment in a P.T.M. system provides a microwave bearer circuit operating in the frequency range 1750-2300 Mc/s for the pulse train produced by the multiplex terminal equipment. The transmitter power is greater than 50 watts peak under pulsed conditions. The equipment comprises transmitters, receivers and aerial systems. At a terminal station, one transmitter, one receiver and two aerials are required while at a repeater, two transmitters, two receivers and four aerials are needed to communicate in both directions. Under special circumstances where two radio links are operated in parallel, a saving in the number of aerials required is made possible by operating two transmitters and two receivers into a common aerial with the aid of a diplexing filter. One transmitter and one receiver are mounted on a common rack and at a repeater, one rack is used for one direction of transmission and the second is used for the opposite direction. Apart from slight differences in the order wire equipment, the radio frequency bays used at a repeater are identical with those used at a terminal station. All the aerial dipoles, reflectors and feeders, both for transmitting and receiving, are identical and do not require any adjustment for different frequencies in the range 1750-2300 Mc/s.

Radio Transmitter: The transmitter consists of a Master Oscillator, Buffer Amplifier, Power Amplifier, Pulse Amplifier, Modulator and associated power supplies. In many respects it is similar in principle to transmitters used on low frequencies but the details of construction are different. The main features of operation of the transmitter may be followed by reference to the simplified block diagram, Fig. 21.

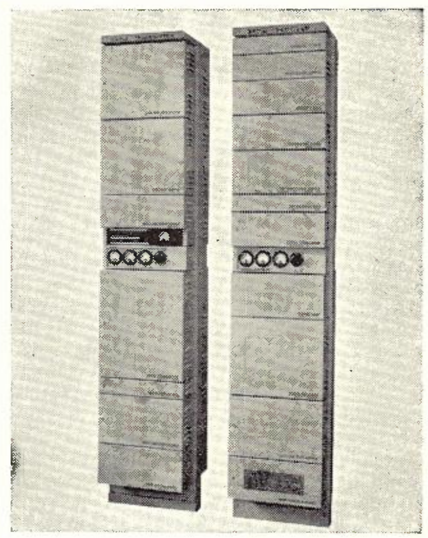

Fig. 20.—Repeater equipment.

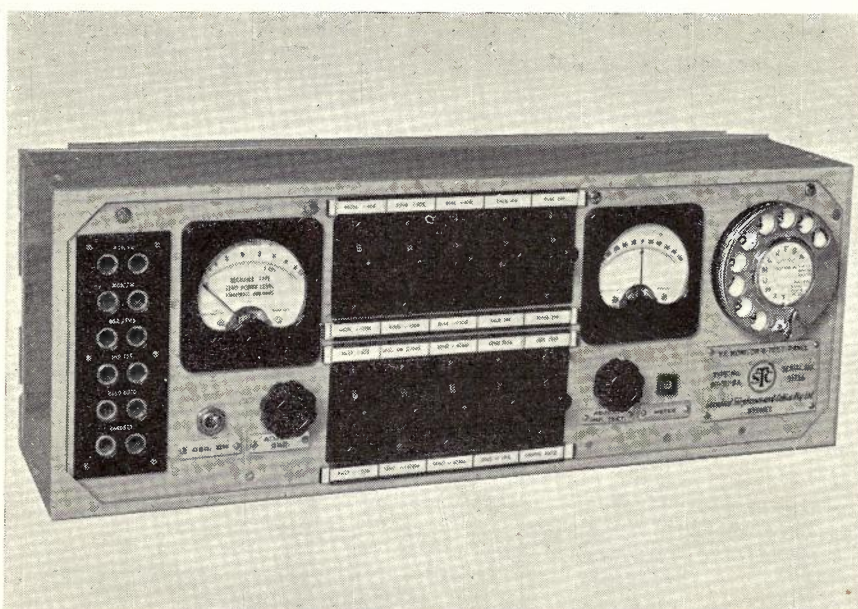

Fig. 19.—V.F. monitor and test panel.

The three radio frequency stages are of similar mechanical construction and make use of a triode valve type 2C39A, in a grounded-grid coaxial-line type of circuit. The coaxial-line circuit associated with each stage consists of three concentric metal cylinders. The valve plugs into one end and tuning is accomplished by moving plungers from the other end to vary the effective lengths of the lines. The inner and middle cylinders form the cathode-grid tuned line and the middle and outer cylinders form the grid-anode line. Each stage thus has a tuned grid circuit and tuned plate circuit and each stage is inductively coupled to the next through a short length of coaxial cable; the tuning-up procedure however, is somewhat different from that used with other equipment.

The radio frequency master oscillator is supplied with regulated high tension voltage and stabilised filament current; it is thus a stable source of radio frequency power in the range 1750-2300 Mc/s. The only slight difference in the construction of the master oscillator coaxial-line is that small loops are fitted between the cathode- grid and grid-anode

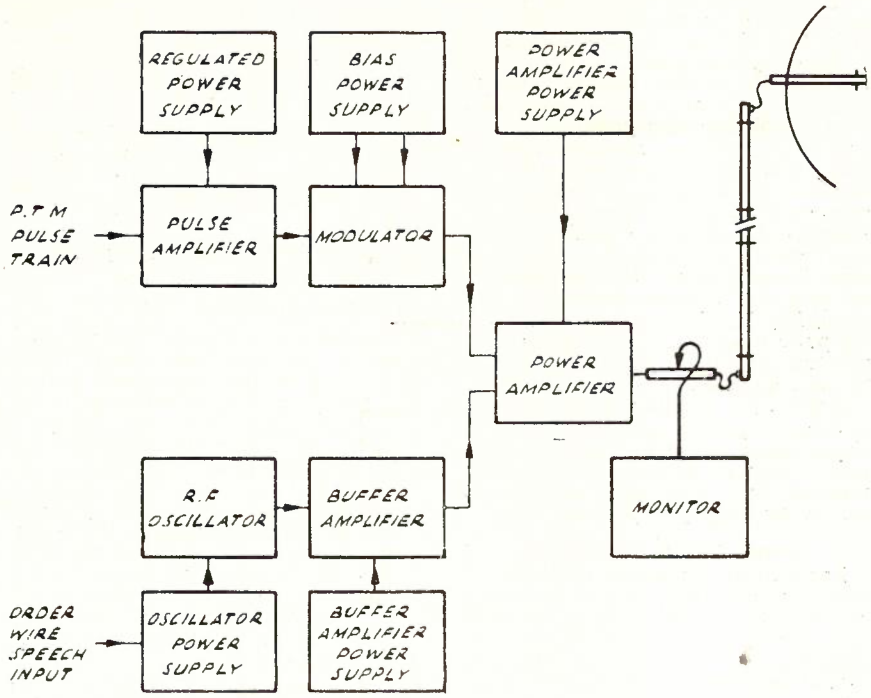

Fig. 21.—Block diagram of P.T.M. transmitter.

lines to promote oscillation. Radio frequency power is coupled from the oscillator output to the cathode-grid line of the buffer and in similar manner the buffer amplifier is coupled to the power amplifier.

The output of the power amplifier is taken from the anode coaxial-line by means of a small loop and connected through a short slotted line to the aerial feeder. A sliding pick-up probe is fitted into this slotted section of line and connected to a monitor which consists of a tuned cavity with a silicon crystal detector and meter to measure the output of the detector. The monitor may thus be used to measure the standing wave ratio in the transmission line. The output of the detector is also used to operate an alarm circuit in case of excessive drift of the transmitter frequency or failure of the output power. The operating conditions of the power amplifier valve are such that, in the absence of pulses, a small amount of power is transmitted which carries the order wire signals as described later. The power amplifier is amplitude modulated by the pulse train from the multiplex equipment after amplification in the Pulse Amplifier. The Modulator consists of a valve in the cathode circuit of the Power Amplifier which operates as a switch under the control of the pulses. This "switch" allows the Power Amplifier to amplify fully only when a pulse is present. The radio frequency output of the Power Amplifier thus consists of a small constant amount of power, about one watt, on which is superimposed a series of radio frequency pulses with a peak power of approximately 50 watts. The timing of the pulses is in accordance with the pulses in the P.T.M. pulse train from the multiplex equipment.

The aerial transmission line may consist of 52 ohm coaxial cable for short distances and a combination of coaxial cable and waveguide for long distances. The loss in a typical coaxial cable is 16 db per 100 feet, and for distances greater than 20-30 feet the use of waveguide which has an attenuation of 1 db per 100 feet is warranted in spite of the extra complication of waveguide to coaxial transitions.

The remaining units in the block diagram are the power supplies necessary for the operation of the transmitter.

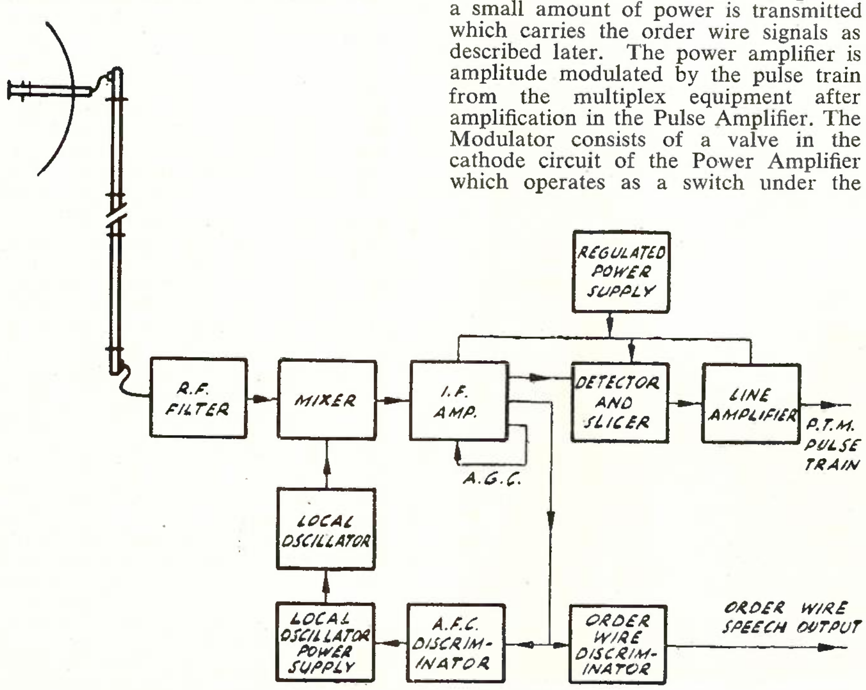

Fig. 22.—Block diagram of P.T.M. receiver.

Radio Receiver: The main features of the operation of the receiver may be followed by reference to the simplified block diagram, Fig. 22.

The incoming signal is intercepted and brought down to the receiver by means of aerial equipment identical to that used for transmission. From the transmission line the signal passes through an R.F. Filter to the Mixer, both of which consist of tuned cavities of similar construction. The R.F. Filter comprises two coupled cavities which give a band-pass characteristic when correctly tuned. The mixer is a single tuned cavity to which three connections are made, namely, the signal input from the R.F. Filter, the input from the Local Oscillator and the intermediate frequency output to the I.F. Amplifier. The intermediate frequency signal, which is centred on 30 Mc/s, is generated in a silicon crystal rectifier incorporated in the I.F. Amplifier connection to the Mixer cavity.

The I.F. Amplifier has a maximum gain of 105 db and is fitted with an Automatic Gain Control (A.G.C.) circuit which maintains a substantially constant voltage output in spite of variations of the input signal.

The output of the I.F. Amplifier is connected to two separate places as follows:

(a) The Limiters and Discriminators. The action of the Limiters is to clip off the pulses from the signal and then to limit the remaining portion so that a constant voltage output is obtained. The output from the limiting circuit is applied to both the Automatic Frequency Control (A.F.C.) discriminator and to the Order Wire discriminator; the use of the latter is described later. The output of the A.F.C. discriminator is applied to the voltage regulator of the Local Oscillator Power Supply and thereby controls the frequency of the Local Oscillator. The effect of this control on the Local Oscillator is to maintain a substantially constant intermediate frequency of 30 Mc/s independent of drift in the frequency of the received signal.

(b) The Detector and Slicer. Here the radio frequency pulses are detected and applied to a slicer which removes the upper and lower portions of the rectified pulse train and accepts only those sections of the pulses lying within a narrow voltage range near the centre of the pulses, see Fig. 23. This is, in effect, a very severe limiting process which eliminates the amplitude modulated noise occurring between the pulses and performs a similar function to the limiting employed in conventional frequency modulated systems.

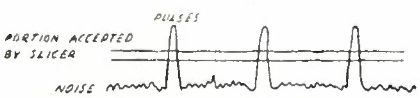

Fig. 23.—Action of slicer on pulses.

The pulse output from the slicer, consisting of the centre portions of the pulses, is amplified and delivered at a level of at least 20 volts peak to the output terminals, The output connection which is made either to the multiplex demodulator or to the input of a transmitter (as at a repeater station) is in coaxial cable with a characteristic impedance of 52 ohms.

The high tension voltage for the I.F. Amplifier, the Detector and Slicer, and the Line Amplifier is obtained from a regulated power supply, thus ensuring operation which is independent of mains supply variations.

Order Wire: The order wire circuit operates independently of the main multiplex traffic channels as it is obtained by frequency modulating a small, continuously transmitted, part of the carrier power. As may be seen by reference to the transmitter block diagram Fig. 21, the voice-frequency input to the order wire circuit is connected to the Oscillator Power Supply where it produces modulation of the high tension voltage which in turn produces a small amount of frequency modulation of the output of the transmitter. At the receiver, the order wire modulation is recovered from the output of the I.F. Amplifier by applying a portion of it to the Limiters and thence to the Order Wire Discriminator. This may be seen by reference to the receiver block diagram, Fig. 22. The limiters ensure that the pulse modulation is removed and a constant amplitude signal is applied to the discriminator.

Order wire signalling is by means of a voice frequency tone sent over the circuit and detected by tuned vibrating-reed detectors. Selective calling is not supplied but calls may be directed aurally by employing a coded ring.

Overall Circuit Performance

For a circuit comprising two terminals and four repeaters spaced at intervals of 30 miles (total route distance 150 miles) and assuming radio propagation conditions equal to those of free space, the overall performance should be as follows:

(a) Transmission loss between terminating trunk switchboards: 6 db.

(b) Transmission loss with pad switching or 4-wire transit operation: 0 db.

(c) Maximum level at transmitting trunk switchboard: +8 dbm (6 mW).

(d) Channel quality: Transmission loss relative to that at 800 c/s:
200-400 and 3000-3400 c/s : +5 db, −1 db.
400-600 and 2400-3000 c/s : +2 db, −1 db.
600-2400 c/s : ±1 db.

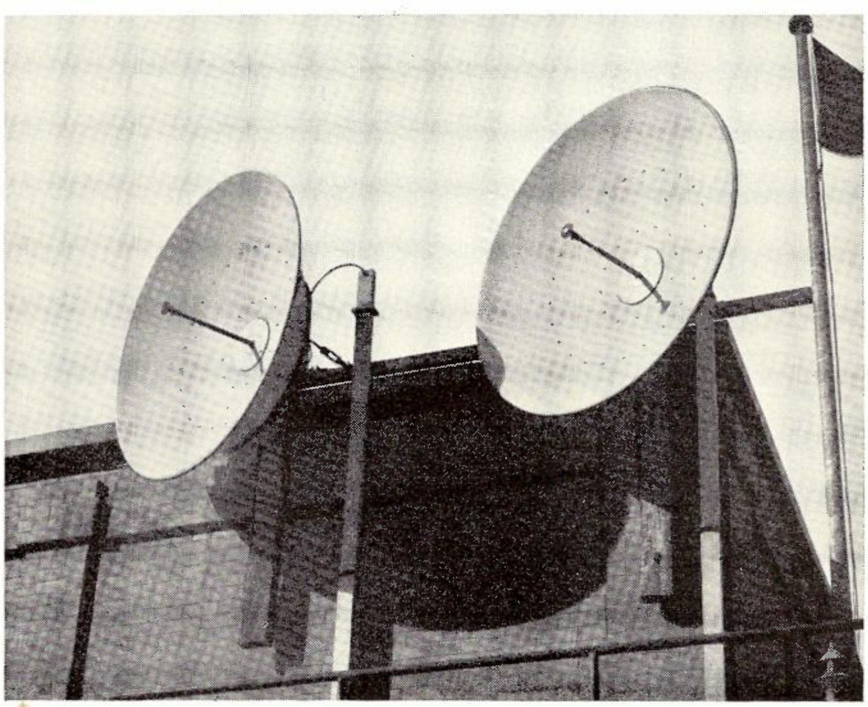

Fig. 24.—Aerials.

(e) Channel linearity: Transmission loss, relative to that of test tone of 0 dbm at transmitting trunk switchboard, within ±0.5 db for levels between −40 dbm and +7 dbm.

(f) Channel harmonic distortion: Less than 5% (26 db below fundamental) for test tone of 400 c/s at a level of +5 dbm at transmitting trunk switchboard.

(g) Automatic signalling: 10 impulses per second, distortion less than 3%.

(h) Magneto signalling: 17 c/s.

(j) Channel Noise Level. The channel noise level has been shown to be made up of three components, namely the radio equipment noise, the multiplex equipment noise and the radio path noise. For 80 db attenuation between each transmitter and receiver, which is a representative condition of operation, the noise at the output of one of the 23 channels is limited by the multiplex equipment as shown in Fig. 25. It should be noted that the noise level shown is that which would be measured at a point of −6dbm test level, using a weighted noise measuring instrument.

As indicated in Fig. 25 there is quite a large margin against fading of the radio signal. The system will fail due to loss of synchronisation in the multiplex equipment when the noise output rises due to the reduced radio frequency signal. The channel noise level does not change from the slack to busy hour due to the nature of the inter-channel crosstalk. This aspect will be described under Inter-channel crosstalk.

(k) Transmission Stability. The level of the output audio-frequency signal is independent of the radio equipment, and likewise the number of repeaters in the link, as the pulse displacement is determined wholly by the multiplexing equipment. The transmission stability therefore depends only on the audio circuits of the modulator and demodulator which can be made extremely stable, without the need for automatic volume control or pilot channels.

(l) Inter-channel Crosstalk. With frequency division multiplexing, non-linear circuits must be assiduously avoided to prevent crosstalk between channels. For time division multiplexing, these effects are avoided as only a single channel is transmitted at any instant of time. The main source of crosstalk is therefore from any tailing of the preceding channel pulse and to a lesser extent from crosstalk arising from the power supply to the channel audio amplifiers. The latter can be eliminated with suitable decoupling and the former can be controlled by careful design. It is therefore evident that the interference on any one channel depends only on whether the previous channel is modulated or not and is independent of the number of channels being modulated. The crosstalk attenuation from the previous channel in this system is 60 db minimum.

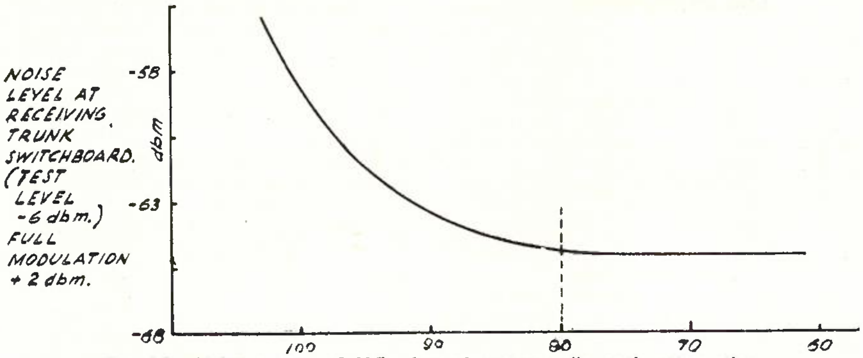

Fig. 25.—Noise output of V.F. channel versus radio path attenuation.

CONCLUSION

Some aspects of the design and a description of a 23 channel Pulse Time Modulation system suitable for integration with the Australian trunk network have been given. Already systems are operating satisfactorily between Sydney-Wollongong (two 23 channel systems in parallel), Melbourne-Warragul, Melbourne-Sorrento and Brisbane-Southport.

The use of pulse time modulation has the advantage that a multi-channel system is produced without the need for accurate crystal filters or frequency generating equipment. All voice frequency channel units are identical, which facilitates setting up and maintenance. The channel performance is comparable to frequency division equipment and the channel equivalent is maintained without the use of pilot tones.

The use of pulse shift signalling makes the system eminently suitable for use between centres such as Sydney and Wollongong where the automatic dialling impulses may be carried directly over the system without the use of voice frequency equipment.

Because of the ease with which channels may be separated before demodulation, the system lends itself to drop and insert of channels at repeater stations. A broadband broadcast channel may be provided by using the pulses of two channels to give a sampling frequency of 18 kc/s making available a channel of approximately 8 kc/s bandwidth.

The multiplex equipment also offers the advantage of compact size, one 10′ 6″ double sided rack being required for 23 channels.

The use of a microwave radio bearer for the modulated pulses has the advantage of economy, ease of installation, and reliability in areas where bush fires, floods and land slides are prevalent. The system is of use for temporary as well as permanent links in such areas. Microwave bearer circuits are in use for frequency division circuits but the degree of linearity and techniques involved in such a system are far more critical than the requirements of a time division system where each channel takes its turn in using the bearer channel.

DEVELOPMENTS IN POWER PLANT FOR TELEPHONE EXCHANGES

*R. C. MELGAARD**

Introduction

The Department has assets in the form of power plant valued at approximately £5,000,000, and the expenditure this year will increase these assets by at least £500,000. These figures do not make any allowance for the very considerable cost of accommodation. Furthermore, an appreciable percentage of the effort involved in maintaining a telephone exchange has in the past been expended on power plant. The annual cost of the electrical energy supplied to exchange power plant is estimated at more than £250,000. In view of the large amount of money involved it is not surprising that a great deal of engineering attention has been directed towards cutting down expenditure on power plant without impairing the reliability of this vital part of the telecommunication system. Considerable savings have been achieved as a result of the changes in power equipment and practices which have occurred in the last five years and a significant proportion of these savings is attributable to the reduction in building space now required to accommodate power plant. The general nature of several of the changes which have occurred was foreshadowed in an article by Messrs. Bulte and McKibbin in the Telecommunication Journal of Australia, Volume 9, No. 2 (1).

Details of the changes which have occurred and a description of current Departmental plant and practices are given in this article.

General

In automatic and modern C.B. exchanges the equipment working voltage range is 46 to 52 volts. Standard practice is to provide two 24 or 25 cell batteries capable of individual or parallel working for the main equipment supply, except in smaller exchanges where one 24 cell battery suffices. The potential of the supply must be within the limits quoted above for the equipment to operate reliably and it is necessary to cater for periods of interruption to the mains supply. Since this supply provides the speaking battery to the transmission bridges the noise voltage content must not be high enough to cause an objectionable noise level in the speech circuits. A second 50 V. D.C. supply, positive with respect to earth, is required for metering in Automatic and C.B. exchanges and also for signalling circuits in "Sleeve Control" exchanges.

There is evidence that the 24 cell battery arrangement is gaining popularity overseas and the following extract from a recent technical publication (3) is of interest:

"The most recent type of power plant now to be described operates on the automatic full float principle. It is the result of the development in the past few years of new types of static automatic rectifiers. These are used with either a single 24 cell battery or in the large exchanges with parallel duplicate 24 cell batteries and will maintain the exchange voltage within ± 1% from no load to full load over most ranges of either the single or three phase mains voltage and frequency variations encountered in practice. With such units it is possible to design power plant that contains the minimum of moving parts and as the batteries are floating at a voltage below the gassing level, maintenance is greatly reduced. As a result a modern 'full float' power plant will supply energy to the exchange for a period of two to three months under normal working conditions without any attention whatsoever and, if the cells are of the enclosed type a separate battery room is not required."

Twenty-four cell batteries have been employed extensively in this country and their use is becoming more widespread. Full float operation has been employed in many countries including America (4), Sweden (6), and by the Department for a number of years. Floating offers a number of advantages as it saves conversion of energy from electrical to chemical and back to the electrical form, thereby increasing efficiency and increasing the life of the cells.

An important change has occurred as a result of the employment of the full float method of operation. Voltage

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control has superseded current control and it is now necessary to pay considerable attention to the float voltage to ensure that the life of the cells is not reduced by cycling. In America, particularly where lead calcium cells are employed, great care is taken to keep the voltage within ± 1% and in practice a figure of ± 0.25% is normally achieved. Working to such fine limits makes it essential that a high grade instrument be fitted on the power board and that steps be taken regularly to see that its accuracy is maintained. This is done annually in the United States (4). Work has commenced recently on checking switchboard instruments for telephone exchanges in Australia by means of a voltage comparator which consists of a sensitive centre zero galvanometer in series with decade type variable resistors. The results of the measurements made so far indicate the necessity for regular checking.

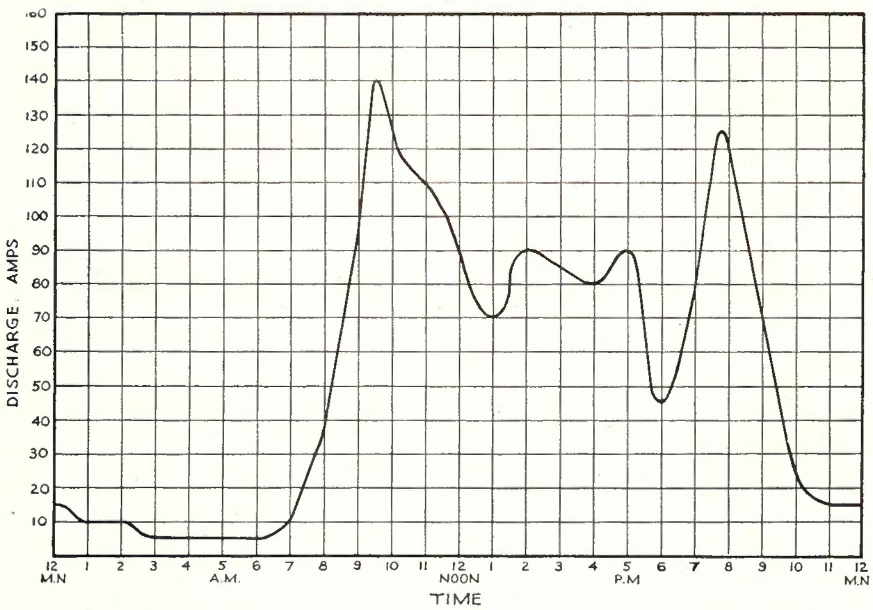


Fig. 1.—Graph Showing Variation in Exchange Load Throughout Day.

The variation in load in a typical branch exchange in a residential area for a 24 hours period is shown in Fig. 1. The busy hour discharge in most metropolitan area branch exchanges is between 30 and 40 amps per 1000 lines. In most cases the energy consumed in a 24 hour period is approximately equivalent to ten times the energy consumed during the busy hour. If then a battery is provided with a capacity equivalent to ten times the busy hour load it will be possible to operate an exchange from the battery for 24 hours. It has been found more economical and convenient to reduce the battery capacity to the equivalent of three busy hours and to provide an automatic start standby alternator than to employ large batteries. This arrangement, apart from saving space, has the advantages that a considerably longer interruption to the main power supply can be tolerated and power is available for auxiliary services such as lighting, skeleton lift services and essential tools as well as for rectifiers for D.C. supplies other than the 50 volt necessary for the main exchange supply. Retention of 3 hours battery reserve acts as a safeguard should the engine fail to start in an emergency. Further reduction of the battery reserve is not expedient because the battery voltage drops with very heavy discharge rates, and arrangements such as end or counter E.M.F. cells would probably be necessary.

Conversion Plant

In the past motor generator sets were employed to convert the commercial alternating current supply to D.C. However, there have been no purchases of motor generator sets for use in telephone exchanges for several years as motor generator sets have now been superseded by static rectifiers. Between December, 1953, and 1957 the Commonwealth percentage of conversion plant (installed in Metropolitan automatic exchanges) which employed static rectifiers increased from 17.5% to 24.3%. The equivalent state percentages are New South Wales 12.7%-22.5%, Victoria 20.7%-26.7%, Queensland 18.7%-21.0%, South Australia 24.2%-51.3%, Western Australia 27.8%-33.2% and Tasmania 18.2%-33.3%.

This trend to employ static rectifiers is world-wide and is being followed by the British Post Office and other overseas Administrations. (3, 4, 5, 6, 7 and 8). Rectifiers offer the following advantages over motor-generators:—

(i) There are no moving parts.
(ii) Circuit breakers which must be re-operated manually if they operate due to overload or power failure are not necessary.
(iii) Less floor space is required.
(iv) Higher efficiency is obtained, particularly at lower output. Consider a motor and a generator each having an efficiency of 80% at full load. Their overall efficiency when combined as a unit would then be about 65%. Since iron, windage, friction and field excitation losses are approximately independent of load the efficiency is much lower at small outputs.
(v) Less maintenance effort is required.
(vi) Installation is simpler and appearance is improved.

Copper oxide discs were employed previously, but selenium is now used exclusively due to its better temperature co-efficient, better power factor, higher efficiency, higher working voltage and consequently smaller space requirements.

Method of Forming Selenium Rectifiers. The selenium used in the manufacture of rectifier elements is all imported as the selenium which is produced in Australia is not of sufficiently high quality for the manufacture of rectifier discs. The best quality selenium comes from Canada. Selenium is purchased in the form of shot approximately 1/16-inch in diameter. One handful of selenium weighs approximately 1lb. and would cost between £8 and £15. The shot may be powdered readily by the application of pressure. After powdering, the selenium is mixed with other ingredients and is heated in an oven for a period of approximately one hour. After this period the mixture is in a molten state and is poured out on to cooling slabs and forms a sheet between 1/16 and ⅛-inch thick which resembles black glass. These sheets are then broken up and placed in a grinder. At the output of the grinder it passes through a sieve with a mesh of 30 to 200 meshes per square inch.

Rectifier elements are made by depositing the selenium powder from the grinder on a thin strip of mild steel after it has been shot blasted and degreased. The selenium may be deposited by either vapourising or pressing. The strip with the thin layer (.0035-inch) of selenium on it is then placed on a heated press which converts the selenium into its vitreous form. The selenium in its present form will not rectify. In fact it is almost a complete insulator. The black vitreous form of selenium converts to the dark grey or Beta form at, or just below, its melting point which is 217°C. The Beta form is produced by annealing in an oven and when in this form the selenium will rectify.

Although the Beta form of selenium is suitable for rectifying it will withstand a reverse voltage of only 4 volts. This is insufficient for the majority of rectifier applications today and so the reverse voltage is increased by various processes. Three methods used to facilitate increasing the reverse voltage are:—

(i) By exposing the selenium in its Beta form to vapours of acid.
(ii) By exposing to vapours of ammonia solution, or
(iii) By immersion in various alkaline solutions.

In one method of manufacture the sheets are dipped in a hot caustic soda solution for approximately half a minute and then rinsed in running water after which they are passed under drying lamps to remove any trace of moisture. It is necessary to obtain an electrical connection to the element and this contact is arranged by either metal spraying or vapourising. The metal used for spraying must be a fine grain size to obtain good adherence. A mixture of tin and cadmium is usually employed. The current flows readily from the selenium to the alloy film, but is restricted in the opposite direction.

At the stage when the element is removed from the caustic soda solution it will still withstand a reverse voltage of only 4 volts, but this is increased by a process known as electro-forming. Usually about four electro-forming treatments are necessary to increase the reverse voltage from 4 to 40 volts. The forming current which is applied in the reverse direction to the normal operating direction of the rectifier is approximately 300 milliamps per square centimetre and the voltage used is approximately double the required reverse voltage. This high voltage is applied for only one second.

A selenium rectifier element 3 inches wide and 12 inches long is rated at 10 amps for air-cooled applications and this is increased to 30 amps if oil-cooling is employed. Air-cooling is used exclusively in Departmental plant even on the largest units purchased which are rated at 800 amps, 50 volts. Oil or water cooling is sometimes employed overseas on large rectifiers.

Improved Rectifier Elements. The technique of producing selenium rectifiers is improving all the time due to constant research and it is expected that rectifiers will soon be produced which are virtually non-ageing. At the present time rectifiers are being produced overseas known as non-genetic layer rectifiers in which a layer of varnish or some similar compound is applied between the selenium and the other electrode. The process is much more technical and difficult than a normal selenium rectifier manufacturing process, but the rectifiers produced have the property of being practically non-ageing.

Germanium and more recently silicon rectifier elements have gained considerable popularity overseas within the last few years due to their high efficiency (95-98%) and their non-ageing characteristics.

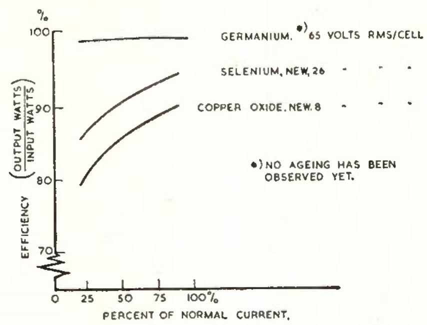


Fig. 3.—Graph Showing Efficiency at Various Outputs of Germanium, Selenium and Copper Oxide Rectifier Elements.

Fig. 2 shows a germanium rectifier rated at 75 volts, 100 amps. It will be seen that this unit is very small compared with rectifiers of the selenium type, although the picture does not show the cooling arrangements necessary for the germanium rectifier.

The efficiency of copper oxide, selenium and germanium discs is shown in Fig. 3 and it will be noted that the germanium unit has an efficiency of approximately 98%. Germanium rectifiers are employed in some plants overseas and advertisements appear regularly in American Magazines for germanium rectifiers for use in telephone exchange power supplies. Germanium suffers from the disadvantage that the maximum junction temperature permitted is in the order of 60°C., however, the manufacturers prefer a much lower temperature, usually about 35°C. As against this, the silicon unit can be operated at 200°C. and for this reason, silicon now appears to be gaining favour overseas at the expense of germanium. The manufacture of silicon rectifiers is rather difficult as part of the process involves an operation at 1400°C. However, the cheapness of the raw material tends to offset the high cost of production and it is expected that silicon rectifiers will be employed extensively within the next few years. A further attractive feature of germanium and silicon elements is that the output voltage does not change as much when the load is varied as other types.

Voltage Control. The automatic voltage control feature incorporated in rectifiers supplied to the Department is designed to confine the voltage to a value constant to ± 1%, even though the output load may vary from 5% to 100%, the frequency change ± 3% and the A.C. mains voltage vary from + 5% - 10%. On battery floating rectifiers automatic overload protection is also incorporated within the control device to limit the output current to the maximum rating of the rectifier in the event of the exchange load rising above this value. Under such circumstances the excess current would be taken from the battery.

Some of the earlier types of rectifiers delivered to the Department rated at up to 1200 watts, and many of those that are at present being delivered, having an output up to 500 watts employ the "Westat" principle. Fig. 4 shows a schematic diagram of a Westat rectifier. Transformer T1 has a gapped core such that its inductance remains constant for varying currents through the coil. Transformer T2, on the other hand, has an inductance which varies in accordance

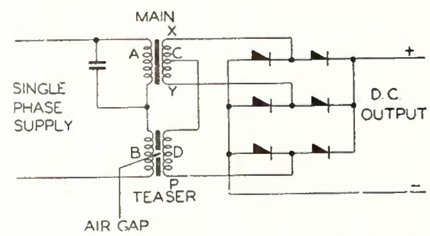
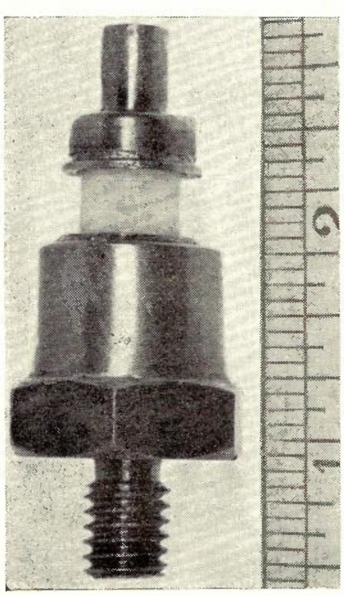


Fig. 4.—Elementary Circuit of Westat Rectifier.

with the characteristic permeability curve of its core material under variations of coil current. The circuit is so arranged that at full load the voltage across the transformer T1 lags the input voltage by 45 degrees and the voltage across transformer T2 leads the input voltage by 45 degrees. The output voltage across the two transformers are thus displaced from each other by 90 degrees.

By arranging the secondary windings in accordance with standard Scott connections a three phase output is obtained and applied via rectifiers to a common feeder. When load is small input to the rectifiers is single phase. The polyphase conditions is established progressively as the load increases causing phase difference to increase to 90 degrees at full load. By this means, the mean value of rectifier load is increased from 0.637, under peak voltage, to 0.95 of the peak voltage. This increase compensates for increases in the potential drops across the rectifier and transformers and subsequent smoothing chokes as the load increases. In this way, the D.C. output voltage obtained is substantially constant. If a charger should become overloaded the three phase condition rapidly reverts to a single phase input to the rectifiers thereby producing a rapid decrease in the output voltage, hence limiting the overload current. This safeguards against accidental overload and dispenses with the need for protective circuit breakers.



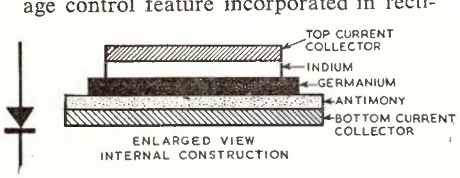


Fig 2.—Germanium Rectifier Rated at 100 Amps, 70 Volts.

The larger rectifier units supplied to the Department all employ the transductor control principle. The basic circuit for a conventional transductor controlled rectifier is shown in Fig. 5. The transductor is placed in series with the A.C. input to the rectifier stack and its impedance is varied by means of a control direct current in such a manner that any tendency for the output voltage of the rectifier to fall is corrected by a reduction in the impedance of the transductor thereby causing an increase in the alternating voltage applied to the rectifiers and vice versa.

Transductors were formerly known as saturable reactors and were, at one time, referred to as magnetic amplifiers although this latter term is now reserved for more complex units incorporating several windings and static rectifiers as will be described later. An early patent for a saturable reactor taken out in America in 1903 included the diagram shown in Fig. 6 which will be used to describe the operation of the transductor. (10). The left hand sketch shows a dynamic hysterisis loop without D.C. magnetisation and it will be seen that a variation in the magnetising force C-C′ causes a large change in flux B-B′. If now a D-C bias O-C is applied as in (B) the operating point changes from O to O′ and the change in magnetising force C-C′ causes a much smaller change in flux B-B′. This smaller change in flux results in lower inductance. An increase in the control direct current to a transductor will, therefore, reduce its inductance.

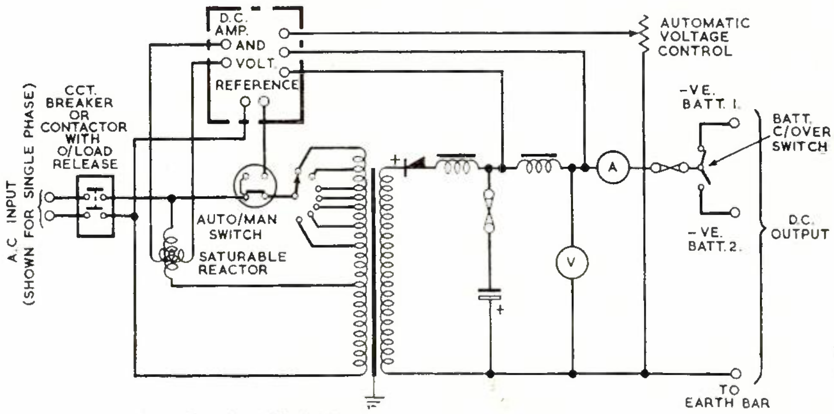


Fig. 7.—Simplified Circuit of Voltage Controlled Rectifier.

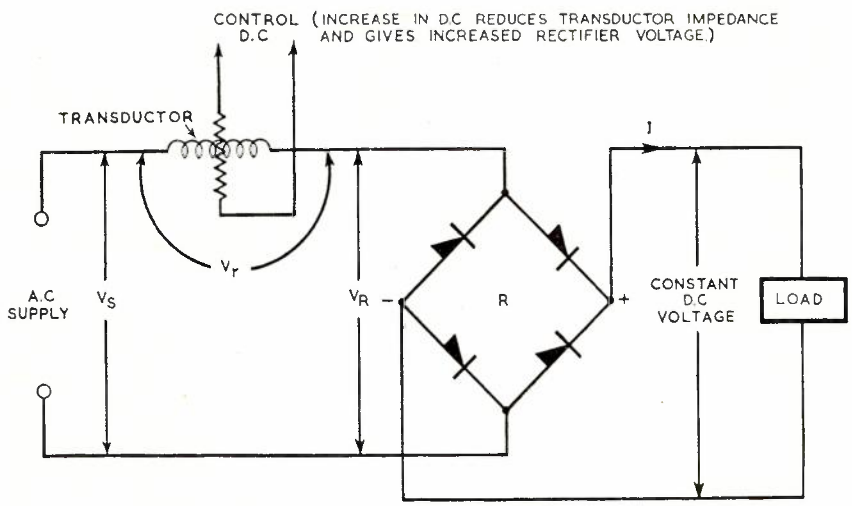


Fig. 5.—Elementary Circuit of Transductor Controlled Rectifier.

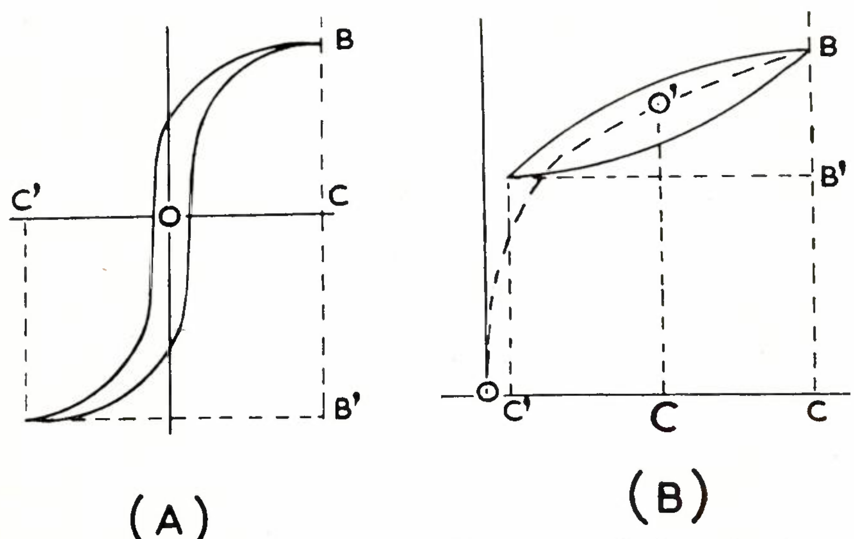


Fig. 6.—Diagram Illustrating Operation of Transductor.

Fig. 7 shows a typical rectifier circuit, incorporating a transductor which is used for automatic voltage control. A switch is provided as shown to permit manual operation of the rectifier. All rectifiers purchased for use in telephone exchanges may be operated in an automatic or manual control condition. In automatic operation, the output voltage of the rectifier unit, after the filter chokes, is fed into a voltage reference and D.C. amplifier in such a manner that a drop in output voltage results in an increase in the output current of the amplifier. This output current passes through the control winding of the transductor thereby reducing its impedance and consequently increasing the rectifier output voltage. The voltage drop across the second filter choke is sometimes fed into the control unit to provide the automatic overload limiting feature. Another arrangement employs a current transformer as described later. When the voltage drop across this choke exceeds the value obtained when the rated output current is flowing, the controller causes the impedance of the transductor to increase, thereby limiting the output current from the rectifier. The D.C. amplifier may be electronic or the magnetic type. Early units supplied to the Department used the electronic type but many of the units delivered since early 1956 have incorporated magnetic amplifiers.

Magnetic Amplifiers. Although the principle of magnetic amplifiers has been known for over 50 years, its development has been overshadowed somewhat by the electronic amplifier. It has been stated (11) that the rapid progress in the development of the vacuum tube was such that the tubes soon became available whose performance overshadowed the solid virtues of static magnetic amplification. The magnetic amplifier is now staging a come-back and in many applications has important advantages over the electronic amplifier. They have

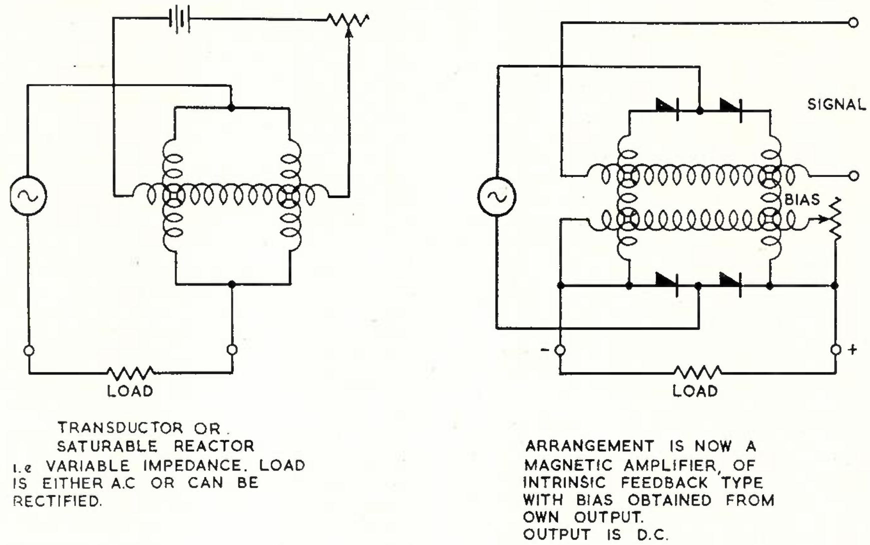


Fig. 8—Illustration Showing Difference Between a Simple Transductor and a Magnetic Amplifier.

no consumable parts and they are not subject to the same variation due to ageing. Within the last few years magnetic amplifier development has made phenomenal progress. In America alone several hundred technical papers have been published on the subject. This development is due largely to the improvements made recently in magnetic core materials and also in the improved static rectifiers which are now available. The desire to find reliable and robust alternatives to sensitive relays and electronic valves has stimulated research into magnetic amplifiers. Magnetic amplifiers can be used as D.C. or A.C. amplifiers or as A.C. to D.C. convertors in conjunction with, or in place of relays or electronic valves (12). Magnetic amplifiers produced today are practically everlasting. Vibrations and shocks, such as encountered in military applications are easily absorbed, and the weight and size of the amplifier have been reduced below those of electronic amplifiers when operating from a 400 c/s power supply. To these advantages may be added the immediate availability (no warm up time) of magnetic amplifiers, their sturdiness and the lack of moving parts. For many years perhaps the main field of application of magnetic amplifiers was in the control of theatre lighting. Nowadays, however, the range of application is as great as that for electronic amplifiers. Magnetic amplifiers are used extensively in military applications, in the pilot control circuit of some carrier systems and in automatic machine tools. No doubt this last-mentioned application will increase greatly as the present trend towards automation develops. It is interesting to reflect that automation has been applied in the telephone industry for many years and it has been said that automatic telephony is really the father of automation.

The difference between a transductor or saturable reactor and a magnetic amplifier is shown in Fig. 8. A transductor is really a variable impedance, the load for which can be either A.C. or it can be rectified. An arrangement which

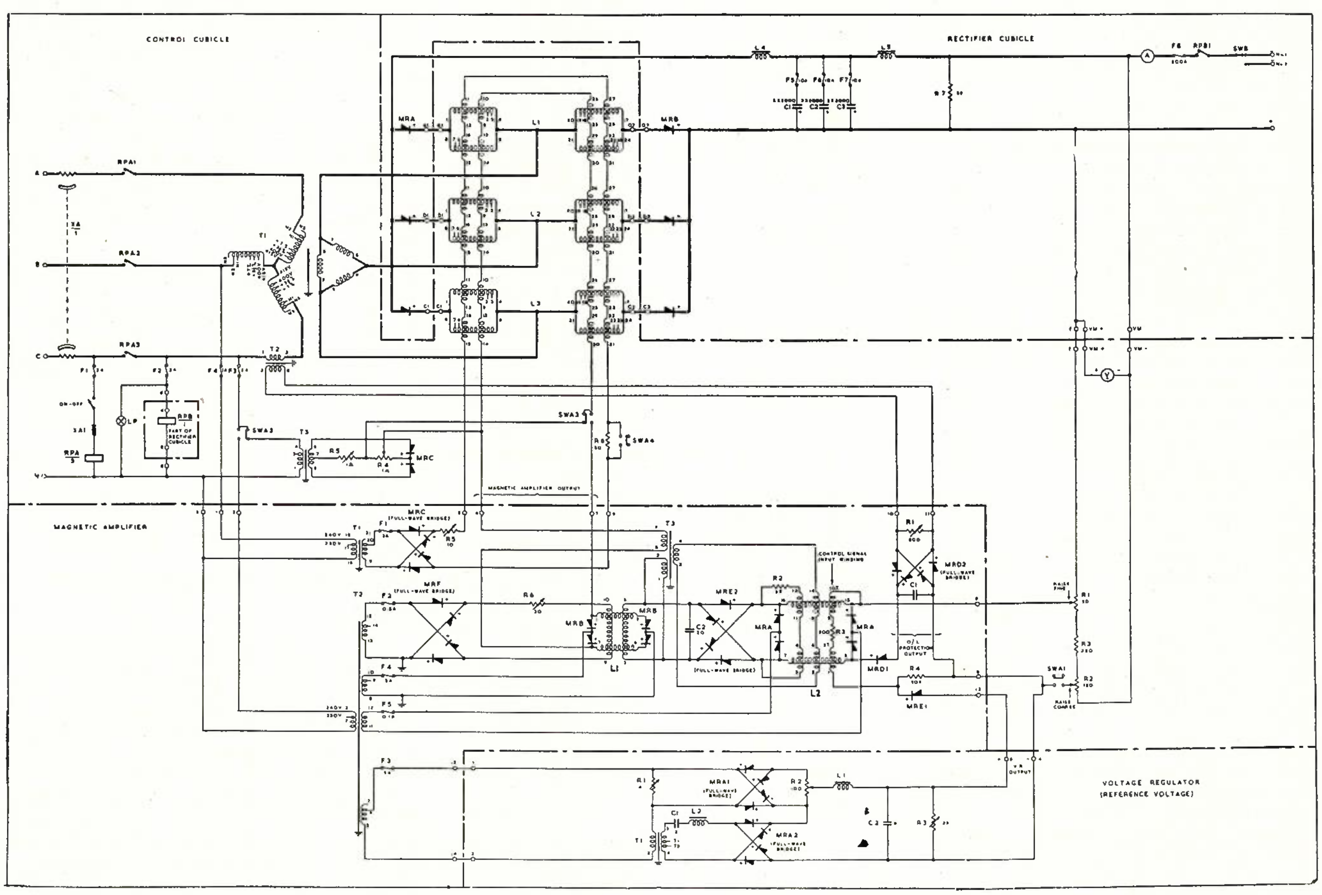


Fig. 9.—Circuit of S.T.C. 200 Amp, 50 Volt Rectifier Employing Magnetic Amplifiers.

is commonly referred to as a magnetic amplifier these days is shown in the right hand figure. It will be noted that a number of rectifiers are employed and several windings appear on the transductor. The type of magnetic amplifier shown in the diagram employs intrinsic feed-back with bias obtained from the amplifier's own output. The output is D.C. Alternate half cycles of the A.C. input are fed through each of the two vertical windings and portion of the output known as the bias is fed through the lower horizontal winding in series with a variable bias control. The other horizontal winding is the signal or control winding which may be regarded as the input to D.C. amplifier, and the current to the load as the output

The first stage magnetic amplifier used in many of the rectifiers at present being delivered to the Department has a gain of 40 db. The input to this amplifier is 0.02 milliwatts (1 mA. into 20 ohms) and the output 50 milliamps into 200 ohms. The coils for this amplifier are housed in a 4012A transformer case which measures 4½ x 2⅝ inches x 4½ inches high. The second stage amplifier employed in these rectifiers has a gain of approximately 20 db with an output of up to 10 watts, although usually only about four watts is required.

Operation of Magnetic Amplifier. A magnetic amplifier, as shown in Fig. 9, consists of a reactor such as L2 in association with rectifiers MRA, biasing resistance and winding and signal winding. The A.C. supplied to the mid points of the rectifier is converted to half wave pulses through each half of the A.C. windings 7-8 and 15-16 alternately. These half-wave pulses are in such a direction that when a D.C. current flows in the signal winding 1-1OT, the magneto-motive forces are additive and thus a comparatively high output is obtained for a small wattage input. With the signal and bias windings disconnected, the amplifier would give an output approximately half of its maximum value due to the half wave pulses providing a self-saturating effect. Consequently, the bias winding is utilised to provide an opposing magneto-motive force to counteract this condition and reduce this output to a low value which would be approximately 2 mA. with the condenser C2 and the primary of T3 disconnected.

Connecting the signal winding and supplying a current through it of the order of 1mA. would cause this amplifier to operate over its entire output range and give an output of approximately 50mA. into a 200 ohm load. The minimum output from amplifier L2 is of the order of 2mA., and this 2mA. has to be neutralised in L1 amplifier by means of bias resistance R6. When correctly biased, the minimum output from amplifier L1 is approximately 0.33 amps and this 0.33 amps supplied to the signal windings of reactors L1, L2 and L3 in the main unit has to be neutralised by approximately equal and opposite ampere turn bias windings numbered 7 to 8 at plus 5% mains and light load condition. The magnitude of this current is adjusted by means of resistance R5.

Operation of Rectifier Employing Magnetic Amplifiers. The circuit of a 50 volt, 200 amp, rectifier incorporating magnetic amplifiers which is shown in Fig. 9, operates as follows. The output voltage of the regulator (reference voltage) is fed in series opposition with portion of the rectifier output voltage to the signal winding of the magnetic amplifier. The regulator, which is adjusted to deliver a constant voltage of approximately 40 volts, will send positive current into terminal 12 of the amplifier which feeds through the signal winding 1 - 2T and 9 - 10T of amplifier L2. This is the high gain (40 db) magnetic amplifier, referred to previously, which employs automatic feedback using self bias from its own output. This bias is fixed by resistance R2. A small increase in signal current in this amplifier brought about by a decrease in the output voltage of the rectifier will greatly increase the amplifier output to rectifier MRE 2, the positive and negative of which are connected to the signal winding 3-5 of the second stage amplifier L1. Rectifier MRE 2 is an isolating rectifier between amplifiers L1 and L2. As amplifiers L1 and L2 are connected in cascade a corresponding increase in output will also occur across terminals 4-7 from amplifier L1, its output being applied to the signal windings of transductors L1, L2 and L3 in the main rectifier unit. This increase in current will lower the impedance of the transductors so that sufficient D.C. output voltage is built up to restore the voltage to its correct tolerance, thereby compensating for increased load conditions or correcting for lower mains voltage.

Rectifier MRE 1 prevents a reversal of signal to the winding of L2 amplifier in the event of the D.C. switch being open-circuited. The transformer T3 in the magnetic amplifier is an anti-hunting device of the derivative feed back type, its primary being connected in parallel with the signal winding of L1 and its secondary being connected to a winding via 5 - 14 of L2 amplifier. If the output of L2 across winding 3 - 5 of L1 happens to fluctuate sharply a voltage is applied to L2 amplifier in such a phase that these L2 fluctuations are dampened.

A current transformer T2 supplies an A.C. voltage proportional to the output current to the rectifier MRD 2, and the D.C. voltage out of this rectifier is controlled by resistance R1. This resistance is set so that when the current reaches approximately 90% of full load, the voltage developed across MRD 2 is greater than the reference voltage supplied from the regulator. Forward current will then flow through blocking rectifier MRD 1 and through the rectifier MRA and the winding 7, 8, 16 and 15 in parallel with MRA and then to terminal 9. Once this forward current flows through rectifier MRD 1, the amplifier L2 is de-sensitised and therefore the unit will commence to drop its voltage, at the same time maintaining a reasonably constant output current. The resistance R1 can be adjusted to limit the output current to values less than 90% mentioned if desired.

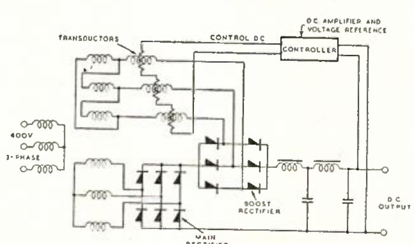
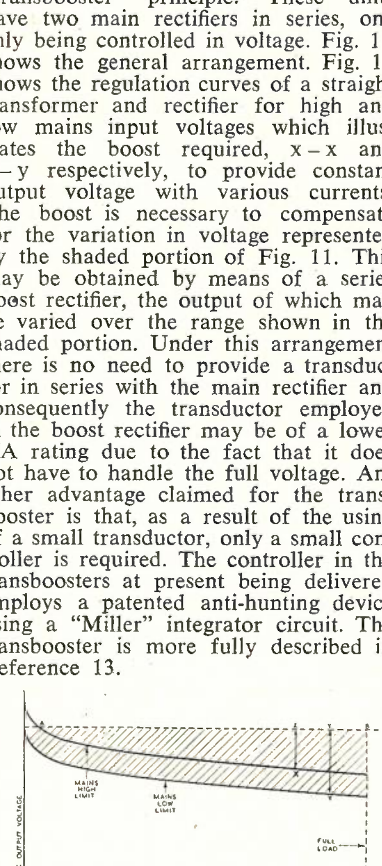


Fig. 10.—Circuit of Three Phase Transbooster Rectifier.

The "Transbooster" Rectifier. Recently the Department has purchased a number of rectifiers operating on the "transbooster" principle. These units have two main rectifiers in series, one only being controlled in voltage. Fig. 10 shows the general arrangement. Fig. 11 shows the regulation curves of a straight transformer and rectifier for high and low mains input voltages which illustrates the boost required, x – x and y – y respectively, to provide constant output voltage with various currents. The boost is necessary to compensate for the variation in voltage represented by the shaded portion of Fig. 11. This may be obtained by means of a series boost rectifier, the output of which may be varied over the range shown in the shaded portion. Under this arrangement there is no need to provide a transductor in series with the main rectifier and consequently the transductor employed in the boost rectifier may be of a lower VA rating due to the fact that it does not have to handle the full voltage. Another advantage claimed for the transbooster is that, as a result of the using of a small transductor, only a small controller is required. The controller in the transboosters at present being delivered employs a patented anti-hunting device using a "Miller" integrator circuit. The transbooster is more fully described in Reference 13.



REGULATION CURVES OF STRAIGHT TRANSFORMER AND RECTIFIER FOR TWO SUPPLY VOLTAGES, SHOWING BOOST REQUIRED TO PROVIDE CONSTANT OUTPUT VOLTAGE

Fig. 11.—Diagram Illustrating the Theory of Transbooster Rectifiers.

Fig. 10 shows that there is no voltage control other than that applied to the boost rectifier, the D.C. output of which is placed in series with the output of the main rectifiers. The unit shown employs a three phase boost rectifier, but smaller units employ only a single phase boost.

Comparison of Various Types of Rectifier. Another means of obtaining a control current for a transductor, which will vary its impedance as required to compensate for the variations in the output rectifier is employed by the British Post Office and described in a recent article (7). Mechanical regulators which are controlled by a voltage sensitive relay connected across the exchange load are incorporated in this scheme. The regulators are motor driven. This type of circuit arrangement represents a completely different approach to the problem of voltage regulation to that made in this country where the tendency has been towards the use of static equipment.

The transbooster rectifiers at present employ an electronic amplifier. Although the tubes used are reported to have extremely long life, the use of any consumable part must be considered a disadvantage, particularly when rectifiers are available incorporating magnetic amplifiers which have no consumable parts. Ultimately the thermionic valves in the transbooster will probably be replaced by transistors. Power rectifiers employing both magnetic amplifiers and transistors have been described in recent American literature. One of the advantages claimed for the transbooster is that it has a high efficiency at low output. This claim has been confirmed by tests made on the units delivered recently. Fig. 12 shows the relative efficiency of 100 amp conversion equipment. The lower curve represents a motor generator set and it will be noticed that the efficiency of this equipment is very poor at outputs below 50 amps. The next curve from the bottom shows the efficiency of a conventional type of transductor controlled rectifier delivered early in 1956. Since that time discs of higher reverse voltage ratings have become available, also redesign of the filtering system towards using more capacity and lower wattage consuming inductances has been effected. The next curve shows the efficiency of a transbooster rectifier and it will be noted that the efficiency is 75% at 25% of full load, and that this falls to only 60% at 10% full load. The other curve shows the efficiency of a prototype rectifier incorporating magnetic amplifiers due for delivery early in 1957. It will be noted that although the efficiency at low output is not as high as the transbooster, it is slightly more efficient above 50% load. The high efficiency at low output obtained in the transbooster is valuable for telephone exchange work where the rectifier may be working at low output for almost half the 24 hour period of a full day. This can be seen by reference to Fig. 1.

The rectifiers incorporating magnetic amplifiers will employ only two selenium discs. Rectifiers incorporating the transbooster principle appear to suffer from a disadvantage in that, assuming discs having equal voltage rating are employed, a minimum of three discs must be employed, two in the main rectifier and one in the boost rectifier. This must tend to decrease the overall efficiency. When rectifier elements are employed such as germanium and silicon which are suitable for working at the full exchange voltage, the conventional type of transductor controlled rectifier will need only one disc per path whereas the transbooster will still require two discs, one in the main rectifier and one in the boost.

A rectifier unit rated at 100 amps 50 volts which is a prototype of the equipment to be delivered by S.T.C. during 1957 is shown in Fig. 13. It will be noted that the bottom half of the front panel is removable to facilitate access to the various components for maintenance

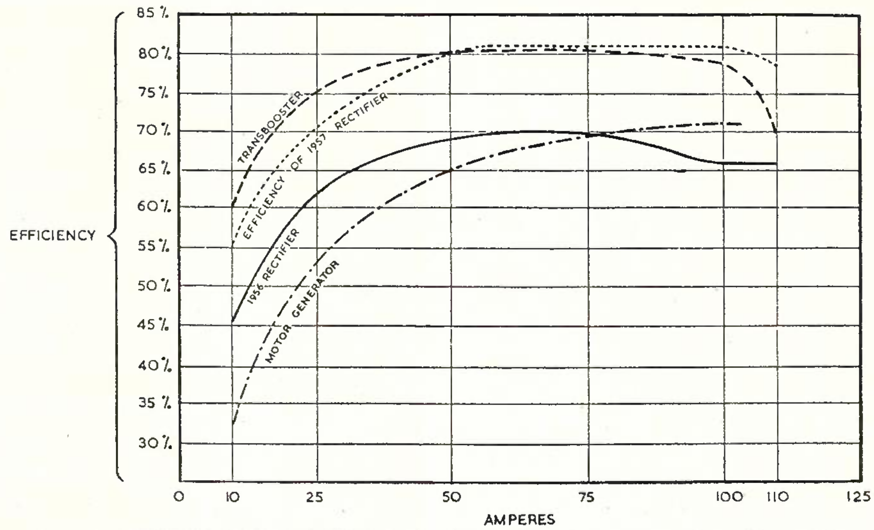


Fig. 12.—Efficiency at Various Outputs of a Motor Generator and Three Types of Static Rectifiers.

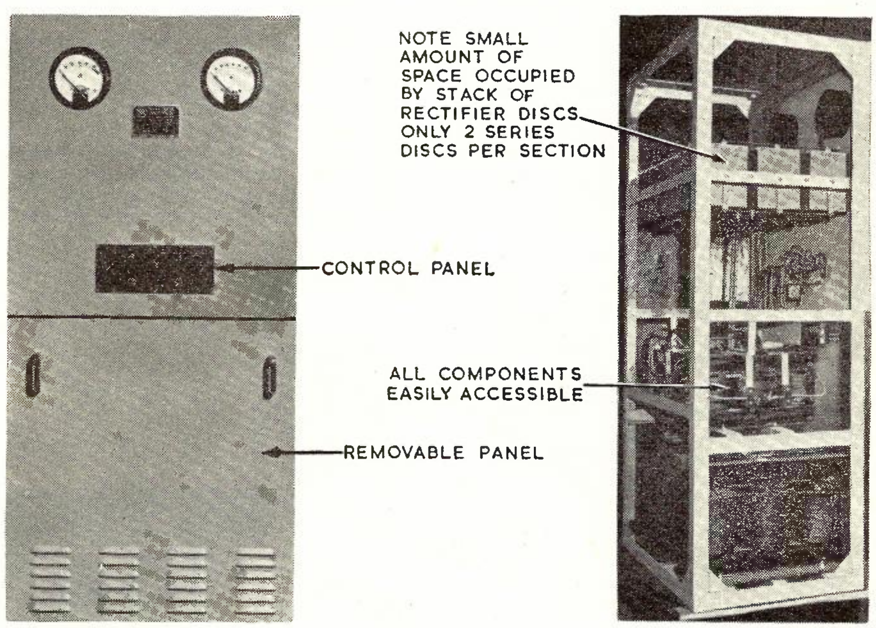


Fig. 13.—Picture of S.T.C. 100 Amp, 50 volt Rectifier.

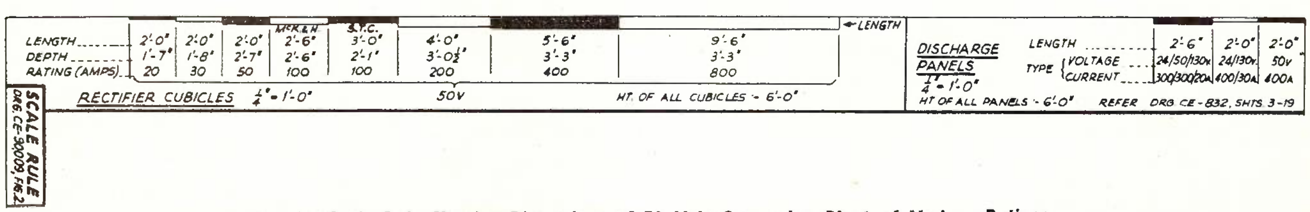


Fig. 14.—Scale Rule Showing Dimensions of 50 Volt Conversion Plant of Various Ratings.

purposes. Contactors are employed instead of a knife switch to connect the output of the rectifier to either Battery 1 or Battery 2. All of the controls are centrally located. A neon pilot light is now fitted to rectifier units to indicate that the power is switched on. Only two discs per path are employed in this rectifier which has an efficiency at three-quarters full load of 81%, as shown in Fig. 12.

A scale rule giving dimensions of the larger voltage regulated rectifiers at present being supplied to the Department is shown in Fig. 14. In addition to those shown in the scale rule, several types of smaller power rectifiers are purchased by the Department. The Serial List of standardised items includes a 10 amp 50 volt cubicle type and wall mounted units rated at 6, 3 and 1.5 amps, in addition to two battery eliminator type rectifiers rated at 1.5 and 0.75 amps. The smallest rectifier at present purchased by the Department is 0.75 amps, although arrangements are in hand to stock a 400 milliamp size for use with cordless switchboards. A recently delivered 0.75 amp battery eliminator rectifier is shown in Fig. 15.

Recently, in order to determine whether battery eliminator rectifiers were more economical than power leads provided from the exchange to P.B.X. subscribers it was necessary to know the average length of a power lead so that the appropriate cable charges could be assessed. As detailed records were not available it was decided to employ a statistical sampling technique similar to that used in Gallup polls to investigate the length of a sample of power leads in a typical metropolitan area and from this deduce a Commonwealth average. The figure obtained using this method was ¾ mile. The annual charges of an eliminator are less than those on ¾ mile of cable pair, and it has been decided to extend greatly the use of eliminators for supplying power to P.B.X's.

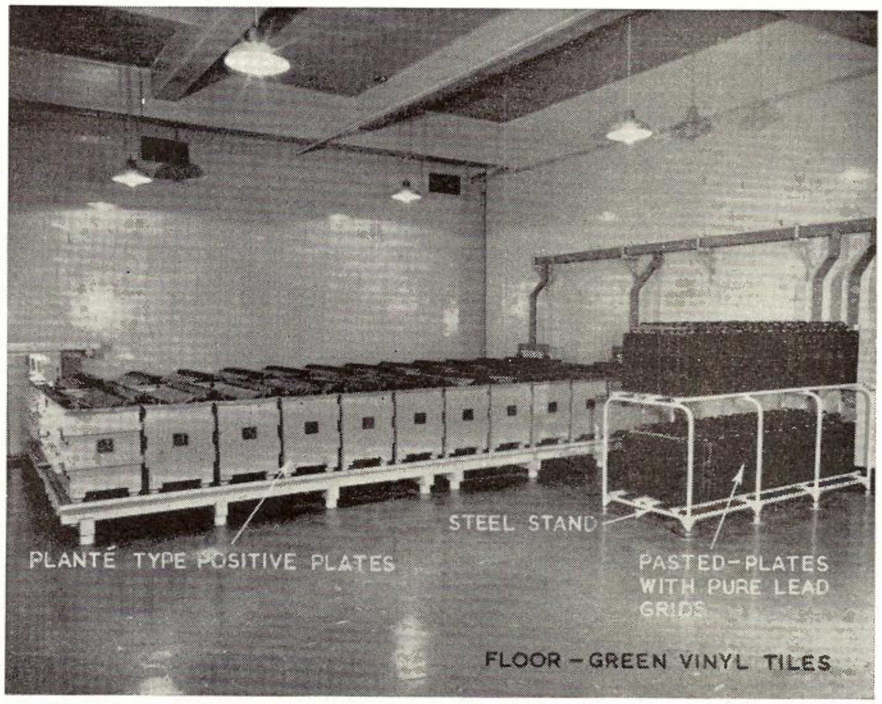


Fig. 16.—Battery Room—Russell Exchange, Melbourne.

Batteries

In the past batteries employing Plante type positive plates and box type negative plates mounted in open glass or open woodboard containers have been employed. Recently these have been superseded due to their high capital, installation, accommodation and maintenance costs. Enclosed type cells employing pasted plates are now the only type of cell purchased for telephone exchange batteries. Fig. 16 shows a rather striking contrast of the old type of open cell and the present day enclosed type cell mounted side by side in the battery room at the Russell Street Exchange, Melbourne. The enclosed type cells shown in the picture form two batteries, each of 500 ampere hour capacity, whilst the wooden lead-lined containers are capable of accommodating plates for a capacity of 4,500 ampere hours.

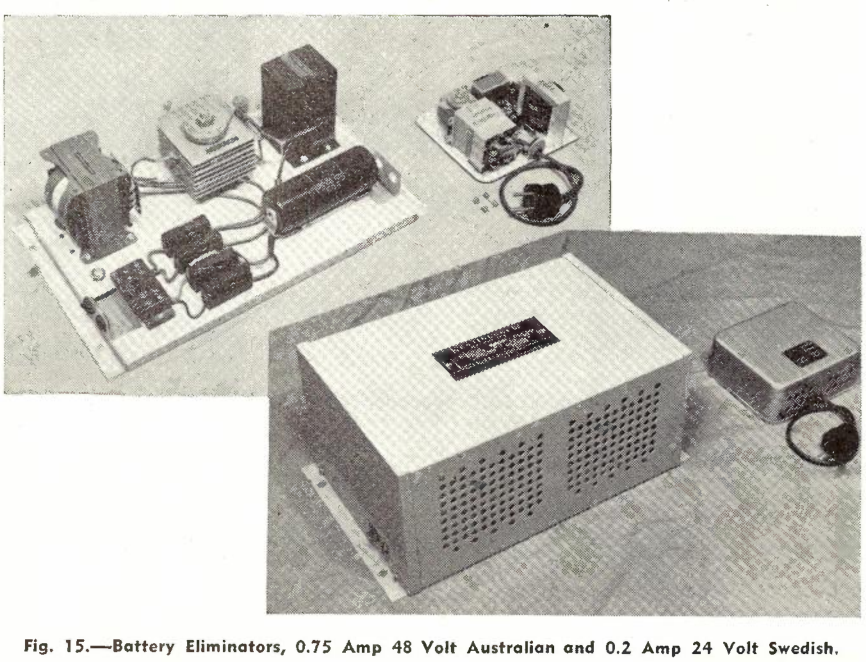


Fig. 15.—Battery Eliminators, 0.75 Amp 48 Volt Australian and 0.2 Amp 24 Volt Swedish.

Enclosed type cells having a capacity of 2,000 ampere hours are at present on order and it is expected that they will be delivered during this year. A bonded fibre glass container will be used with clear plastic inspection ports in the sides. The approximate dimensions are 30 inches high overall, 7 inches wide x 24 inches long, and the weight about 450 lbs. filled. These cells will have pasted plates and will be suitable for controlled float operation. When these larger cells are available they will be employed in large main exchanges to avoid having many banks of 500 ampere hour cells. In America, however, it is not unusual to find eight or nine banks of batteries of various age, size and make, all bolted together in parallel. The enclosed type cells can conveniently be mounted on tiers as shown in Fig. 16, or alternatively in steel cubicles as shown in Fig. 17.

The Department has recently obtained some 200 ampere hour enclosed type cells in clear polystyrene containers. These are also shown in Fig. 17. The advantage of the clear type containers is that the state of the plates and the level of the electrolyte may be easily observed. In addition to clear containers these cells have inbuilt specific gravity indicators consisting of three coloured balls

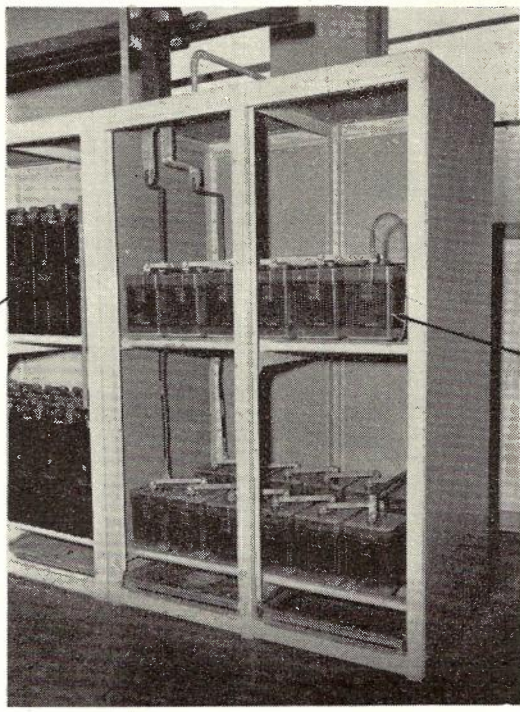


Fig. 17.—Batteries Mounted in Steel Cubicles.

held in a recess on the side of the container. These balls are designed to indicate by floating or sinking in the electrolyte, whether the cell is fully charged, half-charged or discharged. It remains to be seen whether this indication is sufficiently accurate for Departmental purposes, but in any case the inbuilt indicators should allow prompt detection of faults. Hydrometers will continue to be used for more precise information. Later this year the first delivery of 500 ampere hour cells in clear polystyrene is expected.

The 500 ampere hour cells at present being delivered to the Department are mounted in hard rubber containers and employ porous P.V.C. separators known as "Porvic" and the positive plates are wrapped in glass wool. It is now possible to store these cells before installation, whereas the earlier ones had to be placed in service before the woodboard separators dried out. It is expected that ultimately it will be possible to obtain these cells in a dry charged state similar to some automotive and radio type batteries, which have recently become available on the Australian market. When cells are supplied in a dry charged condition it is necessary only to add the acid and give a slight charge of about 5-10% of the capacity before placing the cells in service. As an interim measure arrangements have been made for the cells to be delivered to the manufacturing company's distribution depot in each capital city, to be filled with acid and given an initial charge and test discharge, followed by a recharge before being delivered to an exchange for installation. This arrangement considerably reduces the installation effort and is another advantage gained from the use of enclosed type cells. As a safeguard against accidental ignition, which can destroy fully-enclosed cells, large enclosed cells will be fitted with diffuser-type vents which prevent ignition spreading to gas within the cell.

Pasted plates, as employed in car batteries, use grids which incorporate antimony as a strengthening agent; however, this results in antimonial poisoning of the negative plate and corrosion of the positive grid. To overcome this problem which is brought about because antimony is electro-positive to lead, pure lead grids have been used for the positive plates of many enclosed type cells for use in telephone exchanges. When pure lead grids are used it is necessary to adopt a special grid structure to ensure adequate mechanical strength.

Lead Calcium Grids. Another way of overcoming the disadvantage of lead antimony grids is to employ a strengthening agent which is electro-negative to lead such as calcium. Lead calcium grids are employed extensively in the United States and pasted plate cells employing these grids are expected to have a life of 25 years. Trial installations of batteries imported from America with lead calcium grids have been made in several States. It appears unlikely that lead calcium grids will be produced in Australia for some time, due to manufacturing difficulties brought about by the very close tolerance necessary on the amount of calcium in the alloy, which is only 0.08%. Fig. 18 is a picture of an American cell similar to those recently imported.

One feature about the lead calcium cells is that they are designed for floating operation and for maximum life it is necessary to ensure that the floating voltage does not fluctuate to any great extent. As mentioned above, American practice is that the floating voltage is usually held to within ± 0.25 volts. Correct floating voltage is also necessary if maximum life is to be obtained from any battery. This is demonstrated in a striking manner in Fig. 19, which shows the effect of a fluctuating floating voltage on some cells in a battery whilst the others were properly maintained with an electronic type of automatic voltage control rectifier. The arrangement of tapping the 50-volt battery at Katoomba to obtain a 24 volt supply was necessary due to the acute shortage of space at that office.

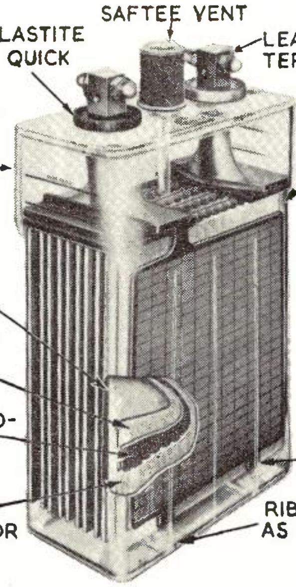


Fig. 18.—American Cell in Clear Polystyrene Container, Manufactured by C. & D.

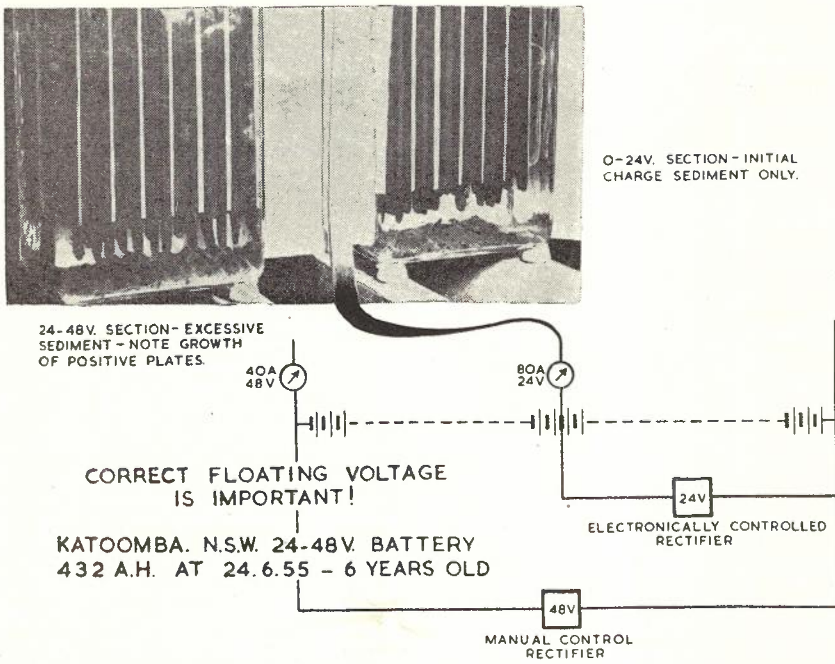


Fig. 19.—Illustration Showing Importance of Maintaining Correct Floating Voltage.

Battery Room Floors. A trial installation of vinyl floor tiles has been made in the battery room of the Russell Exchange, and is shown in Fig. 16. The appearance of these green-coloured tiles is vastly superior to malthoid which has been used in the past. Laboratory tests indicate that they should satisfactorily resist attack from battery acid. A disadvantage which has been noticed in the Russell installation is that the tiles discolour slightly when subject to acid spray during charging of the open type battery. It is probable that this disadvantage would not be serious if all the cells used were of the enclosed type.

Water for Topping Up Batteries. Improvements have been made in the method of obtaining topping up water for batteries for those locations where local water supplies, either from public mains or local rainwater tanks are not suitable for batteries. In earlier days an electrically operated, gas or oil-fired still was the usual method of distilling water for use in batteries. These have now been superseded by a chemical type of water purifying plant known as the Deminrolit. With units of this type it is possible to obtain water of sufficient purity for topping up batteries at the price of approximately 2½d. a gallon. Another method of obtaining topping-up water which is at present under investi-

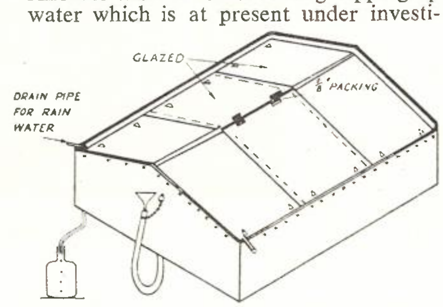


Fig. 20.—Solar Still.

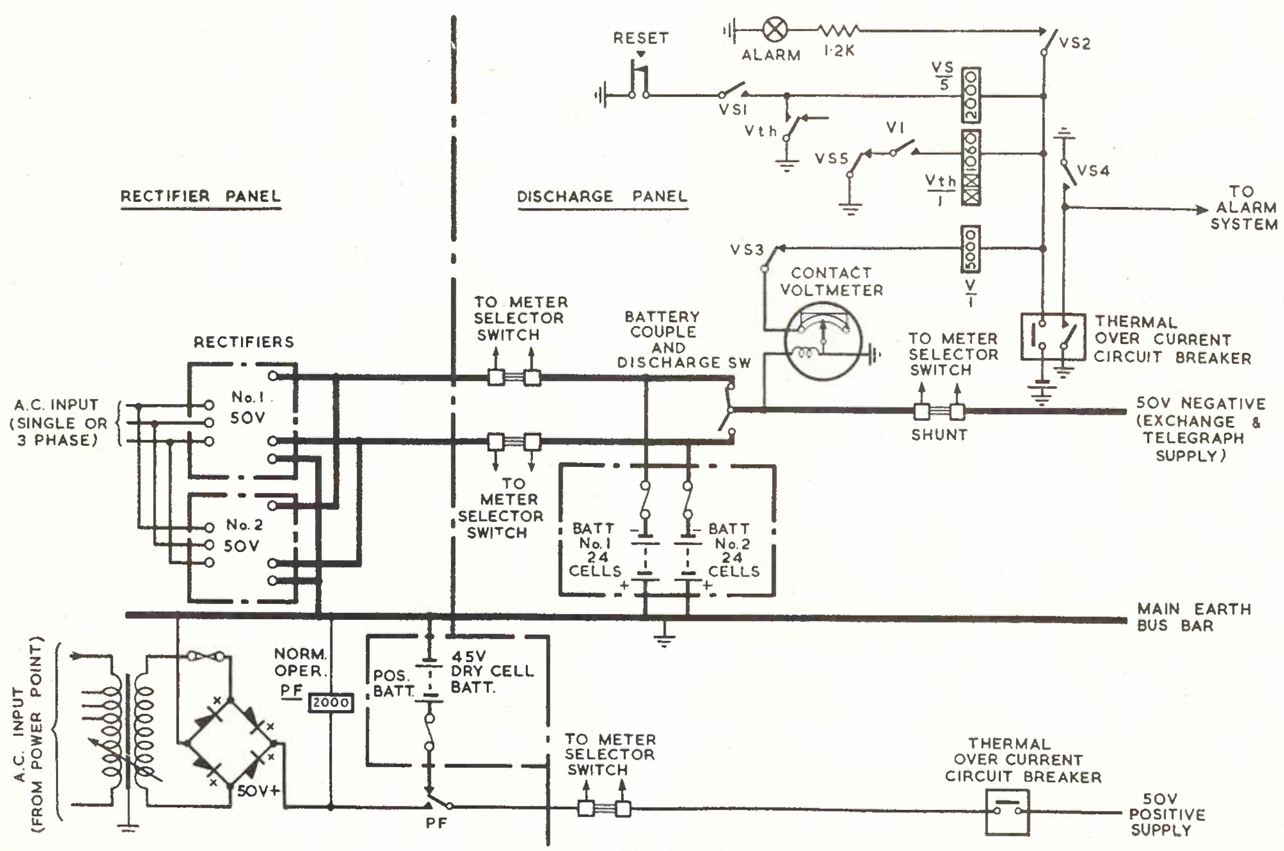


Fig. 21.—Exchange Power Circuit.

gation as a result of a suggestion submitted to the Improvements Board is to employ a Solar still. Solar stills, as the name implies, make use of the radiation from the sun to distill water. It is understood that these units have been used at repeater stations on cable routes by other telecommunication authorities and a considerable amount of developmental work for use in Australian conditions has been performed by the C.S.I.R.O. with a view to obtaining distilled water from saline bore water. Fig. 20 shows a picture of a solar still. Trial units are being installed in some States and it is likely that considerable economies will be achieved by these units, particularly where batteries are situated in remote locations.

D.C. Distribution and Operating Techniques

Power Circuit. The method of connecting rectifiers and batteries together to form an exchange power circuit is shown in Fig. 21. Should more than two batteries be employed the additional strings of cells are then bolted in parallel to form two groups of batteries. Although greater flexibility could be provided it would only be done at the cost of additional expenditure and greater complexity. This seems unnecessary, particularly as a successful American practice is to bolt together eight or nine strings of cells without any switching arrangements. It is usual to float both batteries in parallel as this means a greater effective capacity is obtained and the impedance of the power source is lowered, thereby reducing the noise level on the exchange distribution busbars.

Fig. 22 shows the percentage of the nominal capacity obtained from a battery when it is discharged at various rates. From this graph it will be noted that only approximately 75% of the nominal capacity of the battery is available if it is discharged in three hours. For example, a 400 ampere hour battery in terms of the 10 hour rated capacity is required to provide for a discharge of 100 amps for three hours.

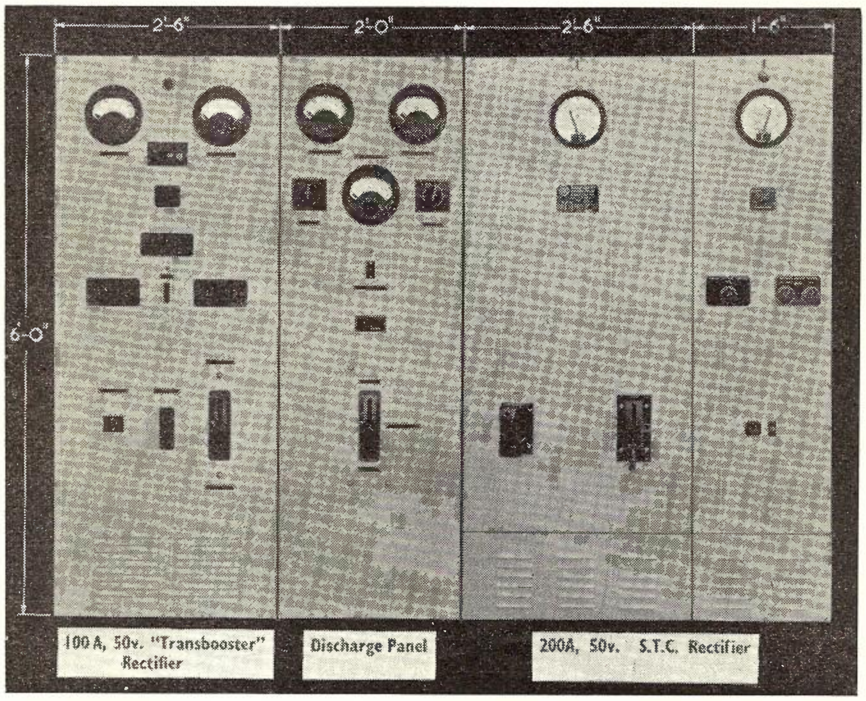


Fig. 23.—Suite of Exchange Power Equipment.

From this it can be seen that two 400 ampere hour batteries connected to the load consecutively, that is Battery 1 discharged and then Battery 2 discharged would have a total effective capacity of twice 100 amps by three hours, which is equal to 600 ampere hours. If now the two batteries of 400 ampere hours capacity are connected in parallel and discharged at half the current per battery, that is, 50 amps per battery, the effective capacity would be much greater. When a 400 A.H. battery is discharged at 50 amps it has a capacity equivalent to 95% of its nominal 10 hour capacity. The final capacity available then if the batteries are discharged in parallel is is equal to 95% of 800, which is equal to 760 hours and is almost 27% more than the 600 ampere hours obtained when the batteries are discharged as described previously. From this the importance of floating batteries in parallel can be appreciated.

Graphs are at present being prepared to show the time standard type cells take to discharge at various rates to typical end cell voltages.

Discharge Panels. Fig. 23 shows a suite of exchange equipment consisting of two auto-manual rectifiers with a D.C. distribution panel mounted between them. The D.C. distribution and metering panel is known as a discharge panel. Discharge panels have been designed to line up with modern rectifiers now being purchased with light grey steel panels and dead front knife switches. The switch on the standardised discharge panel is rated at 400 amps. It will be seen from the photograph of the discharge panel that only one switch is employed, whereas formerly two switches and an amount of busbar work at the back of the panel were necessary. This simplification has been achieved by the development, in collaboration with a local manufacturer of electrical switch gear, of a combined battery paralleling and battery discharge switch of the dead front type. The same technique was originally employed in a few installations on some front of panel mounting switches in New South Wales. Fig. 24 shows the operation of the special dead front type switch and it will be noted that spring-loaded thumbscrews have been provided to retain the switch handle and blade in the central position. This is the normal operating position, as both batteries should be floated in parallel.

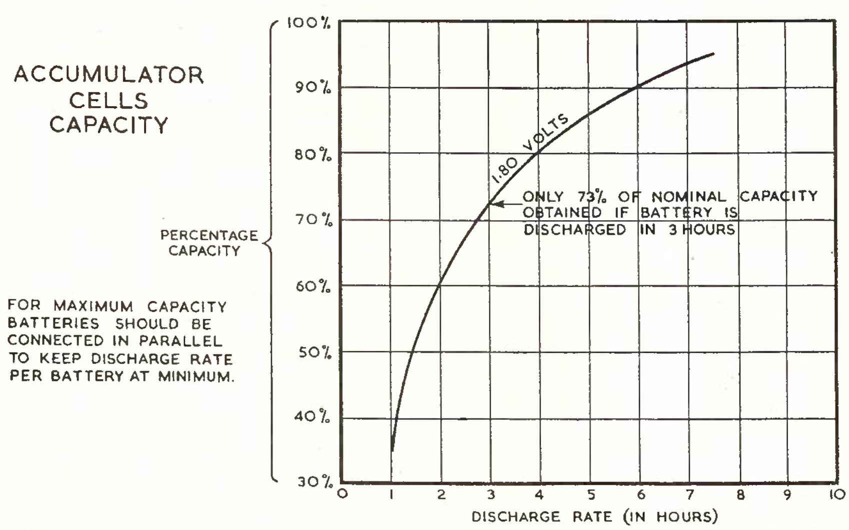


Fig. 22.—Graph Indicating Percentage of Nominal Capacity Available at Various Discharge Rates.

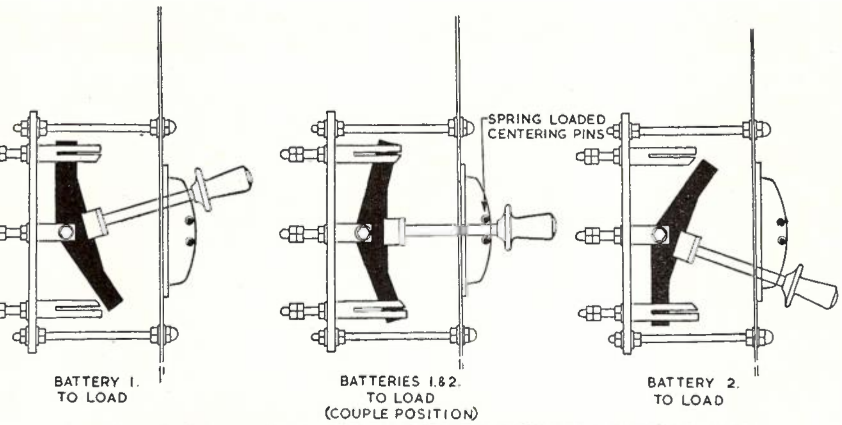


Fig. 24.—Sketch Showing Operation of Battery Parallel and Discharge Switch.

The contact voltmeter is now mounted on the discharge panel to which it is more appropriate than the ringer panel where it was mounted in earlier days. The lower and upper limits of the voltmeter contacts are variable and are usually set at 50 and 53 volts. As a result of a suggestion submitted to the Improvements Board a thermal relay is incorporated in the alarm circuit so that momentary high and low voltages of less than 30 seconds duration do not lock in an alarm condition. This is sufficient time for an automatic start standby diesel alternator set to come into operation in the event of failure of the mains supply.

Due mainly to the fact that voltage control has superseded current control, a centre zero differential type ammeter is no longer required and it has been replaced by a standard type of ammeter which has twice the effective scale length of a centre zero type instrument. Although it is not necessary to read currents to within 1 or 2 amps it is desirable to have the ammeter scale as open as possible.

The effect of further doubling the scale length is achieved by employing an ammeter with a 37½ millivolt movement and a building out resistor such that the meter gives full scale deflection on 75 mV. When the 37.5 mV movement is connected to a 75 mV shunt, it will give a full scale deflection when only half the rated current of the shunt is flowing. At the stage when the current to be measured approaches the half range value it is simply necessary to change from the 37.5 to the 75 mV terminal of the instrument without making any alteration to the shunt. The scale provided with the instrument on standard panels is calibrated 0-200 amps on one side for use with the 37.5 mV terminal and 0-400 amps on the reverse side of the scale for use with the 75 mV terminal.

As a result of the two improvements referred to, the standard 400 amp panel has an ammeter with a scale as open as that which would be obtained with the centre-zero type instrument fitted to the old panels rated at only 100 amps. This arrangement is particularly beneficial where it is desired to standardise on a panel for use at many locations having widely varying loads. The savings which would be obtained by reducing the rating of the switch fitted to the panel from 400 amps to 200 amps are so small that they do not appear to justify the cost and complexity of stocking the smaller-sized panel. The only other component which has a current rating is the ammeter and since this has been made effective over a wide range of currents the panels may be installed in exchanges with widely differing loads.

The secondary type lead acid battery formerly used for the positive battery supply has been discarded in favour of a battery eliminator type of rectifier and arrangements are made on the discharge panel for automatic changeover to a 45 volt triple duty radio type dry battery during periods of mains failure. This is a much more economical arrangement than using secondary type cells with their higher maintenance and installation charges.

A multi-voltage discharge panel suitable for use in buildings housing long line equipment as well as telephone equipment is shown in Fig. 25. The panel is designed for maximum discharge currents of 24 volt 300 amps; 50 volt negative 300 amps; 130 volt positive 20 amps; and 50 volt positive 20 amps. The panel is only 2 feet 6 inches wide and represents a considerable saving in space, capital cost and installation effort when compared with the former practice of installing three panels each 2 feet wide.

Photo-anodised labels are now employed on discharge panels as these are much cheaper and generally superior to the engraved type labels formerly employed. A Santon type rotary switch is employed as the combined battery paralleling and discharge switch on the 130 volt circuit of the multi-voltage discharge panel. It has not been necessary to employ a make before break type of switch as operation of the Santon switch causes an interruption to the supply of only 1½ to 2 milliseconds. These multi-voltage panels and the 50 volt exchange panels are now completely wired at the time of manufacture and very little installation effort is required. As well as convenience, factory wiring achieves a considerable saving in cost. Solderless wiring connections using a crimped type joint will be employed for the first time on the discharge panels now on order. The relays for the high and low voltage alarm circuits are mounted at the rear of the panel.

A combined 24 and 130 volt panel designed along the same lines as the panel referred to above has been

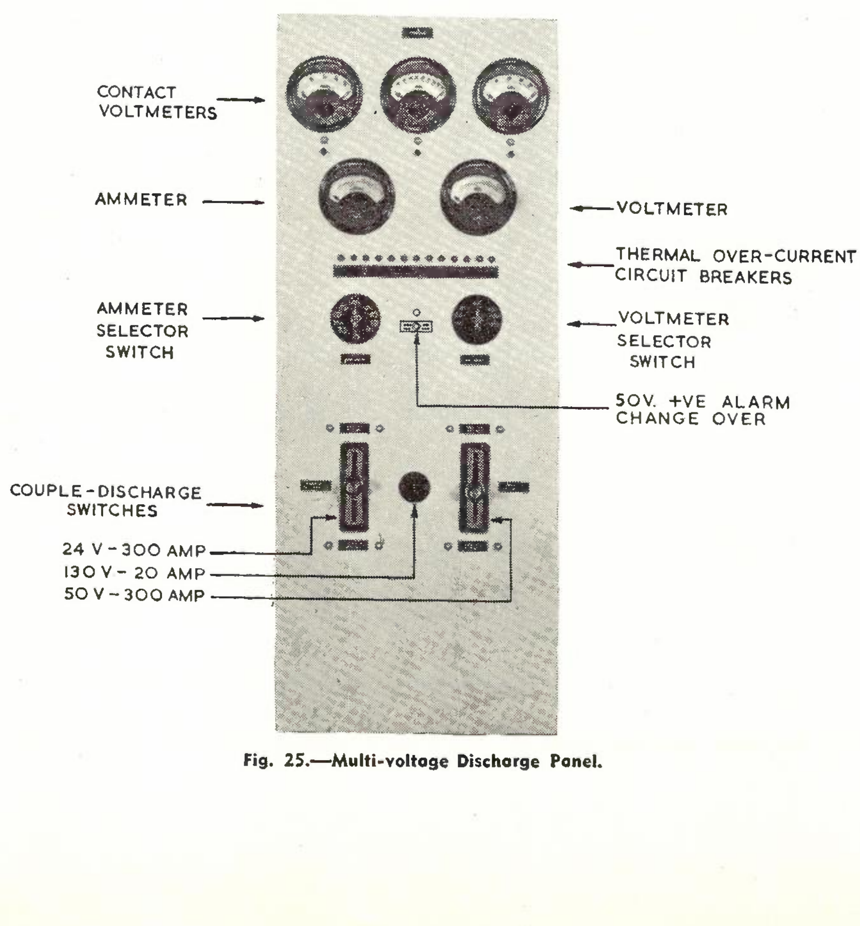


Fig. 25.—Multi-voltage Discharge Panel.

adopted for use with the 400 amp. 50 volt panel for installation where the current drain of either the 24 or 50 volt supplies is expected to exceed 300 amps. The panel is also installed where a 50 volt supply is not likely to be required during the life of the building.

Drawings are available showing details of the ironwork required to convert the discharge panel to a cubicle where it is necessary to install it as a free standing unit. This will generally be the case when the discharge panel is mounted in the exchange equipment room. The advantages of easy installation will, in these circumstances, offset the increased cost of the cubicle construction.

Sequential Switching of Rectifiers. Floating conditions can only be maintained if the busy hour load does not exceed the capacity of the rectifier. Consideration is at present being given to the use of sequential switching, that is a circuit designed to switch in a second rectifier when one rectifier is nearing its maximum output. This arrangement has been employed in a unit installed at North Essendon exchange. Two 100-amp rectifiers are controlled so that either unit may be automatically switched on or off depending on the load requirements of the exchange. A differential arrangement is provided so that the second rectifier is switched on when the load exceeds 90 amps and is not switched off until the load falls to below 70 amps. A third rectifier will soon be added to this suite and this will also be switched on and off automatically. All telephone equipment rectifiers purchased by the Department with a rating of 100 amps 50 volts and higher are provided with a mains input contractor to facilitate sequential switching should it be decided to adopt this technique.

Swedish practice (6) is to employ one automatic voltage control rectifier and a number of rectifiers without automatic voltage control which are switched in automatically depending on the exchange load. It is understood that up to 8 rectifier units may be employed in one installation. (See also Reference 18.) It is interesting to note that this technique has also been adopted in at least one exchange in England. The Kingsway Trunk Exchange, London, which has been in service since 1954 employs selenium rectifiers throughout and has a maximum capacity of 4000 amps at 50 volts. To cater for the rise and fall of the exchange load, rectifier units are switched in and out of service entirely automatically as required, while at the same time the voltage of the supply is maintained within very close limits. This plant is one of the largest completely automatic exchange plants in the world (5).

In an article in a recent G.E.C. Telecommunications Journal (8) entitled "Modern Power Plant for Medium Sized Telephone Exchanges" it is stated that sequential switching is not provided as a standard facility because at smaller exchanges the light load losses due to having more than one charger permanently connected are small, whilst at larger exchanges an engineer is usually in attendance who can switch off all but one charger during the night or at light load periods. The influence of "qualitative" maintenance will tend to make larger exchanges unstaffed and it may be that sequential switching will prove economical, in some instances.

Trial installations of equipment using the same techniques as those employed at North Essendon are at present being made in some States. The circuit to be employed is shown in Fig. 26. It will be seen that a current transformer is placed in series with one phase of the A.C. mains input supply to the rectifiers. When the current exceeds a value equivalent to say 90% of the rated output of one rectifier, the contacts of the Sunvic tube will close and operate a relay which in turn operates the mains input contactor in the second rectifier and brings it into operation. A differential switching arrangement is also included so that the second rectifier will not be switched off until the load has fallen to some figure below that which caused the rectifier to be switched on. This is necessary to prevent frequent switching of the rectifier, particularly when the load increases or decreases gradually or hovers around the discharge value at which the second unit is brought into service.

The Sunvic hot wire vacuum switch is a sealed tube not much larger than an ordinary radio valve. Its operation depends on the fact that when an electric current is interrupted by the separation of two surfaces in a vacuum, no arc is formed. The actual separation need only be about one thousandth of an inch. Therefore a switch operating in a vacuum requires only very light contacts and a very small movement. The movement necessary to close or open the contacts is so small that it can readily be provided by the thermal expansion of a wire through which the control current passes.

It has been suggested that sequential switching in an exchange might be used to switch on a small 30 amp rectifier in place of larger units during the night. Recently, however, the efficiency of rectifiers at low output has been increased. The efficiency of a 30 amp rectifier when delivering 10 amps is 67.5% compared with 57.5% for a 100 amp unit. The amount of energy required is 740 and 870 watts respectively. The cost of this 130 watts of additional energy is so small that it would not justify provision of a small rectifier and sequential switching equipment, even though the current drain at a branch exchange does not exceed 10 amps for about 8 hours of the night as shown in Fig. 1.

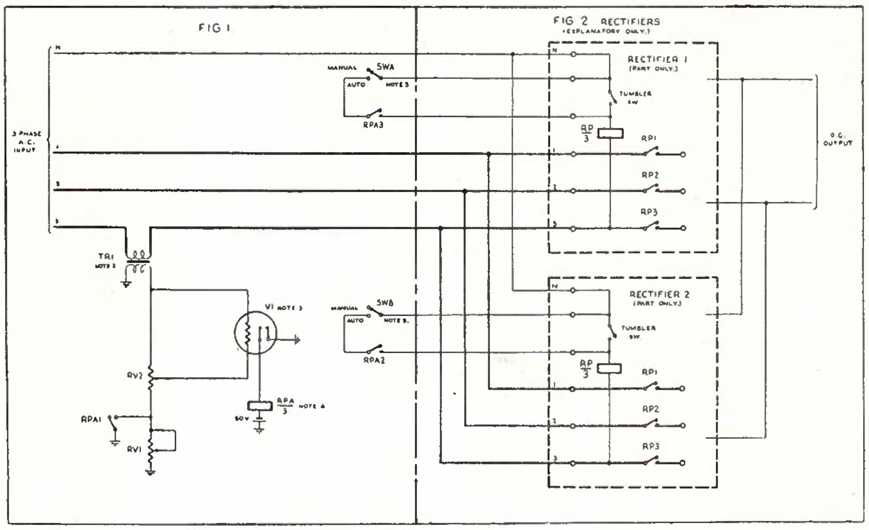


Fig. 26.—S.T.C. Sequential Switching Circuit.

In the past the tendency has been to provide two auto-manual rectifiers, the larger unit being capable of supplying the busy hour load and a second unit which was generally used for charging batteries and was large enough to keep the batteries fully charged over a period of 24 hours in the event of failure of the larger unit. However, it appears that some economy on this basis of provision may be possible due to the fact that it may not be necessary to have a separate rectifier always available for charging as it has recently been demonstrated that batteries may be floated up to their fully charged condition in a period of a few hours. The other factor that will influence the basis of provision is the availability of sequential switching equipment as it may prove satisfactory and economical to provide two 100 amp rectifiers instead of one 200 amp plus one 100 amp unit.

It is of interest to note that in small exchanges or medium sized exchanges with a power consumption up to 2000 ampere hours a day the British Post Office (7) usually employs only one rectifier. Where several rectifiers are used, they provide a common filter, whereas it is Departmental practice to employ a filter in each rectifier.

Distribution. Busbars of either copper or recently of aluminium are usually employed for power distribution in telephone exchanges. In general the minimum size of busbars or power cable in a telephone exchange is determined by the maximum permissible voltage drop rather than a temperature limit. The maximum permissible voltage drop over both the negative and positive leads from the battery to the last distribution fuse on any rack is one volt. In practice the length of the runs is usually so great that the current density and hence the temperature rise is kept low by the limit imposed by the maximum permissible voltage drop.

Greater current density may be employed on short sections of the distribution without greatly affecting the voltage drop. In these cases the maximum permissible temperature rise of 30°C. becomes the limiting factor. In some cases it is desired to keep the size of busbars down to a minimum at the back of discharge panels and this is one instance in which it is permissible to use a high current density provided the temperature rise does not exceed 30°C.

The old rule of 500 amps per square inch as the maximum current density for discharge bars and 1000 amps per square inch for charge bars has fallen into disuse, probably because it doesn't mean very much. As stated above the limiting factor is usually the voltage drop and in other cases the temperature rise. The voltage drop is of course determined by Ohms Law, regardless of current density, and the current carrying capacity will be different for two busbars having the same temperature rise and having the same cross-sectional area if they are not of the same dimensions. For example, a temperature rise of 40°C in a busbar of 4 x ¼ inch would be caused by a current of 1200 amps, whereas the same temperature rise in a 2 x ½ inch busbar which has the same cross-sectional area would be produced by a current of only 920 amps. (Refs. 17 and 18).

Busbars have been covered in the past with manilla and more recently with P.V.C. tubing applied with the aid of a dilator fluid or compressed air. At present use is made of a P.V.C. paint which may be applied by brushing, spraying or dipping. Another method which is at present being investigated is to use a type of P.V.C. tubing such as "Drakavita" which shrinks up to 30% in diameter on the application of heat. A small oven has been developed to facilitate the application of this busbar covering and it is possible to cover a 13 foot length of busbar in a few minutes. The covering shrinks tightly onto the busbar and has a very good appearance. Although the tubing may tend to shrink on the application of heat after a busbar has been installed there appears to be little danger of cracking, particularly if the correct size tubing is selected. The correct size tubing will be the largest tubing which would shrink down to form a neat covering on the busbar.

Considerable attention has been directed recently to the reduction of noise on speaking circuits. One very important and effective way of reducing noise is to reduce the impedance of the power supply. This may well form the subject of a later article. It has been demonstrated that closely spaced busbars give a much lower inductance than busbars employing standard spacing. The inductance per hundred feet of 2 x ½ inch busbars employing standard spacing (4 inches side to side) is 27 microhenries, whilst the equivalent inductance of busbars with only ¼ inch side to side spacing is 5.7 microhenries. Installations of closely spaced busbars have been made in several States and the results of measurements have been fully recorded in Reference 14. This technique of using closely spaced busbars is employed extensively in Sweden as described in Reference 6. American practice however is to use cables almost exclusively. Tests carried out in connection with the noise investigation referred to above prove that much lower inductance may be obtained with multiple cables than is obtainable practically with closely spaced busbars.

The inductance per hundred feet of a group of 10 cables having an effective cross-sectional area of conductor equal to 1.2 square inches is 2.5 microhenries. The inductance referred to above is obtained by laying up cables with alternate polarity.

Swedish practice employs busbars from the battery terminals to a fuse box mounted on the wall of the power room which is usually adjacent to the battery room. Distribution from the fuse box to the discharge panel is by means of cables for installations where the discharge is less than 800 amps. This practice seems attractive as it obviates the necessity for mounting fuses in the battery room and obtains the advantages of low inductance and greater manoeuvrability of cables. A recent report from the American Bell System stated that the choice between busbar or cable distribution involved only economics and space considerations and that the author knew of no case where busbars have been employed. It may well be that we are paying too much for the fine appearance of highly coloured busbars and that more extensive use of power cable would prove economical in many instances. The well established technique of using solderless crimp type cable lugs reduces the cost and difficulty of terminating cables.

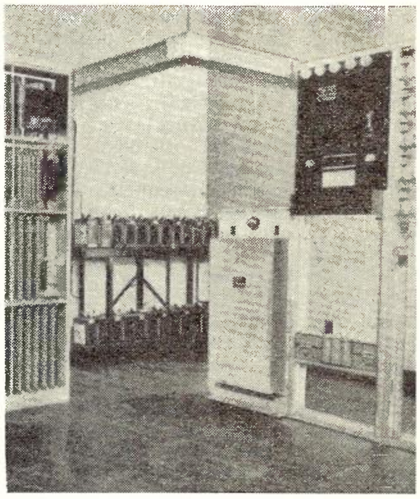


Fig. 27.—Picture of Hanover Exchange, U.S.A., showing Batteries Mounted in Equipment Room.

Accommodation

There appears to be a world-wide trend towards mounting power equipment in the equipment room. This practice has been followed for several years in America. Fig. 27 shows an exchange in America with the batteries mounted in the equipment room without any form of enclosure. In a recent article (Reference 5), mention is made of the fact that in England there is a very noticeable trend in the design of telephone exchange power plant towards the saving of space by breaking down the barrier between the apparatus or equipment room and the power enclosure. With this in mind the design of certain types of power plant has followed telephone equipment practice rather than traditional lines.

In Australia battery cubicles have been designed for accommodating enclosed type cells. These cubicles are steel framed and are suitable for mounting in equipment rooms. Several installations have already been made in a number

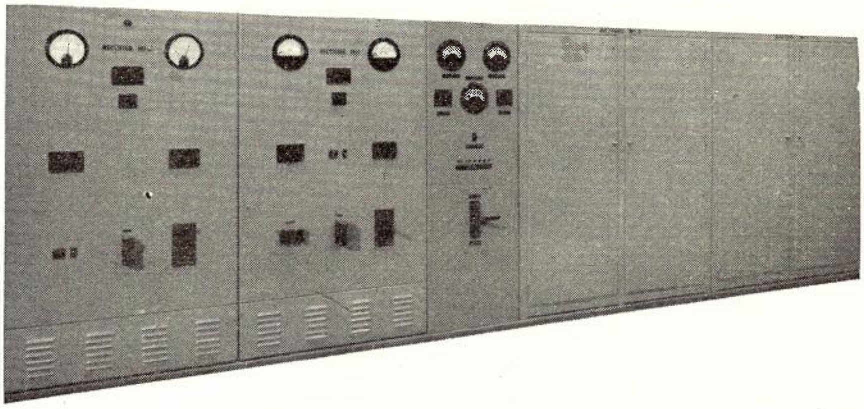


Fig. 28.—Suite of Modern Power Plant Installed in the Equipment Room at Moreland Exchange, Victoria.

of States where the complete power plant is installed in the equipment room, thereby dispensing with power and battery rooms. One example of this type of installation is shown in Figure 28 which shows the power equipment in the equipment room at Moreland, Victoria. Apart from the saving in space and accommodation which results from this practice, there is a substantial reduction in the noise on speaking circuits which is obtained by reducing the length of the power distribution circuit and also the feeds from the discharge panel to the batteries.

Standby Plant

Departmental policy for all except the smallest exchanges is to employ batteries having a 3-busy hour reserve capacity at the 10 year date and an automatic start standby diesel alternator set. The wisdom of the Department's policy in providing standby diesel alternator sets, together with relatively small reserve capacity in batteries instead of only large batteries is already apparent. Recent expenditure on batteries, plates and separators is considerably lower than in previous years. The plans for new buildings also reflect the advantage of the present policy as it has been possible to make a significant reduction in the size of battery rooms. Complete technical details of the requirements of standby plant are given in Reference 15 and a picture of a 15 KVA standby diesel alternator set recently delivered is shown in Fig. 29.

Diesel engines are employed due to their being a lower fire risk than petrol engines and also they have greater fuel economy. The alternators purchased are of the self regulating type such as the McFarlane Magnicon (16). The specification states that the alternator output voltage shall be within ± 2% for any load between no load and full load. The control cubicle provides for automatic start and changeover on failure of any or all phases of the mains supply, cut out on return of supply and also voltage and current metering of mains and standby supply. Alarm and protection facilities are also provided, for example, failure to start, low fuel level, low oil pressure, high temperature of water. The cooling water is kept warm by an immersion heater to facilitate starting. The units are very compact, being self-contained with control cubicles mounted on the same chassis as the engine alternator unit. The control cubicle is not subject to excessive vibration as the engine alternator is supported on resiliant rubber mountings. The form of construction of these units is such that very little installation effort is required to place the plant in service.

It is necessary to provide adequate ventilation in the engine alternator room as the thermal efficiency of a diesel engine is in the order of only about 30%. This means that for a 50 Kilowatt set, approximately 100 Kilowatts of heat must be dissipated. Special acoustical treatment is also necessary to reduce the noise level, particularly where this type of plant is installed in branch exchanges in residential areas. The requirements of adequate ventilation and low noise radiation tend to conflict and a special investigation is being carried out with a view to arriving at a detailed specification for the treatment necessary in engine alternator rooms. A trial installation has been made at South Melbourne exchange in which a 75 KVA diesel alternator set is mounted in a brick engine room which was formerly a portion of the equipment room. The room has a closely fitting sealed door and no windows. Air is taken into and out of the equipment room by means of ducts which have been lined on the inside with a 1 inch layer of sprayed asbestos. This treatment has proved very effective as the noise level outside the engine room with the engine running is much lower than that produced by air-conditioning and other equipment. The noise level from the diesel alternator is about the same as that obtained from a modern motor car. A picture of the ducts is shown in Fig. 30. It is expected that full details of this investigation will be published later.

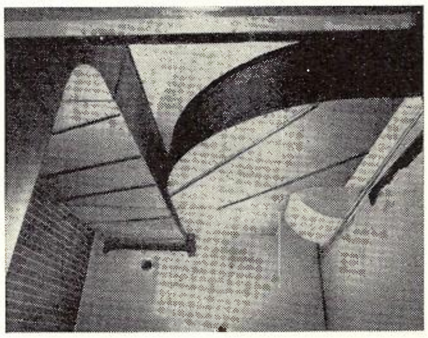


Fig. 30.—Engine Alternator Room, South Melbourne, Showing Acoustically Treated Ducts to Reduce the Noise from Diesel Engine.

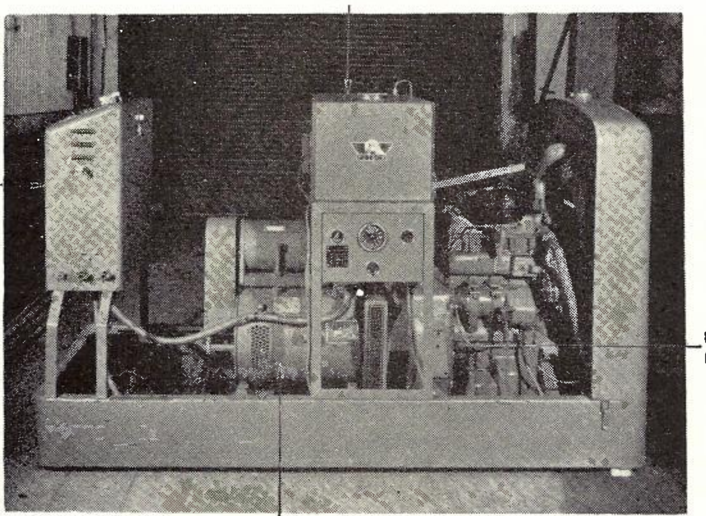


Fig 29.—15 K.V.A. Automatic Start Diesel Alternator Set Supplied by Petbow.

It is considered that the main A.C. mains input distribution panel could often be located in the engine alternator room rather than adjacent to the power rectifiers, as it is necessary for the mains to the essential portion of distribution circuits to be switched by the changeover contactors associated with the engine alternator. Some installations of this type have already been made and it is possible that this arrangement could become standard practice. The standby plant recently delivered to the Department will replace the mains supply in about 15 seconds from the time of failure. It is claimed in Reference 5 that a break period of at least 15 seconds is desirable as it brings the existence of failure to the notice of telegraph operators in cases where no batteries are used to cover short periods of mains failure.

Diesel Alternator Sets for R.A.X.'s

Engine generator sets powered by small air-cooled engines with a rating of 2¼ horsepower, coupled to generators rated at 1,000 watts have recently been purchased. These sets are designed for use at R.A.X.'s where a mains rectifier, wind driven generator and charge-over-trunk methods of battery charging are not applicable. The sets are operated by remote control from the parent station of the R.A.X. which might be located some 20 or 30 miles distant. Low fire hazard and reliability are important requisites of an engine to be run unattended at R.A.X. installations, and it is anticipated that the air-cooled diesels will prove more satisfactory in this application than the water cooled engines previously purchased.

Future Trends

Within the last five years we have seen the change from motor generator sets to static rectifiers which has resulted in considerable economies in capital expenditure and in the accommodation, maintenance and energy charges. No doubt this trend will continue in view of the large savings possible. An improvement of only 4% in the efficiency of the conversion plant employed by the Department would represent an annual saving in energy costs of more than £10,000. During the last few years there has been a constant improvement in the efficiency of rectifiers. The conversion plant delivered during 1957 will have an efficiency of 5 to 10% greater over its complete range of output than the majority of plant delivered last year. Although large orders have been placed for rectifier conversion plant recently, it will be a few years before sufficient plant will have been installed to bring about an average improvement of 4% in the whole of the conversion plant employed by the Department. The improvement made however, is quite considerable. The fact that such large savings are achievable by increasing the efficiency of conversion plant will tend to hasten the introduction by the Department of rectifiers employing germanium or silicon elements. The savings are such that an increase in capital cost could be justified. However, only a small increase in cost should be necessary to obtain these superior type elements as germanium rectifiers having an efficiency of 95% and an output voltage regulation of ± 1 volt from no load to full load are now avaliable in America at the same price as selenium units of similar capacity. Alternatively, silicon elements could be used to replace selenium in this country, particularly in view of the increasing popularity of silicon overseas. Germanium is inclined to be regarded as a step-over point between selenium and silicon and it may be that we will miss this intermediate step. The fact that high efficiency in the order of 95-98% and virtually no ageing is attainable with silicon discs, makes them very attractive. There are some manufacturing and cooling problems to be solved, however, particularly as applying to locally made units.

Although there will be a considerable reduction in the size of conversion plant when the newer type of rectifying elements such as silicon are employed, the saving may not be as great as would appear at first. This is due to the fact that transformers and voltage regulating equipment must still be employed and although the demand on the voltage regulating system may be reduced somewhat, a substantial proportion of the size of conversion plant must be taken up by components other than the rectifier elements. Space must also be provided for the fins and other cooling equipment.

The introduction of the S.E.50 type switch which has a lower current consumption than that of the 2000 type switch will cause a reduction in the power requirements for telephone exchanges in the future. This reduction however will be offset to some extent by the increased calling rate and holding times which is being experienced generally by telephone administrations.

The last five years has seen a change from open type cells employing Plante type positive plates to enclosed type cells with pasted plates and it is likely that in the next few years all the cells delivered to the Department for use in telephone exchanges will employ pasted plates mounted in clear polystyrene containers. It seems certain that we will see a considerable increase in the practice which is already widespread of mounting power equipment, including batteries in the equipment room.

We now employ contactors on rectifiers to switch the D.C. output to either battery 1 or 2. It is likely that the use of contactors for DC switching in telecommunication power plant will increase and the discharge panel as we now know it may be radically changed. Remotely controlled contactors could be mounted in the most convenient position from the busbar layout point of view. Contactors could be used for end cell switching if a decision is made to depart from our simple 24 cell batteries. An interesting type of end cell switch is described in Reference 8. The switch is operated by a 50 volt coil which is energised for only a brief period. Restoration of the switch is accomplished by a similar coil.

Standby plant may be purchased in future with separate control cubicles which can be locally manufactured and will be suitable for use with any type of engine alternator. We may also purchase more air-cooled diesel engines for use on standby plant. It would seem that apart from the other advantages gained from the use of air cooled diesels, this type of plant would lend itself to the type of treatment envisaged for the reduction of acoustical noise as provision is made for connecting inlet and exhaust air ducts to the engine.

It has been stated (5) that "because of the fluctuating loads at telephone exchanges, batteries are usually the most economical form of standby plant at any rate for limited periods of cover." In general, power plants are designed to enable every exchange to withstand unaided a 24 hour interruption in the public power supply. Failures of more protracted nature must be legislated for and can be covered by means of a strategically located fleet of mobile engine generating sets.

Conclusion

The importance of power plant and the large amount of money involved, together with the large savings possible by efficient plant have been emphasized and present equipment and practices have been described. Reference has been made to the need for floating at the correct voltage and also the advantages gained from connecting two batteries in parallel. Overseas practices have also been reviewed and it would appear that Australian equipment and practice in many cases is fairly well abreast of the overseas practices as described in the available technical literature. No doubt many other important and as yet unpublished developments are taking place overseas and the desire for efficiency with economy will bring about just as far-reaching changes in the next 10 years as have occurred in the past decade.

Acknowledgments

The author wishes to thank the staff of Standard Telephones & Cables Pty. Ltd. and McKenzie & Holland (Aust.) Pty. Ltd. who assisted in the preparation of the sections dealing with magnetic amplifiers and the manufacture of selenium discs.

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REVIEW OF PUBLIC TELEPHONE CABINETS IN AUSTRALIA

*H. J. LEWIS**

Introduction

The climatic conditions in Australia vary greatly. The northern areas are sub-tropical with heavy rainfall in the coastal regions while a small highly populated area, consisting of southern Victoria and Tasmania, has a temperate climate with moderate rainfall. Generally speaking, provision has to be made for the warm conditions, as even in the coolest populated parts summer temperatures are likely to reach 100° F, while it is unusual for winter temperatures to fall much below 40° F.

Public telephone cabinets have been used extensively to relieve the shortage of private services as well as provide a public telephone service at key points throughout the cities and suburbs. They are generally good revenue-earners and so warrant attention to their design so that they provide an adequate service to the public. The cabinets are usually installed on the pavement or nature strip associated with the footway, close to the gutter or road kerb. They are also installed in banks of two or three outside railway stations or suburban post-offices where the calling rate is high.

There have been many cabinet designs built from several different materials during the last 60 years. The following sections of this review outline the chief features of the main types of cabinets still in use.

A.P.O. Former Standard Type Cabinet

This type of cabinet was introduced in 1933 and is constructed in several forms, namely—

(a) Glazed half length, 2 sides and door
(b) Glazed full length, 2 sides and door
(c) Glazed full length, all sides and door
or (d) Glazed half length, all sides and door.

Fig. 1.—Former A.P.O. Standard Cabinet, mounted on "cast in situ" Concrete Base.

The material used is chiefly wood, with galvanised-iron for roofing. The floor is linoleum-covered wood and the glazing is provided by $\frac{1}{4}$-inch drawn or plate glass. The cabinet is bolted down to a "cast in situ" concrete base. The general construction is shown in Fig. 1.

Experience has shown the following deficiencies in this design as generally used in Australia:—

(a) The wood joinery is a point of weakness and it is difficult to exclude the weather and maintain satisfactory jointing.
(b) The wood tends to rot around the lower portion of the cabinet due to ingress or absorption of moisture.
(c) The ventilation is inadequate.
(d) The cabinet requires frequent repainting (approximately every 3 years).

Several modifications have been made to improve ventilation, but they have not been adopted as standards pending a redesign of the cabinet to overcome the troubles listed under (a), (b) and (d).

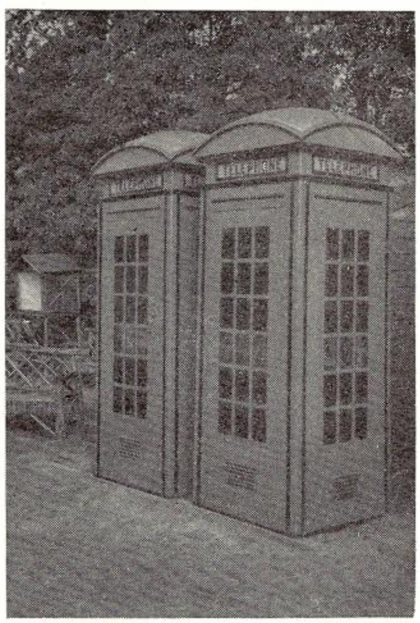

Fig. 2—Steel Cabinet with Domed Asbestos-Cement Roof, and all but one row of Glazing fitted with Non-Actinic Glass.

B.P.O. Type Steel Cabinet

This type of cabinet is a close copy of the design used by the British Post Office and called Kiosk No. 3. It is made of sheet steel instead of the cast iron or concrete used by the B.P.O. Small quantities were made during the war period, but, due to failure of the surface by rust, and poor ventilation; production has been discontinued. The most notable point of design in this cabinet is the introduction of a cast asbestos-cement roof. This material has proved satisfactory and is being used on some of the recent designs. The general construction is shown in Fig. 2.

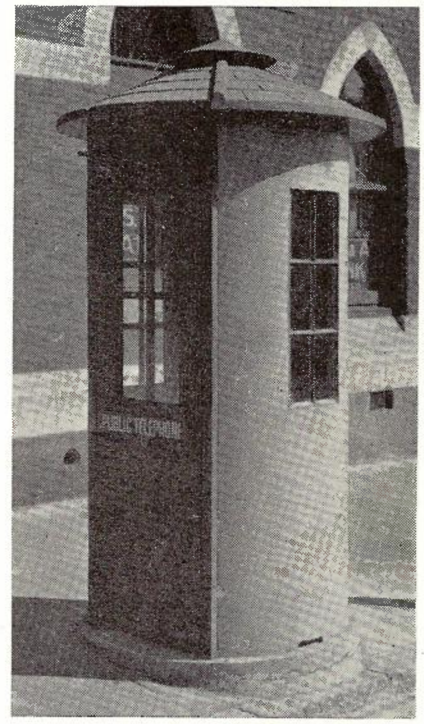

Fig. 3.—Precast "Pipe-Type" Concrete Cabinet with Wooden Door, concrete Floor forming mounting Base and Concrete Roof.

Concrete Types of Cabinet

Two main types of concrete cabinet have been made in Australia. The first of these is illustrated in Fig. 3, and was introduced in 1927. It consisted of a body made from a cylindrical precast pipe with two small half length windows and a wooden door. These cabinets had precast concrete roofs, some of which were flat with a small conical metal ventilator in the centre of the roof whilst others were conical and ornamented to represent small roofing tiles. The cabinets were fitted into a precast base which as well as providing the mounting, served as a floor. 6 x $1\frac{1}{2}$ inch openings were made at floor level around the walls to act as drainage ports for the interior, and also provided ventilation, which is considered inadequate. The other type of concrete cabinet, shown in Fig. 4, was a flat-roofed, square shaped, fully glazed one which was cast in situ.

Both of these cabinets have been satisfactory from a maintenance viewpoint, although if damaged by a heavy blow such as given by a vehicle, they are

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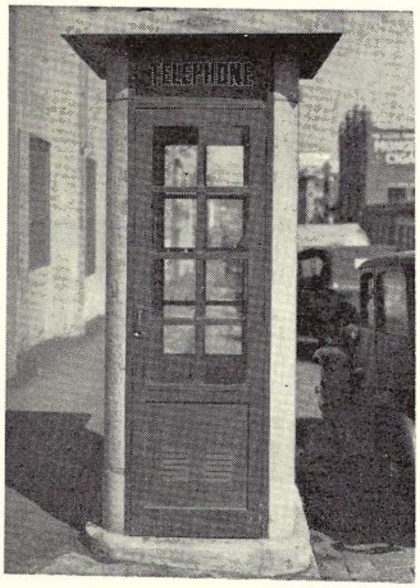

Fig. 4—Concrete Cabinet cast in situ—Metal Door and Window.

more or less a total loss. They also have the disadvantage of requiring much "on-site" work during their installation, and are not readily shifted to another location.

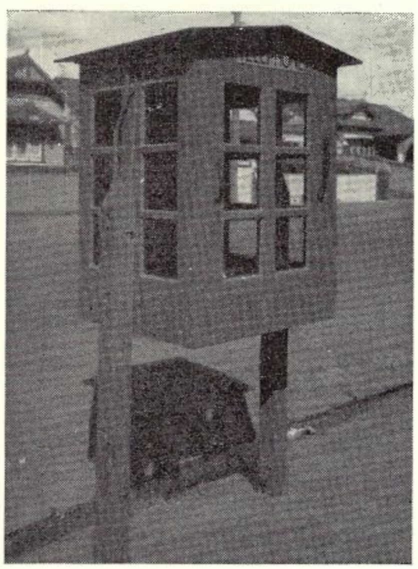

Fig. 5.—"Head-Box" Type of Cabinet Installed in New South Wales.

Head-Box Types of Cabinets

As a measure of economy and for speedy erection during the recent war period, head-box types of cabinet were introduced. As illustrated in Fig. 5, these provided protection for the equipment and shelter for the user above waist level only. They are not greatly favoured by the public, but have proved useful in locations where pavement space was not available for a full sized cabinet. These cabinets were also used in Military Camps where a temporary public telephone service was provided. Despite the usage disadvantages of this type of cabinet, its maintenance costs are very low, its ventilation reasonably good, and it can provide very satisfactory services in special locations.

Special Tropical Types of Cabinet

As well as the louvre-glazed type of cabinet described in a following section of this review, two types of wooden panel-glazed cabinets have been produced in Queensland to suit the tropical climate. These cabinets are shown in Figs. 6 and 7. These cabinets have a somewhat similar appearance to the former standard cabinet. The roof ventilator has been deleted and additional ventilation introduced under the eaves. The lower glazing areas of the cabinet have been replaced with wooden louvres in one type, whilst in the later model a gap has been provided beneath the glazing areas to allow free ingress of air. The roof is galvanised iron and is unpainted. These cabinets suffer from the same faults of wood joinery exposed to the weather as the former standard type.

Fig. 6.—Tropical Type Cabinet Installed in Queensland.

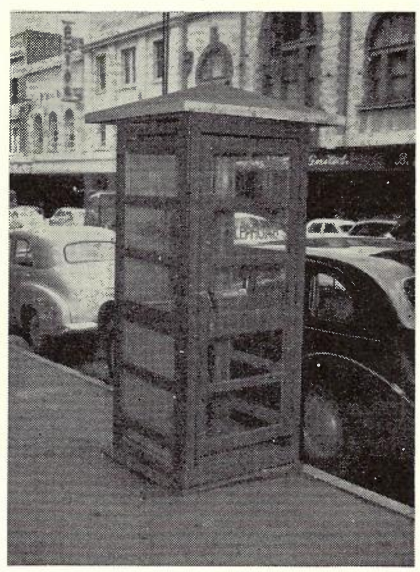

Fig. 7.—Tropical Type Cabinet Developed in Queensland in 1955.

Recent Types of Cabinet

Two recent design changes have chiefly been related to appearance and ventilation. Domed roofs similar to those used on the B.P.O. cabinets were introduced in Victoria on the former standard type cabinet. Initially these were made with a wooden framework covered with lead sheeting. The same design was repeated with cast aluminium and also cast asbestos cement. In the latter types the ventilation area was increased in the roof by adding small cast aluminium ventilators to the gables. At the same time the ceiling and cabinet body ventilating areas were increased, which greatly improved the ventilation in the cabinet. This type of roof is shown in Fig. 8.

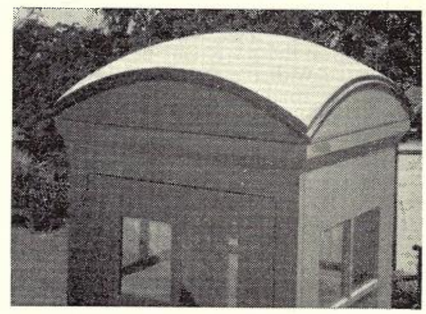

Fig. 8.—Domed Roof Used in Victoria on "Modified-Standard" Cabinets. Ventilators have been added to the Gables of recent models.

In 1951, following the manufacture of a steel cabinet of modernistic design, as shown in Fig. 9, in the Sydney Workshops, two new types of cabinet were

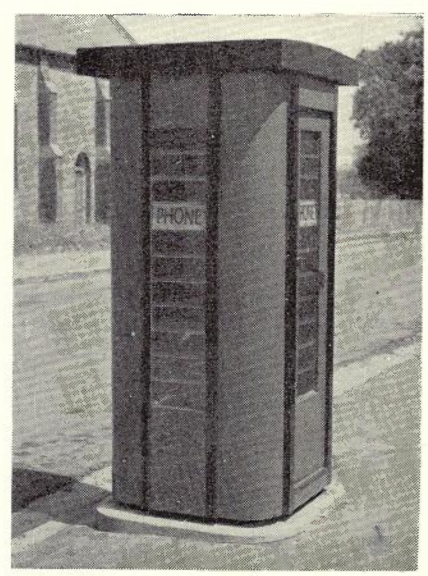

Fig. 9.—Experimental Louvre-Glazed Steel Cabinet Developed in New South Wales.

developed. The chief feature of these cabinets was the introduction of louvre glazing to provide excellent "cross" ventilation. Previous cabinets had been limited to a few square inches (except for the one described in the previous paragraph, which had 48 square inches) of "flue" ventilation whereas the louvres provided approximately 30 square inches on each side of the cabinet for "cross" ventilation as well as small "flue" ventilation in the roof to cool the roof cavity of the cabinet. Other features of this type of cabinet were an alternative roof

Fig. 10.—Recent Experimental Tropical Type Louvre-Glazed Wooden Cabinet.

with large eaves to provide more shade in tropical areas, improved door fittings, flush lighting, acoustic panelling around the upper portion of the walls and rubber flooring. This type is illustrated in Fig. 10.

Although this louvre-glazed cabinet appears to be satisfactory from a ventilation viewpoint, it still retains the same wood joinery principles which are a source of trouble in the former standard cabinet. It also requires frequent painting and is subject to deterioration due to wood rot around the lower portion of the cabinet.

Pending development of a cabinet of durable material, probably cast aluminium, the louvre-glazed cabinet with the domed roof shown in Fig. 11 has been adopted for present manufacture. Modifications have been incorporated in this cabinet which will limit some of the causes of deterioration previously experienced and enable all fittings to be made on a production basis. Previously the practice has been to purchase the basic cabinet shell and add the fittings at the time of installation. This is a costly practice which permits variations in methods of fitting the equipment and so spoils the appearance of the cabinet as well as developing unstandard arrangements. The chief modification introduced to the structure is the elimination of the wooden floor, one of the parts with the most wear and deterioration. In future this cabinet will be mounted directly on a concrete base with a durable surface, by four angle-iron pillars with a $1\frac{1}{2}$ inch gap between the sides of the cabinet and the base. This method of mounting will isolate the wooden sides from the ground and reduce the failure on the lower rail due to capillary seepage of moisture, as well as provide a durable floor which can be readily cleaned.

Artificial lighting is provided by a flush panel fitting mounted in the ceiling, and the ceiling and upper portions of the wall are covered with an acoustic treatment which greatly reduces the "drumminess" of the cabinet and absorbs the external noise. The notice sign "Telephone" is provided on the top glass louvre by a sandwich joined with an epoxy resin adhesive. The lettering is a fused ceramic paint on the inner surface of the outer glass, with black characters on a yellow background. Provision is made for hidden light and communication cabling with two wooden corner strips rising up both the back interior corners of the cabinet. Cables can be brought in underground through these corner strips to the light and instrument, or where necessary, can also be brought in overhead, although the latter arrangement is not favoured.

Fig. 11.—Recently Adopted Louvre-Glazed Wooden Cabinet.

Summary of Desirable Features for Cabinets

The following points appear to be the desirable features for public telephone cabinets for the majority of the settled areas in Australia and for the greatest portion of year—

(a) Good ventilation is essential, with complete natural replacement of the air inside the cabinet at frequent intervals.
(b) Good natural lighting in the daytime and adequate artificial lighting after sunset which can be maintained by the street-lighting patrol.
(c) A complete view into the cabinet from all directions. This is necessary to limit vandalism and misuse of the cabinet.
(d) A floor surface which is durable and does not require repetitive protective treatment.
(e) An exterior surface which is durable and does not require repetitive protective treatment.
(f) Construction with materials which will withstand weather without deterioration, are readily available, repairable and can be fabricated without complex processes.
(g) Readily discernible by the public and yet aesthetically designed to harmonise with local buildings.
(h) Readily transported, erected or shifted.
(i) The fittings subject to damage such as windows, door fittings and lighting fixtures should be designed to facilitate quick replacement or repair in the field.
(j) Acoustic properties which limit the ingress of noise and the egress of conversation.
(k) Door to provide easy entry into the cabinet and easy access for cleaning.
(l) Shade, either by provision of eaves on the roof of the cabinet, or by placing the cabinet in a position where it is shaded by adjacent buildings or trees.
(m) Adequate designation signs either attached to the cabinets, or mounted on buildings or posts to direct callers to the public telephone.
(n) Provision for tidy and easy entry of lighting and transmission cables.
(o) Provision for interference-proof mounting of the equipment with fittings that are built into the cabinet.
(p) Easy access to the coin box for clearance purposes.
(q) Built-in notice frame and directory shelf.
(r) Interior of cabinet to be easily cleaned, finished in a hygienic manner and be not easily disfigured or damaged.

ANSWERS TO EXAMINATION PAPERS

Examination No. 4445—Senior Technician, Telephone. July, 1956.

Telephony II—Section I

Q. 1(a).—What is meant by the expression that the power dissipated in a circuit is X decibels relative to 1 milliwatt?

A.—This means that the power, P milliwatts, dissipated in the circuit may be obtained from the equation X(db) = 10 $\log_{10}$ (P/1) or P (milliwatts) = antilog (X/10). For example, a power of 10 db relative to 1 milliwatt is 10 milliwatts, and a power of 30 db relative to 1 milliwatt is 1000 milliwatts or 1 watt.

Q. 1(b).—If the input and output impedances of an amplifier are each 600 ohms, and the amplifier gain is 33 db, what is the R.M.S. voltage, developed across a load of 600 ohms connected to the output, when the input power is minus 10 db relative to 1 milliwatt. The answer should be accurate to the nearest volt.

A.—If the input power is –10 db relative to 1 milliwatt, and the amplifier gain is 33 db, then the output power is + 23 db relative to 1 milliwatt. From the expression in Question 1(a), this corresponds to a power of 200 milliwatts. The R.M.S. voltage, E, across the load is given by $E^2/R = W$, where R is 600 ohms and W = 200/1000 watt.

Thus $E^2 = (600 \times 200)/1000 = 120$
and E = 11 volt (to nearest volt).

Q. 2.—Describe how you would carry out insertion loss measurements on an open-wire aerial circuit between two points where the nominal impedance is 600 ohms. The required frequency range of the measurements is from 1 to 150 kilocycles per second. List the testing instruments required and give a block schematic of the necessary interconnexions. Mention any special precautions necessary to avoid the possibility of errors due to measuring techniques.

A.—The testing instruments required are:—

Sending End.

(a) Variable oscillator covering range 1-150 kc/s, such as Western Electric 17B oscillator.

(b) Transmission measuring set capable of measuring sending powers in the required frequency range, and preferably with a changeover key to permit the oscillator output to be measured or sent to line, as required, by the operation of the key. A Western Electric 30A T.M.S. would be suitable.

Receiving End.

Transmission measuring set similar to that at the sending end. If the loss of the aerial circuit is high, an auxiliary amplifier may be required also with some types of transmission measuring set.

Shielded patch cords will be required at both ends and screened and balanced transformers if not provided in the transmission measuring sets.

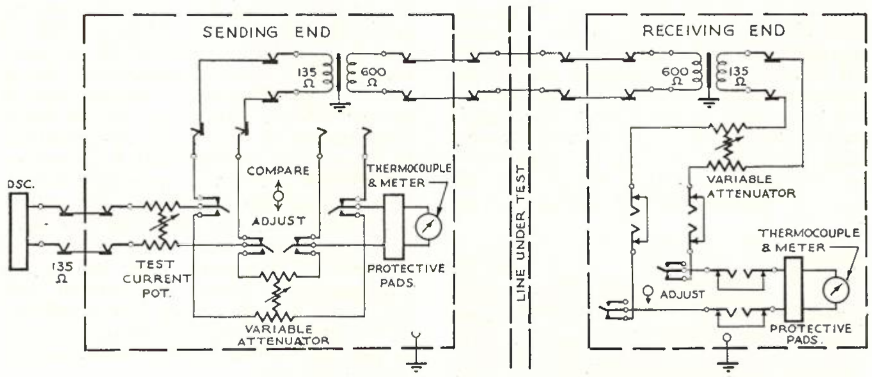

Fig. 1.

In this answer, it is assumed that Western Electric 17B oscillator and 30A transmission measuring sets are used. The block schematic of connections is shown in Fig. 1. It is also assumed that the insertion loss is less than 30 db at the highest frequency.

General Procedure.

(i) Calibrate oscillator and transmission measuring sets after the oscillator has warmed up for the prescribed periods.

(ii) Test the bearer circuit for continuity and I.R. to make sure it is free from faults.

(iii) Set oscillator to 150 kc/s, and the output from the test potentiometers to, say + 25 dbm with the test key in the adjust position. The test current is then sent to line by throwing the test key to the compare position and the received power measured approximately at the distant end.

(iv) If the loss of the line at 150 kc/s is say 16 db, the test current for all subsequent measurements is set to a value of at least this number of decibels above 1 milliwatt, for example, + 20 dbm. This is because the instrument at the receiving end is accurate only if the received powers exceed 1 milliwatt.

(v) Test currents of the chosen value are then sent successively from the send end and read at the receiving end. If the value sent is + 20.0 dbm and the received value is, for example, + 4.7 dbm, the overall loss of the line plus transformers would be 15.3 db. The transformer losses are obtained from the testing instrument handbook or measured separately and subtracted from this loss to give the insertion loss of the line. The frequencies at which tests are made are usually in 1 or 2 kc/s steps from 1 to 10 kc/s and thereafter in 5 or 10 kc/s steps, depending on the required accuracy and the purpose for which the results are required.

Send Level Adjustment. With the variable attenuator set to a value of about 30 db (the maximum output of the oscillator in dbm), the test key is thrown to the "adjust" position and the meter protection pads removed one by one. The output control of the oscillator is varied until the approximate value can be read from the meter. The output control and the variable attenuator are varied successively in such a way that a reading of 0 db is not exceeded until a value of approximately 0 db is obtained on the meter when the value of the variable attenuator is set at a value equal to the required output in dbm. The output is then adjusted to exactly 0.dbm using the variable test current potentiometer.

Receiving Level Measurement. The variable attenuator is set for an attenuation of about 30 db before the test key is thrown to the "adjust" position for the first reading. The protection pads are removed successively while watching the meter to see whether it assumes a steady value on the scale. If no reading is obtained the protection pads are restored and the attenuator is decreased by not more than 10 db. The procedure is repeated, decreasing the attenuator until a reading of ± 1 db is obtained on the meter, making sure that the meter reading never exceeds – 8 db before the last protection pad is removed. If the meter reading is, for example, + .7 db and the attenuator value is 8 db, the received power would be + 8.7 dbm.

Precautions.

(i) Make sure all testing instruments are earthed and that shielded patch cords are used.

(ii) Ensure that the correct test procedure is used with the 30A T.M.S. sets to avoid damaging thermocouples. It is necessary to allow time for the meter to assume a steady value before the next operation of the attenuator or meter protection pads, and to make sure that the meter reading does not exceed – 8 db for example, before a further 10 db pad is switched out, or before the attenuator is decreased further by an amount of 10 db or more.

Q. 3.—A four-wire circuit in a voice frequency loaded cable requires terminal amplifiers to allow the design equivalent to be obtained. The amplifiers are required only at the receiving end of each direction of transmission. Draw a block schematic circuit showing the equipment between the cable and the two-wire path at one terminal station. Indicate briefly the function of each item of equipment.

A.—The block schematic circuit is shown in Fig. 2.

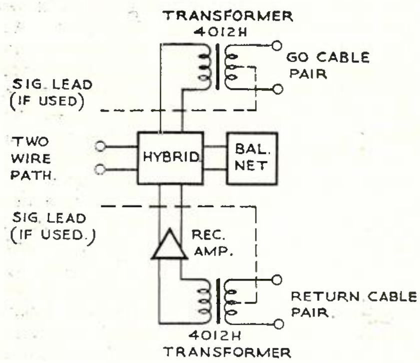

Fig. 2.

Functions.

(i) The 4012H transformers are required to match the equipment, which usually has an impedance of 600 ohms, to loaded cable pairs which usually have an impedance of about 1000 ohms. The transformers also provide centre taps for cailho signalling which is usually used on this type of circuit.

(ii) The receiving amplifier reduces the loss of the return cable pair, transformers and the hybrid coils to the required value of the equivalent. Equalisers are seldom required with loaded cable pairs.

(iii) The hybrid coil and associated balance network are required to separate the directions of transmission. They allow speech to pass from the two-wire path to the go cable pair and from the receive amplifier to the two-wire path, but suppress transmission from the receive amplifier to the go cable pair by an amount depending on the degree of balance between the balance network impedance and the impedance of the circuit connected to the two-wire terminals of the hybrid. The balance network is usually a compromise one consisting of a 600 ohm resistor and 2 microfarad capacitor in series, these values giving sufficient suppression with average lines connected at the switchboard to prevent singing and reduce echoes to a reasonable value.

Section II

Q. 1.—At a carrier terminal station "A", two three-channel systems from two other stations "B" and "C" are terminated. One channel of each system is connected to the switchboard at station "A". The other two channels are permanently connected through at station "A" to provide channels between "B" and "C". Draw in schematic form, a diagram of the connexions between the two three-channel terminals at station "A", omitting the channels, which terminate on the switchboard at "A". Include wiring, jacking and connexions to the I.D.F.

A.—Two alternative schematics of the connections are given in Figure 3. Either one would be acceptable in answer to the question.

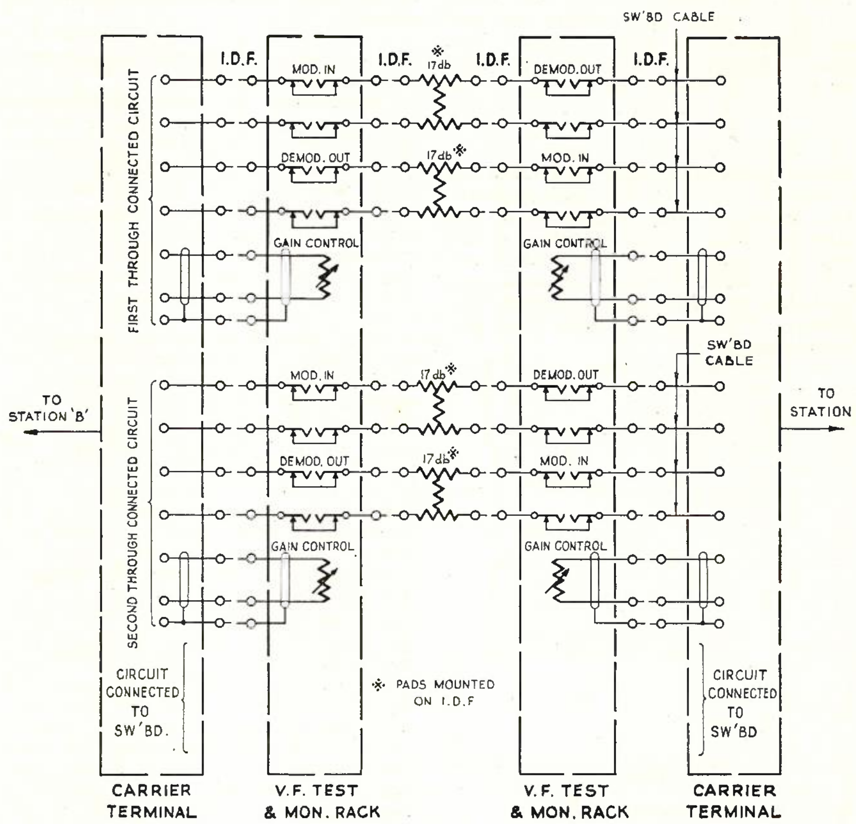

Fig. 3.

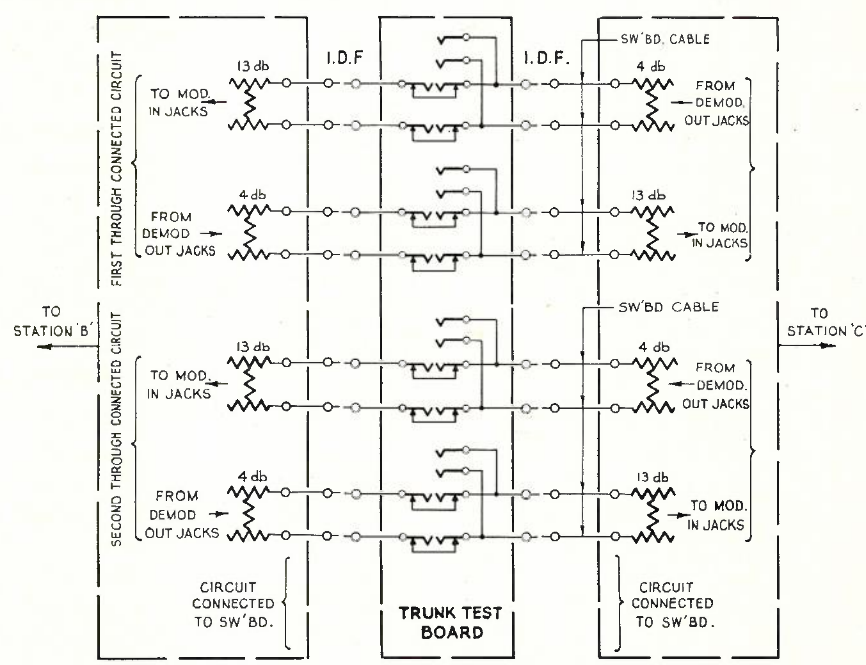

Fig. 3a

Q. 2(a).—What is the particular application of the Murray Bridge facility provided in the wheatstone bridge circuit of the standard trunk test board, and when would it be used in preference to the Varley facility?

A.—The Murray Bridge facility provided on the standard trunk test board is used to locate earth faults on lines and contacts with other circuits. The Murray facility is more accurate than the Varley facility for faults close to the testing station, such as in trunk entrance cables.

Q. 2(b).—To locate an earth fault, a Murray location test has been made on a 50-mile circuit of uniform construction, having a loop resistance of 8.8 ohms per mile. If the resistance of the ratio arm was 10,000 ohms, and a balance was obtained with a rheostat arm resistance of 526 ohms, calculate the distance of the fault in miles from the testing station.

A.—Referring to Figure 4, the total loop resistance R of the circuit is 50 x 8.8 ohms = 440 ohms.

The single wire resistance to the fault, X ohms is given by X/(R–X) = 526/10,000.

or 10,000 X = 526 R - 526X
or 10,526 X = 526 R

$$\therefore \quad X = \frac{526 \times 440}{10{,}526} = 22.0 \text{ ohms.}$$

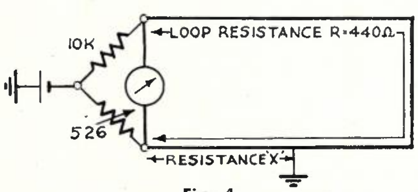

Fig. 4.

As the single-wire resistance of the circuit is 4.4 ohms per mile, the distance to the fault is 5 miles.

Q. 3.—Describe in detail the method of synchronising the oscillators of the two terminals of a three-channel system of the older type, not employing crystal control.

A.—If the carrier system modulator and demodulator band pass filters can be patched out, the method usually used is to synchronise each channel in one direction by the double-sideband method and in the reverse direction by looping back tone from the sending terminal. The carrier system channels are numbered so that each channel can be synchronised in this way without patching out terminal or repeater directional filters or intermediate line filters.

After booking the system out of traffic, channel 2 is first synchronised in the A to B direction by patching an 800 or 1000 c/s tone at the normal test level into the hybrid line or modulator input jacks of the channel concerned and patching out the modulator band filters of the channel at the sending terminal and the demodulator band filters at the receiving terminal. Both sidebands will then be sent to line and will pass to the demodulator at the receiving terminal. The technician at the receiving terminal listens on the system monitoring set at the demodulator output jacks or the hybrid line jacks and adjusts his demodulator oscillator variable condenser until the received 800 or 1000 c/s tone beats at a rate less than 1 beat per second. After locking the condenser, the band filter patches are removed at both ends and at the receiving terminal, the tone is looped back over the channel in the opposite direction to the direction just synchronised.

This can be done by patching from demodulator output jacks to modulator input jacks through a pad of such value as to compensate for the differences in level, for example, a 17 db pad for systems using levels of + 4 db and – 13 db at the respective points. Alternatively, the tone can be looped back by inserting an open circuit plug in the hybrid line while terminating the hybrid net jacks in 600 ohms, if a network of this value is not already connected. At the sending terminal the technician then listens to the beats produced between his sending tone and the tone received back from the distant terminal and adjust the demodulator oscillator of the channel concerned until the beat is less than 1 cycle per second. It is important that the levels of the send tone and received tone should be approximately the same at the listening point for a definite beat to be obtained. This can be achieved by listening at the hybrid net jacks if the tone is applied to the hybrid line jacks, or on some systems or special monitoring jacks associated with the hybrid. On other systems the monitoring set has a facility for listening four-wire to the send and receive directions simultaneously. Alternatively, the tone, telephone receiver and send and receive paths can be connected together by parallel jacks.

Channels 1 and 3 are then synchronised in turn by sending tone from the B terminal and using the double sideband method in the B to A direction. The A to B direction is then synchronised by looping back as described previously.

After the channels have been synchronised, they are lined up before returning to traffic.

POSTAL ELECTRICAL SOCIETY OF VICTORIA

ANNUAL REPORT, 1955-56

During the 1955/56 year it has been necessary to give considerable attention to the financial basis of publication of the Telecommunication Journal. As has been indicated in previous annual reports the Society has been able to continue publication of the Journal since the 1947/48 year only with the assistance of a subsidy from the Postmaster-General's Department. The total subsidy which has now been received is approximately £4,200. When the subsidy was first paid by the Department the Society was requested to present its accounts to the Department in such a form that the Society's actual liabilities and its actual assets should be used as a basis for computing the actual deficit and, consequently, the amount of subsidy. This arrangement was followed and the Society is deeply appreciative of the assistance so obtained. It is, however, true that this form of presentation of accounts untintentionally disguised a more unfavourable aspect of the financial position.

The delay in publication of the Journal, dating from the war-time period, had meant that subscriptions paid at the beginning of each financial year were considerably in advance of the supply of Journals. The basis of determination of subsidy, however, resulted in the Society, within one year, using that year's subscriptions, to pay for Journals which actually should have been issued to subscribers on account of subscriptions paid during the previous year. With the passage of time the discrepancies between dates of Journals and periods of subscription became very confusing to subscribers, who frequently were late in payment of subscriptions. In an endeavour to rectify this situation the Society proposed to the Department that a series of Journals having only 32 pages in lieu of 48 pages (new style type) be published, and that, the basis of subsidy be reviewed so that the Society's financial position could be stabilised with its receipts and liabilities current in one year. The expectation was that smaller Journals, with less information content, would be prepared faster and at less cost, thus eliminating the delay in publication and with a minimum call for financial assistance from the Department. It was appreciated that for some time subscribers would get less for their money but in taking such measures the Society would have been following the course of some of its well-known overseas contemporaries.

When these views were represented to the Department, it accepted the view that the basis of subsidy should be changed, but did not accept the liability for any additional Journals. Indeed, it took the view that publication should be limited to three 32-page Journals each year. Arranging the revised basis of subsidy has been the subject of considerable negotiation, and the Department has finally advised that:

" . . . as to the simplest procedure for implementing these arrangements it has now been decided that the Department will in future pay for the cost of producing the Journal, the Society will continue the distribution of the Journal, and will pay to the Department the excess of receipts from subscriptions and sales over its distribution and other working costs after provision for a working cash balance. This arrangement will be subject to review in the event of any major variation in the proportion that the reinbursement by the Society bears to the total costs."

The Society has been informed that the limit set to this variation is that the Society should contribute at least half of the cost of the Journal.

As it is now no longer possible to contemplate publishing the delayed Journals, the delay has been allowed to grow to twelve months and Volume 10, No. 4, of the Journal has been prepared with the date June, 1956. There are no Journals bearing the dates June 1955, October 1955 and February 1956. Every subscriber will receive three Journals for his 10/-, and very few advance subscriptions (i.e., beyond Volume 10, Nos. 4-6) now held being within our capacity to carry, while the few subscriptions held for the missing year, 1955/56, have been carried forward. To make this explicit, Volume 10, Nos. 1-3, bearing dates in the 1954/55 year, are treated as belonging to that period, and Volume 10, Nos. 4-6 to bear dates in the 1956/57 year will be treated as belonging to the current period. The Renewal Notice which appeared in Volume 10, No. 3, was altered to cover the Journals, Volume 10, Nos. 4-6 rather than for the period of time.

As things stand the present rate of subscription and number of subscribers is adequate to permit the continued publication of 32 page Journals with a slight safety margin to cover any slight upward movement in printing costs. However to increase the size of the Journal without increasing subscriptions, we must increase our number of subscribers. During the past year the Society has canvassed former subscribers and has met with a fairly good response so that the number of subscribers has been brought up to 1700. As stated, however, to be able to increase the size of Journals, revenue must be increased, preferably by an increased number of subscribers. Your committee proposes to continue its canvassing activities, but the assistance of rank-and-file subscribers could also help. If you have workmates who are not subscribers and you interest them in becoming subscribers you will help us to help you.

With regard to the other activities of the Society, during the past year it has been necessary for two of the Editors to resign, Mr. J. Harwood on his transfer to the Department of Supply at Salisbury, S.A., and Mr. C. Griffiths after the very long period of 22 years active association with the Society, due to pressure of other activities. Tributes to these gentlemen have appeared in the Journal. Their places on the Board of Editors have been taken by Messrs. E. Bulte, of the Telephone Equipment Section, Central Office, and A. Hoggart, of the Lines Section, Central Office.

The thanks of members are due once more to the Principal and Officers of the Radio School, Melbourne Technical College, through whose assistance it has been possible for the lecture programme to be held in the Theatre of this school. Likewise their thanks must be extended to Messrs. A. Hart, B. Morrows, C. H. McCall, J. Bryant, J. Pryor and J. O'Shannassy, who delivered lectures in this programme.

The Committee desires to express its thanks to the authors of articles, members of the drafting staff who have prepared illustrations and members who have assisted in the collection of subscriptions.

My personal thanks are due to Mr. A. Halley, who acted as Secretary for a total period of five months during the past year on the occasion of my absence, on a visit overseas, and due to ill-health. These thanks must be doubly extended to Mr. Halley as, during the past 18 months, a good deal of additional work has been done in overhauling the administrative system and records of the Society. My thanks are also due to Mr. J. Coghill, who has contributed a considerable amount of effort to this work. As a result of our efforts it is now possible to keep a much closer account of enquiries and subscriptions.

R. D. KERR,
Hon. Secretary.

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Melbourne