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The

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VERY HIGH FREQUENCY AND ULTRA HIGH FREQUENCY RADIO LINKS IN THE AUSTRALIAN POST OFFICE COMMUNICATION NETWORK*

S. J. Ross

SUMMARY

In this paper is discussed the general problem involved in the introduction of recently developed radio telephone systems into the telecommunication network of the Australian Post Office. An outline of the types of systems available, and their application, is given. Some details of the principles of pulse modulation are included, and the general propagation problems associated with the operation of V.H.F. and U.H.F. radio links are covered briefly. Reference is made to the installation of these systems as part of the trunk line network and a general description of a system installed recently is included. Brief details of equipment developments likely to be incorporated in future systems are given and the paper concludes with some general observations on the application of radio telephone systems to the trunk line service in Queensland.

INTRODUCTION

In a telecommunication network, the ultimate aim is to provide trunk line channels whereby two telephone subscribers, situated at any distance apart, may converse, without conscious effort to overcome the effects of any losses or distortion which may be present in the connection. To achieve this objective, advantage must be taken by telephone administrations of all developments in communication practices.

In the Commonwealth of Australia, there is already an extensive trunk line network representing a capital investment of approximately £28,000,000. This network is composed of aerial wires and wires in underground cables. For all long-distance channels, carrier systems are superimposed on these wires and cables. The development of this network follows a plan prepared in detail so that each addition fits into the complete pattern. The present network is extended in a few cases by fixed or mobile single channel radio telephone systems. The shortage of frequencies and the danger of inter-system interference has hitherto imposed a limitation on the use of radio channels for communications, but with the development of systems making use of the very high and ultra-high frequencies, a new field has been opened up. It is now possible to utilise, in the communication network, single-channel or multichannel radio telephone systems, which possess operating characteristics equal to those of the conventional carrier system, and which operate at frequencies where inter-system interference is avoided.

These radio systems will supplement the existing wire network, provide alternative routes for channels, span country difficult of access, and in some cases, provide auxiliary channels in the event of emergency due to flood, fire or cyclone. In this paper the application of these systems to the trunk network is examined. The general installation problem, choice of suitable frequencies and propagation difficulties are discussed. Some general details of pulse modulation and its application to systems are given, and a general description of the operation of a system installed recently, together with some details of future systems, have been included.

REVIEW OF AVAILABLE TECHNIQUES

General. Since World War II there has been considerable development in the design and use of very high and ultra high frequency radio equipment for communication purposes. This has

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led to the design and employment of this type of equipment for the provision of telephone channels. There are two major classes of equipment in this particular field, namely:—

(a) Radio equipment, using either frequency modulation (F.M.) or amplitude modulation (A.M.), operating in the 100 to 1000 megacycles per second range. This is either wide band equipment, over which a carrier telephone system may be superimposed or equipment providing a single voice frequency channel.

(b) Radio equipment using pulse modulation, operating in the range between 100 to 10,000 megacycles per second. From this equipment up to 24 voice frequency channels may be derived.

Radio channels of the type referred to operate over optical or near optical paths in contrast to channels operating at lower radio frequencies. This means that, as a first requirement, either sites at high altitudes must be available, or towers erected to carry the radiating systems which are, in themselves, small. The radio equipment is relatively cheap, and is designed to simplify maintenance as much as possible. The power requirements are small and the standard of telephone service is equivalent to that provided over a well maintained trunk line. This is in sharp contrast to the service provided on existing long radio telephone channels in which high frequencies are used.

Amplitude Modulation (A.M.) and Frequency Modulation (F.M.). The modulation terms A.M. and F.M. describe briefly the conventional forms of altering or varying the radio carrier wave in accordance with the variations of the modulating frequency. In A.M., the amplitude of the radio carrier wave is varied, the frequency remaining unchanged. In F.M., the amplitude of the radio wave is left unchanged, but the frequency is varied in accordance with the modulating audio frequency. Frequency modulation possesses several advantages over amplitude modulation, the principle one being, that for a given power it gives a considerable improvement in signal-to-noise ratio. Further, the use of frequency modulation greatly simplifies the design of transmitters, which introduce very low amplitude distortion. This is an important point when these are required to act as a bearer for a multi-channel carrier system.

Pulse Modulation.

General Description of Principles: A new method of modulation, known as Pulse Modulation, has recently been introduced into Communication. This system consists essentially of imparting to a pulse the intelligence which is to be conveyed. The method involves sampling the modulating signal for intervals of time too short to allow much change in the modulating signal during the time interval of sampling. Thus, the continuous curve representing the varying amplitude of the signal as a function of time is transmitted in the form of a succession of dashes as shown in Fig. 1. Each dash corresponds to a certain pulse, and its ordinate indicates the duration of width of the pulse. To ensure satisfactory transmission of the low frequency signal by samples, these must be sufficiently close together. That is, the repetition

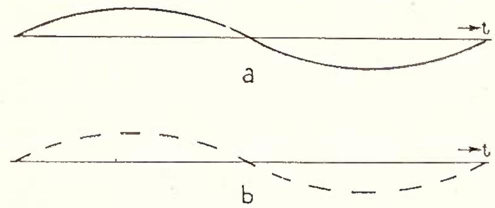

Fig. 1.—(a) Signal as a Function of Time; (b) "Samples" Transmitted in Pulse Modulation

frequency of the pulses must be great with respect to the highest of the low signal frequencies to be transmitted. Good results can be obtained when the frequency ratio is about 2.5 to 1, when distortion from this cause alone is less than 1 per cent. In speech the highest of the frequencies to be transmitted is about 3400 cycles per sec. The repetition frequency must, therefore, be about 9 kilocycles per sec. Expressed in another way, 9000 samples of the speech must be sent each second.

In this system the transmitter does not produce a continuous carrier but a sequence of high frequency wave trains following each other at a certain interval of time. The high frequency voltage is modulated by the pulses.

Types of Pulse Modulation: A number of methods of modulating the pulse train have been developed, and may be described as follows:—

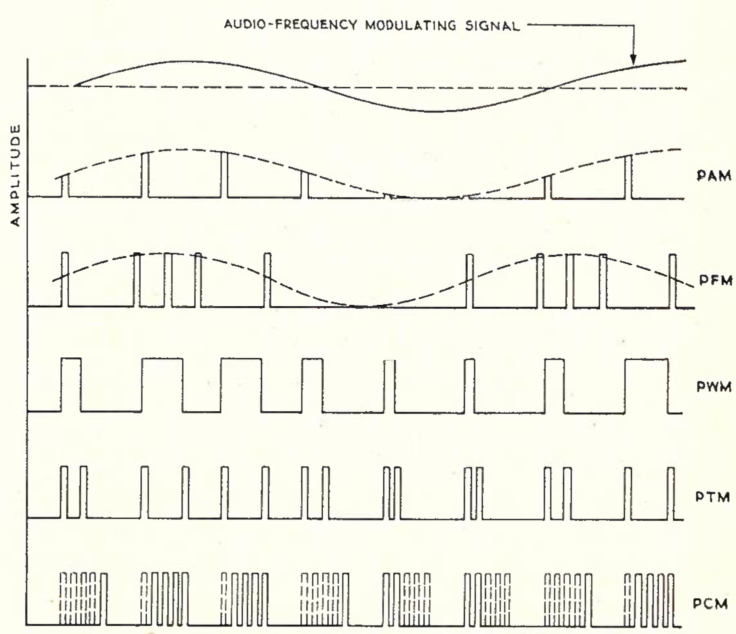

Fig. 2.—Pulse Amplitude, Pulse Frequency, Pulse Width, Pulse Time, and Pulse Count Modulations

(a) Pulse amplitude modulation, in which the amplitude of the pulses is varied (P.A.M.).
(b) Pulse frequency modulation, in which the repetition frequency of the pulses is varied (P.F.M.).
(c) Pulse width modulation, in which the width or duration of the pulses is varied by the modulating signal (P.W.M.).
(d) Pulse time modulation in which the position of the pulses is varied in time (P.T.M.).
(e) Pulse count (or pulse code) modulation in which the modulating signal is sampled in a time dimension as well as in amplitude (P.C.M.).

The various types of pulse modulation are illustrated in Fig. 2. At the present stage of development, the commonly used systems are pulse width and pulse time modulation, and the discussion which follows refers specifically to these systems. Pulse count (or pulse code) described by D. D. Grieg (4) has been developed and tried successfully in experimental installations, and may be incorporated in future systems. In this method, the signal is reproduced in terms of a full unit pulse code, and substantial improvements have been obtained in signal to noise ratios, crosstalk and other transmission factors.

The radio carrier of the complete system is suppressed completely and the pulses to be transmitted are used to trigger the radio oscillator, to release pulses of radio frequency energy. The outline of the radio frequency pulses is a replica of the pulse train because of the trigger action of the latter, the radio frequency oscillator being switched on and off by the pulses.

Pulse Modulated Multi-Channel Systems: When a number of conversations are to be transmitted simultaneously, as in a multi-channel system, a train of pulses with a synchronising or marking pulse is produced. Each pulse in the train is allocated to a particular channel, and it samples at the repetition frequency rate each channel in sequence. A typical pulse train for an eight channel system with the marker pulse, using pulse width modulation, is shown in Fig. 3. To prevent overlapping of channels, and resultant crosstalk, a margin is allowed between pulses.

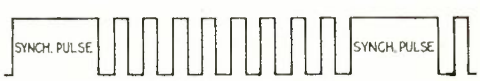

Fig. 3.—Eight-Channel System—Typical Pulse Train

There are several reasons for the use of pulse transmission for multi-channel systems. In multi-channel line carrier telephony, the channels are displaced in frequency, and laid side by side, whereas in pulse transmission, they are displaced in time and laid side by side. This time displacement obviates the need for elaborate frequency separation filter equipment, as the transmitter and receiver are kept in synchronism, and pulses sent for any selected channel are automatically received into the correct channel. The transmission of pulses requires a wide frequency band, but as very high or ultra high frequencies are used, where there is ample frequency space, this disadvantage disappears. Further, working in the V.H.F. or U.H.F. band results in noise reduction. If repeaters are used, they do not introduce any distortion in transmission, as it is the pulse train which is amplified, and the amplitude of the pulses does not have any effect on the modulation.

Generation of Pulse Modulation Wave Form: The following steps are involved in the generation of a pulse modulated multi-channel wave form:—
(i) Generation of pulses.
(ii) Production of pulses at proper time intervals to provide a series for each channel.
(iii) Modulation of each series of channel pulses by the respective audio frequency signal.
(iv) Limitation of the audio frequency modulating signal to prevent crosstalk between channels.
(v) Generation of a marker pulse.
(vi) Final mixing of series of channel pulses and the marker pulses into one interleaved set.

The translation of the radio pulse series of signals back into the audio frequency channels involves the following sequence of operations:—
(a) Removal of the marker pulse from the pulse series.
(b) Separation of the series of pulse of each individual channel from the combined pulse series.
(c) Conversion of the pulse series of each channel into its appropriate audio signal.
(d) Amplification of the audio frequency signal.

The application of pulse modulated multi-channel systems will be referred to later.

FACTORS INVOLVED IN OPERATION AT V.H.F. AND U.H.F.

General. Radio communication systems using very high and ultra high frequencies require for their most satisfactory operation a direct line of sight path between terminals. Obstructions may be tolerated if unavoidable, but their presence seriously affects transmission, and allowances must be made for what is termed "shadow loss." From the theoretical point of view, any radio frequency in the V.H.F. or U.H.F. range may be used, but a number of practical factors limit the choice of operating frequency irrespective of transmission and modulation methods.

In the first place, other services not involved in the tele-communication network, such as mobile services and the like, have urgent need of the channels below about 150 megacycles per second. This fits into the general overall pattern, as the diffraction losses at the higher frequencies are much greater than at low frequencies and the effects of path obstacles would be very serious if these bands were used, say, for mobile services. On the other hand, radiations on the higher frequencies may be concentrated and directed. This is an extreme advantage in the operation of fixed systems to provide trunk channels, as secrecy can be obtained and economy in transmitter power secured.

For frequencies below 1000 megacycles, larger transmitter powers must be used for a reasonable signal-to-noise ratio because of the practical limit of size of antennae and the attendant small antenna gain. This limits the application to short links where ample power is available, and restricts the use of repeaters for long distances owing to the difficulties in providing power supplies. At the higher frequencies, antennae of practical size give large gains, and make the transmitter power requirements small, but certain practical considerations limit the upper frequency. Tower sway causes undue signal fluctuations at the higher frequencies, and economical design limits the rigidity of a tower. Further, as the frequency increases absorption and diffraction losses become more serious, whilst the maintenance of frequency stability, and the availability of components all introduce limitations to the upper frequency.

Operating Frequencies. Tests have indicated that the most satisfactory range for ultra-high frequency or microwave operation is in the band between 1000 and about 7000 megacycles per second. The conclusions reached by J. Z. Millar and L. A. Byam (8) were that systems operating on frequencies up to about 6000 megacycles may be expected to perform in a highly satisfactory manner throughout the year under properly selected conditions of path length, path clearance and transmitter power. These conclusions were reached after a series of tests made between Neshanic, N.J. and New York, N.Y., a distance of 41.7 miles over land, for a period of a year. The performance deteriorates appreciably and progressively at higher frequencies. At about 9500 megacycles shorter path lengths and higher transmitter powers are required to ensure circuit continuity. Fading was observed with greater prevalence during the summer months, and at nights, as a result of changing meteorological conditions.

Propagation. The attenuation of a path between transmitting and receiving antennae is determined by the following factors:—

(a) Attenuation in free space.
(b) Topographical factors.
(c) Atmospheric conditions.
(d) Absorption in the atmosphere.

Attenuation in free space is the loss which a radio wave experiences in an ideal atmosphere, and sufficiently removed from all objects that might absorb or reflect radio energy. Free space attenuation becomes the main factor to be taken into account in determining the predicted performance along a path, if a clear optical path exists, and antennae can be placed at sufficient height to provide a satisfactory path clearance over all obstacles.

Free Space Attenuation: Considering, now, free space attenuation, we have, at a distance d metres from the transmitting antenna a field strength—

$$E_0 = \frac{\sqrt{30 g_1 P_1}}{d} \text{ volts per metre} \quad \ldots\ldots (1)$$

where P_1 = Power radiated in watts.
g_1 = Power gain ratio of transmitting antenna.

For an isotropic antenna which radiates power uniformly in all directions $g_1 = 1$.

From (1) the transmitted power becomes—

$$P_1 = \frac{E_0^2 \, d^2}{30 \, g_1} \quad \ldots\ldots (2)$$

The maximum useful power that can be delivered to a matched receiver can be shown to be:

$$P_2 = \left(\frac{E\lambda}{2\pi}\right)^2 . \frac{g_2}{120} \text{ watts} \quad \ldots\ldots (3)$$

where E = received field intensity in volts per metre.
λ = wave length in metres.
g_2 = power gain ratio of receiving antenna.

For an optical path in free space E may be assumed to be equal to E_0.

The ratio between radiated power and received power is therefore—

$$\frac{P_1}{P_2} = \frac{157.76 \, d^2}{g_1 \, g_2 \, \lambda^2} \quad \ldots\ldots (4)$$

Where isotropic antennae are used, for both transmitting and receiving, the product, $g_1 g_2$ is unity and the power ratio becomes

$$\frac{157.76 \, d^2}{\lambda^2} \quad \ldots\ldots (5)$$

whence the attenuation of the path in decibels may be shown to be—

$$A = 20 \log_{10} 0.042 \, dF \text{ where} \quad \ldots\ldots (6)$$

F is frequency in megacycles
d is distance in metres

$$\text{and } \lambda = \frac{3 \times 10^2}{F} \text{ metres.}$$

Converting d metres to D miles this value becomes—

$$A = 20 \log_{10} 66.5 \, DF \quad \ldots\ldots (7)$$

The effective gain of parabolic reflectors or equivalent type antennae compared with isotropic antennae, for practical purposes, is—

$$g = \frac{2 \pi B}{\lambda^2} \quad \ldots\ldots (8)$$

where B = area of aperture in square metres.

Applying this to (4) the power ratio, in the case of similar transmitting and receiving antennae, becomes—

$$\frac{P_1}{P_2} = \frac{4 \, d^2 \, \lambda^2}{B^2} \quad \ldots\ldots (9)$$

whence the attenuation between two similar parabolic reflectors in free space may be shown to be—

$$A = 20 \log_{10} \frac{600 \, d}{BF} \quad \ldots\ldots (10)$$

Converting d metres to D miles, this attenuation becomes—

$$A \doteqdot 20 \log_{10} \frac{D \times 10^6}{BF} \qquad (11)$$

This formula is a useful one for the calculation of the path loss from the input of the transmitting parabolic reflector to the output of a similar type at the receiving site.

Topographical Factor: Radio systems operating on frequencies higher than about 100 megacycles per second, in general utilise free space propagation. In some practical cases, however, the received signal is the resultant of the free space wave and one or more waves reflected from the surface of the earth. A simple and typical instance of multiple path transmission is shown in Fig. 4(a). The signal received at B will be the resultant of the direct wave AB and the wave reflected at the mid-point, C. With small angles of incidence the phase change at reflection will approach 180 degrees, whilst the co-efficient of reflection will be close to unity.

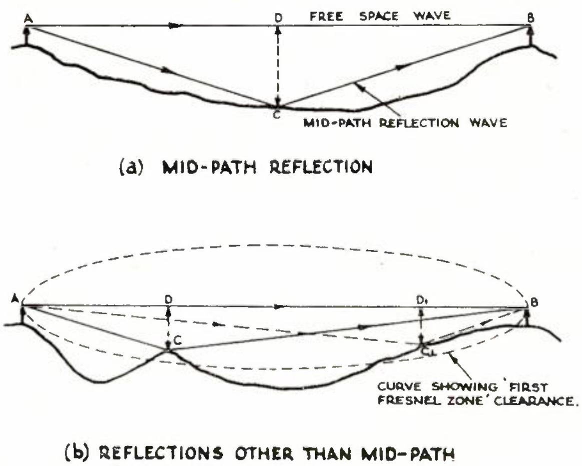

Fig. 4.—Propagation of Free Space and Reflected Waves

The distance of the point C below the line AB has an appreciable effect on the signal received at B. As this distance is increased from zero the signal strength at B will increase from a low value, and, after passing through a maximum, will fluctuate about a value equal to the free space value. There is an optimum clearance, called the "first Fresnel zone" clearance, for which transmission is better than the free space value. Physically, this clearance is of such magnitude that the phase shift along the path of the reflected wave is one half wave length greater than the phase shift along the path of the direct wave. The two waves at B will be in phase and their resultant will be greater than the free space intensity. When the phase difference is one wave-length, the path clears the first two "Fresnel zones" and the reflected wave will cause a reduction in the total signal received at B, as in this case the two waves are out of phase. This fluctuation about the free space value takes place with diminishing intensity as the phase shift varies from an odd number of half wave lengths to an even number of half wave lengths.

An important point is that reflection may not occur at the mid-point of the path as shown in Fig. 4(a), for, in many instances, a hill, or sloping ground in the vicinity of one of the antenna systems, may be favourably located to cause a reflection which may have an important bearing on the propagation conditions, as shown in Fig. 4(b).

In analysing a propagation path, it is usual to take precautions, by the choice of a site and the selection of antenna heights, to ensure that the "first Fresnel zone" clearance is obtained over the full section. As already stated, for lower clearances, the received signal decreases rapidly whilst for greater clearances, the variation in signal strength is relatively small. The conditions necessary for this clearance can be determined by plotting on the profile diagram, a curve showing the limits of the clearance necessary to place the receiving antenna in the "first Fresnel zone." This curve will be an ellipse. The efficiency of reflection decreases as the frequency of transmission is raised. Further, the increased directivity of the antenna used at higher frequencies, tends to reject locally reflected signals. Nevertheless, it is usual to apply the above analysis to all paths, and by the selection of sites and the provision of towers of appropriate height, to endeavour to secure the free space value of field intensity at the receiving antenna.

Atmospheric Refraction: In a standard atmosphere, bending of the radio waves occurs. The index of refraction varies with altitude. The radio waves bend steadily earthwards along their propagation paths, and, in effect, this tends to make the path parallel to the earth's circumference. Alternatively, it may be regarded as leaving the radio beam straight, whilst tending to make the circumference of the earth flat, that is, increasing the apparent radius of the earth.

Many papers have been written on this subject, and complex formulae have been evolved for the solution of the effect of atmospheric refraction on U.H.F. waves, but the generally accepted method of allowing for the effect is to multiply the earth's radius by a factor of 1.33 and plot the resultant "flattened" circumference against the straight radio path.

Diffraction around the Curvature of the Earth: Radio waves are bent around the earth by the phenomenon of diffraction, with the ease of bending decreasing as the frequency increases. The effect of diffraction around the earth's curvature, is to make possible transmission beyond the line of sight, but it introduces a further loss, which increases in magnitude as either the distance or the frequency is increased. Where a clear optical path cannot be obtained, communication by diffraction is possible within limits, beyond obstacles or beyond the optical horizon.

The effect of the earth's curvature or obstacles such as mountain ridges is to cause shadow losses. These shadow losses may be calculated for any path; for practical purposes, however, a complete set of monograms prepared by K. Bullington (9) greatly simplify the problem, and are very useful in the calculation of path attenuation, and shadow loss allowances.

Absorption: Considering atmospheric conditions further, propagation may be greatly changed due to variations or irregularities in the refractive index of the atmosphere. Although refraction varies steadily with altitude in the standard atmosphere, meteorological conditions may make possible the formation of ducts which act as wave guides and transmit the signal over great distances. It is this factor which causes the anomalous propagation of microwaves over hundreds of miles. As this factor is a variable one it manifests itself in the form of fading. In general, when the air is strongly agitated, or in windy weather, standard propagation conditions will prevail over land. In summer, and especially over sea, vagaries of propagation are more likely.

Atmospheric absorption has very little effect on the propagation of radio waves up to about 7000 megacycles. At higher frequencies losses on this account must be considered. Absorption is due mainly to the presence of water vapour in the atmosphere. Snow, sleet, hail and rain can be very serious at frequencies about 20,000 megacycles.

Noise and Power Levels.

Noise: The signal-to-noise ratio at the output of the receiver is the governing factor in determining the performance of a system. At microwave frequencies, static and man-made interference are negligible, and the only sources of appreciable noise are thermal agitation in the input impedance, in the input tubes and in the incoming radiation itself.

It is necessary to plan a system in which the power levels in operation will achieve a specified signal-to-noise ratio for the system. The lowest value of noise that is possible to obtain may be calculated readily, this being referred to as the noise level for the "perfect receiver." The performance of the system receiver can be related to the "perfect case" by means of a "noise factor," which is the amount of inherent noise it possesses in excess of the "perfect receiver."

Taking first the "perfect receiver," the noise power in watts may be expressed as equal to 0.4×10^{-20} watts per cycle of bandwidth. For a bandwidth of 20 megacycles it can be shown from the expression that the "perfect receiver" noise power is 131 db. below one watt.

From this point then, the overall noise level for the system may be predicted. The governing factors in the consideration of a noise level problem comprise:—

(a) The operating receiver noise factor.

(b) A noise improvement factor over amplitude modulation if another system of modulation is used.

In the case of (a), measurements have indicated that the performance of a practical receiver at 2000 megacycles is approximately 20 db. worse than the "perfect receiver," that is, it may be said to possess a noise factor of 20 db.

Referring to (b), if pulse modulation is used there is an improvement in noise level which would be present in a system using amplitude modulation, on which all noise figures are based. Several papers have been written on this subject and complex formulae evolved. In general, the improvement is calculated from a knowledge of the effective bandwidth of the receiver, the highest modulation frequency per channel and the number of channels operating in the system. In computations for systems now being planned it has been the practice to allow for a noise level improvement of 19 db.

Considering all the foregoing factors we reach a value of noise level removed from the "perfect receiver" noise power by figures fixed by the receiver noise factor which reduces the signal-to-noise ratio; and the improvement factor which offsets a part of this reduction.

Power Levels: Considering now system operating levels, there are several factors in the problem. Firstly, the transmitter power fixes the output of the system. For convenience this may be expressed in terms of decibels above or below one watt. Secondly, the path attenuation in free space must be calculated after allowing for the gain introduced by parabolic reflectors, this being a function of the area of the reflector apertures. This figure, of course, is expressed as a loss. Thirdly, in practice it is usual to allow for the following:—

(a) Feeder losses.
(attenuation introduced by transmission lines or wave guides feeding the antennae).

(b) Equipment deterioration factor.
(Overall loss of the signal in the equipment due mainly to deterioration of components.)

In calculating path performance a value of 5 db. at each end is generally allowed for feeder losses, and an overall equipment deterioration figure of 10 db.

A typical example of calculation for noise and power levels is given below.

INSTALLATIONS FOR AUSTRALIAN POST OFFICE

General Installation Problem. In providing a radio telephone system for the trunk line network, it is necessary that the system be capable of fitting into the general transmission plan. It must be engineered to provide 24-hour, all-the-year-round service of a standard equal to the wired channels. Standard facilities must be provided; that is, channels should operate as normal trunk channels providing two-way working on the standard two-wire basis.

The planning, therefore, constitutes a review of the transmission problems, involving a study of the propagation factors, such as signal-to-noise ratio, fading and attenuation, the determination of the number of repeaters required, and their gain and power. A field investigation must also be made to ascertain the availability of line of sight paths, from suitable sites, and the heights of towers necessary.

In the survey for a system these factors must constantly be kept in view. Owing to the limited field operating experience available at the present stage, the planning must necessarily be on a conservative basis. The desirable requirements are, firstly, that there should be a clear optical path between each transmitting and receiving point so that free space propagation conditions may be approached. Experience to date indicates that satisfactory conditions may be obtained between terminals or between terminals and repeaters for distances of 30 miles or even higher. A safe margin has been maintained in plans now being made.

General Plan. Radio equipment in Australia using very high and ultra high frequencies falls into three main groups. These groups may be described briefly as follows:—

(i) Single-channel equipment may be used to provide auxiliary or supplementary services along existing routes, if multi-channel systems are not justified; or an additional channel in the trunk line network, to a location where wires or cables cannot be provided. Typical cases would be to islands off the coast, or the spanning of rugged country, difficult of access.

(ii) Wide band equipment may be used to provide additional facilities or alternative channels parallel to heavily loaded or important trunk pole or cable routes. As the radio equipment provides a bearer circuit, a single or multi-channel carrier system may be patched directly to it without complications.

(iii) Multi-channel equipment may be used to provide groups of trunk circuits if the construction of lines is difficult or costly, such as over water or inaccessible country. It may also be used to parallel existing routes to provide supplementary or additional circuits. In this equipment the voice frequency channels are derived directly from the radio system without the use of carrier or other equipment.

The Department has in hand a programme for the installation of each type of system to fit in appropriately with the particular needs of the service. Several single-channel systems are already operating. They are providing radio extensions to the trunk line network. These systems operate at about 160 megacycles, and frequency modulated transmitters are used.

A comprehensive comparison with the performance of standard wire channels has not been possible to date, as the systems have been in operation for only a short period. Measured noise, distortion and frequency response all indicate that they will equal the performance of the more conventional channels. One important difference between a radio link and a wire circuit is that, in the case of the former, particularly on the higher frequencies and over long paths, the strength of the signals varies to a much greater degree and much more rapidly than in the case of a wire circuit. The effects of these variations can be overcome to some extent by the design of receiving equipment, but in the first place it is necessary to provide the best possible propagation path.

In the engineering and planning of the service this aspect is taken care of by the careful selection of sites and with sufficient terrain clearance if possible; the erection of towers of suitable height and rigidity, the establishment of an optical path, clear of all obstacles, and the limitation of the length of the radio path to satisfactory operating distances.

Planning is going ahead for the application of wide band equipment to the trunk line network. The equipment proposed will operate within the 235-420 megacycles per second band. Frequency modulation will be used and the modulating bandwidth will be from 5 to 60 kilocycles per second. This type of radio system will therefore provide a wide band bearer channel on which a three-channel open wire carrier system or a twelve-channel cable carrier system may be superimposed. Standard voice frequency trunk line channels will be derived from these systems and they will have the normal signalling or dialling facilities.

In addition to the single channel and wide band frequency modulated systems to be installed, planning has reached an advanced stage for the introduction of ultra high frequency multi-channel systems. This equipment employs pulse modulation, which is a new development of the greatest interest. A brief description of the operation of a typical system is given in the following section.

Brief Description of a Multi-channel System.

General: It is now proposed to give a few details to describe the principal features of a system installed in Queensland recently. This system, supplied by the Plessey Company, England, operates between Brisbane and Redcliffe, Queensland. It is an eight-channel system, and provides standard two-way communication channels, with normal signalling facilities, as part of the trunk line network. The channels have a performance equal to the conventional "wired" channel, and each has a bandwidth of approximately four kilocycles per second.

One terminal is on Bartley's Hill, Brisbane, and the other terminal is on a high site near the water supply tower at Redcliffe. The towers supporting the antennae are within optical range of each other. Underground cable circuits connect the radio terminals with their relative trunk exchanges and apparatus has been provided to connect the "four-wire" transmit-receive path to the "two-wire" terminating lines.

Eight-Channel System: Pulse width modulation is used in this system, and the radio frequency of the carrier is in the 4600-4800 megacycles per second band, used in conjunction with a time sharing system to achieve multi-channelling. Each channel audio-frequency wave-form is transmitted by converting samples of the amplitude at relatively infrequent successive intervals into variation of pulse widths.

The width of each pulse represents the depth of modulation applied. The modulated pulses of all channels in turn are used to switch the transmitter valve electronically, at the desired rate, by being applied to a controlling electrode. The width of these control pulses determines the shape of the transmitted radio frequency pulses.

The depth of modulation is represented by the difference in time or duration between a modulated and an unmodulated pulse. If a normal unmodulated pulse is three micro-seconds duration, then 100 per cent. modulation would give pulses varying from 0 micro-seconds to six micro-seconds. In practice the depth of modulation is not allowed to exceed 75 per cent., in order to preserve a safe operating margin. Sufficient time is allowed between each pulse for maximum modulation to take place without interference between channels.

In this system, the pulse train transmitted is shown in Fig. 3. The large pulse is added at the start of each sequence of eight pulses to synchronise the transmitter and the receiver. The repetition rate of the pulse trains, that is, the frequency at which any channel pulse recurs, is nine kilocycles per second, and is controlled by a nine-kilocycles-per-second stable sine wave oscillator, one cycle of this oscillator being used to produce one synchronising pulse and eight channel pulses.

The Transmitter: At the transmitter the sine wave output of a stable nine-kilocycle-per-second oscillator goes through a synchronising pulse shaper which sharpens it to a square pulse 22 micro seconds long. It is also fed to a polyphase unit, the output of which consists of eight sine waves which are displaced in relation to each other. These sine wave forms are fed to eight channel units where they are used to produce the channel pulses in their correct time sequence. Whilst in the channel unit each pulse is modulated by the appropriate audio signal. The modulation is applied to the leading edge of the pulse and gives pulse-width modulation. Means are provided for controlling the depth of modulation, and the correct position of the eight pulses in relation to each other is controlled in the polyphase unit. The pulse widths, which should be identical when unmodulated, are pre-set by pulse width controls on the channel unit.

The correctly sized, spaced and modulated current pulses are then combined across a common load to form the eight-pulse train, to which is added the synchronising pulse. The complete positive pulse train is fed into a cathode follower stage and the output modulates the radio frequency oscillator valve. This valve only oscillates when positive pulses are applied to the screen. Thus, the outgoing transmission is a faithful replica of the modulating pulse train.

The Receiver: At the receiver, the signal frequency is changed to 60 megacycles per second by a frequency controlled local oscillator and crystal detector. The signal is then amplified. The 60 megacycles-per-second carrier is removed by demodulation and the received pulse train is fed to an amplifier which has a substantially flat response up to 5 Mc. to preserve the pulse shape, and thence to the synchronising pulse separator. This produces from the received synchronising pulse a sharp positive pulse which triggers a gate pulse generator in each channel unit. The complete received pulse train is also fed to each channel unit.

Each channel unit therefore receives all eight signal pulses and selects the right one by use of a gating valve operated from the gating pulse generator. The output of the gating pulse generator can be adjusted to select any channel pulse.

The final output of the gate pulse generator, after shaping, is a square positive pulse of seven micro-seconds duration, which is applied to the control grid of the gating valve. This valve is so biased that it only conducts when both a signal pulse and a gate control pulse are simultaneously applied to the suppressor grid and control grid, respectively. Each channel unit, therefore, selects one signal pulse of the eight applied, which can be pre-determined by moving the gating pulse along the pulse train. In practice, of course, channel unit No. 1 is set to receive channel No. 1, and so on, for each of the eight channels. The correct gate widths and position may be adjusted and viewed on the monitor.

The output from the gating valve is fed to the audio frequency output valve via a filter network which removes the 9 kc. repetition rate leaving the audio frequency intelligence. From the output valve the signal goes through the hybrid transformer to the telephone line connecting to the exchange.

Monitoring and Signalling: A monitoring cathode ray tube is provided on the system so that the wave form occurring in different parts of the circuit can be examined. It is by means of this monitor that the pulses are correctly spaced, sized and checked for modulation.

Ringing over each channel is arranged by suppressing the relevant channel pulses at the transmitter. Their absence allows a relay in the distant receiver to operate. It then connects signalling current to the voice frequency line. If the system, and hence all eight pulses, were to fail, all lines would ring. To prevent this, a cut-out is provided, which operates on the disappearance of the pulses on all channels and disconnects the ringers.

A block schematic diagram of the system is shown in Fig. 5.

Special Features of System: There are some special features of this system which are worthy of mention. These are the Radio Frequency oscillator, the aerial hybrid, or Y-branch, and the antenna with its reflector.

The radio frequency output stage consists of a single valve which is a velocity modulated co-axial line oscillator, cavity tuned and with a power output of about 300 milliwatts. The frequency of oscillation can be varied by moving a plunger in or out of the cavity. The R.F. output of the cavity is taken via an adjustable probe to the Y branch or aerial hybrid, and is a replica of the pulse

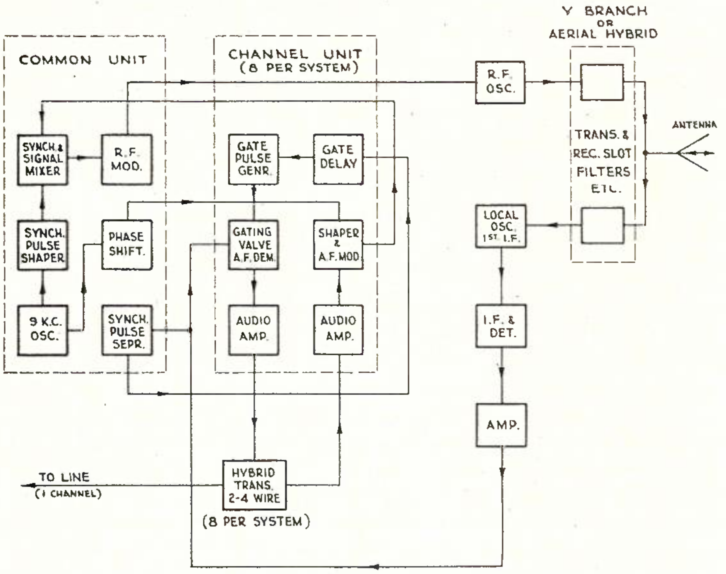

Fig. 5.—Block Schematic of Eight-Channel Pulse Modulated System (One Channel only Shown)

trains applied to the screen of the valve by the output of the cathode follower modulator valve in the common unit.

The Y branch or aerial hybrid is designed to allow simultaneous reception and transmission over the common aerial system. It has two limbs: transmit and receive. Each contains a plunger for matching purposes, a slot filter and a probe.

The signal to be transmitted is launched into the Y branch by the probe at the end of a co-axial link from the transmitting panel, and the position of this probe determines the plane of polarisation. At the distant station the Y branch is at approximately 90 degrees to the near station so that the two transmitters are working on planes of polarisation 90 degrees apart. The slot filters in the transmit limbs are at a critical distance from the probes, and act as a short circuit to the elements of the transmitted waves that are not in the correct plane.

The receive limb slot filters are at a critical distance from the junction of the two limbs and reject the transmitted signal from the other limb of the Y branch. The receive limb probe and slot filters are set to receive the transmission from the distant station which is set at 90 degrees to that at the near station. Thus, in either the distant or near Y branches, transmission and reception are proceeding in planes of polarisation 90 degrees apart. The receive limb slot filters can be rotated over a few degrees to compensate for any twisting of the transmitted plane of polarisation. The common end of the Y branch connects to the wave guide by a rotating joint and feeds the aerial. Details of the Y branch are shown in Fig. 6. A picture of the aerial system is given in Fig. 7. The aerial system is a centre fed paraboloid 4 ft. in diameter, known as the "reflecting dish." The output of the wave guide from the transmitter impinges on a hyperboloid reflector not quite at the focal point, reflects back into the paraboloid and is radiated with a beam width of approximately 6 degrees. The position of the hyperboloid can be varied to give a focus, and matching arrangements are provided. The paraboloid is mounted in a framework with a large level base, and azimuth and vertical controls are provided to alter the position of the paraboloid relative to this framework. The small auxiliary mounting in the reflector is a monitoring dipole which monitors the transmission from each terminal by "tapping in" on the radiated beam.

When erecting the aerial system paraboloid at each end, great care was taken to ensure that each was adjusted to radiate the microwave beam so that the hyperboloid reflector lay in the axis of each beam. The path had, of course, already been surveyed, and a direct line of sight path plotted to ensure its suitability for a microwave link. Tower rigidity is an important feature of the installation, as any sway would vary the path of the radio beam. This would increase attenuation, and raise the noise level.

This particular system comprises eight channels, and the "Phase-shifter" type of modulation described is quite satisfactory for a system using a relatively small number of channels. If applied to a large number of channels certain difficulties in stability and complexity would arise.

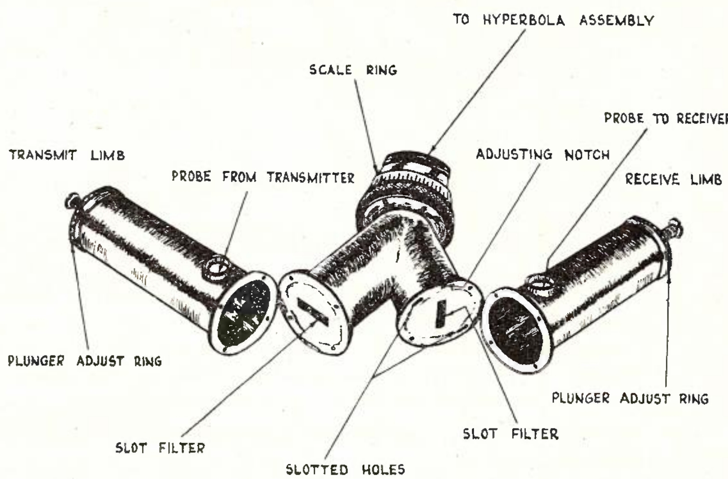

Fig. 6.—Aerial Hybrid or Y Branch

The Cyclophon: Several schemes have been developed to achieve the necessary time division of the radio channel for each circuit in the multi-channel system. One interesting device is a novel vacuum tube which rotates electron beams 8000 times per second, around a number of electrodes. The number of electrodes depends upon the number of channels to be provided. For a twenty-three-channel system there are twenty-four electrodes. This type of tube is known as a "cyclophon" and is used at both transmitter and receiver. Each particular channel is connected every 8000th of a second, and the system is kept in synchronism by a synchronising or marking pulse every cycle.

The tube is based on the standard cathode ray tube. It contains the normal electrode assembly or "electron gun" structure and the horizontal and vertical deflecting plates. In addition, it has a series of special electrodes to produce the multichanneling action. At the face of the tube, special

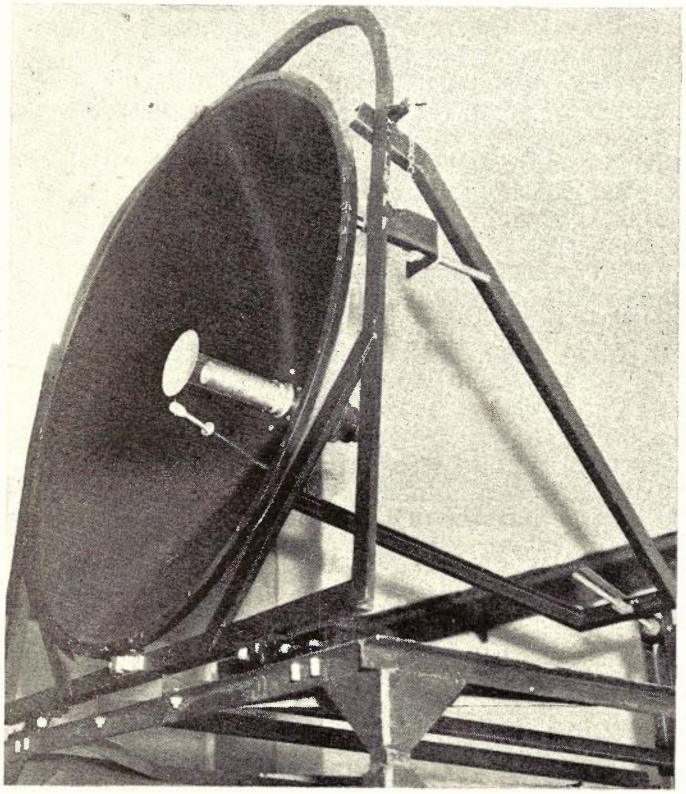

Fig. 7.—Aerial System

electrodes comprise a "stopper" or aperture plate containing as many apertures as there are channels, plus a marker channel and a collecting shoe behind each of the apertures. For a 23-channel system there would be 24 apertures.

An electronic scanning beam is caused to rotate around the end of the tube, at the repetition rate required, by connecting to one pair of the deflecting plates, a sine wave at the base frequency, and to the other pair the same wave through a 90-degree phase-shifting network.

The beam scans the 24 apertures in turn and a series of pulses is produced in each output circuit. This is related in time to the pulse series in other output circuits by the relative mechanical placement of each window around the aperture plate. The pulses produced are applied to the individual channel modulators, in which time-modulated pulses corresponding to the incoming audio frequency signals are generated.

The time modulated pulse series obtained from the channel modulators and the properly shaped marker pulse are combined to yield the composite pulse series. Actually, this is done in steps of eight channels, each group of eight consisting of every third channel. The arrangement minimises crosstalk and, in addition, permits flexibility in building up systems in groups of eight channels.

For demodulation, the principles briefly described for the eight channel system are applicable to systems using a relatively low number of channels. When applied to a large number of channels the same difficulties arise as in modulation, and the "cyclophon" with certain minor modification is used also for demodulation.

The demodulator tube functions in a manner similar to the modulator. The electronic scanning beam is produced in synchronism with the modulator by the use of the marker pulse. This pulse is removed from the pulse series by a marker discriminator, and a sine wave at the base frequency is derived from it, which in turn is used as the deflection voltage and causes rotation of the scanning beam. The grid of the demodulator tube is normally biased to cut-off so that the electron beam is extinguished when channel pulses are not being applied to the grid. Then, as the channel pulses are applied to the grid, and in conjunction with the scanning beam, produced from the base wave, current flows in the aperture plate circuit for that particular channel. The individual channels are thereby isolated and each translated into an amplitude modulated signal. The original modulating signal is then obtained by means of a low pass filter, and each output is directed through an audio amplifier to its own channel. The special multi-channel demodulator tube, therefore, performs the several functions of separation of channels, demodulation of signals and partial amplification of the individual channel outputs.

Field Survey for a System.

Before a field survey is made for a system, maps of the district are studied. Contour maps are used if available. Possible obstructions, such as hills, structures, forests, are noted, and the alternative line of sight paths are plotted on the maps. Generally, field observation is the only satisfactory method of confirming the office information. Observations are made either by regular surveying technique adapted to the case; by using a small portable light projector, the beam of which is received in a telescope or field glasses; or even by direct observation with field glasses from vantage points. Measurements are then taken using portable equipment to verify the predicted results. Whilst the prime consideration is to obtain a direct line of sight path several other factors must be considered. As a radio station has to be operated at the site selected for each terminal and each intermediate repeater station, certain practical points should receive attention. These are accessibility, availability of electric power supply and the practicability of the provision of telephone lines. An access road is necessary for the delivery of plant and for maintenance purposes. Commercial electric power supply if it can be provided at a reasonable cost is very desirable, otherwise power must be generated locally; and telephone aerial or underground lines are required to provide the connection from the system to the nearest telephone exchange. A further point in the selection of a suitable site is the question of a tower to support the antenna system. The antenna should be so placed that a line of sight path may be provided between transmitter and receiver, allowing clearance above all obstacles. The cost of erecting a tower of sufficient height to meet this requirement may be a determining point in the final selection of the site. Usually, several sites which appear suitable are selected for consideration, and a careful examination is made. It is here necessary to produce profile plans of the intervening country between sites to allow for obstacles which exist in the line of sight path and to enable clearance to be computed which will give the condition of free space propagation. In practice it is usual to allow a minimum

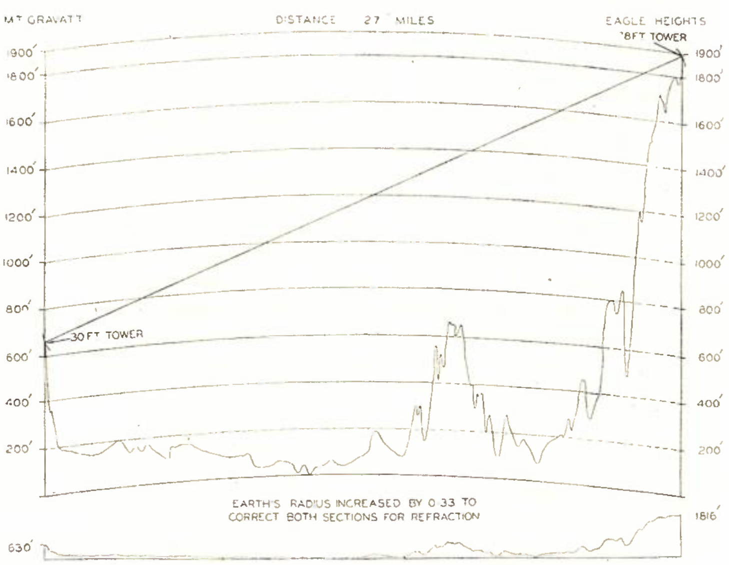

Fig. 8.—Profile Diagram—Mt. Gravatt-Eagle Heights

clearance above obstacles of 100 feet at the centre of the path to achieve this condition. In cases where this ideal condition can be realised only at great inconvenience or cost, the practicability of a circuit must be decided on the signal-to-noise ratio which can be secured. Examples of profile plans are shown in Figs. 8 and 9. Fig. 8 shows a general profile between Mt. Gravatt, a suburb of Brisbane, Queensland, and Eagle Heights, proposed repeater stations on the Brisbane-Southport system. Profiles in two directions were needed at Eagle Heights so that the minimum tower height might be determined for the repeater station here. Fig. 9 shows these profiles in detail.

Calculation of Signal-to-Noise Ratio.

The method of approach to the practical problem of calculating the signal-to-noise ratio of a path is given below. The example quoted is the 27 mile repeater section between Mt. Gravatt and Eagle Heights on the proposed Brisbane to South-

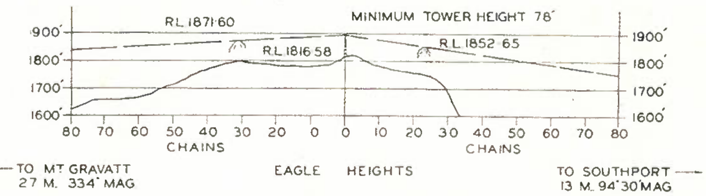

Fig. 9.—Profile Diagram from Eagle Heights

port U.H.F. system. A power level diagram and noise power graph for the section are shown in Fig. 10. In plotting the diagrams, the following factors have been applied:—

Frequency: 2000Mc.
Transmitter peak power: 50 watts = 17 db. above 1 watt.
Parabolic Antennae: aperture area = 3 sq. metres.
Feeder losses: 5 db. per terminal.
Bandwidth: 20 Mc.
Audio Bandwidth: 4 kc.
Equipment deterioration allowance: 10 db.
Receiver noise factor: 20 db.
Number of channels: 23.
Pulse time modulation.

Under normal conditions the designed signal-to-noise ratio should not be less than 50 db.

Referring to Fig. 10, we may express as gains, the power output of the transmitter relative to 1 watt, the relative gains of the transmitting and receiving parabolic reflectors and the effective receiver gain; whilst as losses we have the attenuation of the free space path as well as feeder and equipment deterioration losses. These values are as follows:—

Transmitter Output	+ 17	
Antennae Gains	+ 60	
Receiver Gain	+ 46	
Path loss (free space)		—133
Feeder losses		— 10
Equipment deterioration		— 10
	+123	—153

Signal Level —30 db. (below 1 watt).

Turning now to the noise level diagram, Fig. 10, we have, starting from the "perfect receiver" noise of –131 db. (below 1 watt), the effective receiver gain and the receiver noise factor both of which actually deteriorate the noise performance, whereas an improvement due to the use of pulse modulation is introduced. Setting out these values, we have:—

Noise	db.	db.
"Perfect Receiver" (Ref. 1 watt)		—131
Receiver noise factor	+ 20	
Improvement P.M. over A.M.		— 19
Receiver Gain	+ 46	
	+ 66	—150

Noise level—84 db. (below 1 watt).

The signal-to-noise ratio over such a path is therefore 54 db., being the difference between the two levels of –84 and –30. Tests carried out over channels in the field indicate measured value of the ratio of signal-to-noise to be very close to the theoretically calculated values.

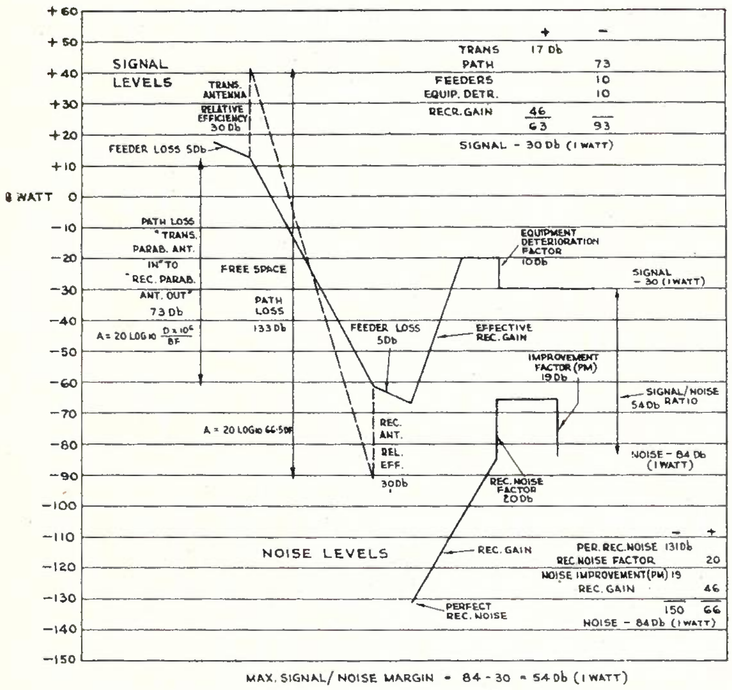

Fig. 10.—Signal Level and Noise Level Diagrams
Mount Gravatt-Eagle Heights—27 miles

Costs of Systems.

Installation costs of systems vary in accordance with distances to be spanned and the number of repeaters necessary. The average cost of a single-channel system is £2,000, which would be increased by about £2,000 for each repeater. A wide-band system averages between £4,000 and £5,000, with a similar amount for each repeater. This type of system, as has already been stated, provides the bearer channel for the standard telephone carrier system. A multi-channel pulse modulated system installed recently, without repeaters, cost approximately £9,000; and the estimated cost of a 23-channel pulse modulated system with two repeaters is £50,000. In general, it is necessary to place repeaters at 30-mile intervals unless topographical conditions make other arrangements necessary. The 23-channel system with its two repeaters would, therefore, span a distance up to about 90 miles. It is difficult to make a general comparison of these costs with those of the more conventional methods, such as aerial wires or under-ground cables and carrier systems, as each particular case requires a special economic study. It may be stated, however, as the general case, that where no facilities exist between two centres, radio channels may be provided more economically. On the other hand, where line plant is available or may be adapted for superimposing carried channels, this means may prove to be more economical, and the need for installing radio channels may be based upon other considerations, such as the necessity for alternative circuits. Sufficient information has not yet been obtained to give any details of maintenance costs, but, in general, equipment will be operated on an unattended basis with regular visits by trained technical personnel. Experience alone will indicate the frequency and duration of visits required.

Programme for Queensland.

Single-channel Systems: Several single-channel systems are already in operation and others are being installed. There is a ready application for these systems for communication between the mainland and nearby islands and the programme includes a number for this purpose.

Wide-band Systems: A state-wide survey is being made to determine the application of these systems and the multi-channel systems (see next paragraph) to the trunk line network. Three wide-band systems are to be installed in the immediate future, and they will carry standard multi-channel carrier systems as an auxiliary to the wired circuits. In case of damage to the line plant by flood or cyclone, these supplementary circuits will maintain standard communications. From experience to be gained from these systems, further installations will be planned.

Multi-channel Pulse Modulated Systems: The first system installed in Queensland provides eight high-grade voice-frequency channels. The operating frequency is 4600-4800 Mc. This system will be followed almost immediately by the installation of two 23-channel systems, the operating frequency of which will be 2000-2500 Mc. The experience which will be gained from these two systems will provide a basis for future planning.

Operational Experience. At the present stage of development field experience with multi-channel pulse modulated systems is very limited. The eight-channel system installed between Brisbane and Redcliffe will form a basis for investigation, and will provide much valuable data on propagation, noise levels, fading, and variations of performance under changing meteorological conditions. Practical information regarding operating conditions in the field, maintenance problems and other general data will form a useful basis for later systems.

CONCLUSION.

In this paper an attempt has been made to give an outline of the problems to be faced in the introduction into the tele-communication network of radio telephone systems operating at very high and ultra high frequencies. The planning and engineering of systems have been discussed and reference has been made to the problems associated with the selection of sites and the calculation of propagation path data. The principles of pulse modulation have been covered briefly, and a general description has been given of the types of systems now available for installation in the trunk line network.

ACKNOWLEDGMENTS

It is desired to record thanks to Mr. C. Faragher, A.M.I.E.Aust., Director, P.M.G. Department, Queensland, for permission to present this paper; to Messrs. C. M. Hall and V. F. Kenna for assistance in the collection of much of the data; to Mr. R. N. Catchpoole for the preparation of the illustrations; and to the many authors whose publications have been of the greatest value.

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MR. S. T. WEBSTER

We deeply regret to record the death of Mr. S. T. Webster on Wednesday, 29th August, 1951. His passing came as a shock to his many friends in the Post Office, and has been a grievous loss to them.

Mr. Webster had done a great deal of work for the Society as a committee man, and, subsequently, as one of the Board of Editors from 1946 to 1950, when he was forced to retire due to ill-health.

His long service in the Telegraph Equipment Sections, both in Victoria and at Central Office, was outstanding. Numerous developments in telegraph practice throughout the Commonwealth will stand as monuments to his name, although, it was characteristic of his nature to always credit others rather than himself with their success. This modesty in respect of his own substantial achievements, courtesy and deference to those associated with him, while none the less solidly maintaining his own view, endeared him to a wide circle of friends.

We extend to Mrs. Webster and her family our deep sympathy in their bereavement, and wish to declare the respect and admiration her husband commanded from all members of this Society.

NOTES ON THE ADLAKE RELAY

J. G. Bart'ett

The Adlake relay is a mercury operated time delay relay having a low fault liability and precise and stable operating characteristics. It may be made to be either slow operating or slow releasing, delays of the order of 1 second to 1 minute being easily obtainable. Its main application in this Department's plant has been in the regulating and alarm circuits of carrier equipment.

The various components which go to make up a relay are shown in Fig. 1. These are:—

(i) A soft iron cylindrical case, which also forms part of the magnetic circuit. A mounting bracket is attached to the case (detail a).

(ii) A die-cast base which is screwed to the case (detail b).

(iii) A moulded terminal block which is fitted to the base (detail b).

(iv) A layer wound coil of enamelled copper wire insulated between layers (detail e).

(v) A yoke and pole piece of soft iron (detail d).

(vi) A mild steel cap (detail c).

(vii) A sealed glass tube partially filled with mercury. In this cylinder are mounted the contacts and a porcelain insert which regulates the flow of mercury about the contacts and, therefore, determines the operating characteristics. A soft iron tubular armature free to move up and down the cylinder floats in the mercury. The normal mercury level is just below the lip of the porcelain insert (details h, j, and k).

(viii) An insulating sleeve, in which is cemented the glass tube (detail f).

(ix) A rubber bush which is fitted to the lower end of the insulating sleeve (detail g).

The relay is assembled by screwing the case and terminal block to the base. The remaining parts are then inserted into the case, the coil and yoke being inserted from the top and the glass cylinder in its insulating sleeve from the base. The ebonite cover and mild steel cap are fitted after the connections to the terminal block have been made. The relay is mounted in a vertical position.

The operation of the relay may be followed by reference to Figs. 1 and 2. The operation explained is that of a KS7812 relay, which has an operating time of 0.5 seconds and a release time of 5 seconds. Different operating and releasing times are obtained by modifying the shape and size of the porcelain insert. A simple section of

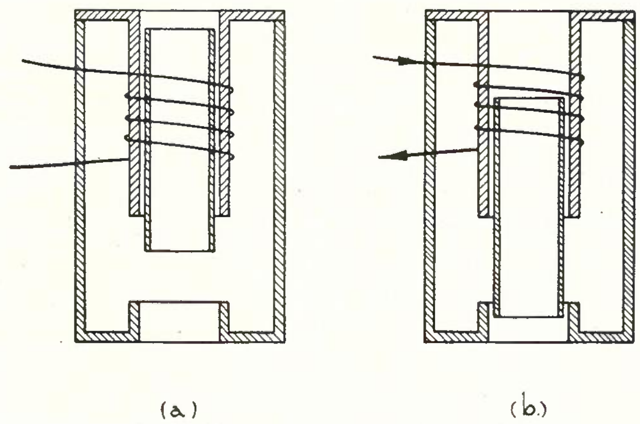


Fig. 2.—Adlake Relay—Magnetic Circuit.

the magnetic circuit, which is made up of details a, d, and k, is shown in Fig. 2. The operated and normal position of the armature are clear from an examination of this sketch. The armature is kept in the position shown in Fig. 2 (a) by the upthrust from the mercury. In the normal position, the contacts are not bridged by mercury. However, when the coil is energised, the downward movement of the armature displaces mercury over the lip of the insert, thus closing the contact circuit. When the armature restores to normal, mercury leaves the small orifice near the bottom of the insert and because of the slow flow, a time of 5 seconds is needed before the contact circuit is broken. Slow operating relays have a small orifice above the normal mercury level so that there is time delay in bridging the contacts.

Because of the relatively large inertia of the mercury contained in the relay, care is necessary when transporting these relays, to prevent breakage of the glass cylinder.

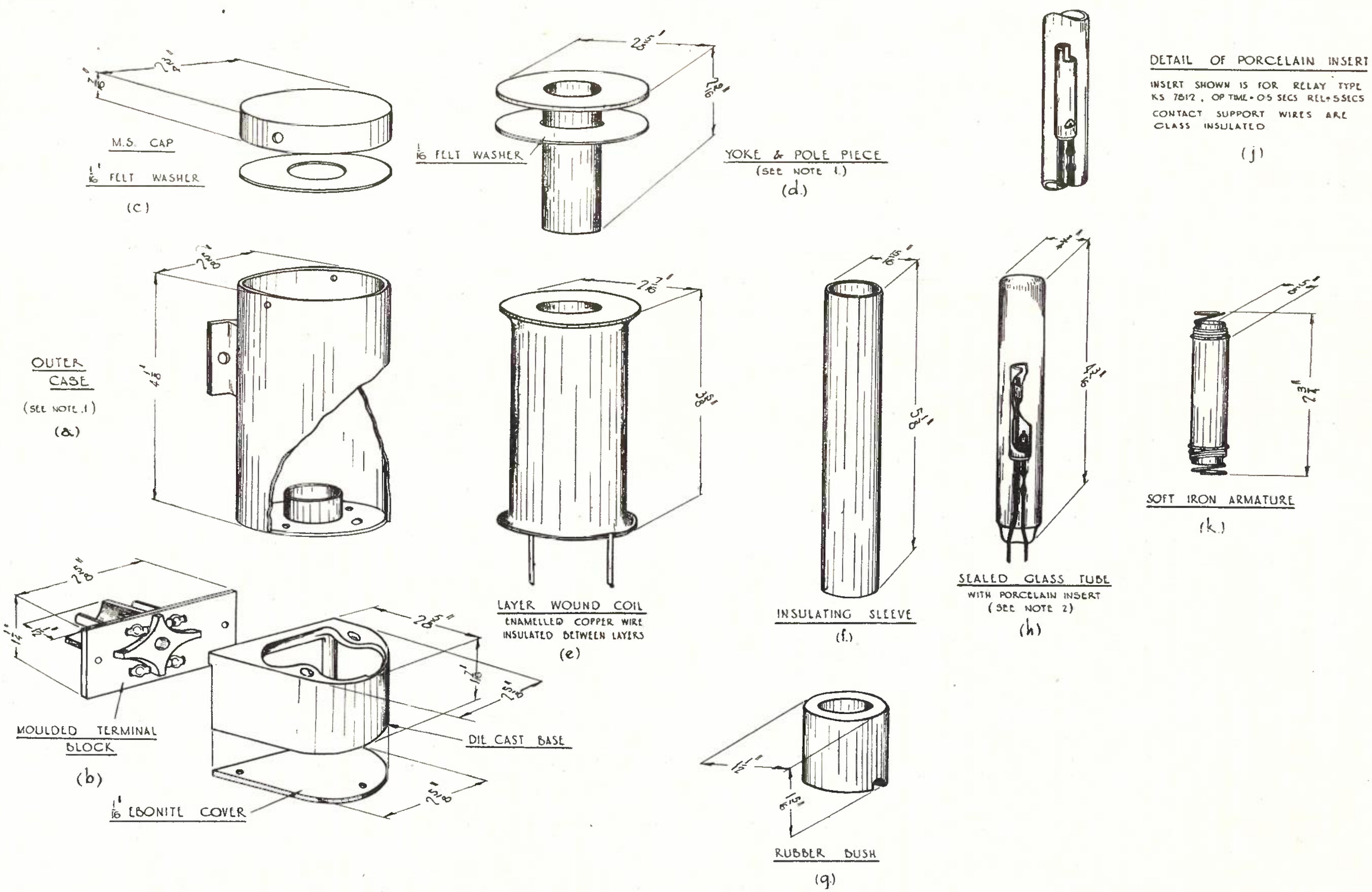


Fig. 1.—Adlake Relay—Assembly Details.

Note 1.—Material for the outer case and the yoke consists of highly annealed iron containing carbon 0.11%, manganese 0.28%, silicon 0.02%.

2. In the unoperated condition the mercury in the glass tube reaches a level just below the lip on the porcelain insert. In the operated condition the mercury fills the insert.

THE USE OF PREFABRICATED UNITS IN THE POST OFFICE BUILDING PROGRAMME

J. I. Bellette

Introduction

In the past, it could be fairly claimed that the building industry was the most conservative of all. Established practices have been adhered to through generations, the most marked change being in the architectural treatment. Timber, stone, bricks and mortar were the principal ingredients and the work was carried out on site without the benefit of any advance assembly. The industry was based on tradition and craftsmanship, and many imposing public buildings are monuments to the patience, skill and perseverance of the artisan. A most important factor was that labour was relatively cheap and plentiful, and usually there was no pressure to complete the work in a short time. Quite naturally, an industry with the background traditions such as the building industry possessed, was resistant to changes in either technique or materials, and many attempts to introduce new ideas met with difficulty because of handicaps resulting from rigid adherence to craft processes. In many other industries we have seen great changes stemming from scientific advancement, and in the mechanical and electrical engineering fields the changes in the past fifty years could only be described as revolutionary. The developments in telecommunication practice in recent times afford a striking example of changes brought about by the exploitation of new techniques and materials.

The almost complete cessation of normal building activity throughout the war years left a very heavy back lag of work to be overtaken, and the shortage of many basic building materials focussed attention on the possibility of using alternative items. The associated shortage of skilled labour, the need to step up the rate of building, and the desirability of reducing costs were all complementary factors which facilitated the introduction of new methods of construction and the employment of different materials. In recent years, therefore, we have seen important changes in building construction methods, and it is obvious that the industry is now entering the transformation stage experienced earlier by many other industries. This is very necessary in the interests of production, efficiency and economy, and it offers some hope of a reasonably speedy solution to the very real shortage of accommodation in the fields of housing, industry and commerce.

The Post Office entered the post-war era very inadequately equipped with accommodation for the many varied activities under its control, and in company with other organisations and instrumentalities found itself facing a highly competitive market for the limited labour and material resources available. This situation still exists, and there are as yet no signs of any marked improvement. The pressing demands for telephone service, for new post offices, and the many associated services required in operating a large organisation could not be satisfied unless suitable accommodation were first made available.

The foundation of a large post-war building programme was laid during the closing stages of the war by preparing sketch plans, working drawings and specifications for a large group of new buildings. As time went on, it became obvious that the resources of the building industry available to the community would not permit of such a large scale post office programme being undertaken with sufficient promptitude, and it became essential to investigate alternative means for meeting the heavy demands. It was decided to turn to prefabrication as a partial solution of the difficulty, and in this article a description will be given of the various types of prefabricated building which have been adopted to meet the specialised requirements of telephone exchanges, long-line equipment buildings, post offices and other departmental activities.

Prefabrication

The specific meaning of prefabrication, as applied to the building industry, is the technique of designing and manufacturing a variety of units which are assembled at some factory or workshop remote from the actual building site, and later transported to the desired location for erection by manual or mechanical effort and so form a complete building. Part only of the structure may be treated in this manner, a substantial proportion of the building being constructed on the site, with certain selected sections or parts being supplied as complete units to be tied into the structure. In its full sense, the complete building above foundation and floor slab level, comprising all external and internal wall units and roof sections, are manufactured elsewhere and put together on the site. The principal advantage lies in manufacturing the building units in a well-equipped factory, where skilled staff can be concentrated and employed at full capacity in conjunction with mechanical aids and the provision of power. It will be appreciated that power for the operation of machinery cannot always be made available on a building site, which may be in an undeveloped portion of a metropolitan area or at some remote country location.

The meaning of the word prefabrication has been broadened in actual present-day use to cover a group of methods, any of which will speed up the erection of a building by using some form of pre-assembled components which are not actually built piece by piece on the site. The three principal methods in use today are outlined briefly hereunder. In each of these main methods there are many variations in technique, and space will not permit a complete description of all the methods now being employed to speed up building work.

Pre-Cut Units. This is a system usually applied to houses and small buildings generally of timber-framed construction, and is a method whereby the various members which go to make up a frame are cut to the required length for their respective uses, notched and halved as required to form a joint with other structural members. These processes are generally carried out by machine at a timber mill or factory, and the members are then packed in selected groups for supply to the building site. The studs, plates, rafters and other building components when received on site can be quickly assembled and spiked together by the workmen. This method, although quicker and, in general, more economical than orthodox construction methods on site, still requires a large proportion of the total number of man hours for the project being spent on the actual job. One of the principal advantages is that the various members can be readily made up into packages for transport over long distances and a number of housing projects have been undertaken using pre-cut components imported from overseas. A typical example of pre-cut construction is shown in Fig. 1, which illustrates one of the Riley-Newsum houses, imported by the Commonwealth Department of Works and Housing as employees' residences.

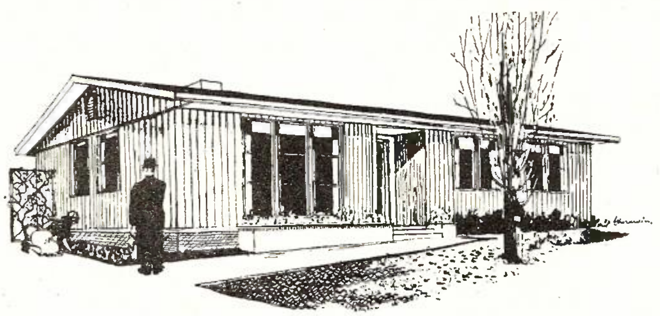


Fig. 1.—Riley-Newsum House built from pre-cut components.

Pre-Cast Units. As the name implies, this method of construction, which is illustrated in Fig. 2, refers mainly to reinforced concrete construction, and this form of prefabrication is being used extensively at present by some housing authorities. Briefly, the method embraces the actual forming and pouring of outer and internal walls at a construction depot. When set, the wall units are transported to the building site, and are usually carried vertically on a steel-framed jig attached to a semi-trailer. Prior to the arrival of the wall panels, the foundations and footing walls of the building are completed to floor height and the concrete wall panels are off-loaded, usually with the aid of cranes, from the transporter and placed directly into position around and inside the building. The pre-cast wall units are quickly bolted together by means of special fixtures which are cast integral with the concrete. All apertures required in the building for doors and windows are contained in the formed pre-cast panels with all necessary fixings attached. This method of construction still necessitates a considerable amount of labour on the job in order to complete the building. It is mainly suited to a reasonably close association between the assembly plant and

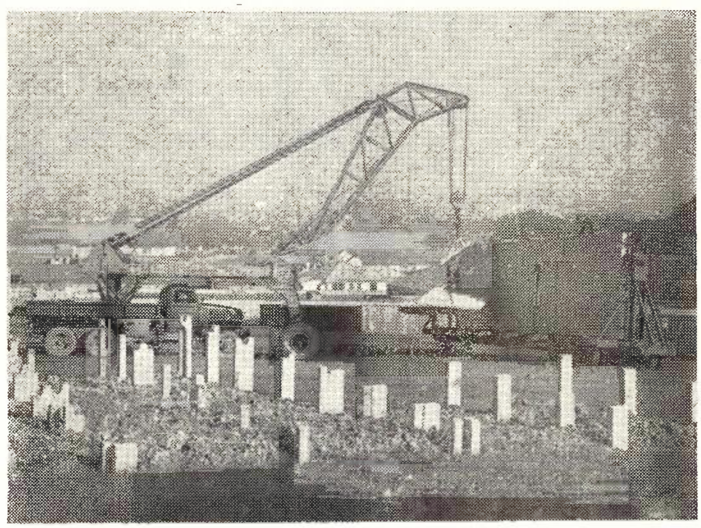


Fig. 2.—Pre-cast Concrete Construction.

the sites on which buildings are being erected, and is particularly efficient in those cases where a large group of buildings of similar type are undergoing construction. It does necessitate the provision of special vehicles for conveyance of the wall units and usually cranes and other mechanised gear at the site to assist in placing the precast panels in position. The scheme is, therefore, most efficient when quantity production is undertaken.

It is interesting to note that the latest development in America with regard to precast concrete construction has been applied to the erection of large multi-floor buildings, using precast columns placed at suitable intervals and later filled in with matching precast wall panels. When this stage is finished, the complete concrete floor slab is poured on the ground as a floating slab, then covered with a bitumastic base building paper over which the concrete slab forming the first floor is poured and allowed to set. This slab is then lifted by hydraulic jacks and lowered into position on to the precast columns. The process is repeated until the required number of floors have been erected.

Prefabricated Unit Construction. The system of using prefabricated units for external and internal walls complete with all doors, windows and other attachments and associated roof sections is rapidly becoming the most extensive method used in the erection of buildings, and is the main system adopted in the provision of prefabricated buildings which are being purchased and erected throughout Australia to assist the Post Office building programme. Complete prefabrication has been assisted by the transfer of the resources of machinery, manpower, and materials from aircraft industries operating during the war years to the problem of manufacturing building components under similar conditions to those employed in the mass production of aircraft sections. In this case, the basic material is aluminium alloy which is anodised for sections which are exposed to weather conditions.

The units are light and can be readily packed for transport over long distances, and can be easily handled without the aid of special gear on the building site. Prefabricated unit construction is, of course, not confined to aluminium alloy, and several other types of construction using light steel members or timber are also manufactured on the same principle. In most cases, a fixed module system is adopted, defining the width and height of wall panels capable of being combined with fixed roof sections designed to permit a number of combinations closely approximating the configuration of conventional structures. The wall panels are available in a considerable variety of combinations, allowing freedom in the choice of glazing and meeting the requirements for external and internal faces.

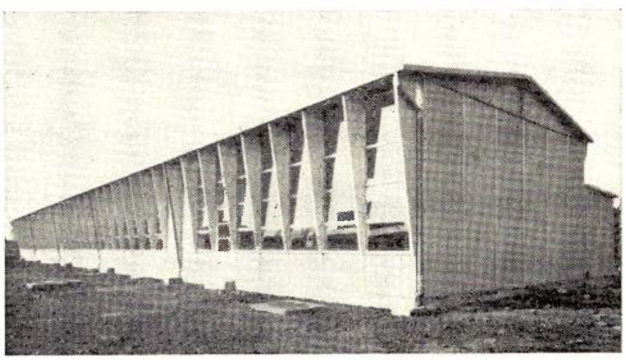


Fig. 3.—Prefabricated Aluminium Alloy Building

The manufacture of the many units is usually carried out on a mass production basis on an assembly line, and machines and special jigs have been designed to produce the components within very close tolerances so that there is little difficulty in associating the various units during the process of putting the building together on the site. Furthermore, the design is usually of such a nature that the panels can be very readily connected together largely using unskilled labour, the working tools required by the operatives being confined usually to a wrench and screw driver. The unit construction principle is possibly the most efficient of all in respect to reducing the "on site" work, which is then confined to site preparation and floor slab and the provision of the necessary services to the building. A typical example of a building using unit construction components is shown in Fig. 3.

Aluminium has played such an important part in the development of prefabricated unit construction that some comment thereon will not be out of place. Aluminium alloys offer a very wide range of properties, from those of the commercially pure metal through a wide range of heat treated alloys. A very wide choice of alloys is now available in several conditions or tempers. Despite the lightness of the metal it has become a prominent structural material because of its malleable qualities, its elasticity and its strength/weight ratio. The strength of an aluminium alloy may exceed that of mild steel, and if the weight of the two materials has to be considered, it is able to compete with the high tensile steels. The elastic modulus is about one-third that of steel, being between 9 and 10 million lb. per square inch for most aluminium alloys. This means that a weight saving of 66 per cent. is effected where a steel structural member is replaced by one of identical form in an aluminium alloy of equal strength and that the elastic deflection will be about three times as great. If this is objectionable, a redesigned member of equal stiffness will weigh approximately half as much as the steel member. The relatively low stiffness is, of course, a distinct advantage under shock or impact loads.

After the cessation of hostilities it was found in Great Britain that large quantities of aluminium were available in the form of discarded aircraft and other implements of war. This situation coincided with a serious shortage of ferrous metals coupled with an urgent need to provide a very large number of homes to replace those destroyed during the war. It was, therefore, a logical step to investigate the potential of aluminium as a building medium, and it was not with any surprise that the world learned that homes were to be fabricated and erected by two of the well-known aircraft companies, namely the Bristol Aircraft Corporation and the Hawker Siddeley Aircraft Group. The success of this developmental work is now manifested by the firm establishment of Bristol Housing Ltd., and Hawksley Construction Ltd. Both firms have played a major part in the rehabilitation of housing in Great Britain, whilst local education authorities have derived great assistance from the introduction of prefabricated schools.

Description of Various Types of Prefabricated Buildings.

The "Bristol" Building

General. The general constructional details of this type are illustrated in Fig. 4. The basic material is aluminium alloy and the components are designed on a unit construction principle conforming to the module system shown in Fig. 5. The production of the components is accurately controlled by jig assemblies and very close tolerances are observed, which result in an ease of assembly and an accuracy of interlocking between units. The erection of these buildings is quite a simple process and relatively unskilled labour is required. No special tools or machines are needed to assist the assembly process and the light components can be handled with ease.

Referring to Fig. 4, the roof unit is formed from 20 gauge aluminium sheet on the underside of which a layer of millboard is secured to prevent condensation dropping to the ceiling. The sheets are riveted in the factory to aluminium purlins which, in turn, are riveted to two light trusses spaced at 4′ 0″ centres. The finished ceiling is fixed to the underside of the trusses, and consists of an insulating board overlaid with a fibre glass silk quilt to provide for thermal and acoustic insulation. This then forms a complete 4′ 0″ wide section of roof of module dimension ranging in four sizes from 16′ 3″ to 40′ 3″ (see Fig. 5), which completely incorporates the structural frame, weatherproof external skin and internal ceiling with an infil of insulating material. The deep eaves of the roof are designed to reduce glare and can be painted on the underside to assist this effect.

The wall panels are of the same uniform width (4′ 0″) with fixed heights ranging from 8′ 3″ to 12′ 6″ (refer to Fig. 5). A more recent development provides for wall panels giving a clear floor to ceiling height of 14′ 4″, designed especially to meet the requirements for standard 10′ 6″ automatic and carrier telephone equipment racks in larger buildings where the cabling density requires adequate clearance above the racks. The design of the wall panels is such that the glass area per panel can be varied vertically in wide ranges by the insertion of solid panels in lieu of glass. A wall panel may thus have no windows, may be quarter or half glazed, or can be entirely glazed, according to requirements. These buildings are used for a very wide variety of applications and the flexibility of the glazing system is an important factor. The side mullions of the wall panels are bolted together, and this forms both the structural frame of the building and the subframe to the windows. The panels, on assembly, are bolted at the base to the perimeter channel, and at the top by means of a special section, to the roof. Wind loading is taken up in the bracing provided by internal partitions or by triangular bracing diaphragms, termed load bearers,

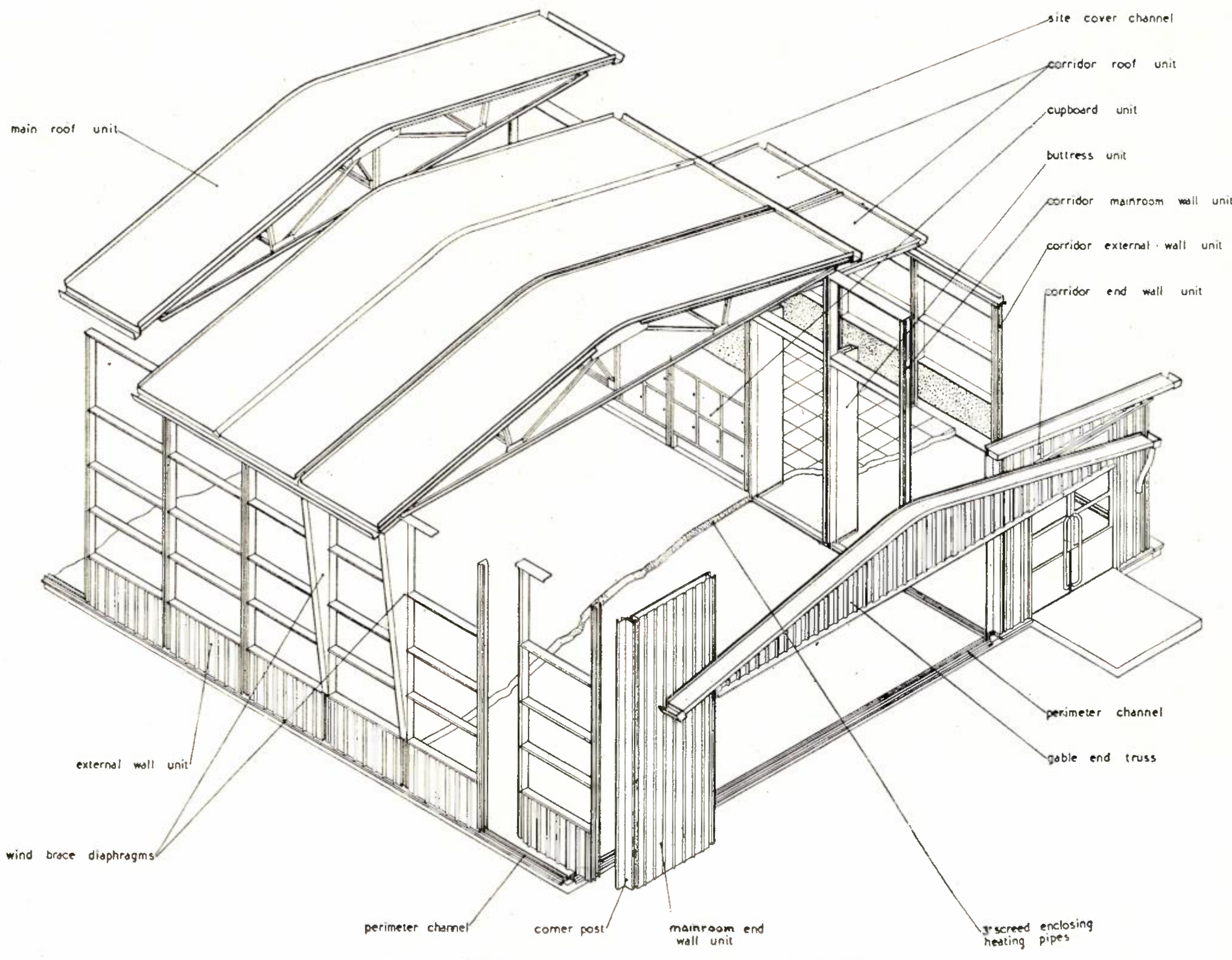


Fig. 4.—Isometric Drawing of Components of a Bristol Building.

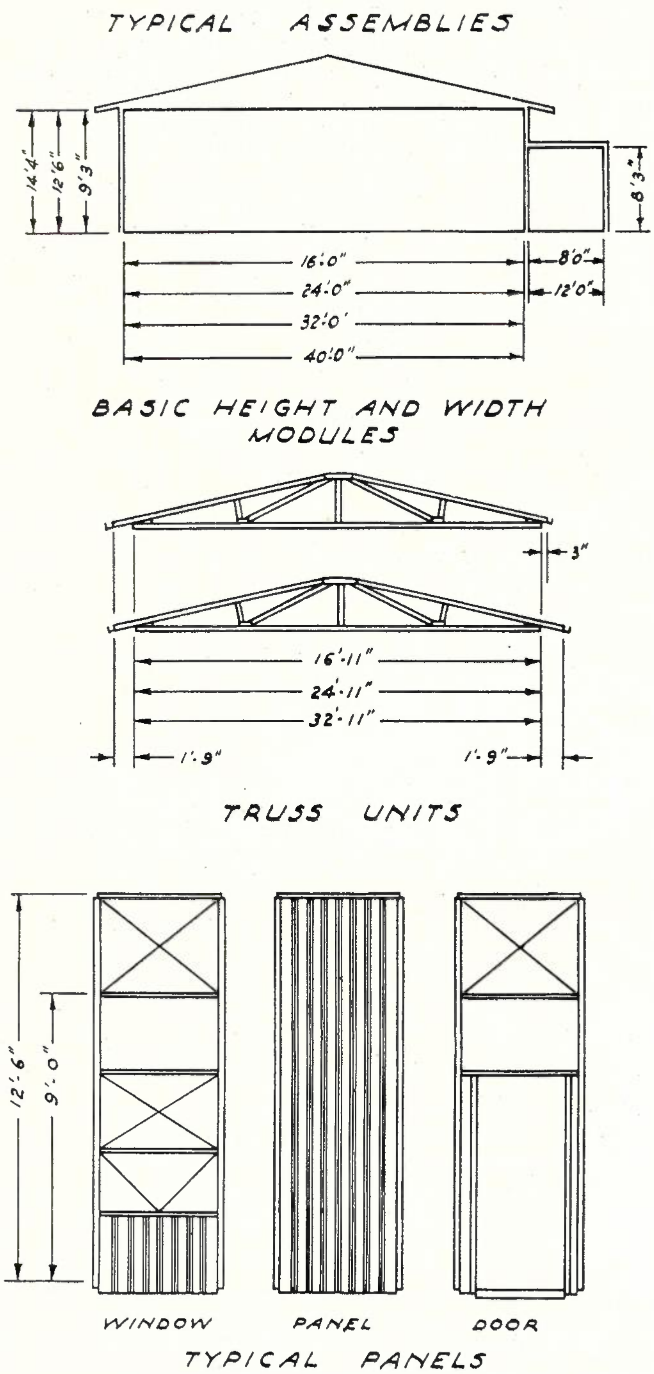


Fig. 5(a).—Module System

attached to the external walls. In the absence of internal partitions the load bearers are required at intervals of 4′ 0″ along the length of the building. Externally the wall panels are clad with vertically vee ribbed corrugated aluminium alloy sheet and internally with hardboard sheeting to 7′ 0″ from floor level, with caneite or similar material extending to ceiling height. The space between linings is filled with glass wool.

End walls are formed from similar sheeting in framed panels filled with glass wool, but as the structural frame of the building is complete at this point orthodox materials such as brick can be employed if desired for purposes of architectural treatment. Partitions are usually framed up in standard panel units, hardboard lined on both sides, but can be built of "in situ" materials if so desired. The use of aluminium has the advantage apart from lightness, durability and ease of handling, of providing a non-corrosive surface which can be treated to give durable and decorative finishes. During the manufacturing process the wall panels are anodised, prime-painted and stoved. The roof panels are left in their natural state and do not require painting. Similarly, when applying exterior finishing coats, it is not necessary and is, in fact, undesirable, to paint the extruded window or door frame sections.

Lighting. The extent of the natural lighting provided to the building is governed largely by the choice of glazing and can be varied over a wide range because of the panel flexibility in this respect. In earlier deliveries the windows were restricted to pivot and hopper types, but the more conventional double hung sash type window, which is extensively used in Australia, is now being provided. Artificial lighting is, of course, provided to required standards, either in incandescent or fluorescent installations, depending on the use of the various areas.

Heating. A wide range of heating can be applied using standard fixed installations. In colder climates a centralised sub-floor heating system can be incorporated in the building during erection.

Constructional Procedure. The general technique of erection of this type of building is shown in Fig. 6. A suitable floor slab must first be provided on site, and for those applications where equipment racks are to be installed a concrete floor is preferred. In some cases, however, where cement has been in short supply, timber floors have been designed with a load carrying capacity of 200 lb. per sq. ft. The aluminium perimeter channels are bolted to the edge of the foundation which should be accurately levelled. The first wall units are then up-ended and braced into position until one gable or cross wall is inserted, when the roof sections can be added. It is interesting to note that even with the largest span the roof units are light enough to be handled without the use of cranes, and they can be readily guided into position by two men and suitable tackle. The remainder of the structure is erected by continuing with two or three wall units on either side of the building and fixing on the roof trusses progressively. A typical example of this process is illustrated by the photographs shown in Fig. 7.

Summary. A summary of the principal features of this type of building is:—

(1) A minimum amount of building materials in short supply locally are required.
(2) The precision with which the components are manufactured facilitates erection.
(3) The light nature of the components decreases

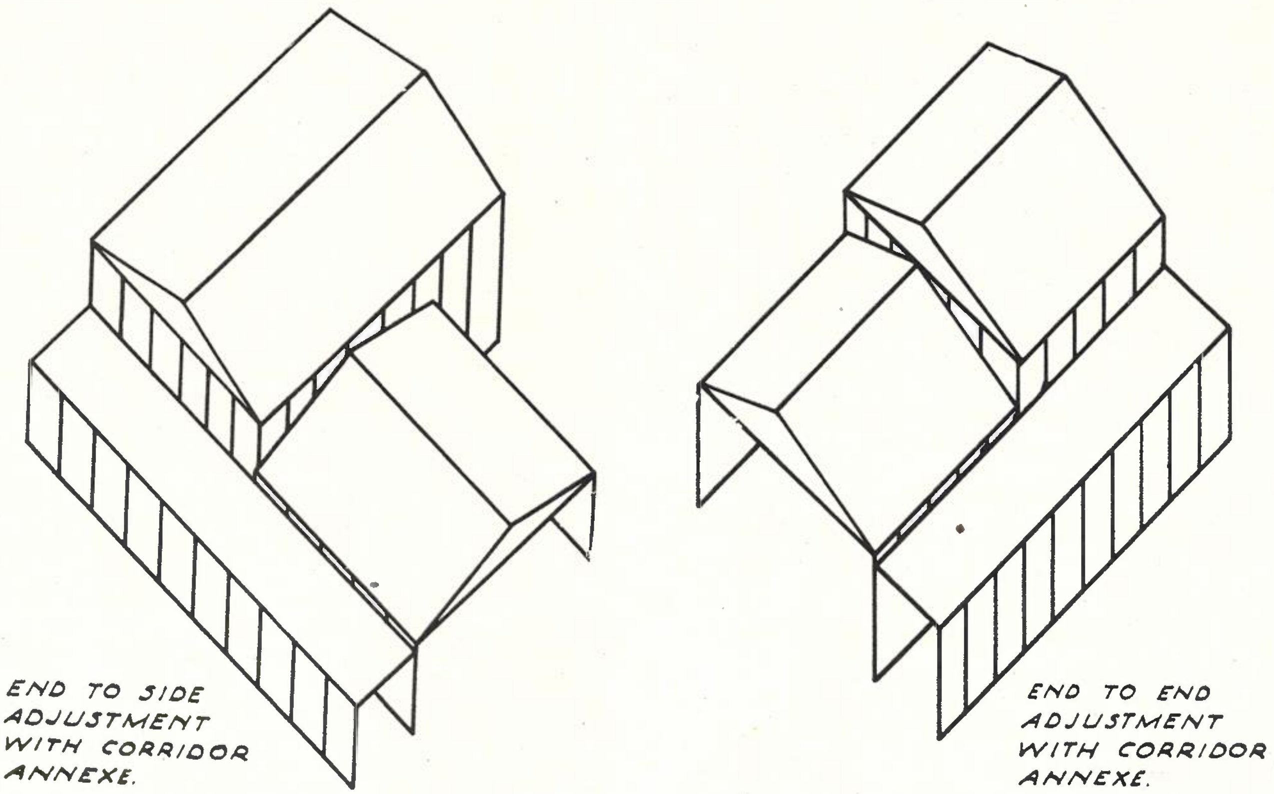


Fig. 5(b).—Typical Assemblies

handling charges and cheapens foundation costs.

(4) The module system is flexible enough to provide relative freedom in planning a variety of layouts.

(5) The use of thermal insulation slows down the rate of air change and the absorptive material holds moisture.

(6) Roof drumming during rainfall is counteracted by millboard secured to underside of roof skin.

(7) Painting is reduced considerably and can be dispensed with if so desired, as the materials have been treated to withstand weather conditions.

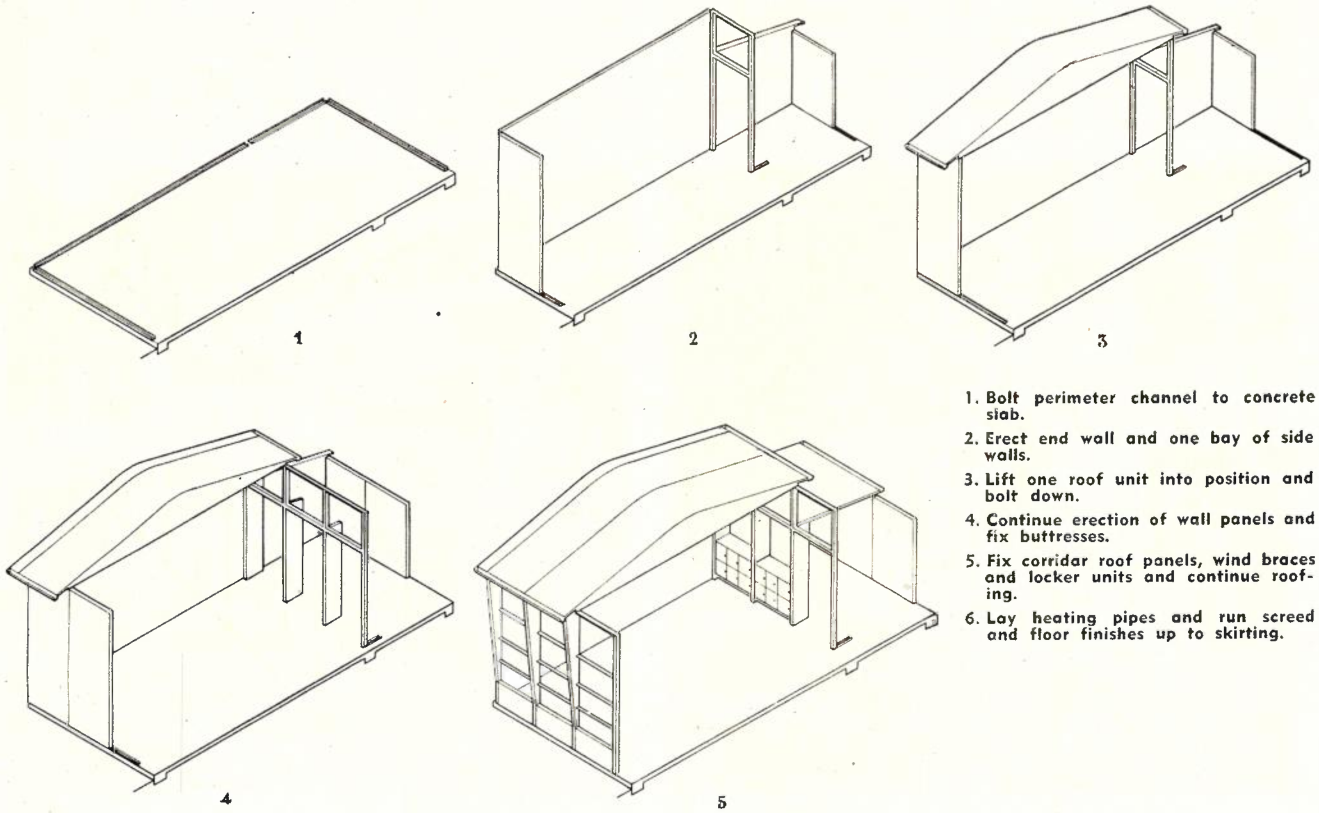
Emphasis has been placed on the flexibility of the unit construction principle, and it will be clear that the module system permits a very close approach being made to any desired layout combination. In the initial design a selection is made of the various types of wall components, etc., to suit the selected layout, but subsequent changes are strictly limited. The positioning of load bearers, external wall components, window treatment and entrances chosen to suit a particular arrangement cannot be easily regrouped to form changed dimensions.

The structural design of the building is such that a length of external wall of up to 28′ 0″ is allowable in any section of the whole building without the necessity of special braced panels, designed to counteract wind load, being incorporated either within a cross partition wall or attached to the external face at 4′ 0″ centres as mentioned previously. It is understandable therefore that difficulties could arise should the components be delivered from overseas to a plan which provided for cross partitioning at lengths of 28′ 0″ or under, and later a moving of partitioning is contemplated which exceeds the allowable safe distance without load bearers. This would not be practicable owing to the absence of the necessary external load bearers. This factor also adds a restriction in flexibility after a design has been completed and the components delivered to the job.

The Hawksley Building

The unit construction principle designed for use with the "Hawksley" aluminium alloy building is similar to that explained earlier for the "Bristol" product, but it is interesting to note the changes in structural design which have been incorporated in the production of the "Hawksley." The length module is set at 8′ 0″ per panel, which must add to the economies effected in the erection time as the weight of each panel is so light that it is easily manhandled to position in the same time as is taken to handle one 4′ 0″ panel of the "Bristol" building.

An interesting point in design is the fact that only the end or external corner panels of a building are braced and stressed to carry the roof and wind loadings. The intermediate panels between corners of the building are purely infills and of



1. Bolt perimeter channel to concrete slab.
2. Erect end wall and one bay of side walls.
3. Lift one roof unit into position and bolt down.
4. Continue erection of wall panels and fix buttresses.
5. Fix corridor roof panels, wind braces and locker units and continue roofing.
6. Lay heating pipes and run screed and floor finishes up to skirting.

Fig. 6.—Structural sequence for erection of Bristol Buildings.

lighter design. This type of construction is achieved because the roof section is designed similarly to an aircraft wing. In effect, if two aircraft wings were placed side by side so as to form the two sides of a pitched roof supported by a post at each corner, this would be a similar arrangement to that adopted in the "Hawksley" roof assembly.

Each roof truss, which is 8 feet wide by a span of either 24, 32 or 40 feet, is designed in such a way that when any number of trusses are bolted together, a main spar is formed which runs the length of the building parallel to the ridges. Because of this, it is only necessary for the supports to be at the four external corners of the building. This is a complete departure from any form of structural design previously adopted for building purposes.

The process of erecting the building, therefore, is very similar to that described for the "Bristol" type and due to the fact that the whole shell and roof of the building can be erected quickly it is unlikely that adverse weather conditions would slow down a project seriously, because the protection of components and workmen is ensured after perhaps two days of erection time. The interior partitioning and fitting out of the building can then be carried out at the same time as the finishing off of the exterior work. The use of aluminium alloy has been restricted by "Hawksley" to the main exterior panels and roof. All internal partitions are formed from a timber-framed panel 4 feet wide, which is sheeted on each side with hardboard. When the panels are in place, the vertical joints thus formed are covered by the application of an adhesive linen tape which, when painted, gives the complete wall the appearance of a fibrous plaster wall which is used extensively as an interior finish in Australia. A typical "Hawksley" building is shown in the photograph, Fig. 8.

The Sydney Williams Building and Similar Types

The advantages of prefabrication must be equally favourable from the point of view of the materials to be used as well as the system of manufacture. For this reason a number of the firms producing prefabricated buildings have chosen as the structural members some forms of steel sections which are produced in quantity for general engineering use and are, therefore, readily obtainable from standard rolling or extrusion mills throughout the world. The most common sections used are channels, I beams and angle sections of dimensions which are common to all manufacturers.

Steel frame, as the name implies, is simply a building frame which is made up of stanchions, girts, braces, and roof trusses which are capable of being manufactured to a selected length, height and width module so that any length or width of building can be purchased and subsequently erected in bays suitable to the size or section used for connecting one column and roof truss to another. The average length of each bay is 10 feet. The system of bracing employed is such that after all girts and purlins are bolted to the frames the whole structure is stiffened usually by the two end bays having diagonal bracing attached. The in Fig. 10. The foot of the column is then usually bolted to steel plates which are located at the required position along the previously formed floor slab. Alternatively, some firms have adopted the use of a trunnion block which is in effect a forked

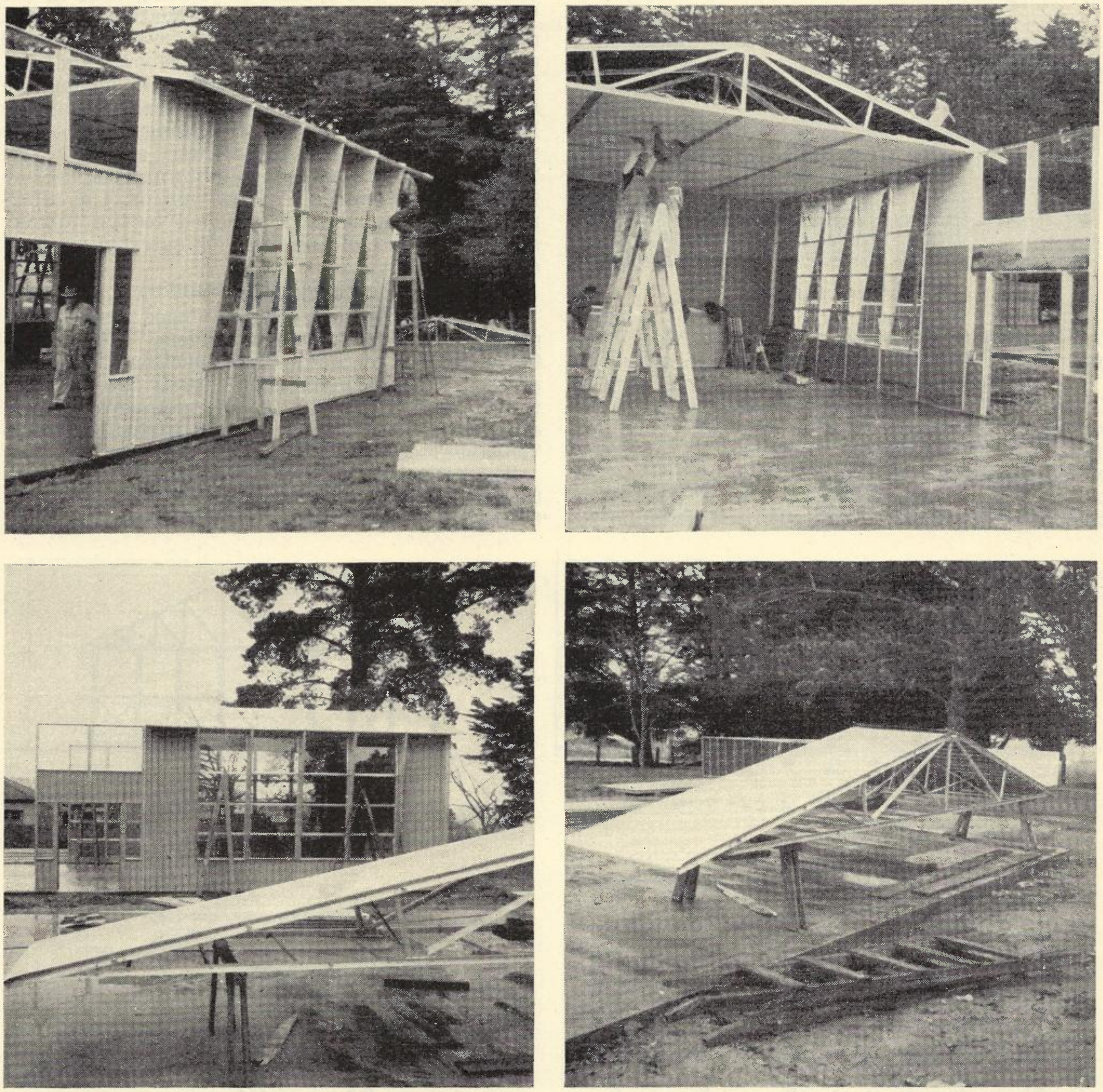


Fig. 7.—Bristol Building—Erection Details.

general constructional details are illustrated in Fig. 9.

In some cases the portal frame has been adopted for ease of erection on site, and is simply a type of frame which embraces the column and roof trusses combined, which is capable of being bolted together on the ground and then lifted from the horizontal to vertical position, as shown member, bored out to take a pin of suitable diameter, which is placed through the feet of the columns and after the frame is assembled the pin acts as a fulcrum so that the columns and truss can be up-ended from the horizontal to a permanent vertical position very readily.

The methods outlined apply to several types of buildings on the local market, such as Sydney

Williams' "Steel Fraim" building, and the "Armco" building, and imported types such as the "John Taylor" building, the "Woodrow" building and the "Pentad Hangar" building, which is a larger type used for storage, primary works and workshop applications. The overall dimensions of

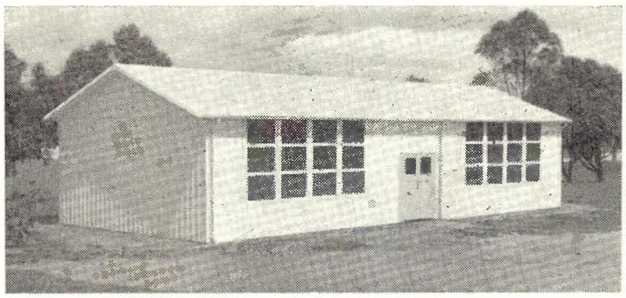


Fig. 8.—Hawksley Building.

this building are 185 feet x 105 feet clear span and 26 feet floor to ceiling clearance. See Fig. 11.

Cyclone and Arcon Types. A few firms, such as Cyclone and Arcon, have used tubular steel for structural members as this material combines lightness with strength. To obviate the necessity of weakening the tube construction by drilling for bolts, etc., it is common practice for the assembly to consist of welded joints where stiffness is required, plus standard bolted or screwed couplings which are available on the market and are seen in common use on modern steel scaffolding.

The buildings marketed by the Cyclone Company of Australia embrace this principle, reference Fig. 12. The system of jointing used in the "Arcon" type building is a combination of bolted and threaded sections of tubing cut to length and connected at junctions by tees, elbows and sockets. See Figs. 13 and 14. By this means the strength of the structure is not weakened by the loss of metal cut away by threading, because the main joints of the roof trusses, etc., are all welded together and the threaded joints are confined to the wall girts, braces and roof purlins. The external sheeting is usually attached to the tubular steel by the use of U-bolts with external washers and nuts.

The Econo Steel Building

Tulloch, of Sydney, have produced a system of pre-cut buildings known as "Econo" steel structures. In this method of construction the use of pressed steel of light gauge takes the place of timber in the forming of the members used to erect a framework. This system is also known as "nailable steel lumber."

The technique of erection in this case follows the procedure for erecting a conventional timber-framed building. Firstly, the floor bearers, which

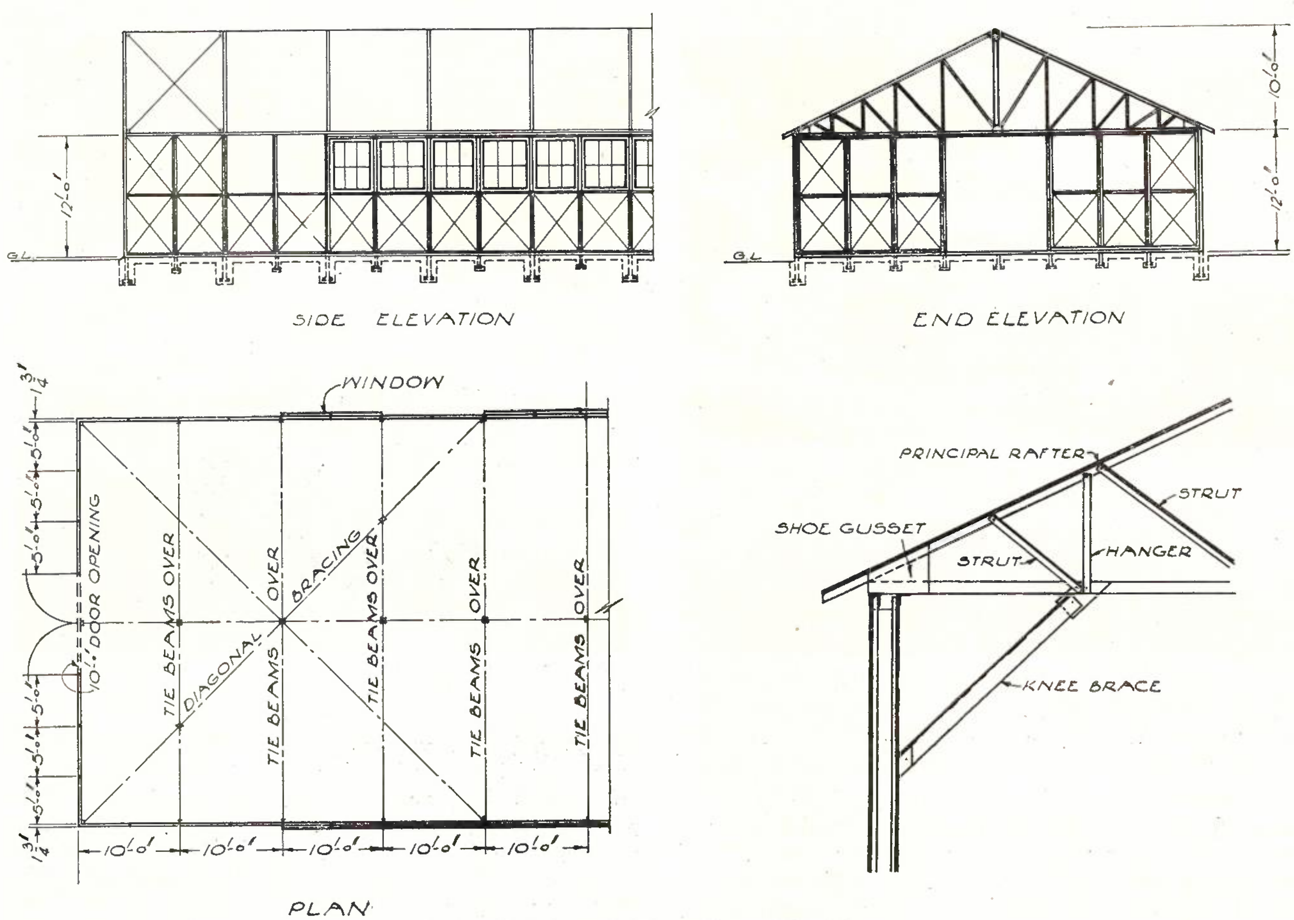


Fig. 9.—Steel Frame Building—Structural Details

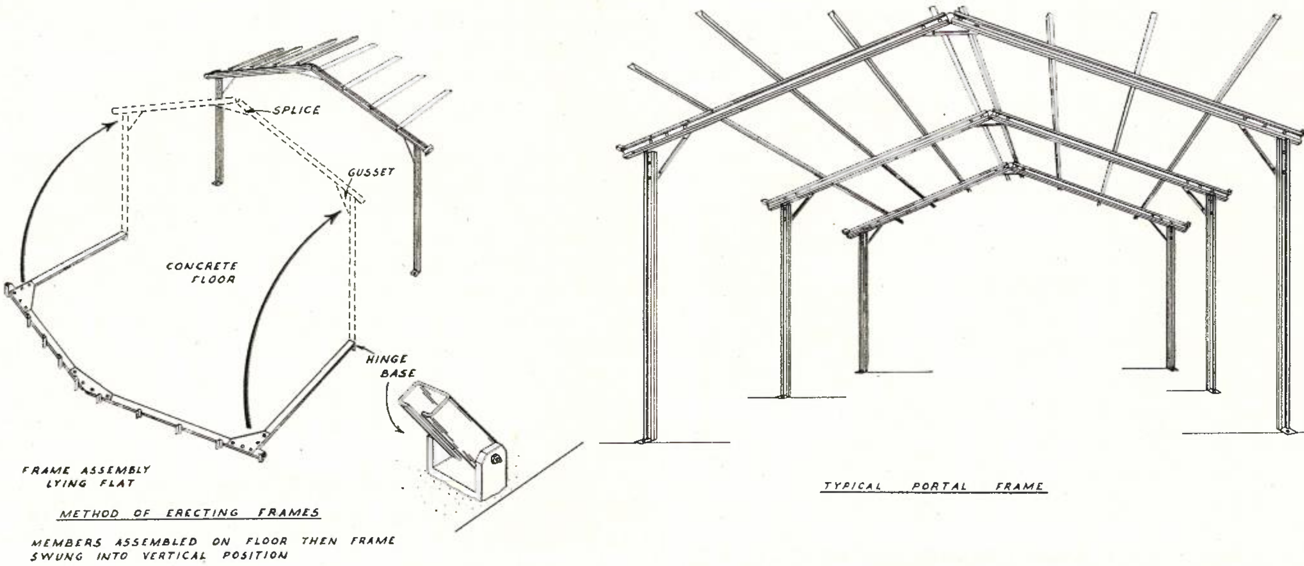


Fig. 10.—Diagram of Portal Frame.

are of rolled steel I section, 5″ x 2″, are laid on concrete stumps and attached by simple straps. The joists are formed of pressed steel 4″ x 2″ channel section, which are slotted along their length to allow for the driving of spikes to attach the timber flooring. The plates are also of 4″ x 2″ pressed steel having slots so arranged at 2′ 0″

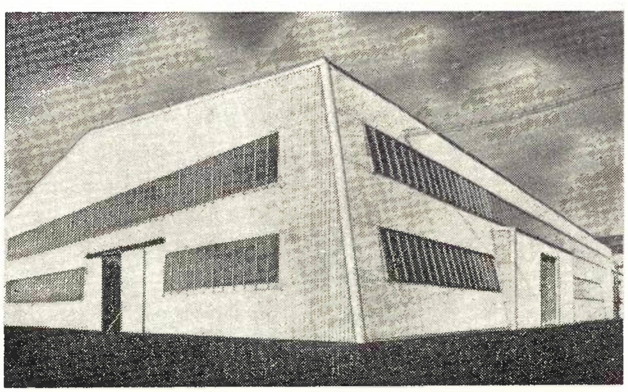


Fig. 11.—Pental Building

centres to take the studs. The studs are 4″ x 2″ of various heights, which have lugs incorporated at the end to fit the slots in the plates and, like the joists, are slotted for the nailing of the external and internal sheeting. The roof members are of T truss design, and are available in various spans to allow for flexibility. A choice of external sheeting is available, namely aluminium weatherboard, timber weatherboard or fibro cement sheet.

Aluminium roof tiles are also available or, if desired, corrugated asbestos cement sheets can be used. Several buildings of this type have been erected in New South Wales, and a repeater station urgently required at Guyong, New South Wales, was erected available for occupation within three months. Details of this type of building are shown in Fig. 15.

Timber Frame Types

The system of using asbestos cement sheets attached to timber framework in the form of panels is also used extensively in New South Wales and Victoria by such firms as Victorian Interstate Airways, Melbourne, and Vandyke Bros., Sydney. It is of interest to record that the

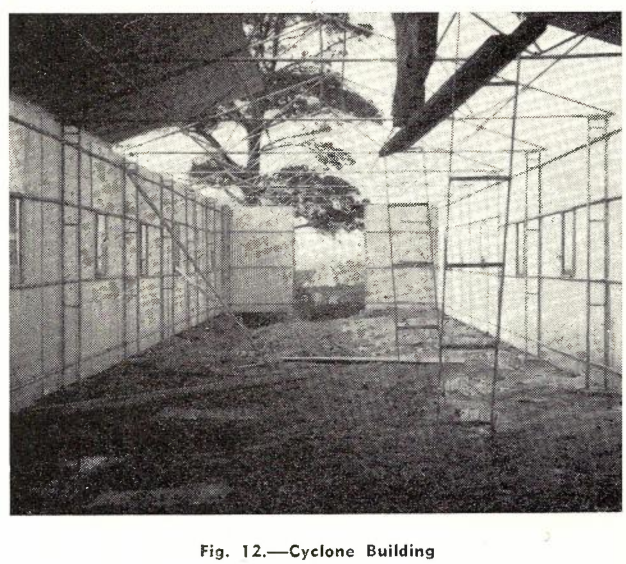


Fig. 12.—Cyclone Building

structural panel is designed on the stressed skin principle used in aircraft construction, which allows the use of a much lighter framework than is possible with orthodox methods. The standard panel comprises two faces of 3/16 inch standard asbestos cement sheet bonded to a seasoned timber frame and core with a waterproof phenolic resin adhesive. The method of bonding is a heat pressure process. The core is closely spaced to stabilise the faces of the panel and render them resistant to breakage. The panels are transported to the site and are usually 3′ 0″ and 4′ 0″ wide by varying heights.

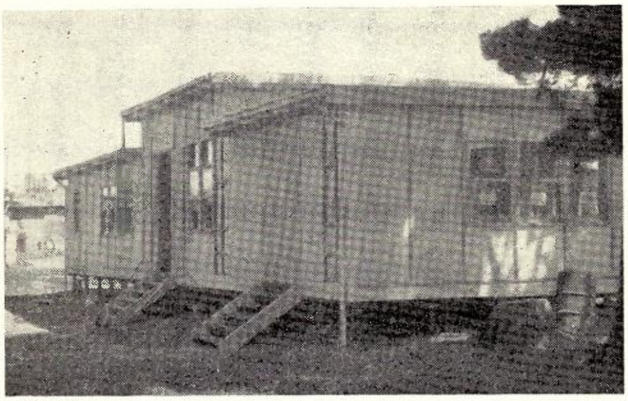


Fig. 13 (a).—Powell Type Building—Exterior View

The method employed when these panels are used is described briefly in the following. The usual floor stumps, bearers, joists are laid and the whole of the flooring is then secured to the joists and the wall panels stood in position, resting on a grooved plate secured to the outside perimeter. Each panel is tongued top and bottom, and at the sides so that a grooved plate is then attached at the top, and by this method the whole of the walls and partitions of a building of normal size can be erected very quickly. Prefabricated roof trusses are available in various spans, and are quickly attached to the top plates, battened and either tiled or sheeted with corrugated asbestos cement. This type of construction has assisted in providing some of the most urgent building requirements in country centres of New South Wales and Victoria.

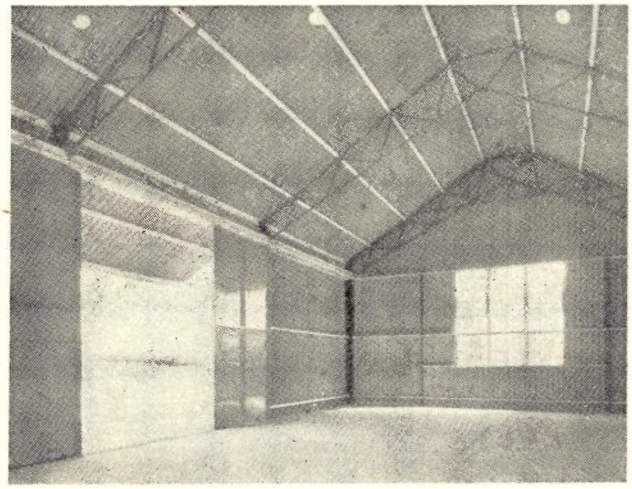


Fig. 14.—Arcon Building—Interior View

Application of Prefabricated Structures to Departmental Buildings

Quite a wide variety of prefabricated building types are being used to-day to supplement the Post Office constructional programme. It will, however, be appreciated that while unit construction principles are flexible to a high degree the applications are restricted and prefabrication cannot be regarded as the complete answer to the problem of providing accommodation.

For instance, single-storey designs are the only types available at present, and in many locations, owing to the large floor areas required for all postal and telecommunication services the erec-

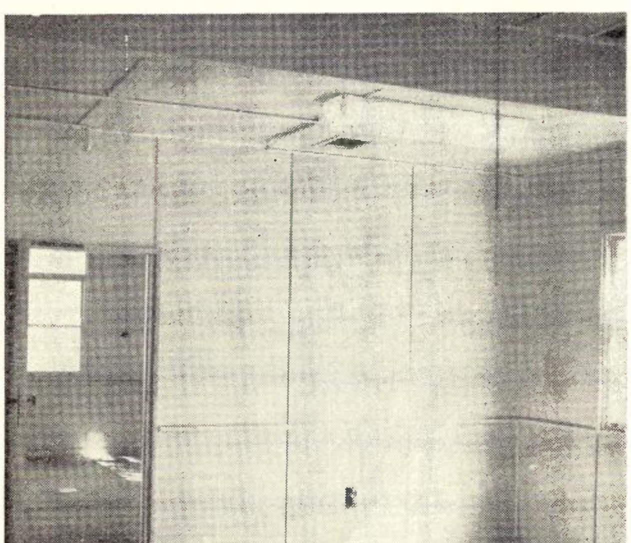


Fig 13 (b).—Powell Type Building—Interior View of Switchroom

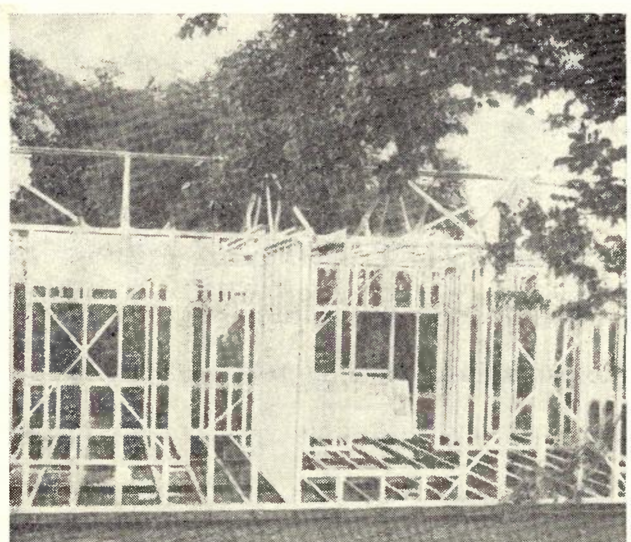


Fig. 15 (a).—Precut Steel Structure (Econo) Partly Erected tion of multi-floor buildings is a necessity. In capital cities and densely populated built-up areas the available sites are not extensive enough to allow the spread of area required to accommodate all activities on one level. A two-storey type prefabricated building in aluminium alloy is now under development, but it seems likely that the upper floor will be restricted to office type loading

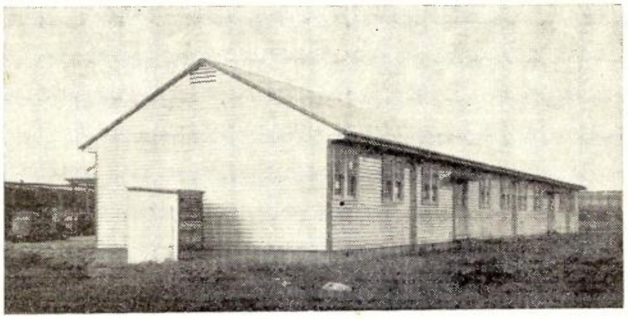


Fig. 15 (b).—Line Depot, Precut Steel (Econo)

(approximately 80 lb. per sq. ft.), and will not be suitable for equipment racks. Of course, prefabrication can be applied in part for multi-storey buildings by using prepared panels as infills for the structural steel framework on external walls and also for all internal partitions. Despite these limitations a brief outline of the use already made of pre-fabrication will show that it is playing a very important part in relieving the pressure for both engineering and Post Office accommodation.

Possibly the first noteworthy example of the use of prefabricated buildings within the Australian Post Office occurred during the early years of the last war, with the establishment of the major new trunk line routes between Adelaide and Darwin and Townsville and Cape York. These routes, each of total distance of the order of 2,000 miles, extending through remote, sparsely populated areas, required repeater stations spaced at 200-mile intervals, and this presented a difficult

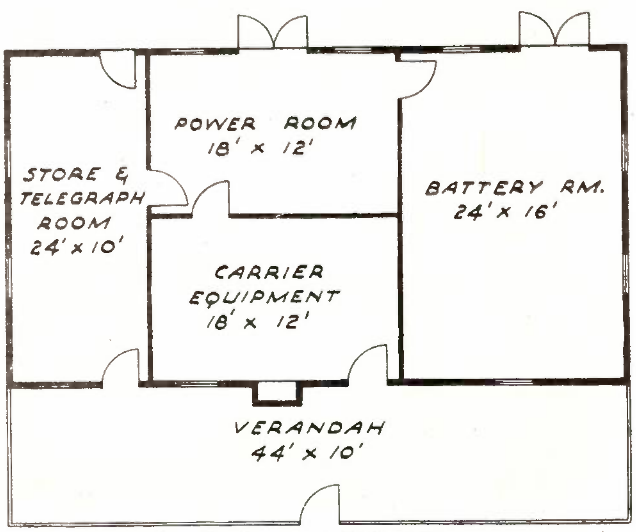


Fig. 16.—Repeater Station Layout

problem in providing suitable accommodation for the carrier telephone and telegraph equipment. The Sydney Williams "Steel Fraim" building was developed in a suitable design for a repeater station and the packaged components were transported to the selected sites and erected very speedily. There is no doubt that this made an important contribution to the speedy provision of trunk line services, which were so urgently required at that time. The layout of the repeater station and a photograph of a typical building are shown in Figs. 16 and 17.

Fig. 17.—Sydney Williams "Steel Fraim" Repeater Building.

More recently it has been decided to establish an alternative trunk route between Melbourne and Sydney, and aluminium alloy long-line equipment buildings to the design illustrated in Fig. 18 are now in course of erection at Narrandera, Jerilderie, Temora and Cowra.

Preliminary surveys have recently been made with a view to establishing intrastate and interstate radio telephone links, and designs have been prepared for prefabricated buildings to house radio equipment. Adjacent radio link repeating points must be within optical range of each other at distances of the order of 30 miles and in order to achieve this the sites are of necessity located on the peaks of high ground. For many of the selected sites access is difficult and special approach roads must be constructed for taking in equipment and for subsequent maintenance. Circumstances such as this are ideally suited to the use of prefabrication, as there are no local building materials available and the light-weight

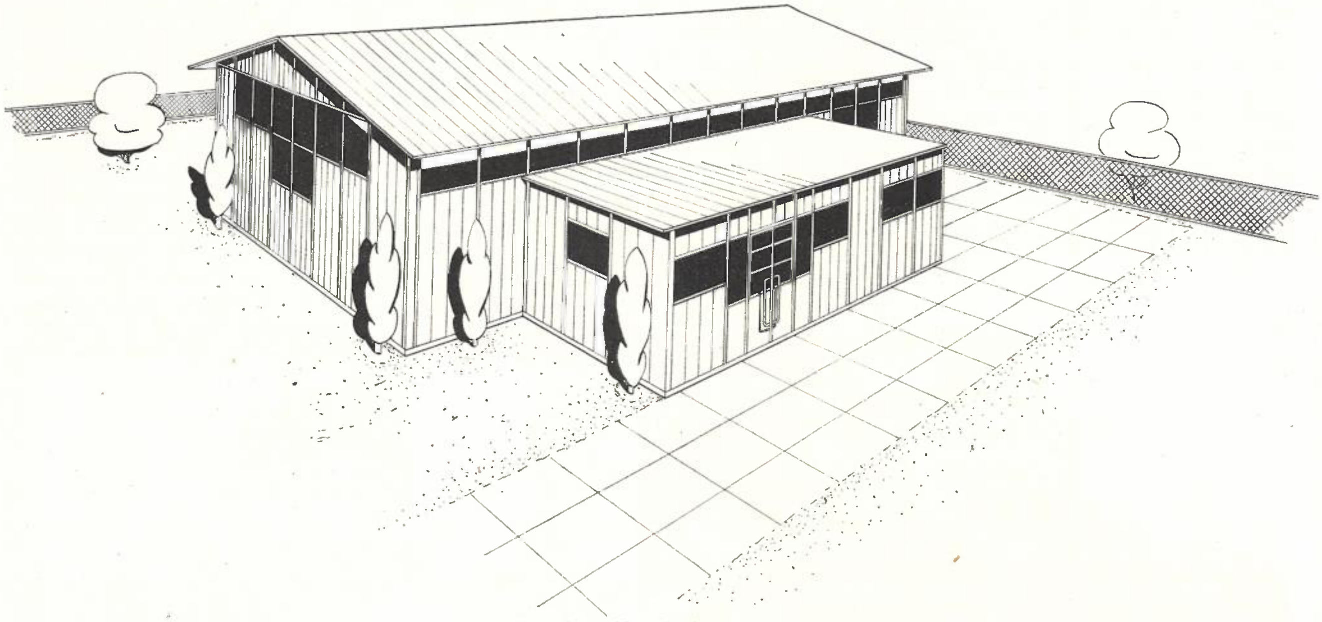


Fig. 18.—Long-Line Equipment Building

prefabricated components can be much more readily transported to the site. The provision of a packaged building, complete in all its parts, is a distinct advantage from the viewpoint of both supply and erection in such applications. Fig. 19 shows the details of the layout of a radio link station using aluminium alloy components. Three types have been designed, differing in provision of sleeping quarters in the more remote locations and in the provision of space for engine alternator plant where the supply of commercial power for the operation of the equipment is uneconomical. In order to obtain a radio transmitter station building required urgently in the development of the National Broadcasting Service, use has been made of the Econo steel framework erected on a concrete pier and beam foundation in one case where it was necessary to raise the floor height above flood level.

The rapid development of the rural automatic exchange programme is another instance in which the use of small prefabricated buildings has assisted in speeding up the work. Two quite different approaches have been made to this problem, principally because of the nature of the locally manufactured prefabricated units in each case. The Victorian Interstate Airways structural panel formed up into a small building 12 feet x 9 feet, complete with floor, has in one application been pre-assembled at a central depot, then transported and placed on prepared block foundation. The R.A.X. equipment is then installed in the building at the site. The supply rate of the buildings is co-ordinated with the equipment installation to ensure a continuous and smooth programme. In the other main group use is made of the Armco "Steelox" building, in two sizes, measuring approximately 13 feet x 10 feet and 10 feet x 8 feet. It comprises a steel grid floor of heavy

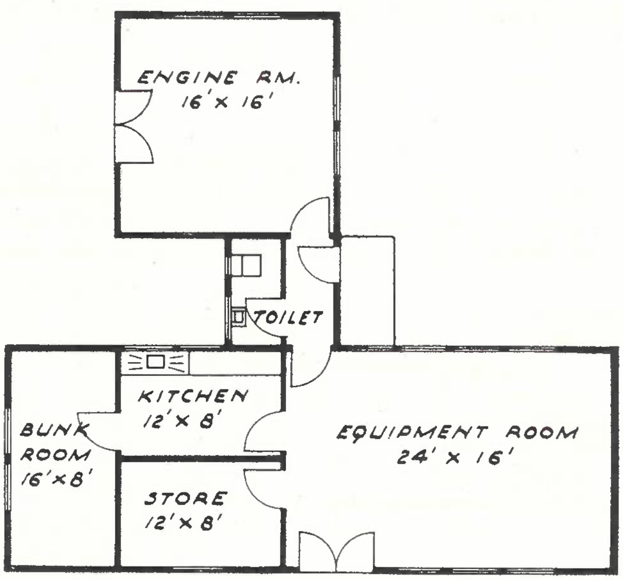


Fig. 19.—Radio Link Building

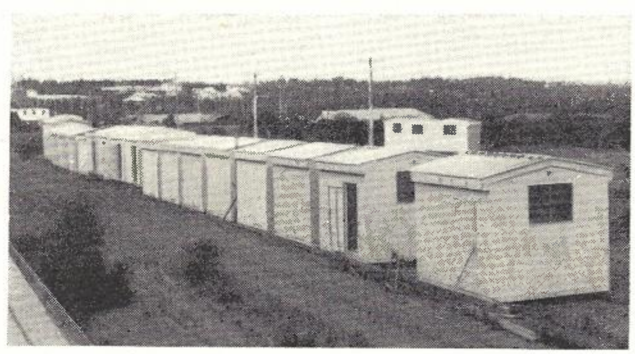


Fig. 20.—200-Line "Armco" R.A.X. Buildings.

Fig. 21.—R.A.X. Building Ready for Transport

R.S.J. members and a steel framework adequately stiffened to permit of the exchange equipment being installed at a central depot. The complete assembly is then placed on a special transporter and taken direct to the site, where it is off-loaded on to the prepared concrete block foundation. The work at the actual R.A.X. site is thus reduced to the absolute minimum, and cut-over is usually effected within 24 hours of arrival at the site. Fig. 20 shows a group of "Steelox" buildings at the depot where equipment installation work is carried out, whilst Fig. 21 shows a completed unit mounted on the transporter ready for conveyance to the site.

Prior to the preparation of designs using aluminium alloy components, steps were taken to utilise a timber-framed asbestos cement sheet assembly for the purpose of providing a group of twenty-four C.B. exchange buildings of temporary character needed urgently to provide relief at country centres throughout New South Wales. This building was designed in four sizes, types A to D, which differ only in the space provided in the switchboard and equipment rooms. At some centres the equipment room accommodates carrier equipment racks as well as the C.B. equipment. These buildings were manufactured by Powell & Sons, Sydney, and complete wall and roof panels, together with floor sections, were despatched to the respective sites, usually at the rear or adjacent to the existing post office and exchange buildings. A very speedy result was obtained in relieving the telephone position in these areas. The space previously occupied for a

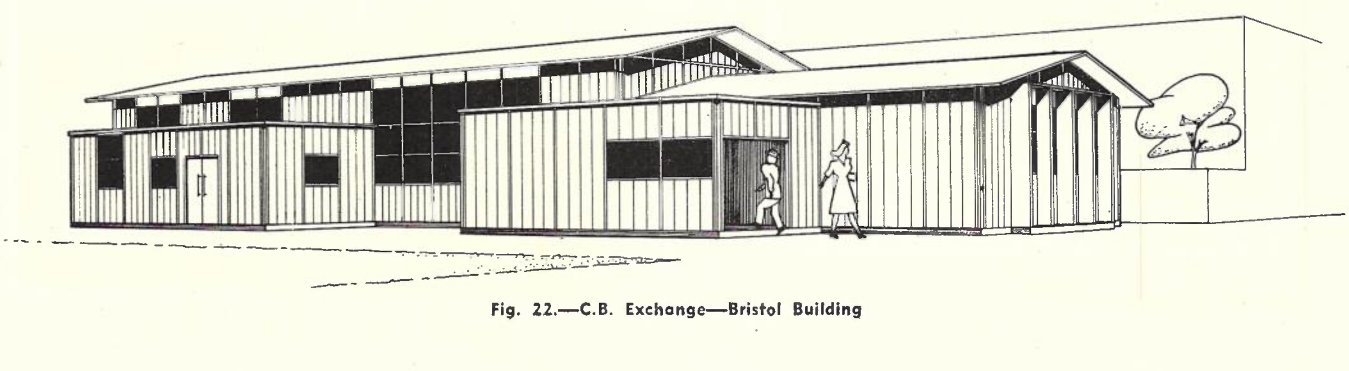


Fig. 22.—C.B. Exchange—Bristol Building

telephone exchange in the post office building was also of considerable advantage in arranging for relief of postal activities. This building is illustrated in Fig. 22.

Following on from adaptation of aluminium alloy construction to other uses, attention was directed to the need for meeting the accommodation requirements for both local and trunk line services in larger country centres, and designs, of which the layout in Fig. 23 is typical, have been prepared to meet this need. These, of course, will provide buildings of a permanent character de-

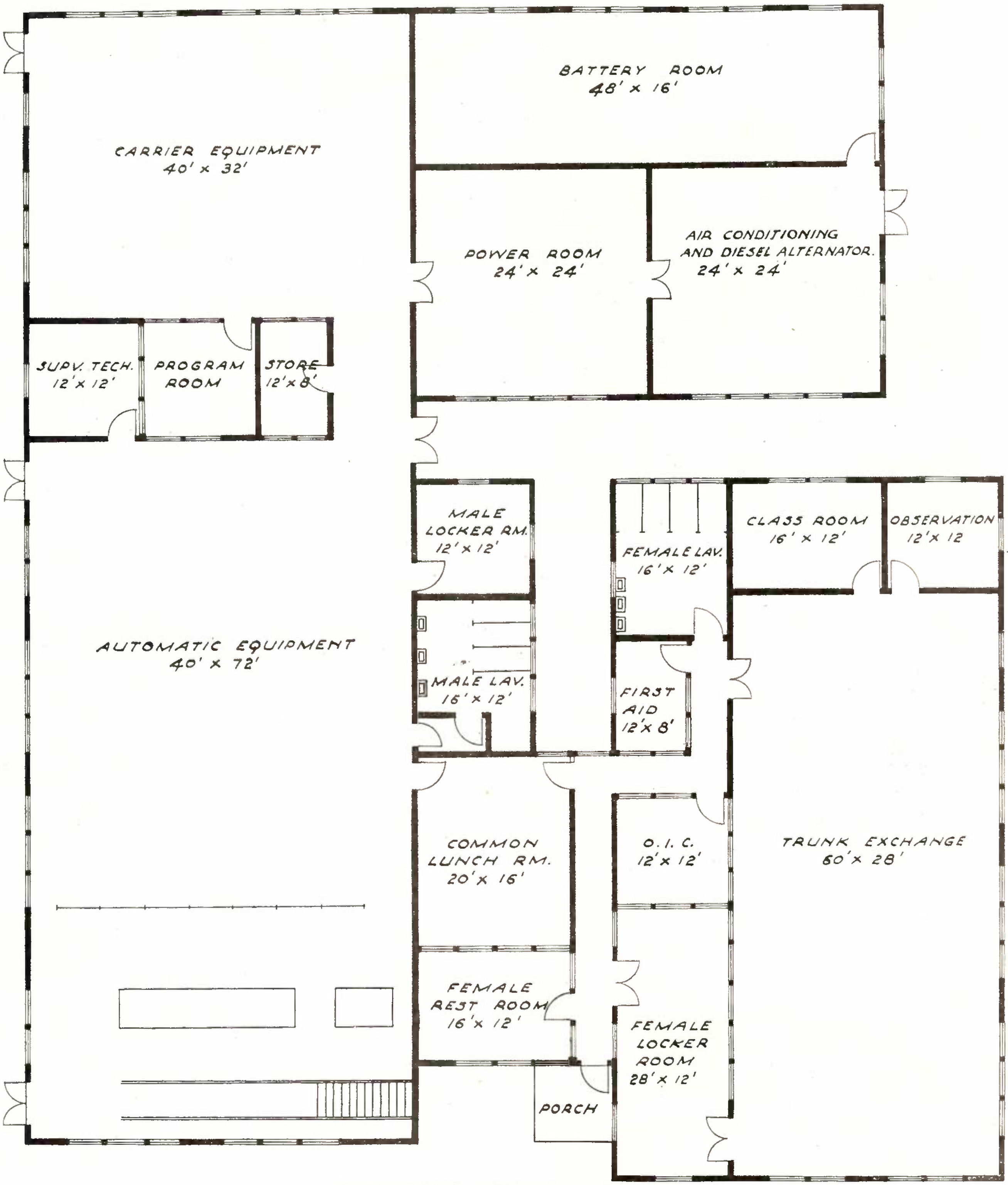


Fig. 23.—Typical Layout of a Country Exchange

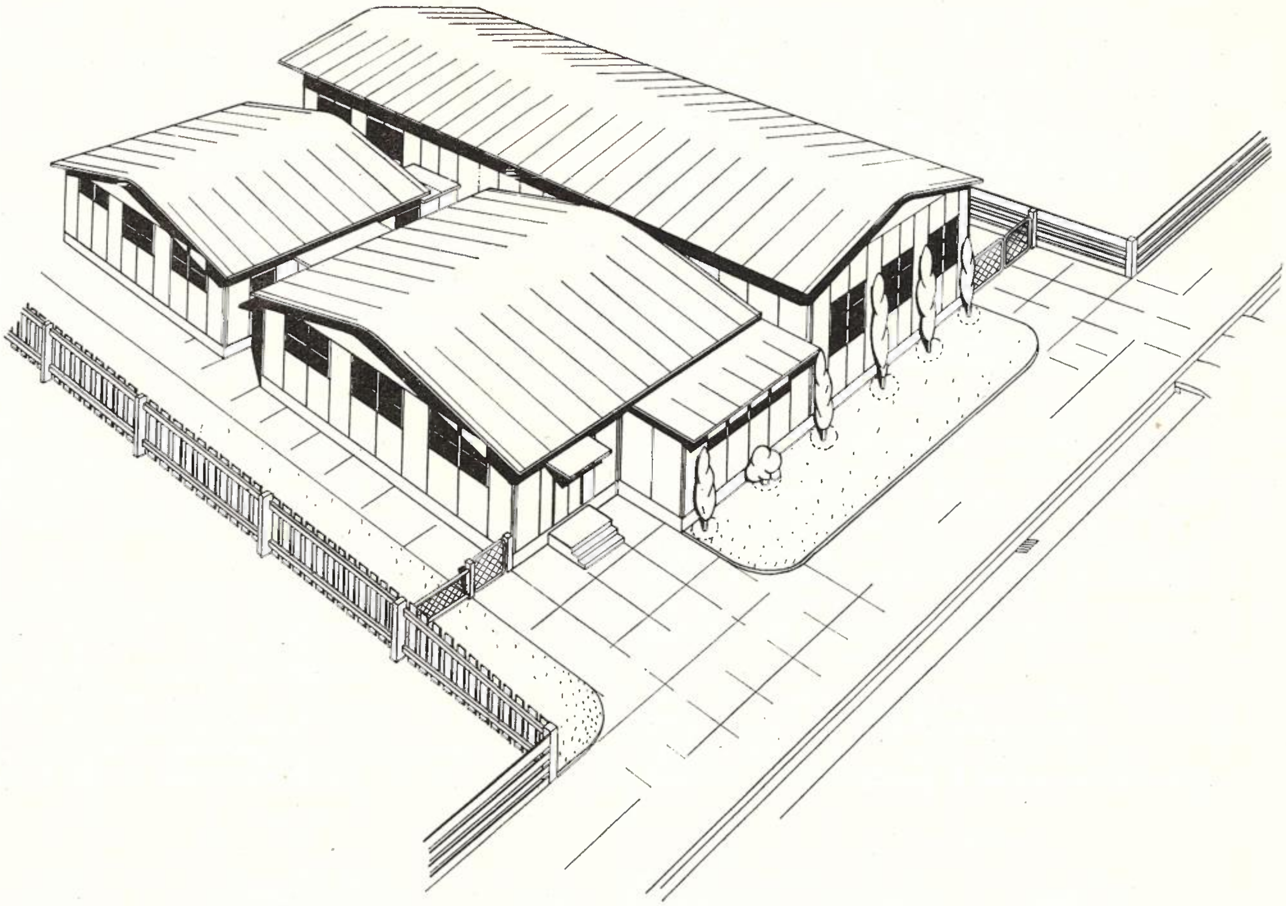


Fig. 24.—Automatic Exchange

signed to meet at least the 20-year development in the area concerned, and also provide for local automatic service, automatic trunk switching, long-line equipment and manual trunk exchange facilities. The layout has been arranged for flexibility, and part only of the prefabricated building need be provided in cases where, say, the manual exchange is already satisfactorily catered for in an existing post office building. Special treatment, using a blending of orthodox construction, can, if desired, be applied to the facade of the building.

Possibly the most important group of prefabricated buildings are those designed to take automatic exchange equipment for use in metropolitan areas and at large country centres which are being converted to automatic working. The initial designs were restricted to the smaller satellite exchange of capacity up to 3000 lines, but the urgent needs for accommodation in some branch exchange areas has now led to the development of designs suited to 9600 line installations. Layout plans for these buildings, for both narrow and wide sites, were included in the Vol. 8, No. 4, June, 1951, issue of this journal (1) (2). A perspective impression of the building designed to suit the wide site is of interest, and is shown in Fig. 24. Approximately twenty of these larger buildings have been ordered to assist in overcoming the lag in the provision of telephone service. In addition, fourteen switchroom units, in aluminium alloy construction, are being purchased for association with existing temporary automatic exchange installations. The plan in the latter case is to use the existing structures for the ancillary rooms required for power, battery and air treatment together with the associated amenities block. The aluminium alloy switchroom unit, measuring 88 feet x 40 feet, with a floor to ceiling clearance of 13 feet 3 inches, will provide accommodation for a full-size branch exchange of 9600 lines capacity.

The application of prefabrication is not confined wholly to relief for telecommunication plant, although, naturally, the pressure for additional local and trunk line telephone service makes this the predominant group. An interesting development is the provision of prefabricated post office buildings, particularly in newly established residential areas, and in cases where business has increased beyond the capacity of non-official premises. Whilst a certain amount of orthodox construction is in progress, all the requirements on the postal side cannot be met this way, and Fig. 25 shows one of the aluminium alloy post offices in course of construction. The colour treatment

Fig. 25.—Post Office Building in Course of Erection

applied to the interior represents quite a departure from past practice, and there is no doubt that these offices are providing excellent facilities to the public for the transaction of postal business. The layout arrangements are along the lines of standard post office buildings, although, principally because the maximum width module of the prefabricated building is restricted to 40 feet, the counter is arranged longitudinally.

The public space, counter provision, and mail handling areas, are equivalent to those provided in the normal Grade 3 office. The lower ceiling height amenities section is placed at the rear, and it will be noted that the high ceiling portion has been confined to the counter and mail working areas. Usually this type does not include exchange facilities, but in some instances, where only a small number of subscribers have to be catered for, a switchroom is provided in part of the mail working area close to the amenity section.

The prefabricated components also lend themselves to an arrangement closely approximating the standard line depot design, as illustrated in Fig. 26, which indicates both the perspective treatment and layout for the station building. The associated garage block and other facilities associated with plant and material storage are provided in the usual manner. An interesting feature is the combination of two differing component wall heights under one roof to allow of a raised floor in the bin store section to provide the loading platform. The next step, of course, is to provide prefabricated garage blocks so as to reduce "on site" work still further.

Buildings of much larger size and with a greater floor to ceiling height are required for a number of the associated activities such as stores, transport depots, workshops, primary works depots and assembly centres. Because of the activities and the size of the buildings they must be of sturdy construction and generally steel-framed buildings, such as the Pentad and Arcon types,

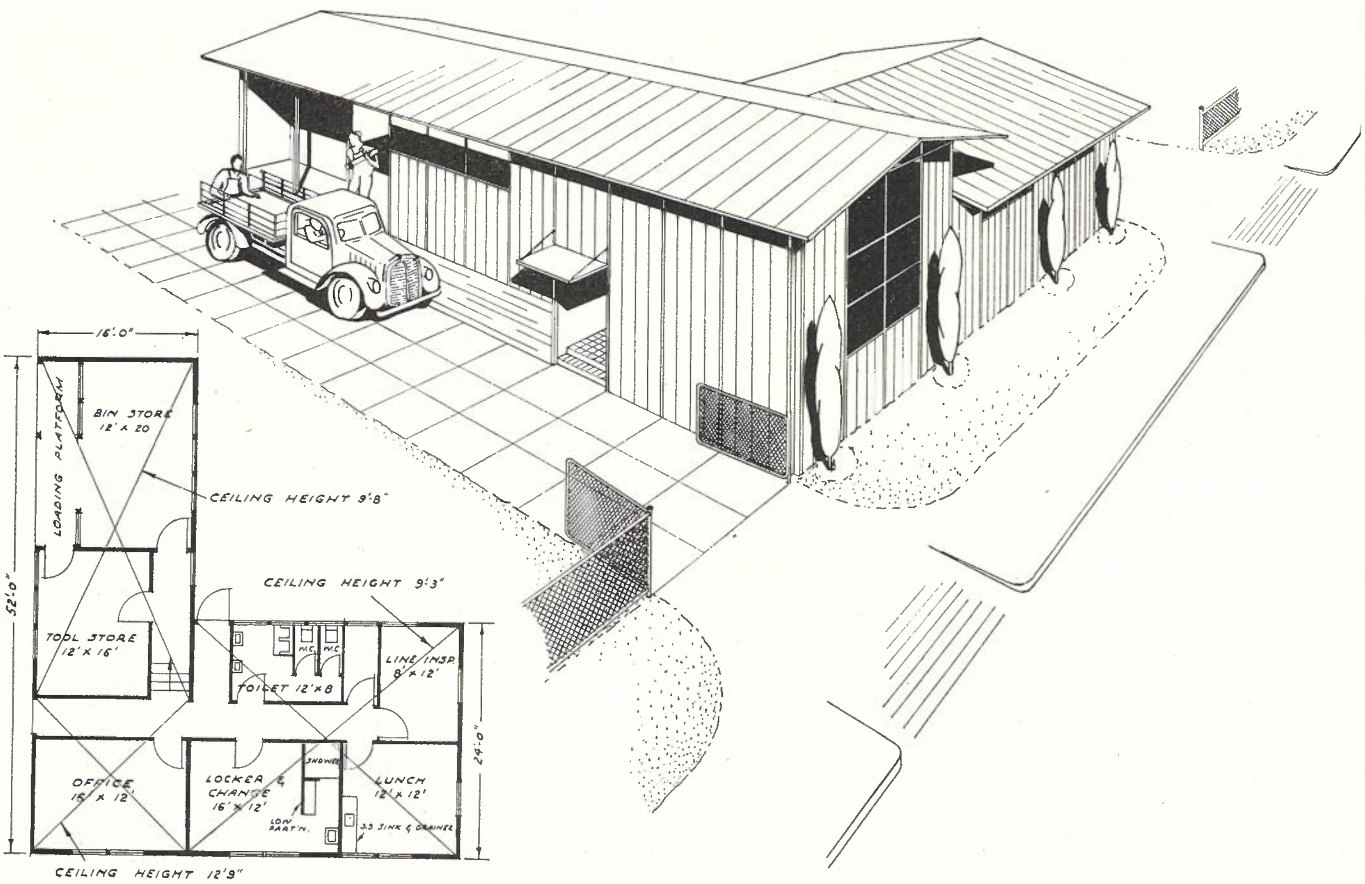


Fig. 26.—Line Depot Building.

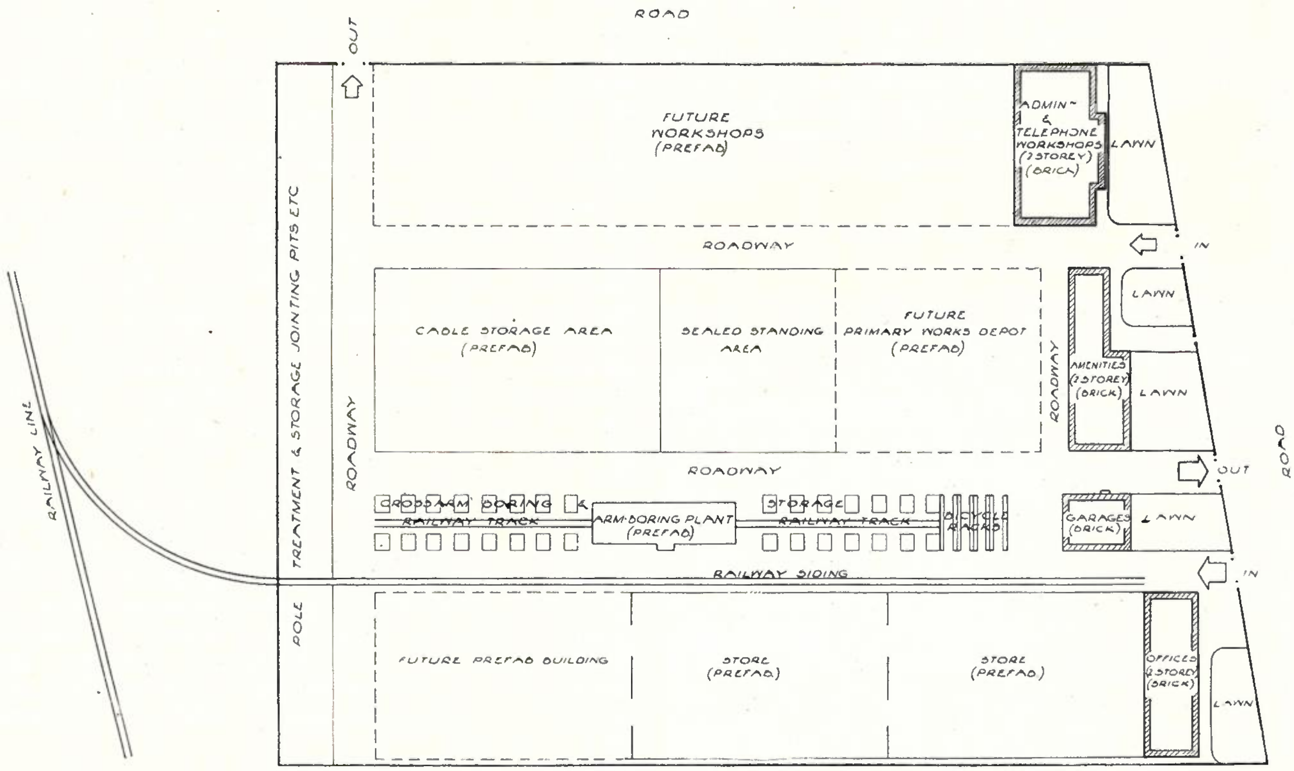


Fig. 27.—Layout of a Pental Building on a Typical Site

are being used for these applications. In many cases just a nucleus installation is provided in the first instance to meet the most urgent need for space, but the layout is carefully planned to provide for additional prefabricated buildings being added from time to time as required. One such layout is shown in Fig. 27, and it will be noted that the site treatment provides for the administrative block and the amenities block to be constructed in orthodox materials, thus presenting a pleasing appearance on the principal frontage of the site. This is in line with modern practice in providing factory buildings in which the more expensive construction is confined to the front portion, sometimes in multi-storey design, the utility sections being adequately provided for by large open areas on a ground floor level.

Last, but perhaps not least, there is a severe shortage of office accommodation, particularly in city areas, and a certain amount of decentralisation is essential if sufficient space is to be provided. Where conventional buildings for exchange or postal purposes are being erected on city sites the design usually provides for a limit height building with several upper floors devoted to office space. Under present day conditions these buildings take a very long time to construct, and it is necessary to meet space needs for administrative staff in the meantime. The general purpose aluminium alloy buildings lend themselves admirably to use as office buildings, and the flexibility of the window treatment permits very good arrangements of natural lighting. A number of office blocks have been designed to meet this need. Another minor requirement is for small lunch-rooms or locker rooms at existing premises where space conditions do not permit sufficient area being set aside for amenity purposes. The small Vandyke building, shown in Fig. 28, using the timber and asbestos cement structural panel, has provided a measure of relief at a large number of centres.

Conclusion

Whilst the manufacture of prepared building sections, in the form of roof and wall panels, represents an important contribution to a reduction of "on site" labour, and thereby can greatly speed up the provision of accommodation, there are many ancillary works which must be closely coordinated and planned to ensure smooth progress in making the building available for occupation in the minimum time. The preparation of the selected site, laying of the foundations and floor slab, plumbing and drainage, lighting and air treatment installations, painting, fencing and paths, the provision of furniture and fittings and garden treatment of surrounds or paving, must all be attended to. In order to achieve the best results it is essential to determine a time-table for the various operations related to the supply rate of the building components. The most effective contribution is to have the site levelled and the foundations and floor slab in position during the period that the prefabricated components are being manufactured in the factory, so that they may be transported direct to the site and erected without necessity for storage and intermediate handling operations, which increase the overall cost of the building. The remaining items should be scheduled for commencement in appropriate order in conjunction with the erection of the prefabricated components.

Experience with the first group of aluminium alloy buildings designed to house automatic ex-

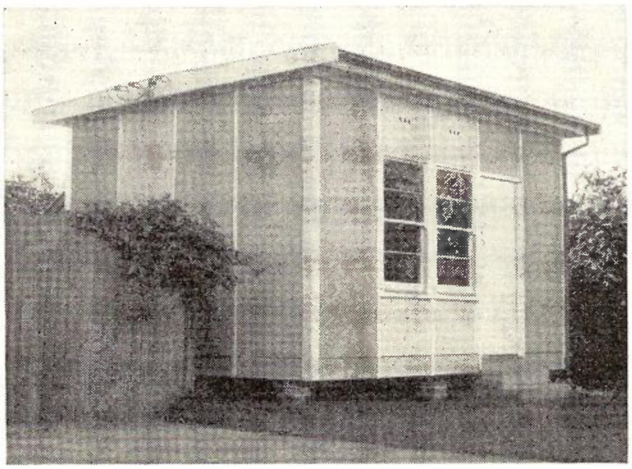


Fig. 28.—Vandyke Prefabricated Hut for a Postal Sorting Room

change equipment showed that the excavation required for the conventional cable tunnel introduced difficulties in attracting contractors, and in the Vol. 8, No. 4 issue (1), an outline was given of the arrangements adopted to eliminate the tunnel. In some areas cement was in very short supply and in these cases specially designed timber floors were substituted to carry an equipment loading and so avoid delay in erection. It is always likely, under present day conditions, that shortage of some essential building material will hold up the programme as scheduled, and constant supervision is needed to avoid serious delays.

Aesthetically, the prefabricated building has, possibly, not the same appeal to the majority of people as the more conventional brick or timber structure, although there are some who hold that the first quality grade of prefabricated buildings are, in themselves, quite pleasing. Much can, of course, be done to relieve the somewhat plain appearance of prefabricated buildings, firstly by careful attention to grouping and relationship of the various sections making up the complete building. The window treatment can also be designed to be decorative as well as useful. Secondly, by paying very careful attention to the choice of colour treatment, both externally and internally, and by proper design and treatment of the area surrounding the building, the appearance can be greatly enhanced. From the viewpoint of the interior, there is little to choose between the appearance of either prefabricated or conventional buildings if proper attention is paid to the decorative treatment.

Externally, a further development has been to tie in a limited amount of brick or stone work associated with the entrance or the front facade to provide a point of architectural interest. Examples of this treatment are shown in Figs. 29 and 30. Whilst prefabrication will continue to have opponents from the aesthetic viewpoint, the necessity for supplementing a conventional build-

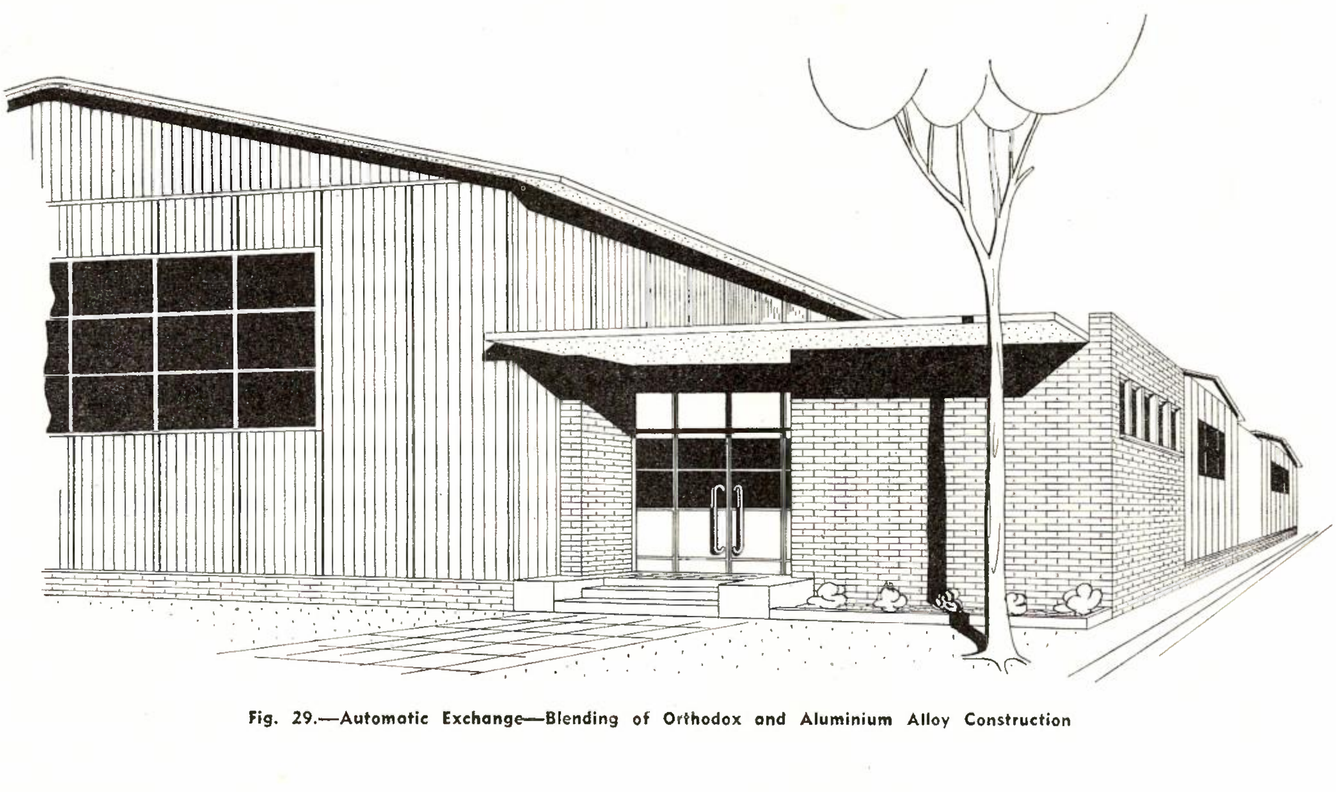


Fig. 29.—Automatic Exchange—Blending of Orthodox and Aluminium Alloy Construction

ing programme under present day conditions cannot be denied, and it seems certain that this state of affairs will continue in Australia for a long time to come. The cost of the first quality grade prefabricated building is relatively high, and is not a great deal less per square than orthodox work, except in the more remote localities. However, it is cheaper and does permit of some saving being made in a large constructional programme. Allied to this, of course, is the fact that accommodation is made available at a much earlier stage to permit the installation of plant which would otherwise lie idle, with a consequent loss in revenue.

The prefabricated buildings used in the Departcent can be broadly divided into two main types, those of a temporary character, erected as an expedient to provide services which would be long delayed waiting for the erection of a conventional type structure, and those regarded as being permanent, with a life of more than thirty years. The emphasis today is largely on the latter type, as even the most temporary construction is costly, and it has also to be borne in mind that the subsequent removal of a temporary plant installation is in itself a costly operation, whilst it absorbs manpower which could be put to better use in proceeding with other installations of a permanent character.

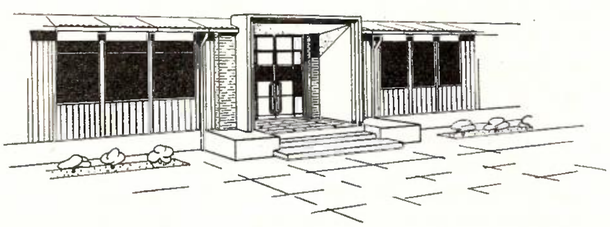


Fig. 30.—Traditional Treatment to the Entrance of a Prefabricated Administrative Block

In concluding this article, it is desired to acknowledge the assistance received from members of the Bristol Aircraft Company, England, at present associated with Overseas Corporation, Australia, Limited, the local agents and members of Hawksley Constructions Limited, England, at present associated with John Hart and Co., Melbourne. Acknowledgment is also made to architects in the Commonwealth Department of Works and Housing, who have assisted in the development of designs suited to the conventional requirements of this Department.

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Erratum

Vol. 8, No. 4, page 247. The title of Fig. 19 should read: "Aluminium Prefabricated Branch Automatic Exchange Building—9,600 lines ultimate capacity."

GOULBURN TELEPHONE EXCHANGE

J. R. O'Sullivan

The plans now being implemented to cater for additional subscribers' lines and the increasing volume of trunk traffic at Goulburn, New South Wales, are interesting, more because of their unorthodoxy and the alternatives considered, rather than from an idealistic view of exchange planning. The scheme, a combination of magneto and automatic local facilities and sleeve control trunk switchboards, was evolved after more customary methods were rejected, and there was a spate of suggestion and counter suggestion before the final plan was approved.

Stated briefly, the problem was to cater as satisfactorily and economically as practicable for an area where there were some 1400 subscribers' lines connected to a non-multiple magneto exchange, with a further 200 persons waiting for services and an annual development rate several times greater than the pre-war rate. Such expansion is typical throughout the Commonwealth generally since the end of 1945.

The limiting factors, which still exist, were:

(a) The switchroom, already becoming congested, could not be extended and other accommodation was not available to house either all or part of the manual suite.

(b) Alterations to the Post Office building to provide an enlarged permanent exchange in a new location in the building could not be completed for some years due to general prevailing conditions in Australia.

(c) The internal transferred traffic resulting from the absence of a subscribers' multiple, was causing serious operating difficulties and an increase in the number of subscribers' lines under the same conditions would have brought about an intolerable situation for two main reasons:—

  (i) Inadequacy of the transfer facilities that could have been made available for the increased transferred traffic.

  (ii) Insufficiency of space for the appropriate number of trunk positions; therefore, trunk lines would have been idle while delays mounted because of inability of the telephonists to handle the load offering. It is estimated that, before the new permanent exchange could be ready for service, each operator would have been required to deal with a traffic load at least twice as heavy as the normal.

(d) The engineering effort and expenditure entailed in providing a subscribers' multiple over all positions, or on "B" positions only, would have been excessive. Multiple "B" positions would have restricted still further the space available for "A" and trunk positions, and to that extent would have reduced the life of the exchange.

(e) Replacement of the magneto exchange with C.B. multiple and sleeve control trunk boards would have eased the position for a few years, but the comparatively limited life of such an exchange due to the small dimensions of the switchroom rendered the cost prohibitive. Furthermore, all concerned wished to convert the whole of the area to automatic operation as soon as possible, and the expenditure of a substantial sum of money on C.B. equipment could have had the effect of deferring the attainment of this objective for many years.

Thus, having been forced to reject, first, expansion of the non-multiple magneto facilities; secondly, provision of a full subscribers' multiple in the magneto exchange; thirdly, installation of magneto multiple "B" positions, and fourthly, conversion of the exchange to C.B. operation, attention was directed to seeing what could be done with automatic equipment.

Complete conversion of the area to automatic operation with direct dialling on trunk lines from distant centres would have reduced appreciably the volume of traffic to be dealt with manually, and thereby would have increased considerably the life expectancy of the existing switchroom. Again, unfortunately, there was no building available, or in sight, which would accommodate an automatic exchange big enough to serve Goulburn for even the next ten years. There was, however, at the rear of the Post Office, a small building of the army hut type, portion of which is in use for mail activities, but the remainder was capable of housing some hundreds of lines of automatic equipment, and it was decided to install sufficient equipment to enable conversion to automatic of all subscribers' lines within a well defined area in Goulburn and leave a margin to meet future development in this particular area. About 800 subscribers' services in an area comprising mostly the main business district will be connected to the automatic equipment. As this will make spare 800 magneto terminations and the automatic exchange can be extended, there will be an appreciable margin to meet future developments.

Unfortunately, this scheme, of itself, would not have smoothed out the operating difficulties. There would still be the internal "A" to "A" and trunk to "A" transferred traffic, naturally in reduced volume at the outset, but unavoidably increasing as more manual services were connected to replace those converted to automatic. It would be necessary also to cater for the auto to manual traffic, but the normal method of dealing with this business by means of an automatic "A" position was deemed undesirable for the following reasons:—

(a) As stated earlier, multiple facilities could not be justified.

(b) A non-multiple "auto A" position would have entailed transfer working from "auto A" to "A."

The effect of all this transferred traffic by the time the Goulburn exchange had developed to 2000/2100 lines, a number which would absorb the maximum effective capacity of the accommodation available for trunk switchboards, unless space could be found to divert several hundreds more manual services to an automatic exchange, can well be visualised.

There is no effective and economical way of eliminating the "A" to "A" and "trunk to A" transferred traffic at present, but, in respect to "auto to manual" calls, the idea was born that worth-while advantages would accrue if subscribers with automatic telephones were to dial directly to the "A" positions on which the manual numbers they wanted were terminated. Initially, special call levels were suggested for this purpose but this method possesses two major disabilities:

(i) The inclusion of detailed instructions to subscribers in the telephone directory; and

(ii) users of automatic telephones in Goulburn would be required to adopt different procedures for calls of basically the same type.

From the Engineering Branch, Sydney, came the suggestion to allot four-figure numbers to both the automatic and manual services and use the first two digits of the manual numbers to direct auto-to-manual calls to the correct "A" positions. The four-figure numbers would be in accordance with the ultimate numbering scheme for full automatic operation, and thereby fewer number changes would be required when this conversion eventually took place.

The advantages were obvious and the details were worked out in the Telephone and Engineering Branches, Sydney. The arrangements eventually adopted are as follows:—

(a) The automatic services are to be allotted numbers in the 2000-2999 range.

(b) The services remaining on the manual exchange are to be allotted numbers in the 3000-4499 range. For example, subscribers' manual services numbered 1-199 will be allotted numbers from 3001 to 3199, those from 201 to 399 will be given numbers in the 3201 to 3399 group, and those from 401 to 599 will receive numbers ranging from 3401 to 3599, and so on.

(c) As the grouping of lines on the 200-line "A" positions follows the order of 1-200 on A1, 201-400 on A3, 401-600 on A5, and so on, the dialling of digits "30" or "31" will take the caller to A1, dialling of "32" or "33" will select a junction to A3, and dialling of "34" or "35" will bring the caller's line up on A5, and so on throughout the manual number range.

(d) Digit absorption is being provided to take care of the third and fourth digits when four-figure manual numbers are dialled from automatic services.

(e) On auto to manual calls metering will take place when the "A" position telephonist operates the ringing key. Although not normal procedure, this method has been accepted at Goulburn. Therefore, rebates will be necessary for ineffective calls. Chargeable calls from manual to auto will, of course, be recorded on "measured service cards" in the usual way.

(f) Subscribers from automatic services will dial Trunk Lines (01), Trunk Inquiry (02), Information (03), Time (04), and Telegrams (05), in accordance with existing standard symbols for these services. Ring-down junction lines will be provided for this type of service from the "A" positions except that requests for the "time of day" will be satisfied by the "A" operator.

(g) Dialling facilities will be provided on certain of the trunk lines terminating at Goulburn, thus enabling distant operators to dial directly to automatic services or to the appropriate "A" positions. These facilities will reduce the amount of trunk to "A" transferred traffic.

(h) Service from manual to auto and from trunk positions to auto will be by means of dialling junctions arranged so that each operator will have access to some individual and some common junctions. This entails using some extra junctions, but inadequacy of space on the positions prevents the full junction field being made available to each operator. The common junctions will have guard lamps.

(i) The internal transfer system will be operated by order-wire service from each "A" position to each other "A" position (except adjoining positions) and from each trunk position to each "A" position. The transfer junctions will be jack ended at the ordering positions and plug ended at the receiving positions, whilst the junction to be utilised for a particular call will be nominated by the telephonist at the position on which the wanted number appears. This is to minimise the difficulty that occurs when the ordering telephonist nominates the transfer junction and rings over the junction line before the plug is inserted in the jack of the wanted subscriber's line.

A manual exchange of the type described requires lamp signalling facilities, and the provision of the lamps and jacks on the "A" positions entails a considerable amount of unavoidable work. In order to limit the amount of work of this nature, it was decided also to replace the magneto trunk positions with sleeve-control trunk switchboards. Another advantage, of course, is that more satisfactory supervisory and timing facilities are available on the sleeve control units. It is planned to bring these into service simultaneously with the main cutover of the automatic unit, which is expected later this year. These positions will form the nucleus of the trunk exchange required when the area is completely converted to the automatic system.

THE SIEMENS No. 17 MAIN AUTOMATIC EXCHANGE SYSTEM

*B. A. Hensler**

The No. 17 MAX System is the counterpart, for local area switching, of the No. 17 TAX System already in use in Australia, for handling long-distance telephone traffic. The aim of its designers has been to evolve a simple and reliable system having a long life and a low fault liability, requiring little maintenance attention, giving a high grade of service, and with features enabling economies to be made, particularly in plant external to exchanges. It is an equipment embodying the same functional and call-establishment principles as the more familiar two-motion selector type of local exchange, but with a main distinction that number-recording and outlet-selection are effected by separate items of apparatus each designed to perform its own functions in the most efficient manner. Another general difference is that all main switch racks are totally covered, a provision rendered practicable by the use of a special circuit facility which, under fault conditions, enables the backward tracing of calls without the necessity to remove covers to identify the wiper settings of individual selectors.

General

Switching Medium

Motor Uniselectors are exclusively used for all finding and selecting purposes, being made to search for a marked outlet or group of outlets, and being stopped on the selected one by the usual high-speed relay action.

*Siemens Bros. & Co. Ltd., England.

In selector ranks the marking is determined by the setting of a Digit Switch controlled by the dial or keysender. The Digit Switch has been designed purposely for the system; it has a high durability and its moving parts are of an unusually low mass, a feature which enables it faithfully to record impulses of wide variation in make/break ratio.

With one exception the Digit Switches and selector-controlling elements do not form part of the selectors themselves, but are accommodated separately in double-covered "Control Units" each serving a number of selectors. The exception is that incoming selectors, terminating 2-wire junctions, are individually controlled.

Trunking.

The basic trunking, in its simplest form, is shown in Fig. 1. Three main objectives were borne in mind during the development of the system, viz.:

(a) To make full use of the selector multiple in accordance with the requirements of the particular numbering scheme; that is, not to waste multiple on "dead levels" or numerals that will never be used.

(b) To enable selector multiple outlets to be divided into groups which are adapted in size to the traffic loads they have to carry; that is, to provide the facility of "variable availability."

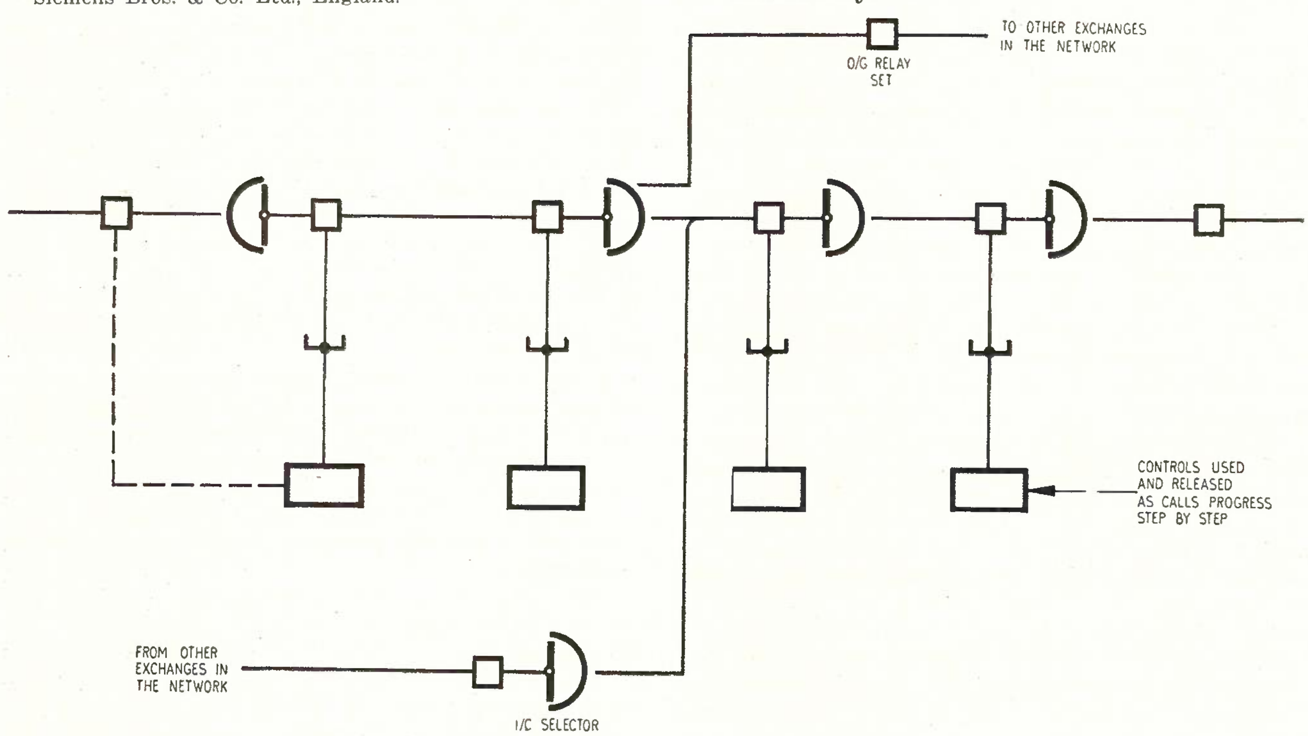


Fig. 1.—Basic Trunking Diagram

(c) To combine groups of traffic so that resultant groups are fewer in number, and each larger in size, thus allowing economies to be made in the overall quantity of equipment and line plant required.

These objectives have been achieved to a highly satisfactory degree without resorting to trunking, circuit or mechanical complications.

Variable Availability.

Variable availability is made practicable by a combination of the following five features of the motor uniselector:—

(a) Wipers move only in one plane and in one direction.

(b) Each wiper traverses an arc of 52 contact segments.

(c) Arcs are grouped into sections each of 50 outlets according to the number of wires used per outlet.

(d) The whole 50 outlets in a section can be tested, one at a time, between successive impulse trains.

(e) Any combination of outlets in the section can be marked for testing simply by joining the marking wire to a marker segment relevant to each outlet.

A selector provides for a total of 200 or 250 outlets according to its function, the bank thus comprising 4 or 5 sections. Each section in turn is divisible into groups. It may comprise only one group taking up the whole 50 outlets, or it may cover a number of groups. In the latter case—which would be the more usual—the groups need not be consecutively arranged, nor need the outlets of a group be adjacently disposed; they can appear anywhere within the section. In the case of groups to be given full availability, the number of outlets allocated per group will, of course, be in accordance with their respective traffic loads. Where gradings are involved, the number of outlets allotted to each of the groups in a section will usually be adapted to the respective traffic loadings of the gradings involved. If, however, the circuits diverge widely in cost, then this factor is also taken into account, in that groups serving the costly circuits are given a greater availability at the expense of those serving the cheaper circuits. Owing to the flexibility in allocating groups, a common pool of spare outlets can be provided in each section for serving any of its groups which eventually may increase in size.

Pairing.

This principle is used to combine groups of traffic corresponding to two numerals of a particular digit so that it is routed over one group of outlets. Thus, for a given size of bank the number of outgoing groups is halved and the availability doubled. This is achieved, fundamentally, by each group of outlets serving not one numeral of the digit concerned, as is usual, but two numerals; the way it is done is best explained by first considering traffic routed from Pre-final to Final Selectors. Fig. 2 shows the trunking for a typical 5-digit exchange.

The No. 17 Final Selector serves 200 lines. When an outlet from a Pre-Final is seized, engagement of the Final Selector and associated Control is accompanied by a momentary signal indicating which of the two "hundreds" is involved. Having in mind apparently similar arrangements in other systems, the point to note, in the No. 17 case, is that outlets leading to Final Selectors each have only one appearance on the bank of each Pre-final Selector concerned.

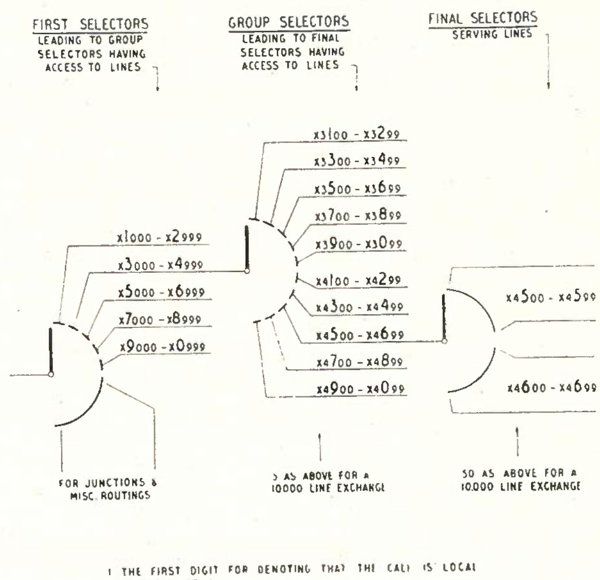


Fig. 2.—Local Trunking, with pairing for a typical 5-digit exchange

The Pre-final Selector is 200-outlet, so for an average availability of 20, it has access to 10 Final Selector groups. As each group in turn has access to 200 lines, the Pre-final Selector thus has access to a total of 2000 lines. The inlets to the Pre-final are paired similarly, only one group being required to carry traffic for 2000 lines. Thus in a 10,000-line exchange, the total number of groups entailed at the "thousands" selection stage is 5; and if the average availability is 20, these 5 groups use only 100 of the 200 or 250 outlets available. As access to 10,000 lines can be obtained using 100 outlets of the First Selector the remaining 100 or 150 outlets are available for outgoing junctions and miscellaneous routings.

In the No. 17 MAX, the First Selector is arranged to take two digits on local calls, the first determining the call as local and the second digit selecting one of the 5 outlet groups, each of which carries traffic relevant to two numerals of the second digit. By taking two digits on the First Selectors, a rank of switches is thus eliminated on local calls.

The action involved on a local call is best explained by assuming a number, say 63579. On receipt of the first digit, "6", the First Selector control determines that the call is local, so it suspends selector search until the next digit has been received. This is "3", which is paired with the "thousands" numeral "2". The First Selector then searches for a Pre-final, and on seizure of the latter and its associated Control, the First Selector Control signals that selection is to proceed via the part of the Pre-final bank having access to Lines 3000-3999.

The "hundreds" numeral "5" is then dialled into the Pre-final Control; it results in seizure of a Final Selector having access to Lines 500-699. At the moment of seizure, the Final Selector Control is informed that selection is to take place in the part of the bank serving Lines 500-599. The Final Selector Control then receives the "79" and establishes connection to the required subscriber —No. 63579.

Actually, the First Selector is more flexible than has been indicated, as it may be of the 200 or 250 outlet type and can be arranged to deal with both the first or first and second digits on local calls as well as junction and other routings. The basic circuit arrangement is shown in Fig. 3.

Of the 100 or 150 outlets not used for local switching, a few may be used for miscellaneous routings with the remainder divided into junction groups. Since spare numbers do not use outlets, a high average availability can be provided for junction groups. In addition, the pairing principle can be applied to inter-exchange traffic in a multi-exchange No. 17 network. This results in an increased average availability per junction group and a reduction in the outside plant required to carry the traffic.

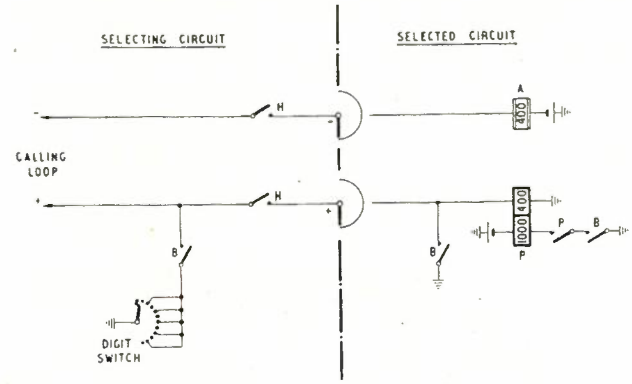
Since the availability can be varied, the factor of junction cost can be considered in apportioning the outlets between the various groups. Those leading to expensive circuits are given a high availability out of proportion to the traffic to be carried. This is very important from the economic aspect when considering the cost of a telephone network as a whole.

P.B.X. Working.

The system overcomes many difficulties normally experienced with P.B.X. working. The facilities provided are given in detail later, but two important points are mentioned here. All final selectors cater for P.B.X's. The other point concerns the situation which so often has confronted Administrations, namely, the inability to add new individual subscribers in spite of there being plenty of idle numbers and line circuits—which cannot be used as they have been allocated for future possible extension of P.B.X's. For all practical purposes, this situation cannot arise with the No. 17 System.

Inter-working with Other Systems.

From the nature of its design, the motor uniselector is adaptable to various methods of control. In the Siemens No. 17 semi-automatic trunk system, for example, the trunk selectors are not impulse-controlled, but have their groups marked for search by instantaneous-type codes applied from a Sender; search commences immediately on reception of the code. The same principle could be applied in a local exchange system and certain systems have actually employed this principle. In the No. 17 MAX, however, its use has been purposely avoided. The reason is that the system has been designed primarily for incorporation in networks already using the step-by-step switching principle. That is, all Controls are actuated by dial impulses and calls are progressively established in accordance with the digits received.



1. ACCESS TO THE SELECTED CIRCUIT IS SHARED BY TWO DIGITS ONE OF WHICH IS ODD, THE OTHER EVEN.

2. WHEN THE SELECTING DIGIT IS EVEN, EARTH IS APPLIED TO THE +VE LINE WIRE FOR A BRIEF PERIOD TO PREVENT RELAY P OPERATING CONSEQUENT UPON SEIZURE OF THE SELECTED CIRCUIT.

3. DIFFERENTIATION BETWEEN SELECTION BY AN ODD OR EVEN DIGIT IS EFFECTED BY THE OPERATION OR NON-OPERATION RESPECTIVELY OF RELAY P.

Fig. 3.—Pairing—the Differentiating Signal

Line Conditions.

Subscribers' lines can be up to 1000 ohms resistance with junctions up to a maximum resistance of 1500 ohms. The junctions are sectionalised by transformer bridges, which increases the degree of immunity from inductive interference. The impulsing performance is such that 1500 ohm junctions can be connected in tandem until the overall attenuation of the connection makes speech unsatisfactory although impulsing and signalling are still possible. The minimum insulation resistance is 50,000 ohms wire-to-wire or wire-to-earth for both subscribers' lines and junctions.

Transmission.

This conforms to Australian Post Office standards, but with improvements in two respects. As just mentioned, the inter-exchange connections are sectionalised by means of transformers, thus improving the speech to noise ratio under interference conditions. A small decrease in attenuation occurs due to the bank multiple wires being almost straight connections between switches. The "wire-length" ratio between a No. 17 multiple and a two-motion selector multiple is about 3:7, and when other wiring and cabling is also taken into account, the ratio becomes even more divergent.

Common Services.

The system operates on 50 volts and employs a 50 volt positive battery for metering. Ringing and tones conform to present standards.

Apparatus

The Motor Uniselector.

The motor uniselector has already been described in Paper No. 25, "The Motor Uniselector and High Speed Relay," by H. E. Humphries, and "The New Melbourne Trunk Exchange," by C. L. Hosking, in Vol. 3, No. 5 of this journal. The latest type, shown in Fig. 4, has been improved in certain respects from that described earlier:—

(a) The interrupter has been redesigned to ensure a more exact control of the torque conditions.

(b) The wipers have been redesigned to avoid their tracking over the feeders. Their adjustment has also been made easier.

(c) The feeders have been made a separate assembly which can be removed to facilitate periodic cleaning of the bank.

In all its main characteristics the motor uniselector remains unaltered.

The Digit Switch.

The Digit Switch employed in the No. 17 MAX System is ratchet-driven because it has to respond to impulses. Fig. 5 shows two switches mounted in a Control Relay Set, each occupying the space of four relays. The switch consists of two parts, mechanism and bank; the latter is attached to the mounting, such as the baseplate of a relay set. The mechanism is removable or replaceable without any adjustments being effected. To replace it, the mechanism engages in slots in the bank and is secured by two screws. The maximum bank size is 8 arcs each of 12 segments (10 + home + connecting purposes. The latter is furthest from the mechanism. The detail fitted to the outermost last contact), with a 9th dummy arc for cross-

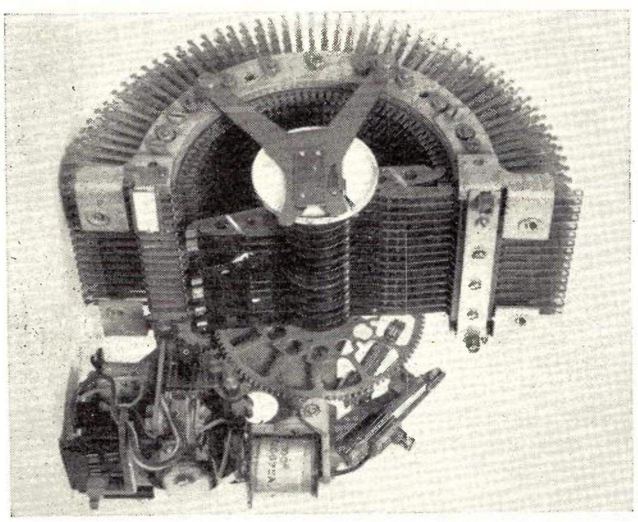


Fig. 4.—Motor Uniselector—Upper View

end of the bank is a protective device which also allows an unmounted switch to be stood on end with the mechanism uppermost.

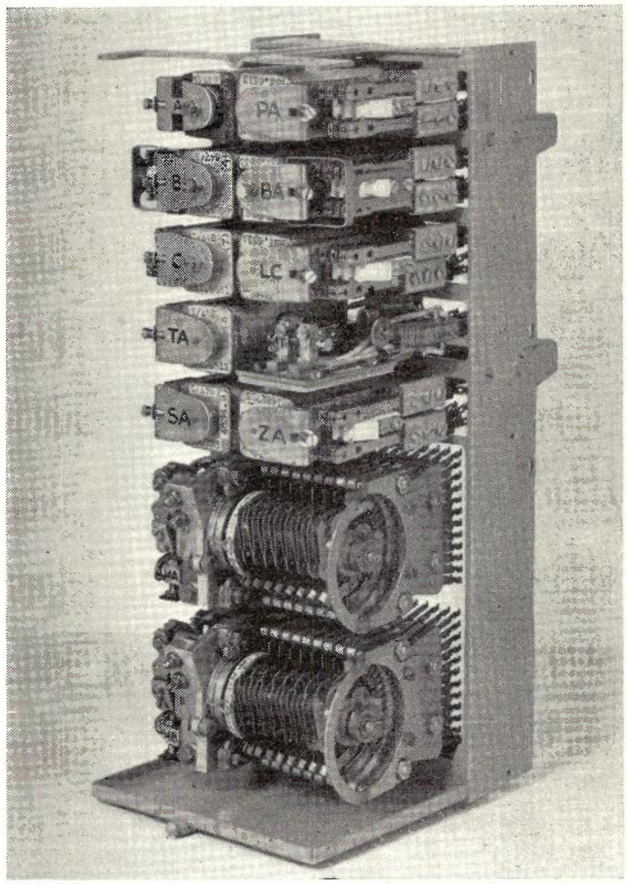


Fig. 5.—Digit Switches mounted in a Control

The wipers comprise pairs of quadruple-ended nickel-silver blades each engaging both sides of relevant arcs of segments which are of the same material. There are no feeders in the usual sense; the equivalent is a pair of sectors per arc—one connectable to six segments via two of the four pairs of wiper blades, and the other to the remaining six segments by the same method. The lower sector in each case is a feeder to segments 6-10 plus last contact and the upper a feeder to the homing position plus segments 1-5.

The rear of the bank presents a flat wiring field with rigid wiring tags in the same plane as that of the relay tags. Feeder wiring tags project into channels in the bank assembly; they are strapped to a feeder wiring strip attached to the rear of the bank. The basic part of the mechanism is an aluminium alloy diecasting. It mounts five main items, namely magnet system, retention pawl, adjusting screws, homing springset, and mechanism terminal block. The switch is reverse-drive, with a sturdy machined driving pawl of very small mass. Wiper overshoot on the driving stroke is prevented by the crown of the pawl engaging against a backstop screw. A separate backstop takes the impact of the armature "drive" movement. Driving pressure is imparted by a flat steel spring.

Adjustment of the self-drive springset is by moving it backwards and forwards, by screw action, into the mean position between early and late drive-failure positions. Every adjustment can be made from the front of the switch—a very desirable feature from the maintenance point of view. The self-drive speed of the switch is 60-70 steps per second on 50 volts, and is governed

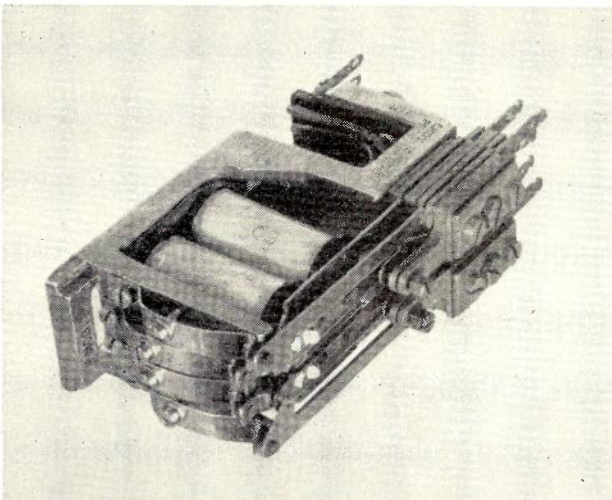


Fig. 6.—High Speed Relay with two changeover contacts

mainly by the electrical characteristics of the magnet. The switch has been designed to perform up to a million sweeps over its bank without need for re-adjustment, and very considerably more than that before part replacement is necessitated.

High Speed Relays.

Two types are used; the familiar single changeover contact type used for drive stopping purposes, and a two changeover contact relay of recent introduction, illustrated in Fig. 6, used primarily for impulse repetition.

The high speed relay with two-changeovers uses the same control principle as the single-changeover type, that of contact operation by a direct pull on an armature located between the contact points and the fixed ends of the springs, but its layout and method of adjustment differ.

The basic part is a diecast frame designed to maintain the correct relationship between faces under extremes of temperature and under all normal conditions of handling. There are two armatures, one per springset, both controlled by the same electromagnet system. The location of the break and make contacts in relation to those on their respective centre springs is adjusted by altering the bow of positioning springs. As the degree of bow is lessened, so the contact springs are lifted away from the main body of the relay. The degree of bow is controlled by means of adjusting screws. By these arrangements, all contact openings can be adjusted from the front end of the relay. Break contact pressure is applied by two screws, one per changeover, which engage details for levering upwards the free ends of the two armatures. The fulcrum line is the rear poleface of the magnet core.

The coils are of a larger type than those used on the single-changeover high speed relay; this is to obtain the required sensitivity under the most adverse line-impulse conditions encountered in a network. For its main use as an impulse-repeating relay, as embodied in bridges of the repeating coil type, the main advantage of this relay is not merely that it is high-speed, but also that this characteristic allows a more important requirement to be met, namely faithful repetition of impulses under variation of line conditions, impulse speed, and exchange voltage. It is this fidelity of repetition, coupled with design features in other parts of the system, which enables the impulsing performance in a No. 17 network to be of an outstandingly high order.

All other relays in the No. 17 MAX system are of the BPO 3000 type, including those used in the subscribers' line circuits.

Main Exchange Circuits

The circuits of the No. 17 MAX System follow, in general sequence, much along the same lines as those of the two-motion type of step-by-step system. Only the main circuits are described here. The usual miscellaneous circuits such as Alarm circuits are not described as they differ only in minor respects from conventional practice.

Line Circuits.

A simple 2-relay Line Circuit is used in which the calling condition to a Linefinder and the free condition to a Final Selector is always the presentation of a battery potential to the P wire. Metering is effected over a fourth wire from the Linefinder and consists of a pulse, or pulses, of "positive" battery. The metal rectifier involved with this type of metering is not part of the Line Circuit.

Linefinders.

In designing the system, the question arose as to whether the linefinder principle should be followed in all cases. In reaching a decision consideration was naturally given to the relative capital costs for varying call densities, but equal importance was attached to relative annual costs. A comparison was also made with linefinder secondary working omitted, partly for traffic reasons and partly on the grounds of providing the maintenance man with the simplest possible arrangement to understand and maintain.

The decision was in favour of linefinders, for three principal reasons:—

(a) As explained later, a linefinder system without secondaries is less sensitive to traffic overload than any other method of connecting subscribers' lines to First Selectors.

(b) The high speed of finding, movement of wipers only in one plane and in one direction, and the exclusion of secondary working allows speedy connection to callers with simple and straightforward control arrangements.

(c) The operations entailed by the No. 17 System in finding a calling line are not much different from those of a forward-hunting line switch, with which latter scheme the number of switches required is several times greater. Added to this, of course, is the use of a finding medium, the motor uniselector, with a very low fault liability.

An individual Linefinder consists of a motor uniselector and two relays; it is directly and permanently connected to an associated First Selector and has access to 200 subscribers' lines. The

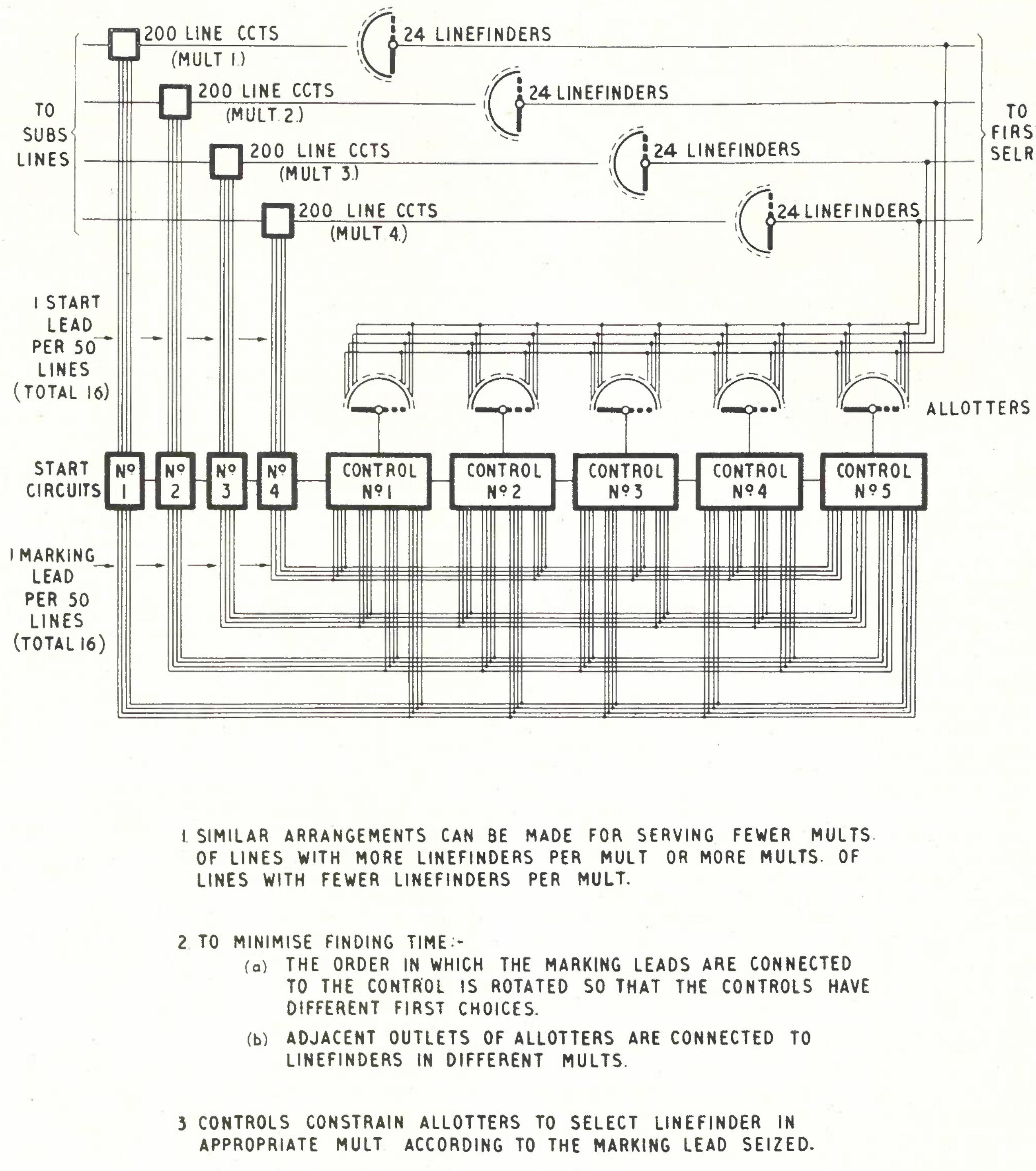


Fig. 7.—Typical arrangement of Line Finders, Start Circuits and Controls

basic arrangement of the Line, Start, Control, and Allotter circuits is illustrated in Fig. 7. The purpose of the marking leads between Start and Control circuits is to set an appropriate Linefinder in operation, and to signal the particular set of wipers it must use for locating a calling line. A set of Linefinders each with access to the same 200 lines is called a Multiple. Finding action commences with a signal passed over a Start Lead which is common to a Group of Line Circuits, the number commoned depending on the traffic requirements; it is usually 50. The Start Leads relevant to a Multiple (thus usually 4) all terminate in a Start Circuit. A Start Circuit in turn actuates a Control and associated Allotter, the latter being a motor uniselector. The Allotter has access to a maximum of 102 Linefinders, from which it follows that it can serve more than one Multiple. The Linefinder traffic density determines the number of Multiples which may be served; it can be 2, 3, 4 or 5 Multiples. A Control and its Allotter can thus serve a Division of Linefinders comprising a maximum of 102 Linefinder Circuits, having access to as many as 1000 lines, For adequate service, the rate of provision of Controls and Allotters is usually four per Division.

Calling action, briefly, is as follows:—A Start Circuit signals all Controls that a line requires finding, and, by means of a high-speed relay-search action, all the free Allotters start searching for the Start Circuit concerned. One of the Controls finds it, and its Allotter is marked to select a Linefinder having access to the Multiple in which the calling line is situated. The average time between a caller removing his receiver from the telephone cradle and being found by a Linefinder is less than 0.5 second.

When a subscriber makes a call, only **one** Linefinder is set in action. If, before he is found, a call is originated in another Group, another Linefinder is immediately set in action—and so on. The only case in which this principle cannot be followed is when two calls in the same Group are made, and even then they would have to be made simultaneously. One call would have to be found before the other could start a Linefinder, but with so small a finding time it is a limitation which is not noticed in practice.

In the design of the Start and Control circuits, care has been taken to avoid the permanent association of particular Controls with particular groups of lines. The principle has been followed of ensuring that Controls give equality of service to all groups of lines concerned. For example, there is no equivalent in the No. 17 System of the condition which can arise in a two-motion type of line-finder system, where, if a sudden rush of calls occurs, a calling line situated late in the multiple (such as "00") has to wait until the rush ceases before it can be found.

First Selectors.

An individual First Selector consists of a motor uniselector and three or four relays, depending upon whether it is a 200 or 250 outlet type. Main facilities have already been covered earlier in this article, but it should be noted that 100 outlets do not necessarily have to be allocated for junction and miscellaneous routings, with the remaining 100 as a fixed allocation for local traffic; the proportion can be varied.

A Control normally comprises 2 Digit Switches and 11 relays, which include two for time measurement under "permanent loop" signalling conditions. When the Control Held alarm is actuated, a "PG" lamp lights on the associated Linefinder to assist in rapid identification of the line concerned.

Groups of outlets are marked by strappings on the bank multiple field. The determination of which numerals of a digit are paired is done by means of strappings inside the Control.

The 250-outlet First Selectors are similar to the 200-outlet type, but the outlets are arranged in five sections. Two wiper-selecting relays and a common marking bank are employed. Normally 150 outlets are available for first-digit selection and 100 for second-digit selection.

Group Selectors.

An individual Group Selector comprises a motor uniselector and three relays with the associated Control consisting of a Digit Switch and 14 relays. The selectors are arranged to deal with calls on a "paired numeral" basis, and consequently are capable of routing traffic relevant to 20 numerals. That is, they route traffic in conformity with the numeral value of the digit which their associated Controls receive, which can be any one of 10 numerals. This quantity is doubled by reason of the inlets to the Group Selectors carrying traffic relevant to two numerals of the preceding digit.

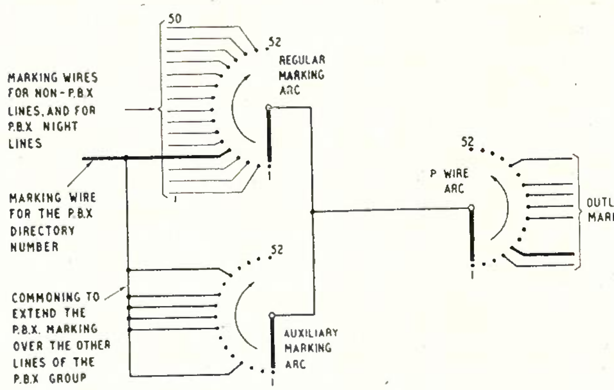
As the outlets of a Group Selector are normally arranged for "paired numeral" working, the number of outlet groups served is only half the quantity of numerals served; that it, a maximum of only 10 groups has to be catered for with an average availability of 20. 100 outlets are for routing calls relevant to the odd numeral of the preceding digit, and the other 100 for even-numeral routing.

Final Selectors.

An individual Final Selector consists of a motor uniselector and three relays. The associated Control consists of 2 Digit Switches, one for the Tens and the other for the Units digit, and 12 relays. The Selector is of the universal type in that it serves both ordinary and P.B.X. lines. The switch bank is arranged so that pairs of adjacent sections each serve 100 lines; the pairing signal transmitted from the preceding Control determines in which 100 the selection is to be made.

PBX groups may consist of from 2 to 51 lines, may be interspersed with ordinary lines, may have "0" as the Units digit, and the lines do not have to be consecutively arranged. If any PBX line other than the main directory number is dialled, the action is the same as for an ordinary (non-PBX) line. The marking method is shown in Fig. 8. When a P.B.X. requires more than 51 lines it is treated specially and a type of Final Selector is supplied to meet such cases.

As ringing is not applied from the Final Selector, a Control is engaged only for the period taken to accept the Tens and Units digits and for the selector to make connection with the required line.



1 A SEPARATE AUXILIARY MARKING ARC IS REQUIRED FOR EACH P WIRE ARC, BUT THE REGULAR MARKING ARC MAY BE COMMON TO ALL

2 THE STANDARD Nº17 FINAL SELECTOR CATERS FOR GROUPS OF FROM 1 TO 51 LINES

3 P.B.X LINES MAY BE INTERSPERSED INDISCRIMINATELY WITH ORDINARY LINES

4 EXCEPTING THE P.B.X DIRECTORY NUMBER, ANY LINE OF A P.B.X GROUP MAY BE CALLED INDIVIDUALLY FOR NIGHT SERVICE

Fig. 8.—Final Selector Outlet and P.B.X. Group Marking principle

Incoming Selectors

There are three types of Incoming Selectors to consider:—

Incoming Group Selector from No. 17 Main Exchange.

Incoming Group Selector from Non-17 Main Exchange.

Incoming First Selector from Satellite and Trunk Exchanges.

Other types of Incoming Selector may be required to meet special cases, but the above are the three main types used in the system.

Each of these three types of Selector has an overall outlet availability of 250. The outlets are arranged in 5 bank sections each of 50 outlets, the sections being permanently associated with pairs of numerals, namely 0 and 1, 2 and 3, 4 and 5, 6 and 7, and 8 and 9. Outlet marking in each of the sections is controlled by a marking arc common to all sections, from which it follows that all sections must be alike with respect to availability. It does not mean that groups are subject to fixed availability such as in a two-motion system; the sections can be divided into groups according to requirements. It does mean, however, that sections are not independent of each other with respect to providing variable availability, but this is compensated by the unusually large availability afforded.

Incoming Group Selectors from No. 17 exchanges—from which traffic is received on a "paired numeral" basis—are arranged to give access to five paired groups of outlets per numeral. That is, a total of 10 paired outlet groups is catered for, the average availability being 25.

Incoming Group Selectors from non-17 exchanges—those which cannot pass for traffic on a "paired numeral" basis—can give access to paired and non-paired outlets as required. For paired groups the outlet availability is 50, but for non-paired groups this availability is split into two.

Incoming First Selectors— similar to local First Selectors—provide for outlet search after the receipt of one or two digits; in the case of 2-digit reception, 20 different selections can be catered for, 10 relevant to each of two numerals at the first-digit stage. In the case of traffic routed after one digit, 10 groups each of 10 outlets are normally available. For traffic routed after the receipt of two digits, which traffic is dealt with on a "paired numeral" basis, provision is made for 10 paired groups each of an availability of 15. With respect to both 1-digit and 2-digit calls, the availability per group can be adjusted to meet requirements. Pairing is also applicable to first-digit selection.

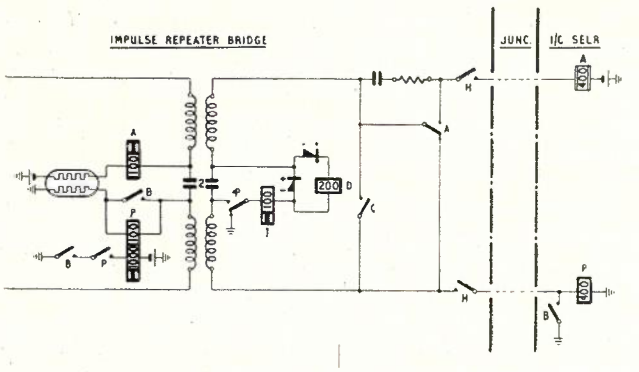
Incoming Selectors from a trunk exchange, do not necessarily need access to all the routes served by other Incoming Selectors, for the reason that direct access from the trunk exchange to other exchanges in the network will usually be provided.

All Incoming Selectors are individually controlled, and each type involves one motor uniselector and one digit switch. The number of relays used varies with the type of circuit, being 6, 5 and 8 respectively for the three types of Selectors listed above.

Transmission Bridges.

The local transmission bridge does not form part of a selector, but is an entirely separate unit; it consists of a relay set which accommodates the apparatus for two bridges. Each circuit has 6 relays and one ballast resistor. This arrangement has been adopted to effect economies in the provision of transmission bridges, the bridges being fitted where the fewest are required. This is normally between the First Selector and the subsequent Group Selector, but there may be trunking conditions which warrant some of the bridges being fitted elsewhere in an exchange.

To simplify impulsing and signalling conditions during the setting up of calls, the transmission bridge is by-passed until connection is made to the called line, operation of a relay within the unit brings the feeding elements into circuit at the appropriate time. The bridge is of the "capacitor" type, It provides a ballast type of feed to the called line, controls the application of ringing current, ring tone and metering current and provides for an alarm under Called Subscriber Held (CSH) conditions. Facilities are provided for the rapid identification of calling circuits which bring about such alarms. It is a scheme which enables the Linefinder or Incoming Selector concerned to be directly identified without involving examination of intermediate switching circuits. This call tracing can be used for the backward tracing of calls from any switch rank or outgoing junction relay set. The maintenance man is led to the point of entry of the call to the exchange by a trail of flashing lamps.



1. IN ADDITION TO THE NORMAL FUNCTIONS OF THE IMPULSE REPEATER BRIDGE, THIS CIRCUIT RELAYS THE DIFFERENTIATING SIGNAL EMPLOYED IN CONJUNCTION WITH PAIRING

2. GREATLY IMPROVED OPERATIONAL PERFORMANCE IS OBTAINED DUE TO THE USE OF THE NEW TWIN CHANGEOVER HIGH SPEED RELAY FOR RELAYS A,P AND I

3. WHEN CIRCUIT SEIZED, RELAY P OPERATES IN SERIES WITH A EXCEPT WHEN THE DIFFERENTIATING EARTH IS APPLIED TO THE +VE WIRE BY THE PRECEDING SELECTOR.

4. THE DIFFERENTIATING SIGNAL IS REPEATED BY A P CONTACT. AT THE DISTANT SELECTOR P OPERATES IN SERIES WITH A ONLY IF THE BRIDGE P RELAY IS OPERATED

Fig. 9.—Impulse Repeater Bridge element for junctions with pairing

An important feature of the circuit is that it prevents the false operation of Linefinders in the case of the caller clearing first. In such cases, the bridge releases the "calling" side of the connection but holds the "called" side. A period is then measured off to allow the called line to clear and only if this period is exceeded will a Linefinder be brought into use.

Outgoing Junction Relay Sets.

All Outgoing Junction Circuits embody principles which avoid many of the difficulties experienced in the past. These principles have resulted in a type of circuit that is very simple indeed. Relays are saved and a substantial reduction has been made in the number of relay contact points used. These Outgoing Junction Relay Sets are of the Impulse Repeater types, embodying a repeating coil for sectionalising inter-exchange connections. Fig. 9 shows the skeleton arrangement for this type of bridge. The impulse-repeating relay embodied in the bridge is the recently developed high-speed relay with two changeover contacts. By the use of this relay, in conjunction with the bridge arrangements employed, impulse distortion is eliminated for all practical purposes. The OGJ relay set used for working between No. 17 exchanges also repeats the pairing signal, as is shown in Fig. 9.

Typical Trunking.

Fig. 10 shows the principal circuits used in a typical 6-digit main exchange, and Fig. 11 performs the same function for a 6-digit satellite exchange. In these two figures, "X" indicates the location of the transmission bridges. The local transmission bridge is by-passed during the setting up of a connection. Access to special services may be obtained, as required, from the First, Discriminating or Group Selectors. It must be emphasised that the trunking arrangements are very flexible and can be varied considerably from those shown to meet differing numbering and traffic requirements.

Satellite Exchanges

Except for the substitution of a Discriminating Selector for the First Selector (and, of course, the associated Controls), and the provision of outgoing junctions to the parent exchange, satellite switching arrangements are the same as for a main exchange. The following description, therefore, refers only to circuits peculiar to satellite working. The trunking diagram for a typical 6-digit exchange appears in Fig. 11.

Discriminating Selectors.

An individual Discriminating Selector comprises a motor uniselector and three relays. A separate junction finder is not used—the function being performed by the motor uniselector, via a group of early-choice outlets. This is another case where advantage is derived from severing the mechanical relationship between the device which records the number dialled and the device which selects outlets. The Control records the dialling until discrimination is complete, up to which stage the motor uniselector will be engaging a junction to the parent exchange; if it is then determined that the call is local, the motor uniselector simply moves, at the appropriate time, to a position further round its bank.

When a call is originated, a Linefinder locates the calling line, the relevant Discriminating Selector Control is engaged, and a junction to the parent exchange is selected. The dial impulses are both recorded in the Control and repeated to the Incoming Selector at the parent exchange.

The Control determines the eventual direction of the call; it provides for discrimination at the first, second, or third-digit stage. The connection to the parent exchange is released if the call proves to be local, and the Control is released as soon as the Discriminating Selector is switched to an outlet leading to the next local switching stage. If the call proves not to be local, the Control is released after discrimination to that effect has been completed. A control com-

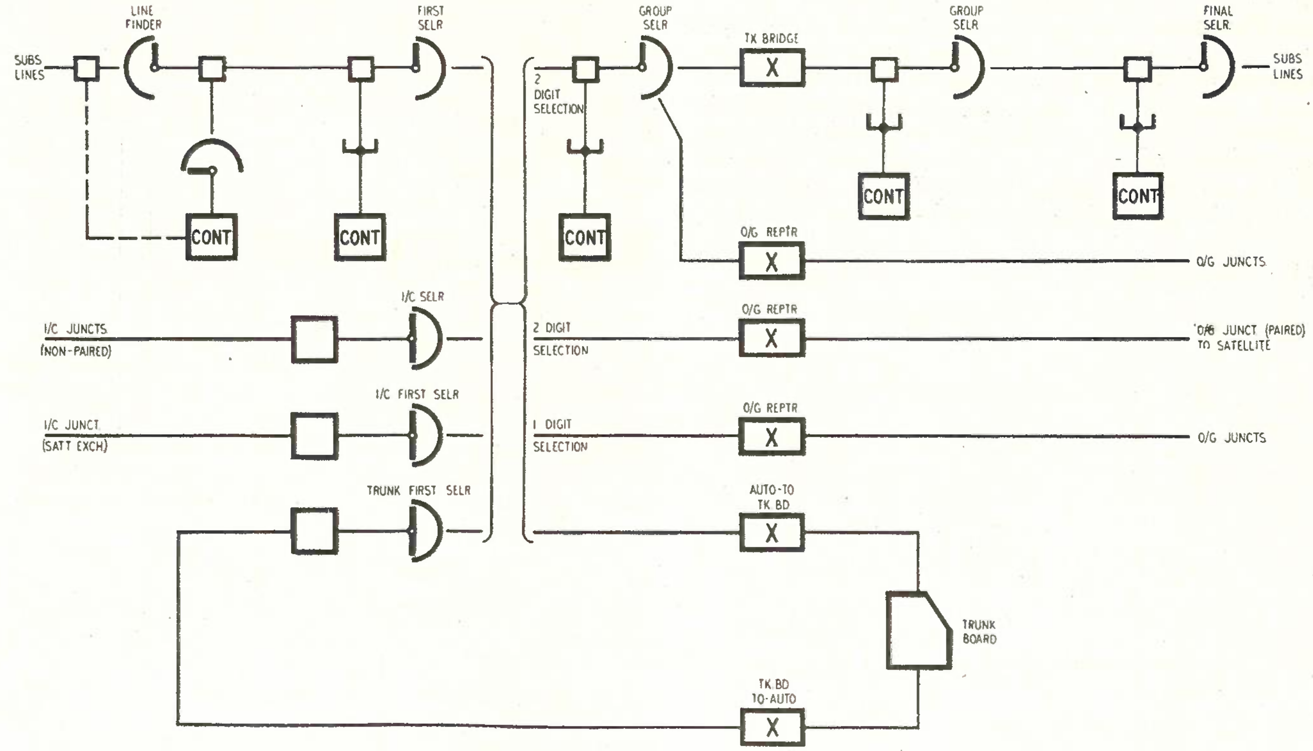


Fig. 10.—Trunking diagram for a typical 6-digit Main Exchange.

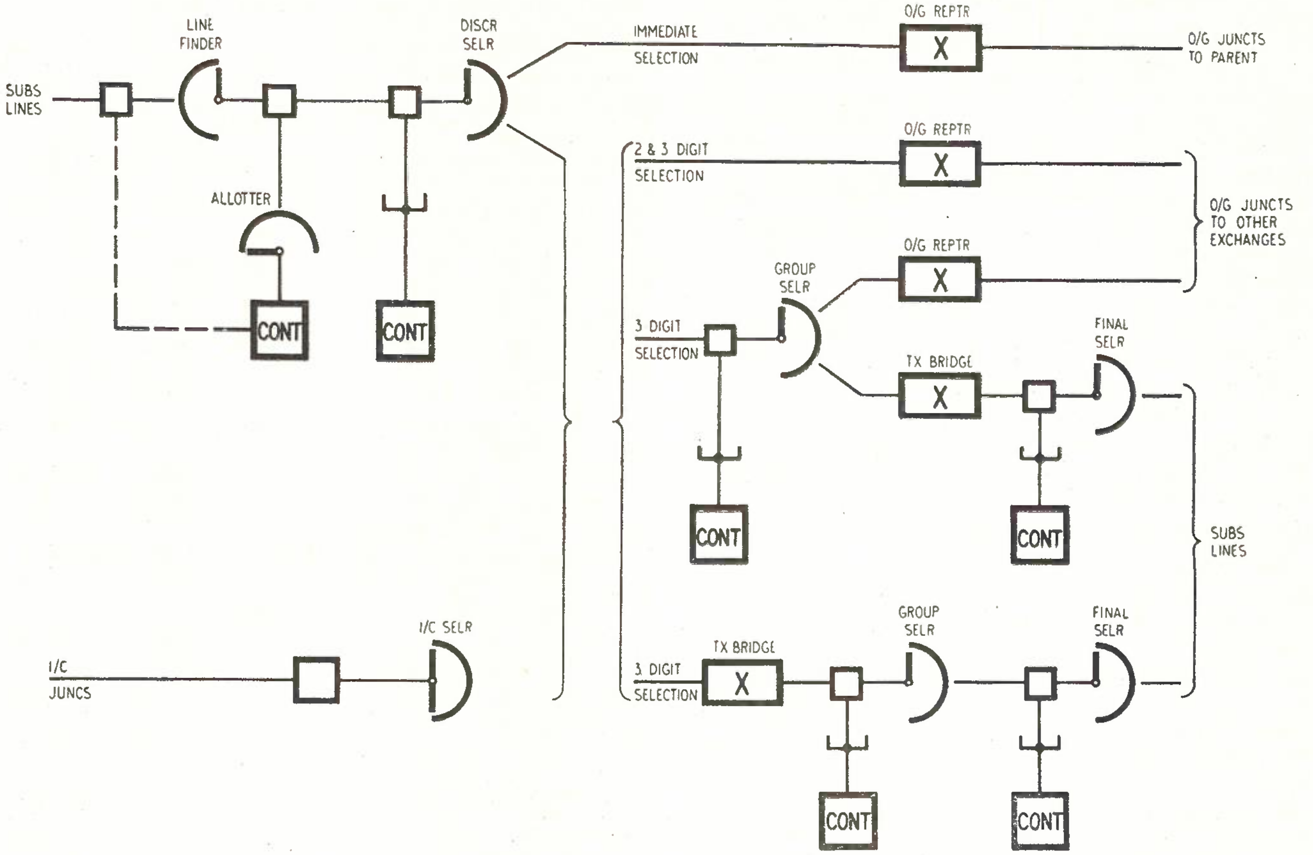
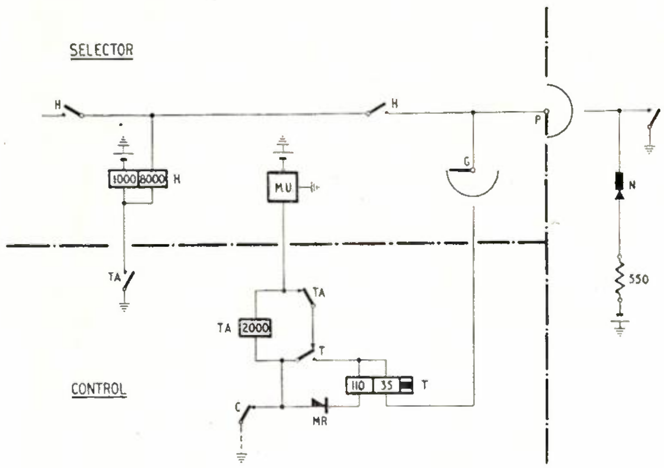


Fig. 11.—Trunking diagram for a typical 6-digit Satellite Exchange

prises a number of relays and three Digit Switches; the latter correspond to the three digits which a Control can take, from which it will be evident that, by the multiplicity of ways in which it is possible to cross-connect between the bank of one Digit Switch and the wipers of the next, an unusually high degree of flexibility in discrimination is possible. In cases where such a wide range of discrimination is not required, a Control of the comprehensive type just referred to would of course, not be necessary, and would be replaced by smaller Controls having fewer relays and Digit Switches.



1. RELAY T - THE HIGH SPEED TESTING RELAY - OPERATES VIA A FREE P WIRE SEGMENT (550 OHM RESISTANCE TO BATTERY.)

2. THE T CONTACT STOPS THE SWITCH, ENGAGES THE P WIRE SEIZED AND ALLOWS THE HIGH RESISTANCE RELIEF RELAY TA TO OPERATE IN SERIES WITH THE MU. LATCH MAGNET.

3. TA OPERATES THE SWITCHING RELAY H WHICH SUBSEQUENTLY HOLDS VIA ITS HIGH RESISTANCE WINDING TO THE EARTHED P WIRE.

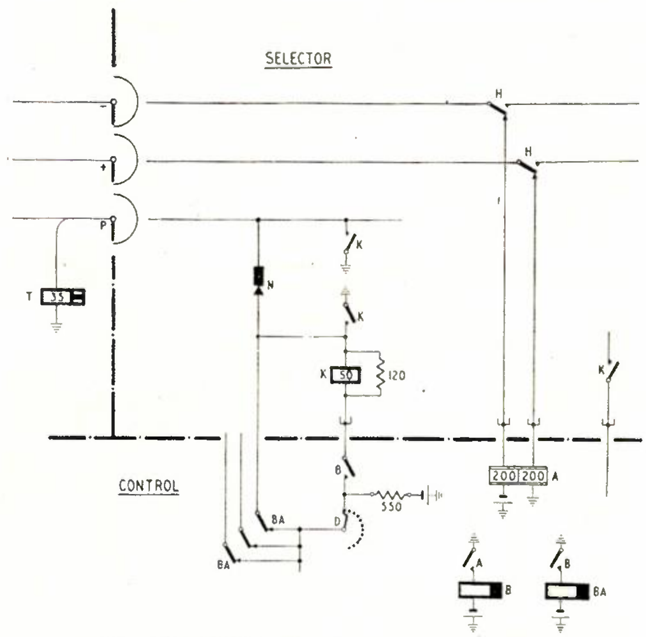
Fig. 12.—Outlet testing and switching principle

Apart from those allocated to parent exchange junctions, the outlets of the Discriminating Selector can be allocated either for local switching only, or for both local and miscellaneous switching, in accordance with requirements. The outlet grouping arrangements are extremely flexible, and, due to the use of pairing, availability is ample for all purposes.

Outgoing Junction Relay Sets.

The Outgoing Junction Relay Sets on satellite-to-parent and adjacent exchange junctions will be the same as those employed at main exchanges unless multi-fee metering is required. They will then differ due to the determination of the meter fee taking place in the Discriminating Selector Control, from which point it is transferred to the Outgoing Junction Relay Set which impulses the caller's meter when the called party answers.

The arrangements are such that the fee may be determined at a stage earlier or later than that of route determination; for instance, a Control may determine at the second-digit stage that the



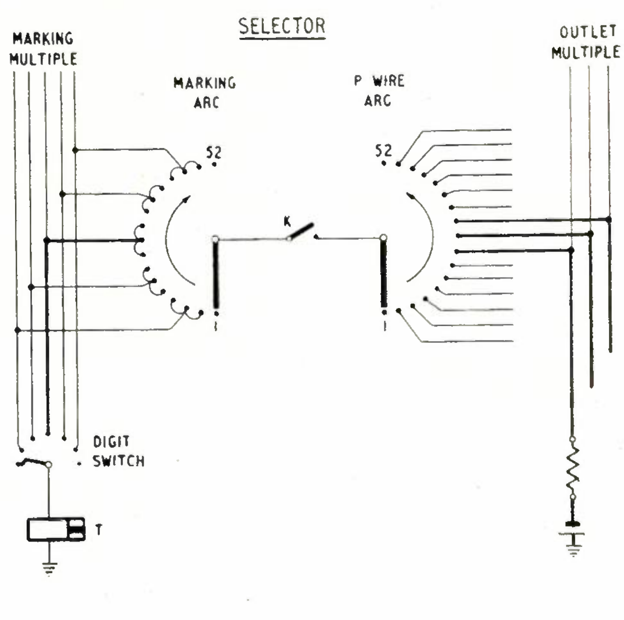
1. PROVIDING SELECTOR & CONTROL NORMAL, THE PRECEDING T RELAY OPERATES TO BATTERY VIA 550 OHM RESISTANCE

2. RELAY A OPERATES VIA CALLING LOOP; B OPERATES FOLLOWED BY BA.

3. RELAY K NOW OPERATES & ITS CONTACTS COUPLE REMAINDER OF CIRCUIT TO CONTROL.

4. THE P WIRE MULTIPLE IS EARTHED VIA RELAY K AND THE COMMON TO THE OTHER SELECTORS.

Fig. 13.—Method of coupling Selector to Control



1. THE DIGIT SWITCH CONNECTS RELAY T TO THE MARKING LEAD RELEVANT TO THE GROUP REQUIRED.

2. DURING ROTATION, WHILE THE MARKING ARC WIPER MAKES CONTACT WITH THE MARKED SEGMENTS, RELAY T BECOMES CONNECTED TO THE P WIRE ARC WIPER AND CONSEQUENTLY TESTS FOR A FREE OUTLET IN THE RELEVANT GROUP.

Fig. 14.—Group selecting principle

call is to proceed via the parent exchange, but it may not be until reception of the third digit that the fee to be charged is determined.

Circuit Principles

The main circuit principles special to the No. 17 system have all been employed in the Melbourne Automatic Trunk exchange and, in consequence, are not described here in detail. Fig. 12 shows the outlet testing and switching principle, Fig. 13 the method of coupling a selector to a control, and Fig. 14 illustrates the group selecting principle. Principles not peculiar to the No. 17 system follow standard practice.

Equipment Arrangements

From the point of view of appearance, and largely with respect to detailed construction, the racks fall into the following categories:—

Linefinders, and all Selectors except Incoming types.
Incoming Selectors.
Line Relay Racks.
Meter Racks.
Racks accommodating only relay sets.
Alarm Equipment and similar racks.

The Incoming Selectors fall into a category of their own as individually-controlled circuits have only two panels of selectors per rack, whereas all other Selector racks are equipped with three panels.

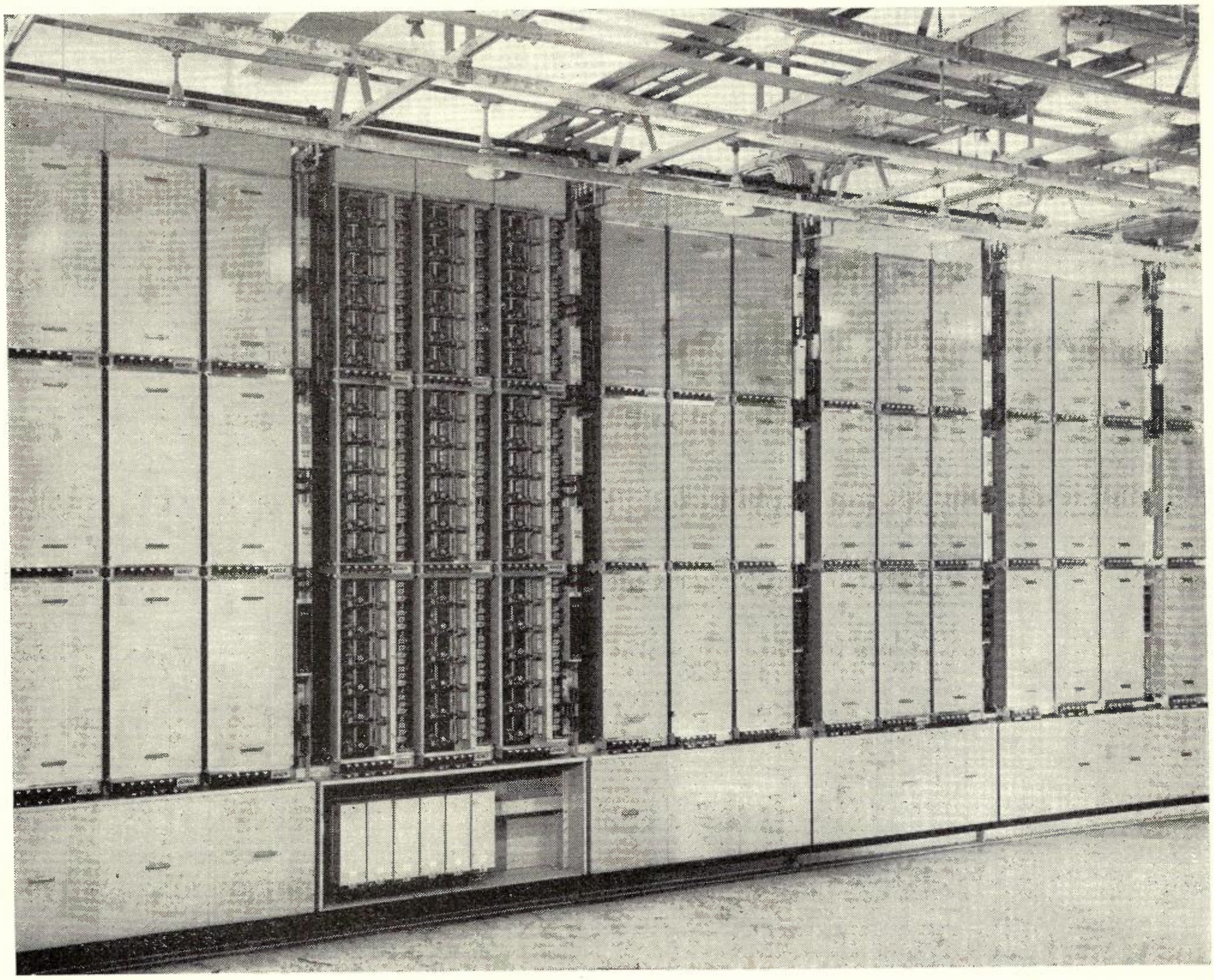


Fig. 15.—Suite of Selector Racks

General Features of Switch Racks.

The 3-panel type of rack covers Linefinders and First, Group and Final Selectors. In external respects, all these racks appear alike; internally, they differ only in respect to detailed apparatus and wiring arrangements.

Overall dimensions are 10′ 6½″ high, 4′ 3″ wide and 1′ 0½″ deep. That is, a rack is the same height as for standard two-motion selector systems, but is slightly less in width and depth. Figs. 15 and 16 show front and rear views respectively. Five main items go to make up a complete rack; they are the rack framework itself, the Control Compartment, and three Panels. Each Panel comprises three Blocks, each with capacity for 6 motor uniselectors and associated spark quenches and relays. The front view of an uncovered Block appears in Fig. 17. Of the remaining apparatus, cabling terminals are mounted above each Panel, busbars and fuse mountings appear on the left hand side, and miscellaneous relay mountings on the right hand side. Mounted below the front cover of each Block is a set of 6 test jacks and busying keys, whilst those associated with the Controls are mounted on the top cover of the Control Compartment. The busying keys have handles which rotate and, when operated, clearly show against the light finish of the cover supporting detail just above them.

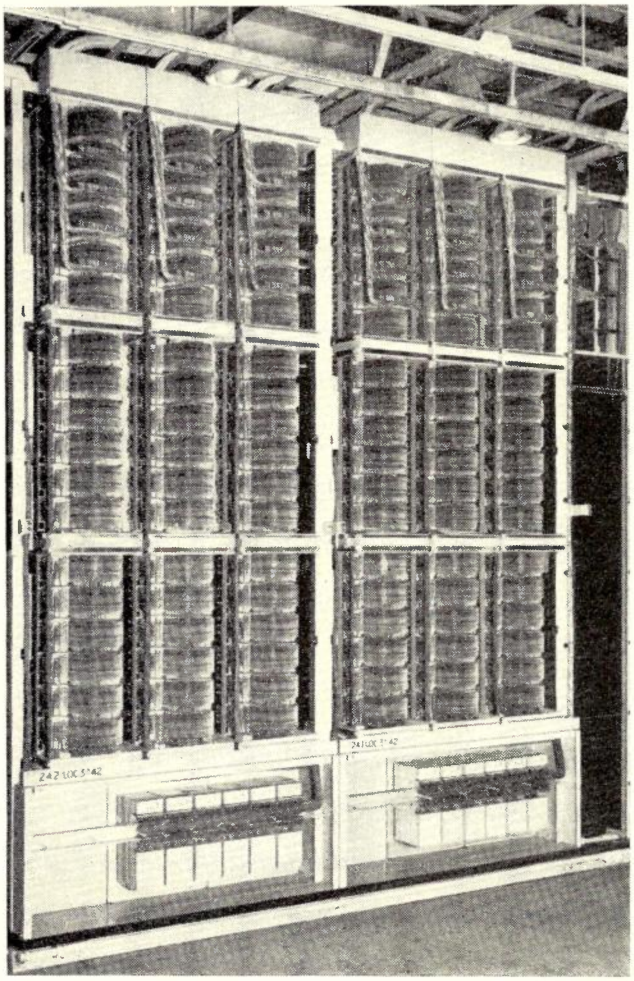


Fig. 16.—Rear view of Selector Racks with all covers removed

A rack is shipped completely equipped, except that relay sets for the Control Compartment are boxed and shipped separately, and the terminal strips above the Panels are bolted, for transit, into a position in which they come below the level of the rack top detail.

The height of 10′ 6½″ actually is that of the rack, plus a channel-section packing piece which fits between the top of the rack and the overhead framework (Fig. 18). With the packing piece detached, a rack can easily be moved into position without risk of fouling anything, as the completely cabled framework is temporarily supported at the correct level by means of tubular steel pillars forming part of the installation tool kit. With the pillars aligned in what will eventually be the rack gangways, the bringing and fitting of racks into position, just prior to the wiring stage, presents no difficulties.

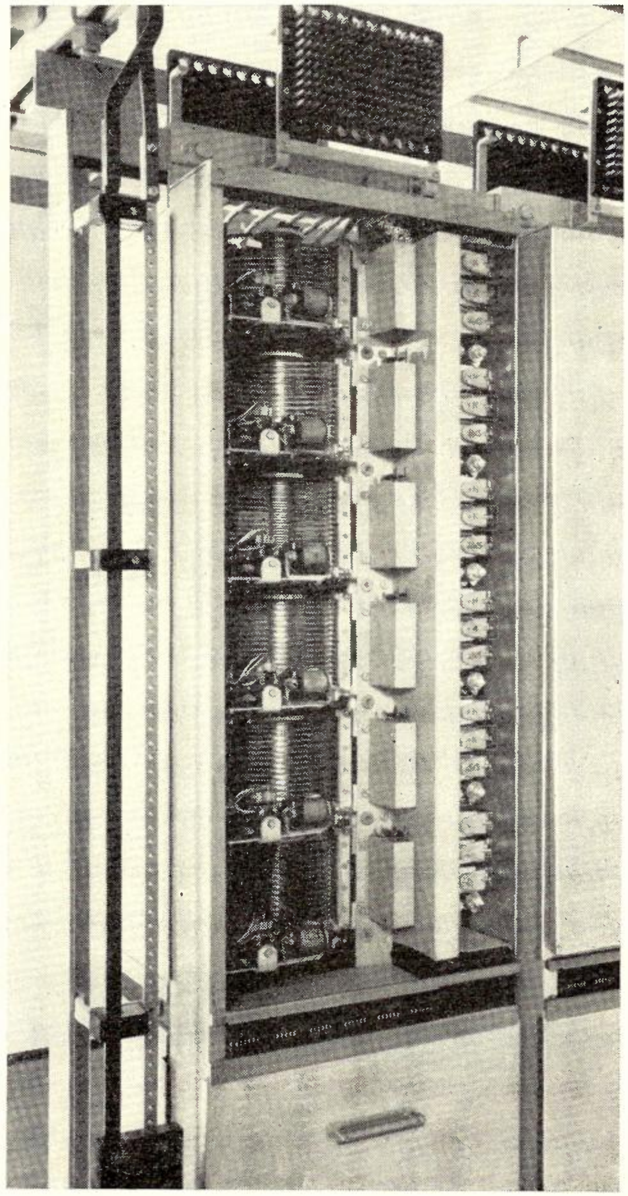


Fig. 17.—Block of Selectors

Except for the rear cover of the Control Compartment, which is secured by means of quickrelease screws, all front and back covers are removed by the familiar "lift and withdraw" action. The side covers of all Blocks are removed by sliding them out of position. With a rack thus stripped of covers, apparatus and wiring are readily accessible. In the case of the Control Compartment, three front covers are used, the centre one locking the two outer covers in position. All covers are constructed of sheet aluminium, appropriately edged to give stiffness.

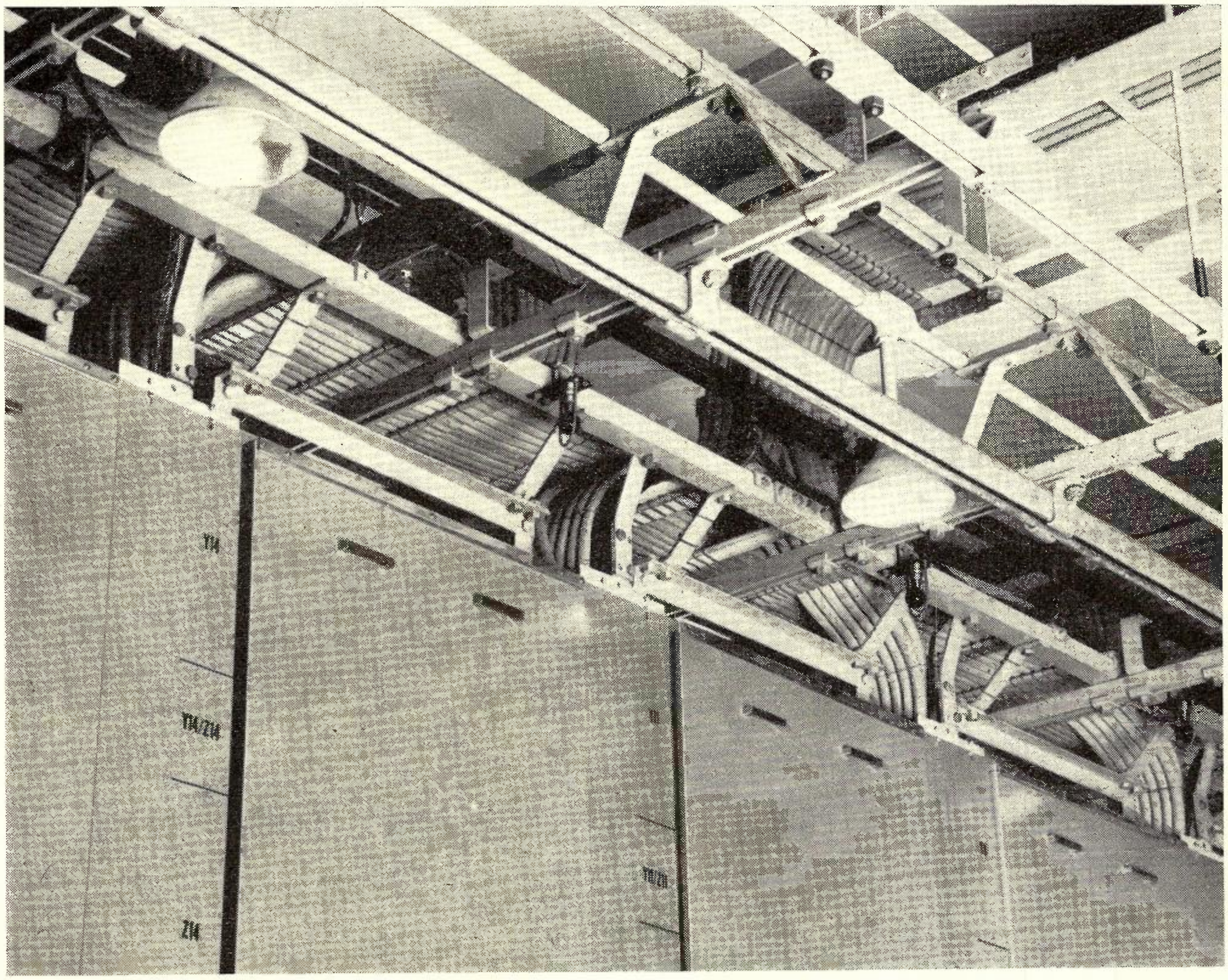


Fig. 18.—View of overhead cabling

The problem of "parking" covers, especially in the case of a maintenance man up a ladder, has been solved by providing clips behind the cover handles; these enable a removed cover to be hung on the handle of an adjacent fitted cover, then another hung on top of that, and so on. It is also arranged that a cover can be reversed, so that its inside faces outwards to preserve the outside finish whilst final installation work is proceeding. Removable side covers are also provided with clips for "parking" purposes.

The main external difference between a 3-panel and a 2-panel rack is that the panels in the latter are wider because they have to accommodate the apparatus for individually-controlled Incoming Selectors. In consequence, there is no Control Compartment, the space thus being available for mounting miscellaneous equipment. Each Block accommodates 6 circuits, so that the rack capacity is 36 circuits.

With the exception of Linefinders, all 3-panel racks accommodate 54 individual circuits, with provision for up to 9 Controls per rack. Linefinders involve 3-panel racks considered in pairs, 9 Blocks on one and 8 Blocks on the other accommodating the 102 Linefinders of a Division; the remaining Block accommodates the Allotter switches. Controls and Start circuits are mounted in the Control Compartment.

A rack presents two main types of finish. The framework is the usual type of grey paint. The covers have a stoved glossy mottle-grey finish, which is extremely durable. The mottle effect, though slight, is sufficient to mask accidental defacement.

Multiple.

The maximum size of the ribbon multiple is 18-pitch, relevant to the 18 bank positions in a Panel. 6-pitch and 12-pitch sizes are made for meeting cases where a split is required either between the centre and upper Block or between the centre and lower Block. Normally, multiple "tails" extend from the topmost "pitch" position to a bank at the top of an adjacent panel. It is by this method that multiples are tied together to form a grading group. The number of ribbons per multiple is 50.

Switch Rack Design.

A switch rack comprises a framework of rolled steel section which is welded to all joints. To this the Panel frameworks are hooked, and then bolted top and bottom, after all wiring relevant to the Panel itself has been completed. The Control Compartment is built up of brackets and sheet details and encloses the lateral bar on which the relay set mountings are accommodated.

The Panel framework comprises vertical members extending the full length of the Panel and constructed of pressed steel sheet formed to give adequate strength against bending during transport. One of the vertical members is of deep "U" section, which forms a channel for accommodating multiple tails from intermediate bank positions when the multiple is split; the tails enter the channel immediately above the topmost bank of the multiple, disappear behind a relay plate mounting covering the channel, and reappear at the top of the Panel. With this arrangement, multiple tails are fully protected, and accessibility to intervening wiring and multiple is not impaired. Motor uniselector banks are fixed directly to two of the vertical members. Relays are plate-mounted; in the case of 3-panel racks, there is one plate per Block, whilst with 2-panel racks, there is one plate per circuit, also mounting the associated digit switch.

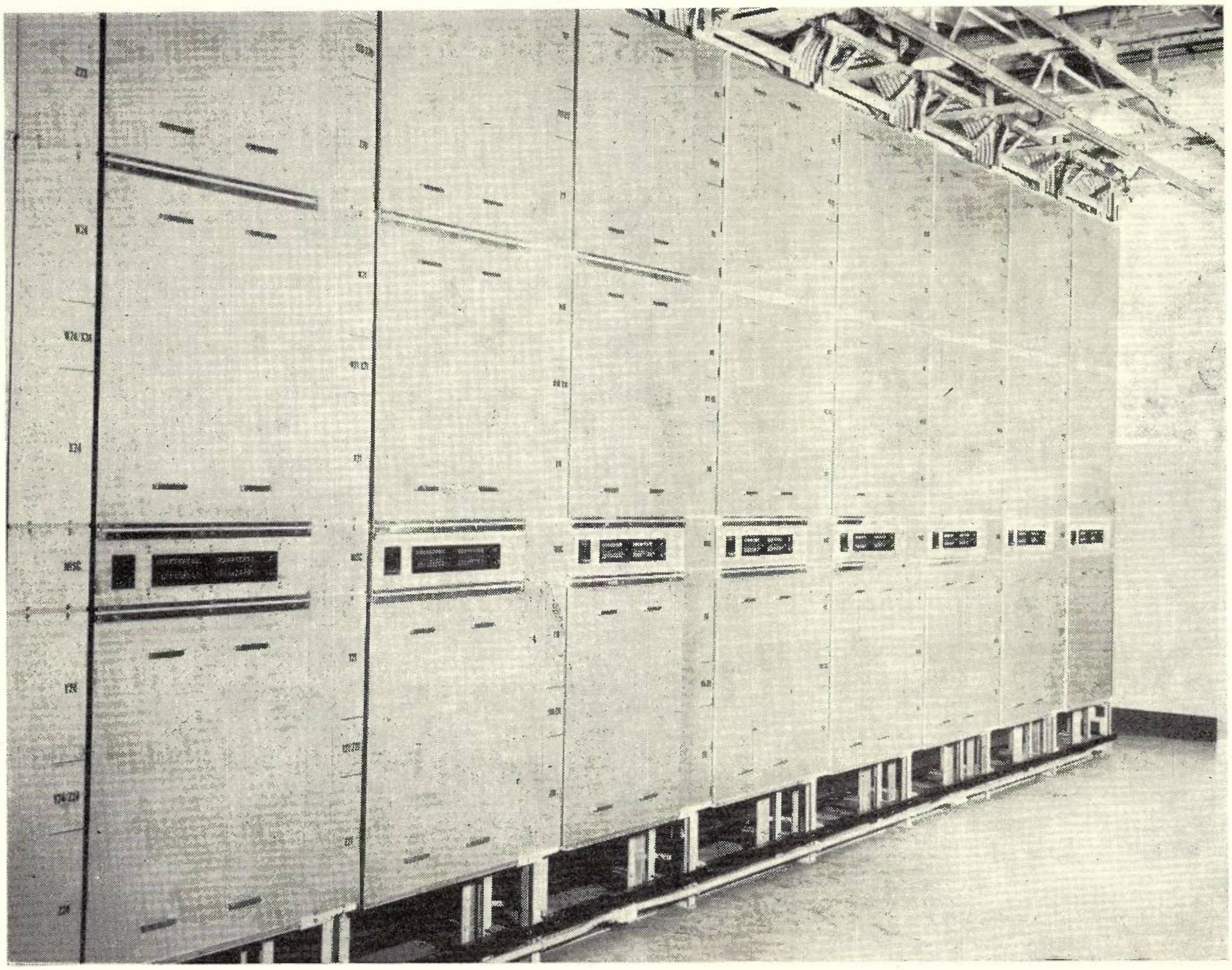


Fig. 19.—Suit of Subscribers' L & K Relay Racks

Line Relay Racks.

Subscribers' L & K relays are mounted on racks which when completely enclosed are similar in appearance to a panel of individually-controlled selectors. As can be seen from Figs. 19 and 20, the removal of a cover exposes 100 subs. ccts. mounted on five plates of 20 circuits each. Since both sides of the rack are identically equipped, each rack caters for 600 Line Circuits, together with the relevant fuses and Subscribers' Disconnect keys, which are equipped on a small miscellaneous panel. Access to the wiring of relays is obtained by using simple outrigger tools which enable a relay mounting plate to be drawn forward and hinged through 90° as shown in Fig. 20.

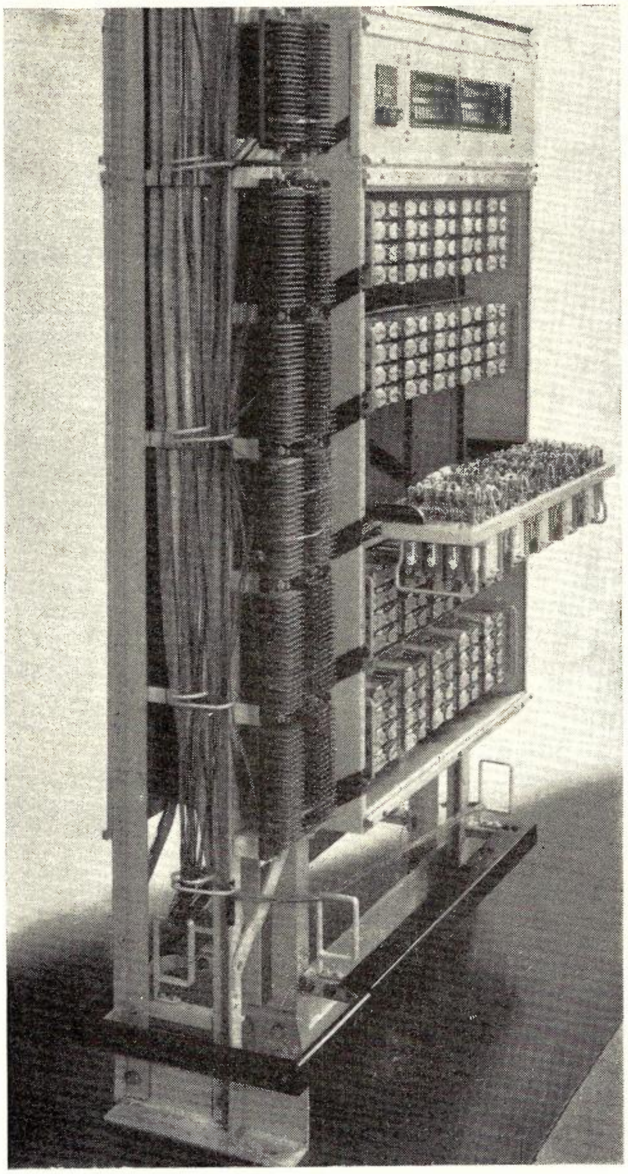


Fig. 20.—Lower Section of a Subscribers' L & K Relay Rack showing relay plate on outriggers and De-centralised IDF arrangements

On either side of each relay rack is located a framework which supports the terminal strips associated with the relay plates, accommodates the cabling from the linefinders, final selectors, etc., and provides decentralised IDF jumpering facilities. These frameworks are positioned in advance of the relay racks to facilitate pre-cabling, and the wired relay plates are despatched separately to site to avoid handling difficulties.

General.

Meter racks, relay set racks and other miscellaneous racks follow conventional practice except that double-covering is used for any items of a "key" character and wiring is brought to terminals at the top of the rack when the alternative of cabling directly to the apparatus would impede installation of the main equipment items. The remaining items of equipment, such as the MDF, follow conventional practice and conform, in general, to present-day standards.

Installation.

A feature which will be of interest is that the erection of a new exchange is not carried out on the principle of building a house around its furniture. It is only after all cabling has been completed, to the stage of wires from finished butts being ready to thread through rack terminal blocks, that racks need be brought into the switchroom. The rack design permits of this being done easily and in a straightforward manner.

Traffic Considerations

Given reliable apparatus and well-designed circuits, efficient service depends on having sufficient equipment grouped in an economical manner. The No. 17 MAX System provides a number of different facilities, each of which promotes efficient grouping, and which, in combination, enable economies to be effected. The flexibility of the arrangements permits these facilities to be used in such a way that, for any particular case, a maximum overall economy can be achieved. The following are some of the many factors which were taken into consideration before the No. 17 System was evolved. The term "trunk" as used in this section of the article means a connecting link between a multiple on one rank of switches and the incoming terminals of a switch in the next rank.

Outlet Capacity of Switch.

It is well known that the greater the availability afforded by a switch, the greater is the traffic-carrying capacity of the trunks to which it gives access. The rate of increase of the latter falls off, however, as the former increases, so that a point is reached where the economy due to the increased availability is offset by the cost of providing it.

The precise point at which increased availability is offset by cost depends on a variety of factors. Our investigations have shown that the optimum size of a group of outlets occurs somewhere in the neighbourhood of 20. This calculation was made on the basis of apparatus within the exchange itself, leaving, for treatment by special means, outlets leading to abnormally expensive circuits. Assuming an average of 10 routes outgoing from each rank of switches, this fixes the optimum outlet capacity at 200.

Volume of Traffic per Route.

One advantage derived from the No. 17 "pairing" principle is that it enables the traffic relevant to two numerals of a digit to be combined into a single route. The overall number of routes required is thus reduced, resulting in the volume of traffic per route being increased. The following table illustrates the point:

Two groups of traffic

TU's per Group	Individually handled	Combined into a single route
5	$2 \times 13 = 26$	20
10	$2 \times 20 = 40$	36
20	$2 \times 36 = 72$	68

Availability.

The outlets within any section of the bank can be allocated to the different groups in accordance with the traffic distribution and the costs of the various circuits. Spare numerals do not use any outlets. These facilities can result in an appreciable saving in trunk costs.

Two-digit Selection.

In the No. 17 System, the First Selector has been arranged to provide for both one and two-digit selection, thus combining the functions of the First and Group Selector in a 2-motion selector system, and thereby eliminating a rank of switches on certain routes.

Owing to the fact that the number of outlet groups is reduced by pairing, this saving is normally possible without any reduction in availability or increase in the size of the switch. For the case of an exchange with a large number of junction groups, a 250-outlet First Selector has been specially designed.

Control of Switching.

The principle of a Control common to a number of selectors would, on the face of it, indicate a grade of service lower than that for an individual-control type of system. This admittedly would be so were the blockage effect of common control working not taken into account, but in the No. 17 MAX system such effects are compensated by the provision of additional selectors. The increase, for the short holding time of No. 17 Controls, is quite small, comparable, in most cases, with that resulting from an improvement in the grade of service from .002 to .001. For First Selectors there is one Control per 6 selectors with one Control per 9 Group or Final Selectors.

Notwithstanding this effect of more selectors being required for a given grade of service, the savings due to the use of coupled Controls more than compensate for such increase in selector equipment. Experience with the No. 17 System, to date, has supported the opinion that this method of controlling selectors leads to a reduced overall fault incidence.

Linefinders.

For many years there has been a growing prejudice against linefinder systems, arising almost entirely from difficulties experienced with the adaptation of two-motion selectors to that purpose. Having in mind that the two-motion switch was designed as a selector, the difficulties encountered are perhaps not unexpected. Moreover, in the pursuance of capital economies, secondary working was introduced, giving rise to various complications as well as making the system more sensitive to overload conditions. Such criticisms cannot be levelled at the No. 17 Linefinder scheme for two reasons. The motor uniselector is used in the capacity for which it was designed, and secondary working has been avoided.

With regard to traffic-handling capabilities, investigations have shown that the No. 17 Linefinder scheme is less sensitive to overload than any other method of connecting lines to First Selectors. The Table below gives extracts from such findings. It is assumed that the TU per line is .05, and comparisons require to be made against a normal grade of service of .002.

Grade of service for:—

	10 per cent. overload Linefinders			20 per cent. overload Linefinders		
Number of Lines	No. 17 scheme	With secys.	25 pt. Line Switch scheme	No. 17 scheme	With secys.	25 pt. Line Switch scheme
1000	.004	.010	.006	.009	.025	.025
2000	.004	.015	.008	.009	.035	.020
4000	.004	.020	.008	.009	.040	.020

Grading.

The arrangements in the No. 17 System provide for multipling switches in panels of 18 with facilities for a split at 6 or 12, which gives a high degree of flexibility in the formation of gradings. Any number of panels or racks can be multipled together and the multiple can be extended between suites by means of tie cables. The separate multiples are cabled to the TDF where they are graded together, as required, by means of jumpers.

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4. "Melbourne Automatic Trunk Exchange," Siemens Engineering Bulletin, Nos. 213-4, 215, 216, 217, 218, 220, 222.

5. "Motor Uniselectors," Siemens Engineering Bulletin, Nos. 113, 252.

6. "High Speed Relays," Siemens Engineering Bulletins, Nos. 110, 193, 248-9.

7. "Digit Switch," Siemens Engineering Bulletin, No. 251.

Editor's Note: A Siemens No. 17 Exchange has been ordered by the Department for North Essendon, Victoria. A description of this installation will be the subject of a subsequent article.

A VARIABLE EQUALISER FOR BROADCAST PROGRAMME CIRCUITS ON TRUNK LINES

C. M. Hall

Introduction.—Many difficulties were formerly associated with the satisfactory long-term equalisation of broadcast programme circuits on trunk routes in Queensland, where several circuits are 800 miles in length, and two exceed 1,000 miles. Equalising was generally carried out in sections of 100 to 250 miles, and after the first section, each succeeding equaliser was designed to compensate for the frequency distortion of the particular section, plus the small discrepencies left after an equaliser had been installed on the previous section. The usual method applied was to send a special team out to carry out the measurements, then design the requisite equalisers in the laboratory and forward them to their respective stations.

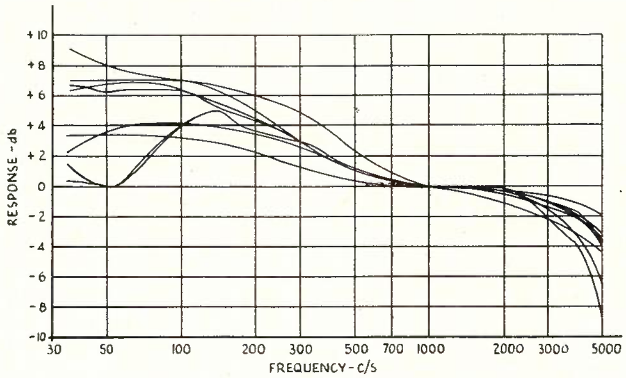


Fig. 1.—Broadcast Programme Lines on Trunk Circuits—Response Characteristics

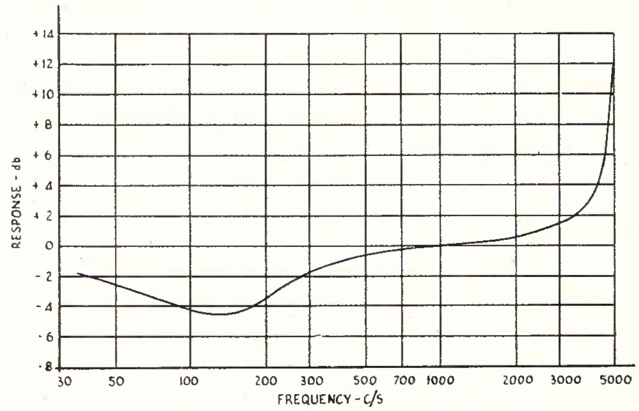


Fig. 2.—Required Characteristic Curve

When whole circuits had been equalised, it was inevitable that alterations such as the replacement of some aerial wire portion by cable, or substitu-

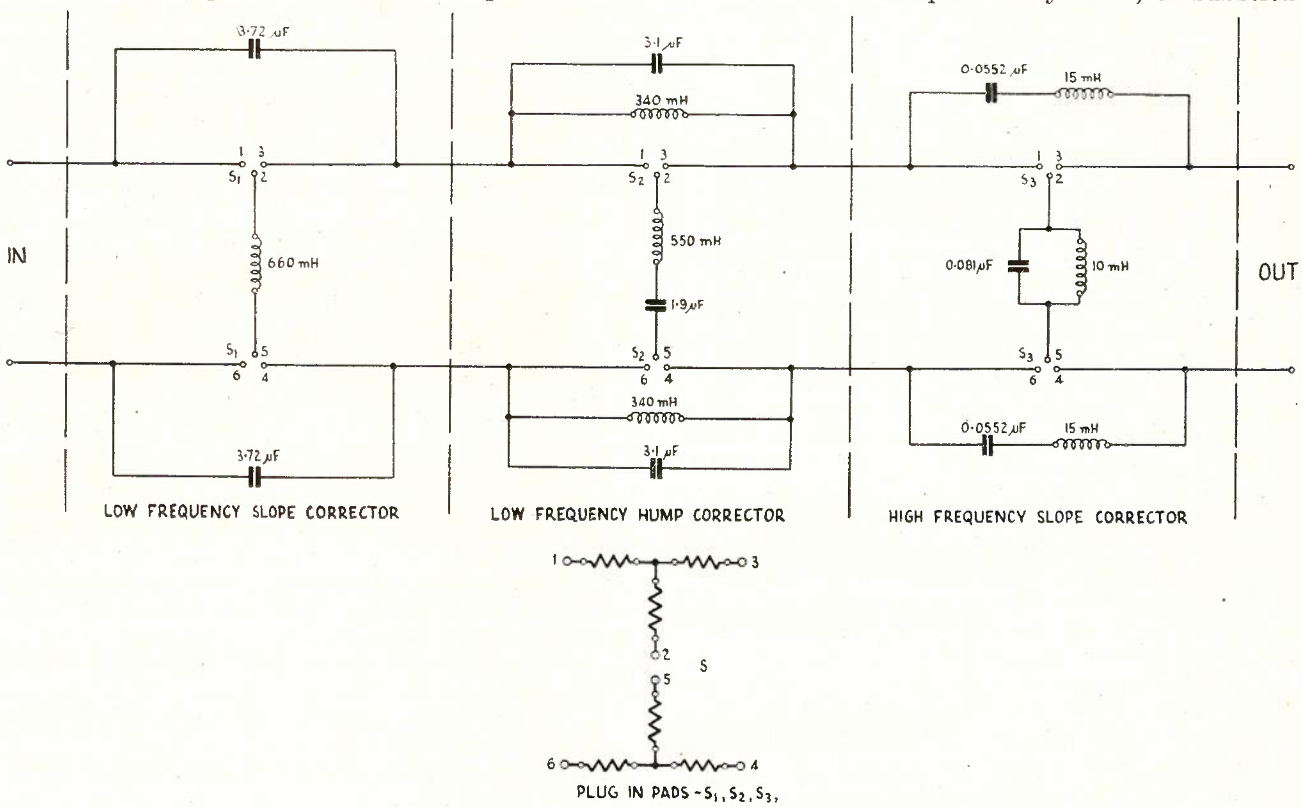


Fig. 3.—Variable Equaliser Schematic.

tion of loaded for unloaded cable, would occur with the resultant necessity to re-equalise the section in question. This in turn, of course, meant designing a new equaliser.

To simplify the problem, consideration was given to the provision of constant impedance variable type equalisers, a number of which were already available, but suitable only for circuits consisting mainly of unloaded cable. It was decided finally to design a single variable equaliser suitable for all programme lines on trunk circuits.

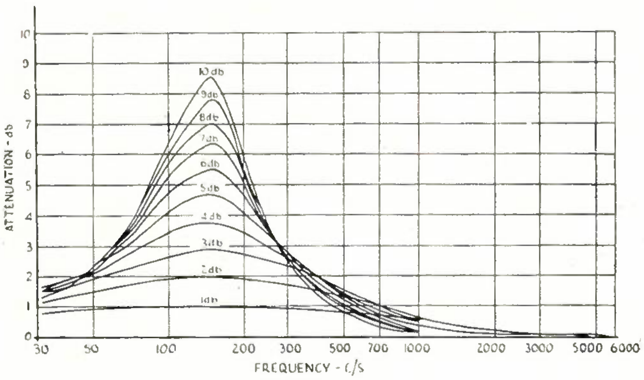


Fig. 4.—L.F. Hump Corrector

Preleminary Investigation: The first step was to obtain measurements of as many sections as possible, each with different characteristics, and to plot all their response curves on one sheet of graph paper, thus obtaining a general picture showing the limits of the equaliser's requirements. Fig. 1 shows a sample of the various responses obtained. It is interesting to note that in many circuits a "hump" appears at about 150 c/s, and, furthermore, when a number of sections are

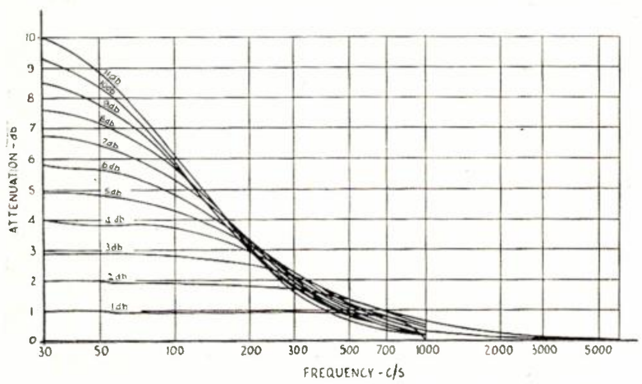


Fig. 5.—L.F. Unit

joined together, each section added increases the magnitude of the hump.

A study of Fig. 1 shows that the equaliser required the following general characteristics:—

(1) A section to correct the 150 c/s "hump" evident on many circuits.

(2) A section to correct the increasing loss versus frequency above 1 kc/s of the average circuit.

(3) A section to correct the remaining slope on a circuit between 35 c/s and 1 kc/s after the 150 c/s hump has been corrected.

These characteristics are shown in Fig. 2.

Design of Equaliser: The three respective sections were designed in the orthodox manner as bridged H type equalisers, and plug-in type pads were provided so that any reasonable degree of equalisation might be obtained in each section. 6-pin valve bases and 6-pin plugs to suit were

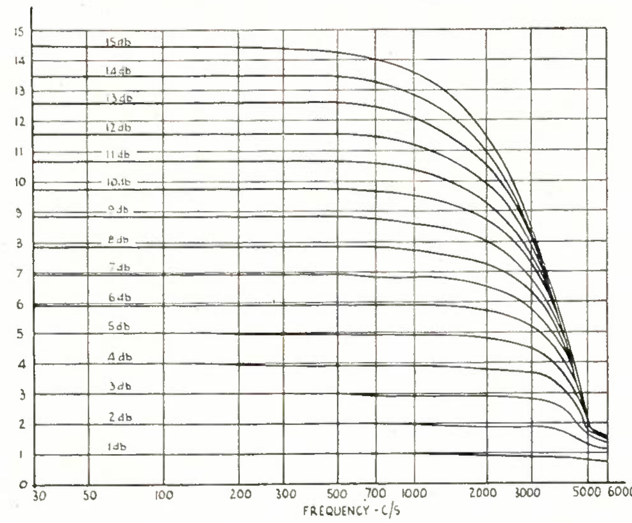


Fig. 6.—H.F. Unit

used. The attenuation pads were mounted on the plug by one brass metal thread screw, and the connections between pad terminals and plug pins were of heavy gauge copper, passed through holes in the pad former in such a manner as to prevent

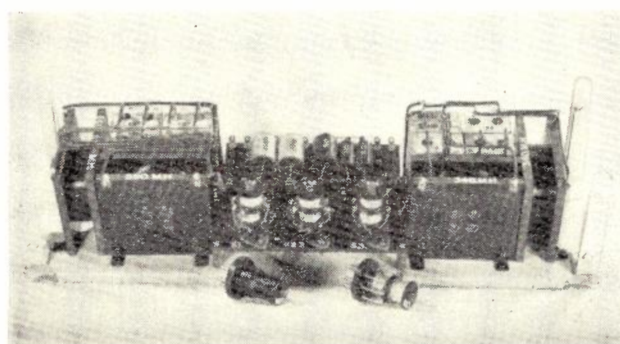


Fig. 7.—Construction of Equaliser

movement of the pad relative to the plug.

A schematic circuit of the complete equaliser is shown in Fig. 3, and graphs of the attenuation versus frequency characteristics for each section are shown in Figs. 4, 5 and 6.

A photograph of the equaliser, Fig. 7, shows details of construction clearly, and indicates that all the inductances used in the low frequency sections are air core type. Boxes containing a complete set of plug-in type pads from 1 to 10 db are forwarded to a station where the equalisers are to be adjusted initially, or amended subsequent to some line alteration. Immediately the adjustment is completed, the boxes and surplus pads are returned to Brisbane, or forwarded to another station. Any plug-in pads that were used are replaced from stock.

Method of Equalising a Programme Line Section: The principal steps in equalising a line are set out in the following:

(1) Fit 0 db pads (short circuit in series arm and open circuit in shunt arm) in each of the three sections of the equalisers, and insert the equaliser in the receiving end of the required programme line.

(2) Measure the circuit attenuation at 50 c/s, 150 c/s and 1 kc/s and record as response thus:—

Frequency	50 c/s	150 c/s	1000 c/s
Line attenuation	− 15.5 db	− 14 db	− 19 db
Response	+ 3.5 db	+ 5 db	0 db

Divide 50 c/s response by 2 and deduct this from the 150 c/s response to obtain the required correction for the 150 c/s "hump," in this case 5 − 3.5/2 = 3.25 db. From Fig. 4, it will be seen that a 4 db pad will serve the purpose. Therefore, remove 0 db plug from the hump corrector section and replace it with a 4 db plug.

(3) Remeasure and plot again line plus equaliser. The result obtained in this case should be:—

Frequency	50 c/s	100 c/s	1000 c/s
Equaliser — Line attenuation	− 14.5 db	− 14 db	− 19 db
4 db hump	− 2.1 db	− 3.8 db	− 0.5 db
Line + equaliser	− 17.6 db	− 17.8 db	− 19.5 db

Insert a pad in the low frequency slope corrector section of a value equal to the attenuation difference in db between the 1000 c/s and 50 c/s values of the line plus equaliser. This results in the following:—

Frequency	50 c/s	100 c/s	1000 c/s
Line attenuation	− 15.5 db	− 14 db	− 19 db
Equaliser 4 db hump	− 2.1 db	− 3.8 db	− 0.5 db
Equaliser 2 db L.F. (See Fig. 5)	− 2.0 db	− 1.85 db	− 0.5 db
Line + equaliser total	− 19.6 db	− 19.65 db	− .20 db

(4) Re-measure and check that the line plus equaliser response is "flat" between 35 c/s and 1 kc/s as indicated previously. Then include 3 kc/s, 4.5 kc/s and 5 kc/s in the attenuation measurements of line plus equaliser.

(5) Plot attenuation curves of line plus equaliser; thus:—

Frequency	50 c/s	150 c/s	1000 c/s	3000 c/s	4000 c/s	5000 c/s
Line + 4 db hump + 2 db L.F.	19.6 db	19.6 db	20 db	21.3 db	23 db	24.5 db
Apply 4.5 db correction with 7 db pad in H.F. section (See Fig. 6)	6.9 db	6.9 db	6.8 db	5.7 db	3.5 db	2.0 db
Final line + equaliser	26.5 db	26.5 db	26.8 db	27 db	26.5 db	26.5 db
Final response	+ 0.3 db	+ 0.3 db	0 db	− 0.2 db	+ 0.3 db	− 0.3 db

Conclusion: Following several tests in the field, 24 equalisers were produced in the Brisbane P.M.G. Workshops, and a number were installed on various programme lines. The cost of manufacture of the 24 equalisers was approximately £5 each.

One circuit, Rockhampton-Brisbane, a distance of 400 miles and consisting of three repeater sections, was equalised in October, 1950, using one equaliser at Bundaberg, Gympie and Brisbane.

The frequency responses before and after the equalisation were as follows:—

Three months after the initial equalisation the circuit still had a flat response, that is, within ± 1 db over the range 35 c/s to 5 kc/s, as compared with 1000 c/s.

	35 c/s	50 c/s	150 c/s	1 kc/s	3 kc/s	4.5 kc/s	5 kc/s
Before	+ 3.0 db	+ 6.0 db	+ 7.5 db	0	− 1.0 db	− 4.0 db	− 8.0 db
After	0	+ 1.0	0	0	0	0	0

ANSWERS TO EXAMINATION PAPERS

The following answers generally give more detail than would be expected in the time available under examination conditions. The additional information should be helpful to students.

EXAMINATION No. 2906—ENGINEER LINE CONSTRUCTION.

PART A—GENERAL

Q.3.—Enumerate the conditions applying to the crossing of telephone wires by low and medium pressure electric power wires.

Explain the term "anchor" and "semi anchor" structures as applied to electric power line crossing telephone lines and the circumstances under which each is used.

A.—(a) Low and medium pressure electric power wires are permitted to cross P.M.G. telephone wires subject to observance of the requirements specified under Statutory Rules, 1934, No. 30, which are regulations under the Post and Telegraph Act, 1901-1934.

Such crossings may be effected in an approved manner by the following methods.

(1) Overhead crossing clear of the telephone aerial construction.

(2) Overhead crossing by attachment of the power wire to the top portion of a telephone pole or to an extension of this pole.

(3) Under crossing of the telephone wires clear of telephone aerial construction.

Generally the methods adopted and the practices followed in carrying out work under the conditions referred to above, are designed to secure maximum protection of P.M.G. plant and personnel from possible damage or injury due to accidental contacts with the power lines. For this purpose standards of construction have been specified which apply to all power line construction. In addition, observance of authorised separations between the power and telephone wires is required and where attachments are made to telephone poles the material and construction employed must conform to the accepted designs approved by the P.M.G. Department in collaboration with the Electricity Supply Association of Australia.

The requirements relating to crossings of telephone wires may be summarised as follows:—

1. **Overhead Crossings**—Clear of telephone wires.

(a) Subject to observance of the required factors of safety for all elements of an aerial line of an electric authority as specified under Statutory Rules No. 130-1934 and to the proviso described under (b) hereunder, the aerial wires of an electric authority may be erected over the telephone wires of the P.M.G. Under these conditions low or medium pressure electric power wires must be maintained at separation of not less than two feet from any telephone wire.

(b) If the low or medium pressure aerial lines of an electric authority when taken in a direct line from an electric light pole to another electric light pole or to their point of attachment to a consumer's premises, would be at any point less than eight feet distant from any telephone pole, the low or medium pressure aerial lines shall be attached to the head of the telephone pole or an extension of that pole as provided under (2).

2. **Overhead Crossing.**

By attachment to a telephone pole.

Attachment of low or medium pressure aerial lines to a P.M.G. pole must be made in one of the following ways and in a manner satisfactory to the Postmaster-General.

(a) By approved insulator fittings attached to the head of the telephone pole or an extension of that pole.

(b) By attachment of a crossarm to the head of the telephone pole or an extension of that pole.

Where attachment cannot be made to the top of a telephone pole using approved insulator fittings or crossarm construction, the approved methods of effecting crossings of P.M.G. wires by attachment to an extension of a P.M.G. pole require the use of two types of raiser, each having as its main component a 4" x 4" hardwood spar or equivalent steel section attached to the P.M.G. pole to provide an extension thereof for the support of the power wires. These two types are designed to enable crossings to be made under the following conditions:—

(i) Where the wires may be supported directly by the spar. Up to three wires may be attached in this case, using approved type insulator fittings as shown on Dwg. C.836.

(ii) Where it is necessary to provide an arm bolted to the spar in a line parallel with the P.M.G. arms to give the necessary clearance of 2 ft. between the power and telephone wires at either end of the telephone arm. In this case a maximum of two power wires may be attached to the raiser structure as shown in Dwg. C.837.

In each case covered by (a) and (b) it is necessary to provide a minimum clearance of 4 feet between the lowest power wire and the centre of the top telephone cross arm, at the centre of the pole, and in addition to maintain a minimum separation of 2 feet between the lowest power wire and the outer telephone wire on the top arm of the telephone pole.

3. **Under Crossing.**

Where it is impracticable for low or medium pressure service lines of an electric authority to pass over telephone wires they may be erected below the telephone wires subject to observance of the following:—

(i) Low or medium pressure aerial lines shall not in any case be permitted to pass under the telephone wires where the service lines of the electric authority would pass within 8 feet of any telephone pole.

(ii) In every case where low or medium pressure aerial lines pass under telephone wires the neutral wire shall be run above the live wire or wires.

(iii) Where concentric type service cables are used for this purpose the outer conductor must be connected to the neutral distribution wire.

(iv) All low or medium pressure aerial lines must be kept 2 feet clear of the telephone lines in all directions.

(b) The terms "anchor" and "semi-anchor" structures as applied to electric power lines crossing telephone lines may be defined as follows: —

(i) **Anchor Structure.** This means a support at which all conductors are terminated or are connected therewith as if they terminated at the support, and which is capable, in the event of the breaking of all the conductors on any one side of the support being broken, of withstanding the consequent stress.

(ii) **Semi-anchor Structure.** This means a support having each conductor so attached to the insulators as to be able to withstand, without slipping, the full tension arising from the breaking of any such conductor in the adjacent span. The support must also be capable, in the event of any two conductors on any one side of the support being broken, of withstanding the consequent stress.

Anchor structures must be provided by electric authorities for the support of high pressure and extra high pressure aerial power lines where these lines cross over telephone wires under the following conditions:—

(i) If the pressure exceeds 66,000 volts between conductors, and a horizontal angle occurs in the extra high pressure aerial line at one or other of the structures supporting the crossing span such structure must be an anchor structure.

Semi-anchor structures must be provided by electric supply authorities for the support of high pressure or extra high pressure aerial power lines where these lines cross over telephone wires under the following conditions:—

(i) If the pressure exceeds 66,000 volts between conductors, and no horizontal angle occurs in the extra high pressure aerial line at either structure supporting the crossing span.

(ii) If the pressure exceeds 11,500 volts between conductors, but does not exceed 66,000 volts between conductors, and more than one telephone wire or two telephone wires forming one circuit are carried by the telephone pole route.

PART B—CONDUITS AND CABLES

Q. 4.—Discuss the advantages associated with the correct rotation jointing of P.I.L.C. telephone cable.

Enumerate and explain the tests and identification methods you would apply to a newly-jointed cable before commencing to transfer working lines thereto.

A.—Correct rotation jointing of P.I.L.C. cable reduces time spent on initial installation, and neater joints can be made more economically. At the two ends of any length of cable, of which the intervening joints have been jointed correctly in rotation, individual wires, pairs or quads can be identified readily without recourse to the use of identification or jointing schedules.

During maintenance operations identification is simplified, and any changeover to new cable may be made without individual wire testing.

Tests and Identification Methods for a Newly Jointed Cable Prior to Transfer of Working Circuits.

As it is proposed to transfer working circuits to the newly jointed cable, it is assumed that the cable is jointed through and terminated on open circuit fuse mountings on the M.D.F.

Preliminary tests will be to verify that all wires have satisfactory insulation resistance to the sheath or earth and also to all other wires. These tests will be carried out with a 500 Volt Megger. As the cable under test will be terminated on the M.D.F. these tests may be conducted at the "cut-over" point, where the wires should be fanned out and all ends stripped of insulation for approximately ½".

The wires should then be separated into groups; quad cable four groups, i.e., A. B. C. and D wires; twin cable two groups, A and B wires. One group should be connected to the "line" terminal of the megger and all others to the "earth" terminal, from which a connection is taken to the sheath or earth. Initially the megger handle should be turned slowly, to check for earths or contacts between wires in groups. A zero reading would give indication of this, and if the megger were rotated at full speed and a fault condition existed, the needle might be damaged. Any faulty condition should be located and rectified prior to the full test, in which the megger should be rotated at maximum speed. A reading equivalent to 5000 megohms per mile should be obtained for the new cable. Each group should be tested in this way before proceeding with the next test, which will be for wire to wire insulation resistance. Insulation resistance between wires is tested by removal of the earth connection and joining the separate groups of wires to the two terminals of the megger. At full speed rotation a reading equivalent to 2500 megohms per mile should be obtained.

Upon completion of the I.R. tests described, the transfer of working circuits may be commenced. It is assumed that wire continuity has already been verified to the M.D.F., but if not this should be tested by means of buzzer, bell or detector between the "cutover" point and the fuse tags on the M.D.F.

Prior to any actual circuit transfer, cable records should be checked and notes made of any circuits requiring special identification, such as public telephones and fire alarms.

Transfer to a rotation jointed cable can then proceed circuit by circuit, each being identified at the subscriber's end by means of lineman's handset. Arrangements should be made for co-operation in the exchange with jumper provision, as each circuit is transposed. Communication with the exchange will be facilitated by use of the last pair in the new cable as a "speaker" line.

If the new cable is not rotation jointed, it will be necessary to set up instruments at the M.D.F. and the "cutover" point to identify each pair prior to transfer. The instruments used may be either:

1. Buzzers and receivers.
2. Trembler bells.
3. Lineman's Detectors, or
4. 1000 ohm bell and exchange ringing lead.

Upon identification of each circuit at the subscriber's end and the pairs to the exchange, transfers may proceed. As each circuit is transferred a full test should be conducted by the exchange testing technician.

Q. 5.—Explain the importance of adequate and suitable supports for cables in tunnels and manholes.

Show, with the use of sketches, the arrangements you would suggest for use in (a) a tunnel, (b) a manhole, when each accommodates a large number of cables.

A.—(a) Reasons for the importance of adequate and suitable supports for cables in manholes in particular are as follows:—

(i) Statistics show that a very high percentage of faults in U.G. cables is caused by failure of the lead sheath at points of support.

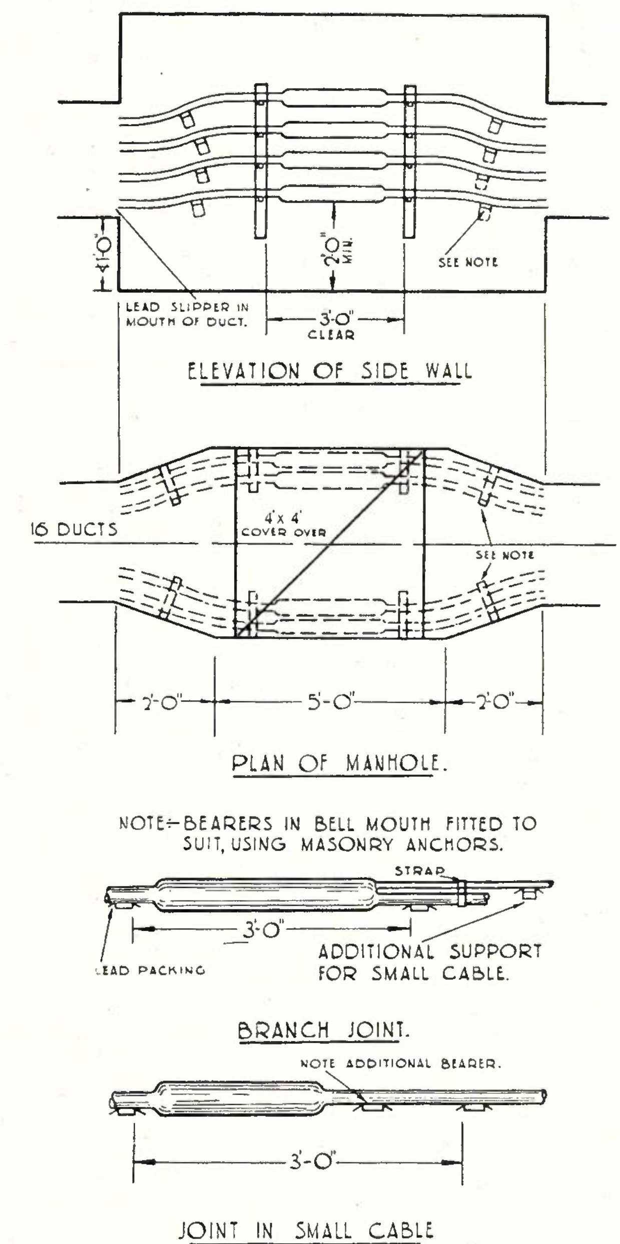
(ii) Unless detected during routine inspections faults due to poor supports are costly to repair and may involve replacement of cable lengths and possible extra duty payment.

(iii) Cable failures may interrupt service for lengthy periods and this is particularly undesirable where junction circuits and essential services are concerned.

(b) Compared with cables in ducts which provide continuous support and protection from mechanical damage, however, cables in manholes are exposed to increased hazards and must be supported in a manner which will facilitate installation and maintenance operations. These requirements suggest further reasons why the supports provided in manholes must be adequate and suitable.

(i) Cables require to be formed out between ducts and the side walls in order to obtain maximum clear central space for cable hauling and a convenient layout for jointing operations. For such an arrangement of cables and joints continuous support is uneconomic, if not impracticable. It is all the more important, therefore, that the individual bearers which are provided shall be adequate in strength and spaced at appropriate intervals to prevent cables sagging and causing possible fracture of the lead sheathing.

(ii) In forming out or changing the direction of cables in manholes, the lead sheath may be kinked or unduly stressed, especially where the manhole design is unsuitable or workmanship is faulty.



Q. 5—Fig. 1.

(iii) The over-application of heat or other faulty workmanship during plumbing operations may result in deterioration of the cable sheath.

(iv) Cables are exposed to mechanical damage by workmen entering or leaving manholes, and may be disturbed or damaged during cable hauling operations or work on other cables.

(v) Particularly during and after storms water may accumulate in manholes which are not drained, or when drains and ducts become blocked. Apart from actual submersion, the presence of water is a contributory cause of electrolytic and galvanic corrosion at points of possible contact with metal bearers.

(c) Specific points which should be observed in the support of cables in manholes are listed hereunder: (See also Fig. 1.)

(i) Manhole design should be adequate, should provide for bellmouths and walls should be offset from the line of ducts. These features will permit an even sweep of cables from ducts to bearers without sharp or unnecessary bends and will permit cables being moved slightly with a pivot action only.

(ii) Bearers should be of cantilever design and cables should be racked one per level where practicable, and not more than two per level where a large number is to be accommodated. With one cable per level at 6"-8" separation convenient access may be obtained with minimum displacement of the cable and without moving other cables. Cables should be housed clear of walls also.

(iii) Bearers should be of adequate strength and firmly secured and should be treated (galvanised) to withstand corrosion. A wide and smooth, or shaped bearing surface should be offered to cables and sheet lead packing used between cables and metal bearers to limit corrosion. Movable bearers facilitate positioning cables.

(iv) Bearers should be placed as close as practicable to the ends of each joint (3' apart for large cables) and additional bearers should be provided in large manholes to reduce spans to lengths which will not permit cables to sag. Small lateral cables should be bonded to main cables and given additional support throughout their length around a manhole.

(v) Lead slippers should be placed over the mouths of all occupied ducts.

(vi) Unseasoned hardwood should not be used to support cables. Asbestos cement sheeting is preferred where continuous support between bearers is practicable.

(vii) Manhole steps or ladders should be provided to ensure that workmen do not stand on cables when entering or leaving the manhole.

(viii) The bottom joints in a manhole should be above the level of the lowest ducts, and should be approximately 2' above the floor for convenience in jointing.

(d) In **tunnels** the main cause of failure of lead sheathing is lack of adequate support causing cables to sag and resulting in intercrystalline fracture at the cable bearers.

Remedial measures include:—

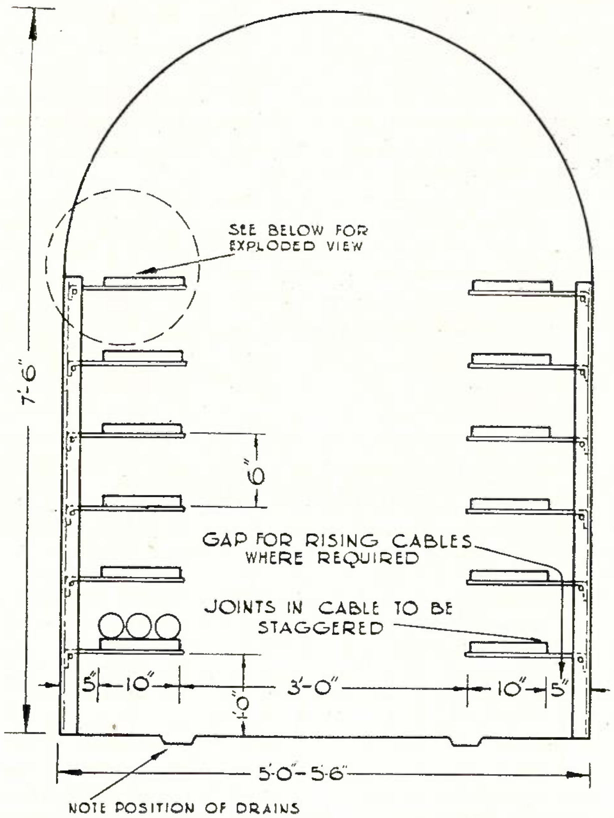
(i) the provision of continuous support between bearers in the form of runways sheeted with flat fibro cement sheeting (see Fig. 2),

(ii) placing suitable wedges under the cable sheath at each end of joints to prevent sleeves flattening,

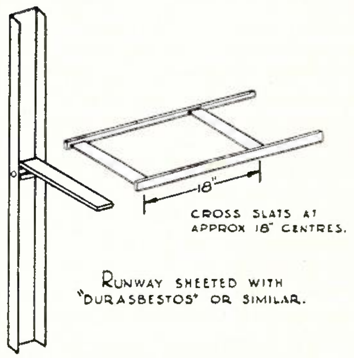
(iii) keeping cables clear of walls,

(iv) effective drainage of the tunnel system,

(v) providing adequate support also for lateral and riser cables.



SECTION OF TUNNEL.



EXPLODED VIEW OF CABLE BEARER.

Q. 5—Fig. 2.

Q. 6.—A section of an existing telephone subscribers' cable route includes 1,000 pair, a 400 pair and a 200 pair 10-lb. cables occupying three ducts of a four-way E.W. conduit. 6½ lb. cable would provide satisfactory transmission in most cases. Survey figures are:—Present 1,400, 8 year 2,100, and 20 year 3,200 lines.

Indicate the arrangements you would suggest to provide for immediate relief and for the ultimate needs of the route.

Give a list of material which you estimate would be required for installing and jointing a mile of 800 pair 10-lb. cable.

A.—(a) With an estimated development of 3200 lines in 20 years, the existing conduit provision on the telephone subscribers' route, is such that, to avoid installation of additional ducts in this period, it will be necessary to utilise to the fullest advantage, the existing spare duct. To obtain immediate relief for the existing cables which in the total are at present $\frac{1400}{1600} \times 100 = 87.5\%$ full and at the same time provide sufficient capacity to permit the recovery of one or more of the smaller existing cables and thus free a duct or ducts for further relief measures, it is essential that as large a cable as possible should be drawn into the existing spare duct.

In this case 6½ lb. conductor cable will be satisfactory for the majority of the services, and it should be sufficient to retain only the largest of the 10 lb. conductor cables, this being desirable in order to secure the maximum ultimate gain in the number of pairs on the route. In these circumstances, the provision of a new 6½ lb. of the largest size that can be accommodated in a duct of the dimensions provided by the standard four way E.W. conduit, would be the most economical procedure having in mind that a single duct costs approximately £2000 per mile to lay, under present conditions.

It is assumed in this case that the four way E.W. conduit is of the older type with internal duct dimensions of 3¼" x 3¼". This size of duct is, however, suitable for the accommodation of the maximum size 6½ lb. cable, namely 1400 pairs. This cable has an external diam. of 2.57 inches, and may be safely drawn into ducts 3¼" x 3¼".

A satisfactory cable relief scheme could be designed on the following basis.

Immediate Relief.

The expected development in 8 years, which is the normal period for which main cable provision is designed, amounts to 2,100 lines. It is desired to retain the largest existing 10lb conductor cable for the reasons mentioned in the foregoing. This is a 1,000 pair cable and the additional provision to meet the 8-year development figure is, therefore, 1,100 pairs. However, the duct capacity on this route is limited and generally it is advantageous on existing routes to utilise to the fullest extent the duct space that is available particularly where it is apparent that by doing so the provision of additional ducts may be postponed for many years or even obviated.

In this case, therefore, a 1400 pair 6½ lb. conductor cable should be laid over the section and with the subsequent recovery of existing 400 pair and 200 pair 10 lb. conductor cables, a total of 2400 pairs will be available. This provides adequately for the development over and beyond the 8 year period. Two ducts become spare, making provision for later development and emergency requirements.

Future Provision to Meet the Ultimate Needs.

The single 1,000 pair 10 lb. conductor cable will provide sufficient circuits for subscribers' services requiring this weight of conductors from transmission considerations, as a 6½ lb. conductor is satisfactory in most cases. It will, therefore, be possible to make provision at a later stage for an additional 6½ lb. conductor cable to meet the 20 year development and at the same time retain one duct for emergency purposes.

The 20 year development figure is 3,200 lines, and for this development, it would be sufficient to provide an additional 800 pair 6½ lb. cable, but the actual size of cable which should be installed at the stage when relief is required would be governed by the probable future requirements at that time.

As an alternative to the above arrangement, the design for the initial relief could be planned on the basis of installing a smaller size 6½ lb. conductor cable to replace only the 200 pair 10 lb. conductor cable in the initial stage. This new cable would need to be only a

800 pair cable to provide for the immediate needs. The second relief would then be accomplished by installing a 1400 pair 6½ lb. cable and recovering the 400 pair 10 lb. conductor cable. In each operation a spare duct would be retained for emergency purposes, and from an engineering aspect the design would be sound on the basis of the expected development. Economically, this design would be favourable as the greater expenditure involved in the overall provision to meet the ultimate needs would be postponed, until the second relief was required, and this would be reflected in a saving in annual charges associated with the plant provided on this route.

This economic gain would, however, be partly offset by the lower recoverable value of the cable to be withdrawn from the ducts during the initial relief. Depending on local considerations and other unknown factors, it is probable that the design providing for the installation of the 1400 6½ lb. cable in the initial relief proposal would prove to be the more advantageous since it provides for the maximum use of the available duct space, and this leaves some margin to meet possible unforeseen development up to and beyond the design period.

(b) List of material required for installing and jointing a mile of 800 pair 10 lb. cable, assuming 88 yard sections.

Cable P.I.Q.L. 10 lb.	1800 yds.
Cable pulling compound	200 lbs.
Waste cotton	20 lbs.
Kerosene	8 gals.
Lead Sheet, 7 lb.	448 lbs.
Solder, wiping	112 lbs.
Sleeves, paper	3400
Tags, linen	40 sets
Gas, Acetylene	300 cu. ft.
Gas, CO_2	100 lbs.
Paper, Brown	8 rolls
Sperm	6 lbs.

PART C—AERIAL

Q. 7.—Discuss the various factors affecting the spacing of wires, crossarms and poles on main trunk telephone routes.

What alternative arrangements might be adopted when it is not practicable to place transposition poles in locations near enough to correct locations, e.g., at wide road or river crossings?

A.—(a) The two main considerations associated with the spacing of wires, crossarms and poles on main trunk telephone routes are the:—

(i) Physical aspect,
(ii) Electrical aspect.

Physical Aspect.

The first requirement of any pole route is that it should possess adequate stability as a whole, and the second, that the construction should be such as to provide at all times and under all conditions reasonable security from interruption to the circuits carried on the poles. The number of poles erected in any given length of line is a measure of the stability of the route and its strength to withstand the maximum loading stresses due to normal wire and wind forces acting upon it. Provision and maintenance of suitable factors of safety in pole structures, and in the line wires carried on the poles, will ensure freedom from interruptions due to pole collapse or line wire breakages.

This basic requirement being satisfied, the main effect of the pole spacing on a route is in relation to the sag which may be given to the line wires. For the prevention of undue sway of the line wires, the sag given to these wires should be a minimum having regard to the ultimate breaking strength of the wire. The important thing to provide against is the possibility of contacts between any of the wires erected on a pole line, and it can be shown that at any wind velocity normal to the line, this probability is a function directly of the sag and inversely of the wire spacing, and, to a lesser degree, of the length of the span. Reduction in the length of the span between poles permits a much greater reduction proportionately in the sag of the wires with the same factor of safety maintained in the wires. It is, therefore, feasible (without increasing the fault liability) to reduce the spacing between wires, and consequently the arms, if this is desired, by reducing the spacing between poles.

The physical aspect of the spacing of wires, arms, and poles, therefore, concerns chiefly the stability of the pole route, and the avoidance of contacts between the wires carried on the route. From the latter viewpoint, each has a definite relation to the other.

Electrical Aspect.

The electrical characteristics at any frequency of transmission of a pair of wires are affected by the separation of the two wires. This affection becomes greater at the higher carrier frequencies employed for telephone transmission. Similarly, the electrical coupling of any two pairs of wires forming separate circuits is changed by a variation of the separation between the wires of each pair, and between both pairs of wires. This is brought about by a change in the mutual induction of the pairs which follows from the alteration in the relative positions of the wires. Generally, a reduction in the spacing of the conductors forming a circuit results in an increase in the attenuation of the line currents, but at the same time the inductive coupling with other circuits on the same poles is reduced. At the expense of transmitted energy, which may, however, be replaced in the circuits at intermediate points, the induction taking place between one circuit and another can be reduced by bringing the wires of a pair closer together, so that the amount of crosstalk between these circuits is also reduced. In other words, the crosstalk attenuation is increased.

This attenuation is also increased by the increase of separation of the circuits. It follows, therefore, that by increasing the separation of the circuit pairs of wires on an arm (in conjunction with a reduction in the spacing between the wires of a circuit pair) and also by increasing the spacing between the arms on the pole, conditions favourable to the operation on a common route of a number of carrier frequency telephone systems can be obtained.

A prerequisite for such conditions is that the wires of the circuits concerned should also be so transposed with relation to each other as to provide a degree of capacity balance between the circuits, and at the same time give a neutralising effect to such line currents as are induced from neighbouring circuits. To be effective at the high frequencies associated with carrier telephone systems, this transposing requires to be intensive, and in the extreme case may necessitate 256 transposition intervals in the nominal full length transposition section. Depending on the particular crosstalk requirements, these sections may have varying lengths up to 8 miles, and the spacing of poles in these sections is, therefore, largely determined by the transposition design required on the route, and consequently the length of the transposition interval.

It is apparent from the foregoing that the spacing of wires, arms, and poles has a very important bearing on the transmission limits and channel capacity of an aerial open wire trunk route.

(b) Where it is not practicable to place poles in a position close to the correct location for the required transposition interval, alternative arrangements as follow may be adopted:—

(i) Attachment of "inspan" transposition fittings to the wires at the correct transposition position between two poles. This method would normally be employed at road or river crossings where only one transposition point is involved.

(ii) Erection of a catenary span across the obstruction, for the support of a crossarm framework in the correct transposing position. Transpositions may then be formed on the crossarms carried by a framework.

The method would be followed for crossings of wide rivers where more than one transposition point is involved, or an extremely long span is required which will not permit retention of the normal wire spacing.

Q. 8.—Assuming that a route for a new trunk telephone pole line has been selected—

(a) Enumerate the various steps associated with the measurement of the route and the pegging of pole locations.

(b) What staff would you provide for this work? Briefly indicate the functions of the various members.

(c) What equipment would you provide for the survey?

A.—(a) The line for a new trunk telephone pole route having been determined by a preliminary survey of the route to be traversed, the following steps would be taken to complete the layout and peg the positions of poles on the proposed line.

1. Measurement over the route.

An accurate measurement on the line of the pole route should be undertaken for the purpose of obtaining the overall distance between the terminal points of the aerial open wire circuits. This information forms the basis of the transposition layout for the route upon which the pole spacing interval frequently depends. At the same time the location of circuit discontinuities in relation to the proposed transposition sections of the route may be determined enabling suitable adjustments to be made to the transposition layout in the design stage.

During this survey a field book should be prepared to show the location and extent of every obstruction or variation in the topography along the line of the proposed pole route. Such items should include angles in the line, road crossings, rivers, ravines, gateways, railway crossings or sidings, creeks, waterholes, abrupt changes in ground levels, etc. In the course of this measurement of the route a bench mark should be made at least every mile, and on more important routes every ½ mile, to facilitate checks and further measurements of sections of the route.

2. Subdivision of route distance for transposing purposes.

This work is undertaken in conjunction with the final planning stage of the design for the route, and involves a consideration of the points of circuit discontinuity as at important intermediate offices or where large groups of circuits terminate or leave the main route. Normally discontinuities in the telephone route must be transposition section boundaries, and between these boundaries the standard transposition sections are inserted. As far as possible these sections should be of standard length and each will contain a definite number of transposition intervals in which there must be placed a specified number of intermediate poles.

3. Preparation of Pole Position Sheets or Diagrams.

The number of transposition intervals is dependent on the particular crosstalk requirements of the route, and to secure the desired electrical conditions it is necessary that the poles to be located at these intervals should be placed as near as possible in their correct positions.

The transposition pole positions must therefore be examined in relation to the location of obstructions on the line of the proposed route, and necessary changes in the pole positions noted for the purpose of adjustment of adjacent transposition pole positions, or in the extreme cases of the transposition section itself, in order to obtain the required degree of regularity for the transposition intervals. Subject to this examination the positions of transposition poles should then be set out in tabulated form on suitable sheets. In special cases this detail may be shown on straight line diagrams which indicate also the location of the intermediate poles and the salient features of the route as recorded in the field books. Alternatively, it will be necessary to employ the pole spacing sheets in conjunction with the prepared field book in fixing the pole positions in the field.

(b) The staff that would be required to perform the work of measuring and pegging out a new trunk route would be composed of the following:—

For the Measurement of the Route:

1 **Leader** for the party, preferably a Line Foreman, who shall direct the measurement and record details in the working field books.

1 **Assistant** to drive the motor vehicle and prepare copies of the field books from working copies during progress of the measurement.

2 **Chainmen** for measuring and clearing the survey line.

For the Pegging of the Route.

1 **Leader** for the party, who, from the detailed information supplied on the pole position sheets or route diagrams, shall direct and assist in fixing of the correct pole position.

1 **Assistant** to drive the motor vehicle and handle the distribution and driving of pegs and the marking of peg positions on adjacent fences or trees, including erection of stakes or pickets where necessary. An additional man may be required to assist in the driving of pegs and marking positions.

2 **Chainmen** to carry out measurements along the line, including check measurements to bench works as well as over transposition intervals.

(c) The special equipment which would be required by a party on the work should consist of the following:

1 Surveyor's steel tape.
2 Brass plumb bobs and cords.
11 Steel spikes with looped heads and red cloth tags.
1 Optical square with tripod for offset work.
1 Prismatic compass.
Lumber crayon or brush and paint.

In addition, for the pegging operation, it is convenient to provide a 200 lb. G.I. wire accurately measured to the length of a transposition interval, and with the position of the intermediate poles marked on it. Subject to regular checks, of the peg positions with bench marks provided during the accurate survey, this wire will greatly facilitate the pegging out of the pole positions in reasonably flat country. It should be used with discretion in hilly country, or where the route is intersected by gullies and ravines which would introduce errors due to sag in the wire.

Q. 9.—Discuss the various causes of faults (other than broken wires) on aerial wires on telephone routes and the preventive and remedial measures which might be adopted.

A.—The various causes of faults on aerial line wires other than interruptions brought about by broken line wires, may be classified under three main headings, namely:

(a) Structural weaknesses.
(b) Insulation weaknesses.
(c) Variable electrical characteristics.

Such defects when occurring on telephone pole routes may result in a partial or complete interruption of one or more circuits or may contribute to indifferent channel performance with consequential lost traffic time.

The defects which may result in such a disturbance of telephone circuits can be summarised as follows:—

(a) **Structural Weaknesses.**

(i) General instability of the pole line resulting in pole and arm movements and slackening of wires ultimately causing contacts to occur between line wires or between line wires and stay or pole fittings. This instability may be due to—

(a) Insufficient strength in the poles for the load of wires under conditions of maximum wire loading. In extreme cases this weakness may cause complete collapse of a telephone pole route.
(b) Poor holding ground with insufficient bearing strength to withstand the pressure of the poles. this may be partly overcome by the use of bed plates or logs.
(c) Inadequate provision of holding stays at angles and other points in the route where additional support is required for the poles because of the factors referred to under (a) and (b) or because of extreme exposure to strong winds or other conditions. The remedy in these cases is to strengthen the route with additional poles and/or stays.

(ii) **Defective Arms and Pole Fittings.**

(a) Wooden arms are subject to weathering and decay, and to the ravages of termites, which may eventually cause the arms to split or collapse and permit the line wires to come into contact with one another or with earthed metal. Replacement of the arms is necessary in such cases.
(b) Bolts holding arms, braces, combiners or transposition plates may become loose due to timber shrinkage and permit movement of the wires which, if it does not result in an electrical contact of the wires, may permit sufficient displacement of the wires as to affect the electrical characteristics and therefore the operation of multi-channel carrier systems. A regular tightening of the bolts is therefore an essential requirement of any maintenance procedure.

(b) **Insulation Weaknesses.**

(i) Defective insulators are the usual cause of poor insulation on line wires. Insulators may lose their insulating qualities after years of exposure from various causes, chief of which are—

(a) Mechanical damage.
(b) Chipped and cracked surface glazing resulting from temperature effects or inherent manufacturing weaknesses.
(c) Punctures or fractures from lightning discharges.
(d) Accumulation of dust or deposits of salt, ash, or other industrial waste products.

In most instances low insulation due to these causes can be rectified only by replacement of the insulators. Depending on local conditions, and engineering as well as economic considerations, it is sometimes feasible to carry out a procedure for the systematic cleaning and washing of the insulators where dust or other deposits are the primary cause of low insulation.

(ii) Low insulation can be caused in varying degrees by contact with trees, particularly where pole routes are erected in close proximity to ornamental street trees in town areas. Rapid secondary growth along cleared routes in heavily timbered country districts can also result in foliage coming into contact with the line wires. In these cases leakage occurs, and under adverse conditions almost complete interruption may be caused to the telephone circuit. Regular cutting or pruning of trees in town areas and the removal of secondary trees or undergrowth along country routes is necessary to prevent interference to circuits from these causes.

(iii) A further cause of loss of insulation is the construction of birds' nests between wires on arms causing leakage to occur, particularly when pieces of wire have been used by the birds in the manufacture of their nests. In localities where this occurs, which is usually in areas devoid of large trees, it is not practicable to prevent the birds from using the poles for nesting and removal of the nests as they are built is necessary. It is essential to avoid leaving scraps of wire in the areas concerned.

(c) **Variable Electrical Characteristics.**

While not causing complete interruption to a circuit, noise arising from the inductive effects of neighbouring power circuits can render an aerial wire circuit unworkable under some conditions. Correctly placed transpositions inserted in the telephone circuits will neutralise the effects of direct metallic induction from balanced or residual currents and voltages in the power line. Longitudinal voltages and currents induced in the telephone circuit can, however, act upon unbalances in the telephone circuit to produce indirect metallic induction effects resulting in excessive noise. These unbalances may be either self unbalances such as high resistance joints or unbalanced leakage or may be mutual inductance or capacitance unbalances to other wires of the line or to ground.

Similar unbalances may also result in the indifferent performance of channels due to increased crosstalk effects between circuits carried on a common pole route.

Removal of defective joints and irregularities in wire spacing and wire sags is, therefore, an important feature of the maintenance of high quality aerial wire telephone circuits.

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