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LONG DISTANCE PROGRAMME TRANSMISSION — PART 2

J. G. Bartlett

AUDIO FREQUENCY TRANSMISSION EQUIPMENT

Programme transmission at audio frequencies over physical circuits has formed the backbone of the Australian programme network for many years. Although programme circuits over broad band carrier systems are now coming into prominence, the physical programme circuit will still be the major long distance programme link for many years to come.

Transmission at audio frequencies has the advantage that it is the cheapest method of providing programme channels, and, in addition, the equipment used is of a very simple design. The major disadvantage, which is very real as far as music transmission is concerned, is that the highest frequency of transmission on open wire lines is limited to 5.6 kc/s by the line filters used to separate the carrier and audio frequency transmission circuits.

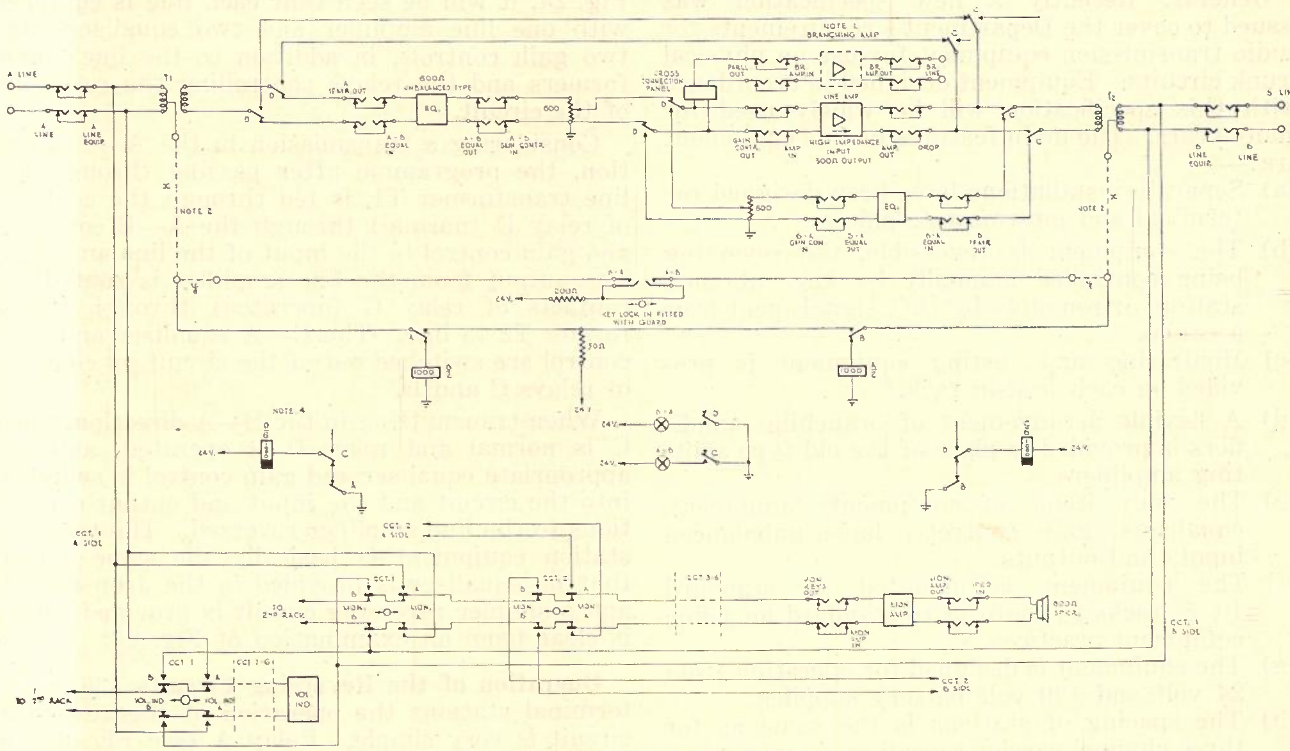


Fig. 24.—Intermediate Station Equipment.

Note 1.—Branching amp. wired only, equipped when wanted.
2.—For remote control of reversing, insert straps "x" and cut straps "y".
3.—All jacks shown are to be mounted on central jack field.
4.—Either relay C or D normally operated.

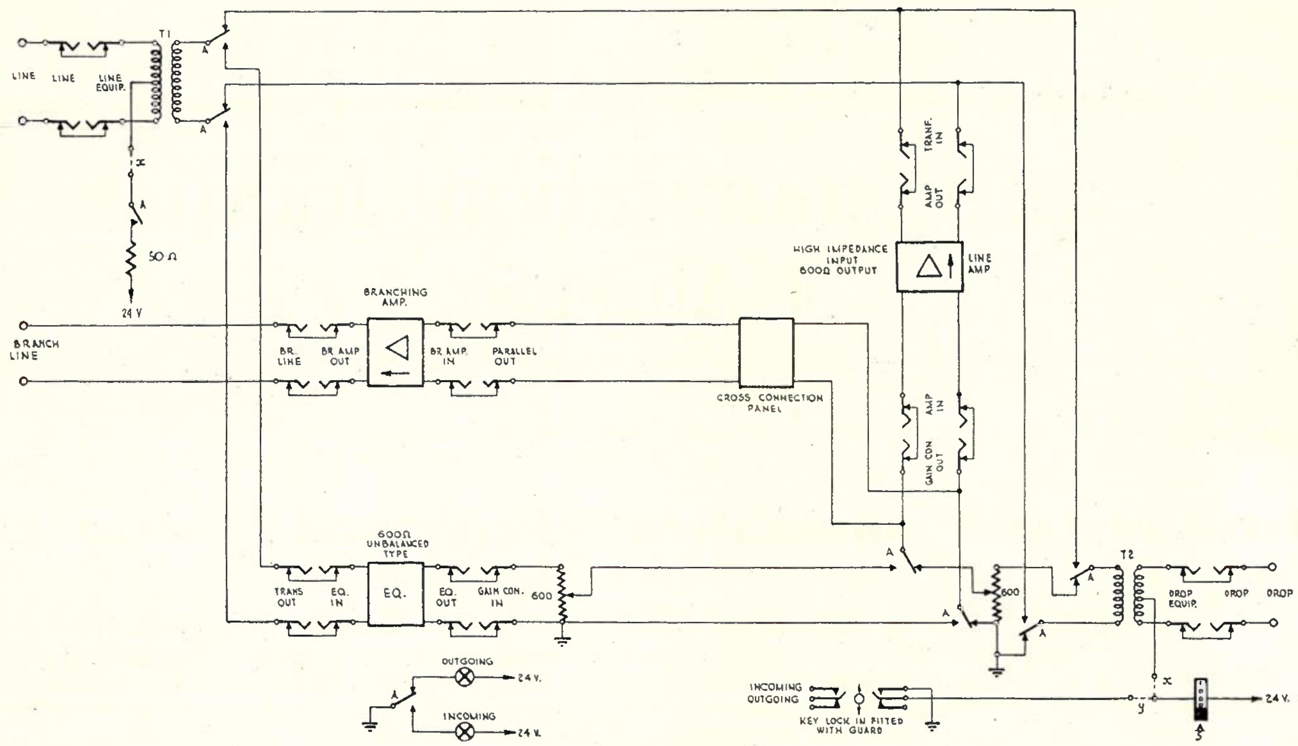


Fig. 25.—Terminal Equipment.
Note 1.—When equipment is used in conjunction with automatic switching scheme insert strap "x" and cut strap "y".
2.—Monitoring facilities are similar to those shown on Fig. 24.

Standard Physical Programme Line Equipment

General: Recently a new specification was issued to cover the Department's requirements for audio transmission equipment for use on physical trunk circuits. Equipment designed in accordance with this specification will be widely used for many years. The main features of this equipment are:—

(a) Separate installations have been designed for terminal and intermediate offices.
(b) The equipment is reversible, the reversing being controlled manually by keys at each station, or remotely by D.C. signals sent over a cailho.
(c) Monitoring and testing equipment is provided on each first-in rack.
(d) A flexible arrangement of branching amplifiers is provided in place of the old type splitting amplifiers.
(e) The main items of equipment (amplifiers, equalisers, gain controls) have unbalanced inputs and outputs.
(f) The equipment is mounted on standard 10′ 6″ racks to conform to standard long line equipment practices.
(g) The equipment is designed for operation from 24 volt and 130 volt battery supplies.
(h) The spacing of stations is the same as for three channel carrier repeaters.

Circuit Arrangement: The circuit of an intermediate installation is shown in Fig. 24, and that of a terminal installation in Fig. 25. Referring to Fig. 24, it will be seen that each line is equipped with one line amplifier and two equalisers and two gain controls, in addition to the line transformers and the relays controlling the reversing of the circuit.

Considering a transmission in the A—B direction, the programme after passing through the line transformer T1, is fed through the contacts of relay D (normal) through the A—B equaliser and gain control to the input of the line amplifier. The output from the line amplifier is routed via contacts of relay C (operated) through transformer T2 to line. The B—A equaliser and gain control are switched out of the circuit by contacts of relays C and D.

When transmitting in the B—A direction, relay C is normal and relay D is operated, and the appropriate equaliser and gain control is switched into the circuit and the input and output connections to the line amplifier reversed. The terminal station equipment is basically the same except that no equaliser is provided in the drop circuit, and a simpler reversing circuit is provided. This is clear from an examination of Fig. 25.

Operation of the Reversing Circuits (26): At terminal stations the operation of the reversing circuit is very simple. Relay A (see Fig. 25) is operated by earth fed over the cailho of the drop circuit, or from the reversing key (this will depend upon whether manual or automatic reversing is being used). At a terminal station, key reversing will always be used unless the equipment is associated with an automatic programme switching scheme. Relay A in operating reverses

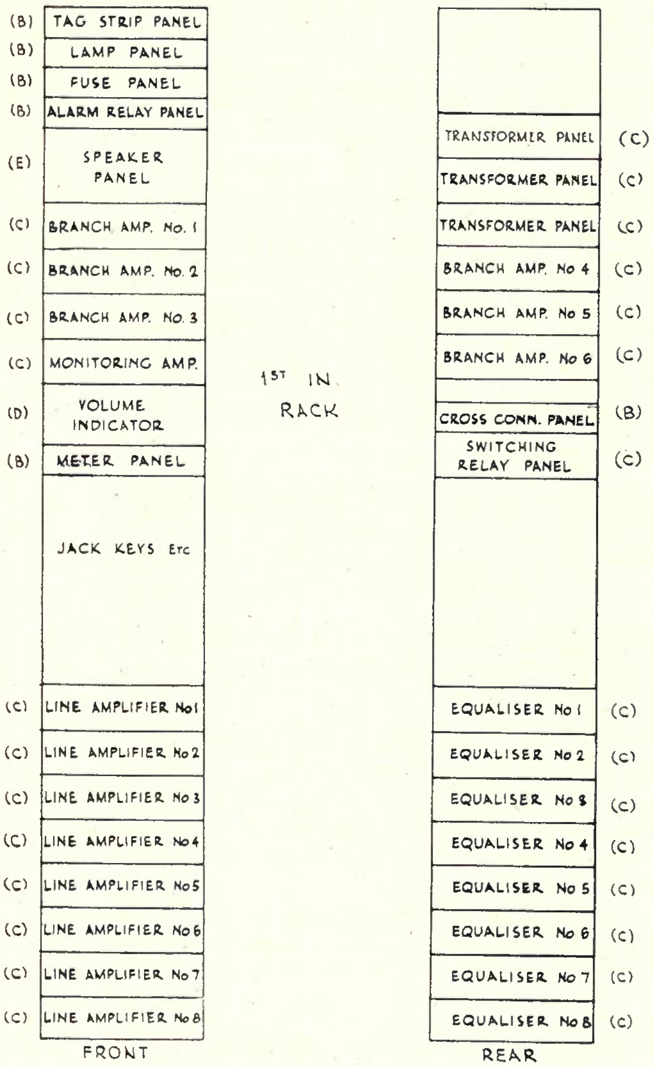


Fig. 26.—Terminal Station Rack Layout.
Note.—(A), (B), (C), (D), (E) = maximum sized panel to be used.

the connections to the line circuit, lights the appropriate direction indicating lamp and (if automatic reversing is used) feeds battery over the cailho to the next station. It will be seen that the normal condition of the circuit is for outgoing transmission.

A more complex reversing arrangement is employed at intermediate stations, this being done so that reversing signals from either direction may be accepted. For an A—B transmission, relay A is operated by battery from the cailho on the B line, or the reversing key. Relay A prevents relays B and D from operating and feeds battery through the centre tap of transformer T1 to the next station. As relays B and D are normal, relay C will be operated, thus arranging the line equipment in the A—B direction and lighting the appropriate direction indicating lamp.

When transmission in the B—A direction is required battery is removed from relay A which releases, removes battery from the cailho on the A line, and prepares a circuit for relay D. Relay D cannot operate, however, until relay C releases. Relay C is locked until relay B operates. When battery is applied on the A line, relay B operates, releasing relay C, operating relay D and feeding battery to the cailho on B line. With the operation of relay D and the release of relay C, the reversal is completed and the appropriate direction indicating lamp is lit.

It will be seen that when automatic reversing is employed, reversal is effected only when a signal is received from the receiving terminal station and none is received from the sending terminal station, and that after reversal is effected the

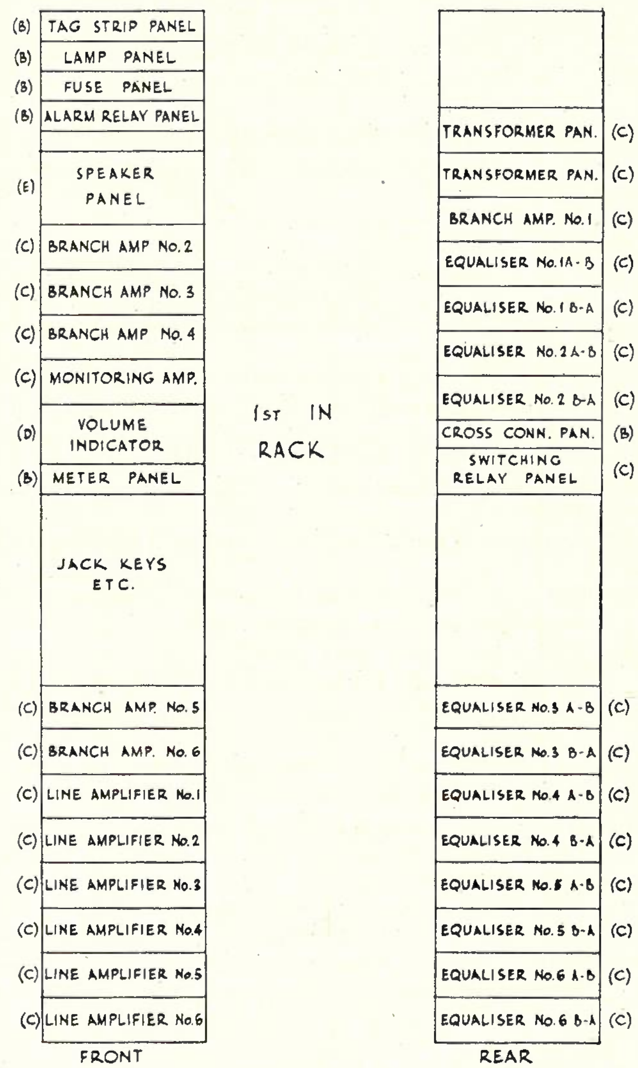


Fig. 27.—Intermediate Station Rack Layout.
Note.—(A), (B), (C), (D), (E) = maximum sized panel to be used.

absence of a signal from the latter station will not cause the direction of transmission to be altered.

Equipment Mounting: Double sided mounting on 10′ 6″ racks is employed. The number of circuits per rack is shown in Table 1.

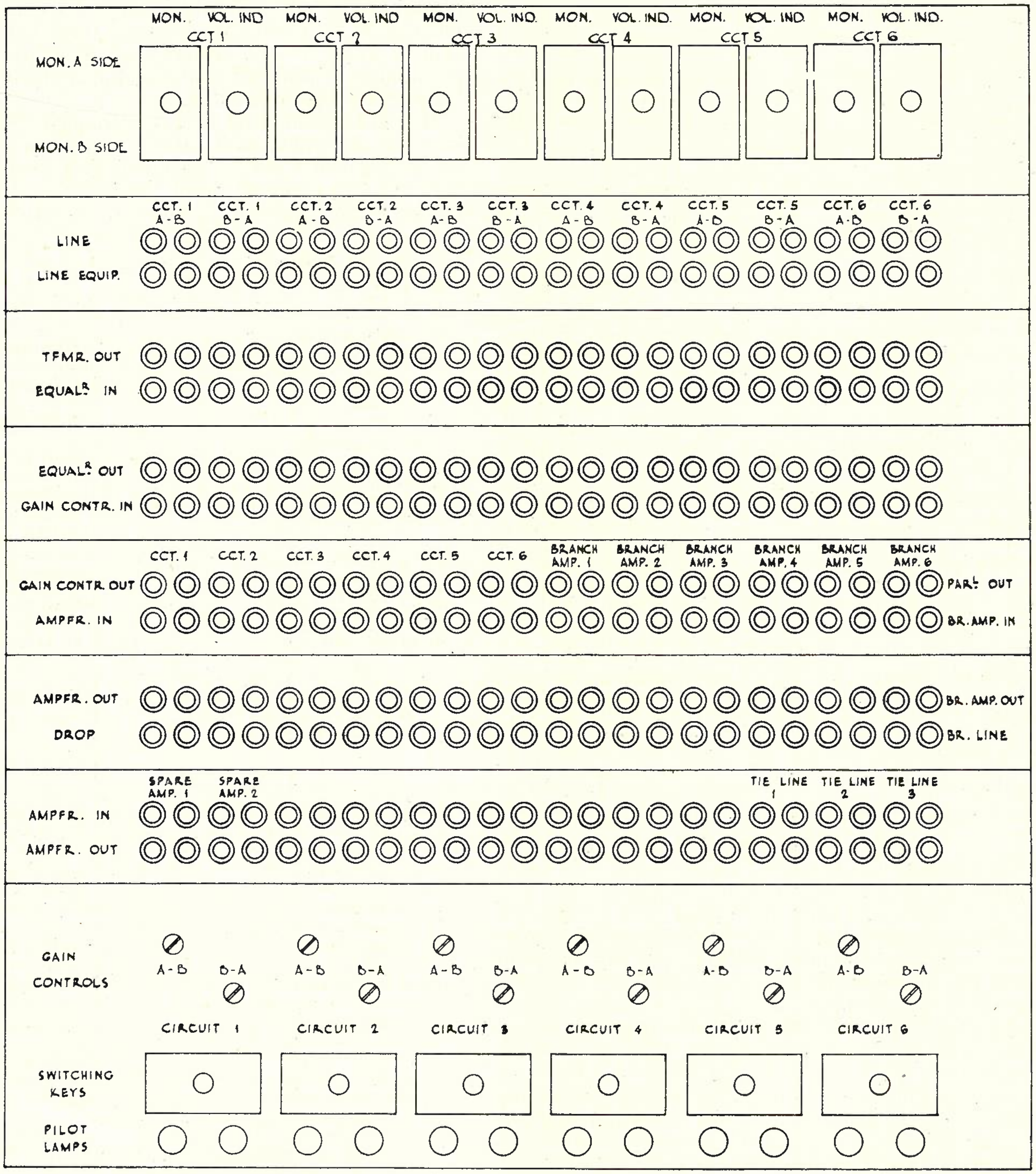
Typical rack layouts for terminal and intermediate stations are shown in Figs. 26 and 27.

Amplifiers: The line and branching amplifiers are identical in design and construction. The amplifiers have a high impedance unbalanced input and a 600 ohm output circuit. No gain control is provided, the amplifiers having a fixed gain of at least 35db and are capable of delivering a peak power of +21 dbm.

Controls: The gain controls, which are the only adjustable components used in the equipment, are of the wire wound potentiometer type

(B)

(C)



INTERMEDIATE RACKS

Fig. 28.—Line Equipment Jack and Key Layout.
Note.—(B), (C) = Panel Sizes.

having a resistance of 600 ohms. They are centrally mounted in the positions shown in Fig. 28. The shafts are slotted for screwdriver adjustment.

Equalisers: No equalisers are supplied with the equipment, the intention being that equalisers will be designed and constructed to match the particular lines associated with each circuit. It has been found necessary to use a three section equaliser to adequately compensate for line losses

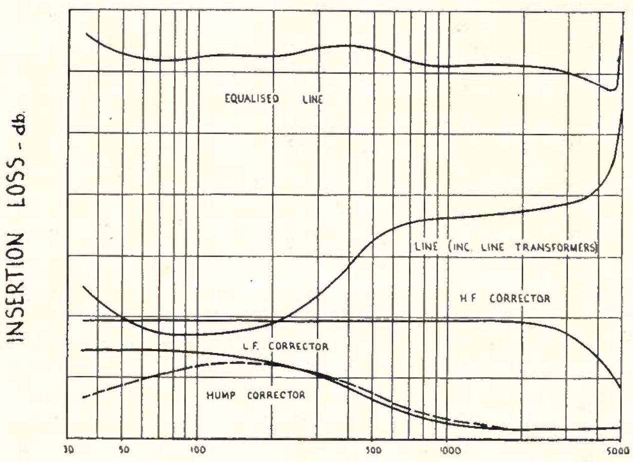


Fig. 29.—Line and Equaliser Characteristics.

and the characteristics of a typical equaliser and line connection are shown in Fig. 29. A full description of this type of equaliser was given in the previous issue of this journal.

TABLE I

Amplifiers

Type of Equipment	Line ccts	Branching	Spare	Testing & Monitoring Equipment
Terminal 1st in	8	6	–	Provided
Terminal 2nd in	8	6	2	Not provided
Intermediate 1st in	6	6	–	Provided
Intermediate 2nd in	6	6	2	Not provided

Testing and Monitoring Equipment: The testing and monitoring equipment, which is fitted to first-in racks only, comprises a monitoring amplifier and loud-speaker, a v.u. meter (which is described later), and meters for measuring plate and filament currents, together with the associated jacking and key circuits.

The monitoring amplifier has a high impedance input circuit, a maximum gain of 35db, and delivers an output power of +36 dbm. A gain control is associated with the amplifier. Separate keys are provided for monitoring with the loud-speaker and the v.u. meter. The monitoring keys are wired in a series circuit and it is possible to monitor at the input and output of each circuit.

Jacking: All major components are jacked to facilitate patching and testing. These jacks are centrally mounted, as shown in Fig. 28.

Branching Arrangements: The branching arrangements provided are particularly flexible. This flexibility is achieved by means of a cross-

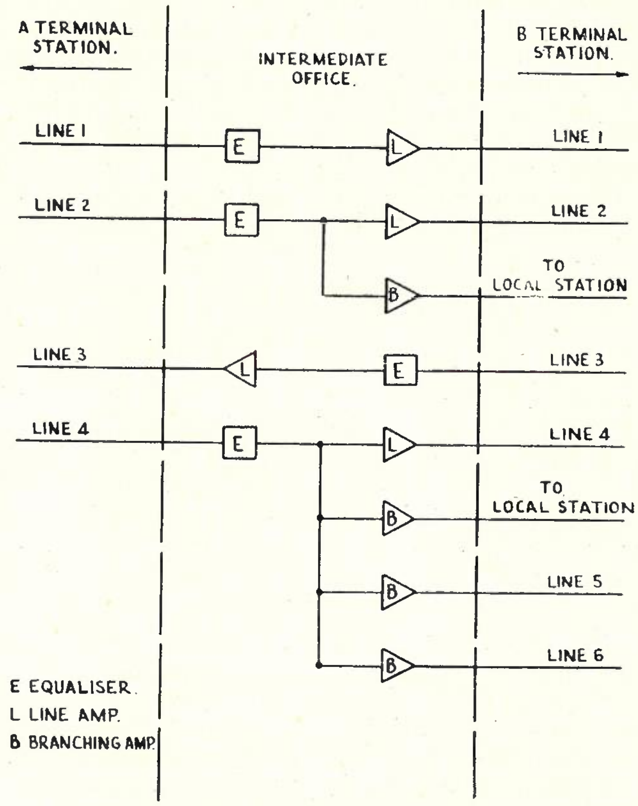


Fig. 30.—Branching Set-up.

connection panel which provides facilities for connecting branching amplifiers to line circuits in any combination, subject to the limits imposed by the number of amplifiers provided. If need be, all branching amplifiers can be connected to any one line circuit. No bridging loss is introduced as the amplifiers have high impedance inputs. A typical connection of branching amplifiers to line circuits is shown in Fig. 30.

Performance: The following details give an indication of the performance of this type of equipment. However, the overall performance of an audio programme circuit will be inferior to that shown because of the inherent limits imposed by the line and because of the necessity to connect large numbers of stations in tandem to derive the overall link. The equipment is designed for a transmitting level from each station of +8 v.u. The frequency response is linear to within +0.5 db from 50 to 8000 c/s, although when used on open wire lines an upper limit of 5.6 kc/s is imposed in most cases. In addition, the frequency response is finally dependent on the accuracy of the equaliser design.

Noise on any circuit and crosstalk between circuits on the same rack is negligible. Again, the line used will determine the values of noise and crosstalk on the overall circuit. The level of harmonic products, when a sinusoidal input of 1000 c/s is applied at a level which gives an output of +12 dbm, is at least 50 db below that of the fundamental frequency. This seemingly severe limit is necessary, as the distortion over a circuit having many amplifiers in tandem is cumulative, and the overall distortion figure will be much worse than that for a single unit.

Delay distortion of this equipment when used over open wire lines is negligible. Considering the overall performance of audio transmission circuits, it is impossible to achieve results which compare favourably with circuits operated over broad-band carrier systems and this will result in the gradual displacement of major audio transmission circuits, although it must be emphasised that this displacement will not occur in the foreseeable future.

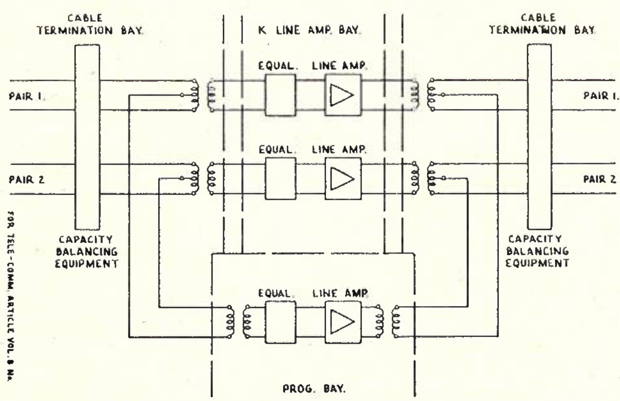


Fig. 31.—Phantom Transmission Block Schematic

Audio Transmission over Cable Circuits.

In the past, audio transmission circuits have not been operated over carrier type cables as physical operation of these circuits would seriously complicate the cable carrier equipment and would prove economically unsound. However, where local V.F. trunk cables have been laid with the carrier cables, it has been possible to obtain programme circuits by providing 10 kc/s loaded pairs and using them in conjunction with normal audio programme transmission equipment.

An arrangement (27) which uses the phantoms of carrier cable for programme transmission purposes has been tried in Great Britain and on the Continent with satisfactory results, and it is likely that this method will be used in Australia in the future. With this arrangement frequencies of up to 12 kc/s should be capable of effective transmission without being affected by crosstalk from the K systems using the same pairs and without crosstalking into the K systems. It is doubtful if these programme circuits could be used on cables carrying 17 channel systems because these carrier circuits transmit frequencies as low as 4 kc/s and phantom to side crosstalk would probably render the circuits unworkable.

The basic elements of the scheme are shown in Fig. 31, and it will be seen that the circuit is straightforward. The connections of the programme equipment to the cable are made at the cable termination bay. The transformers used to derive the phantom circuit must meet two main conditions:—

(a) They should be accurately balanced to reduce crosstalk between the phantoms and side circuits.

(b) The return loss at carrier frequencies between the transformers and the cable pairs must be sufficiently high to prevent the performance of the carrier system from being degraded.

On long cables temperature changes will have an adverse effect on the frequency response because of the large variation of the equivalent of the cable with frequency and temperature. This drawback may be overcome by providing equalisers which correct for different cable temperatures and patching in the appropriate equaliser to fully compensate for the temperature existing at any time. As the temperature of an underground cable changes very slowly, only an occasional change of equalisers will be necessary.

ANCILLARY EQUIPMENT

Volume Indicators

It is necessary that some means be provided for visually monitoring the programme level at offices containing programme equipment. In the past, many different types of meters have been used for this purpose, and because of the differing dynamic characteristics of the various meters, no correlation could be made between readings on different meters. To overcome this difficulty, one type of meter has been standardised for use with programme equipment. The standard meter is the volume indicator based on the volume unit (v.u.) (7, 8), and when used with programme transmission equipment the meter is fitted with the "A" scale (i.e., one in which the v.u. markings are prominent).

Volume Indicators with Extended Range: To increase the usefulness of volume indicators, units have been designed which can read lower volume levels than the standard meter. This has been done by associating the meter with a two-stage negative feed-back amplifier. Volume levels as low as —40 v.u. and up to +33 v.u. can be read with this instrument.

A schematic circuit of an extended range volume indicator is shown in Fig. 32. It will be seen that the instrument consists of a simple two-stage feedback amplifier with the v.u. meter in the feedback path, and having two variable attenuators

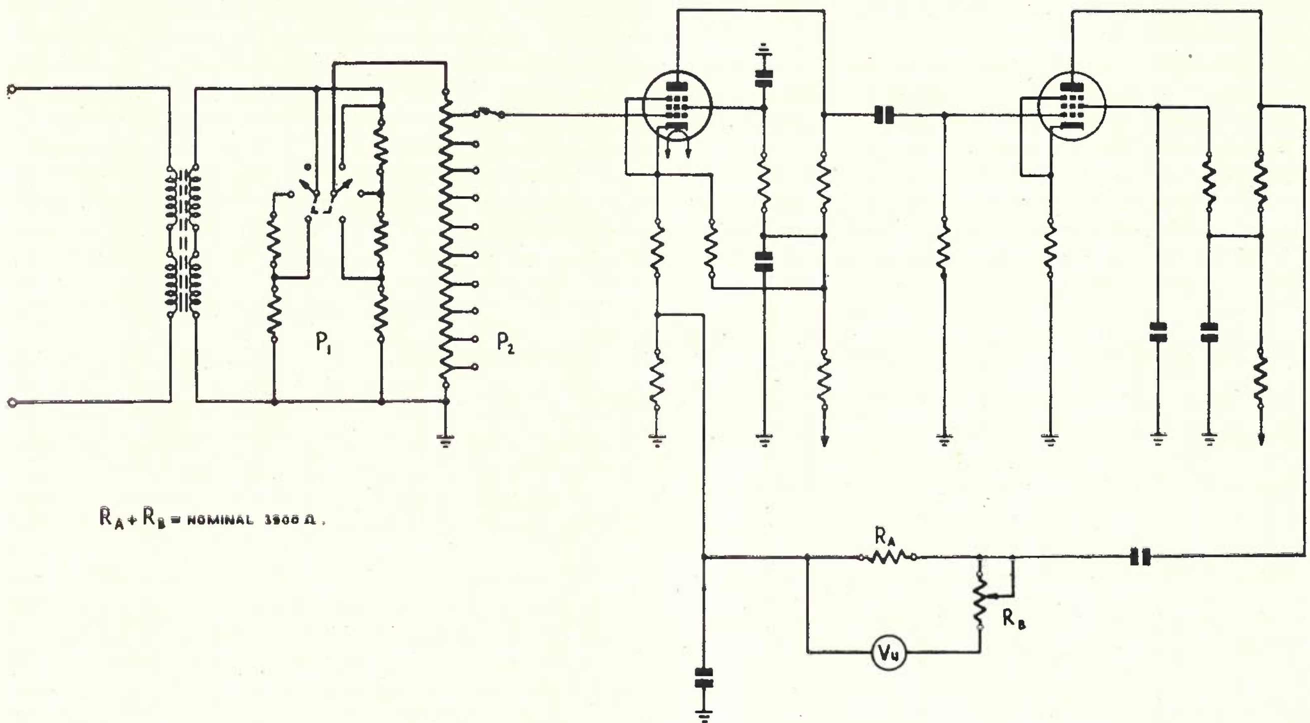


Fig. 32.—Volume Indicator Schematic.

P1 and P2 in the input circuit which has a high impedance so that bridging measurements may be made. Attenuator P1 has three settings, with losses of 0, +10 and +20 db respectively, while P2 covers a range of attenuation of 20 db in 2db steps.

The circuit of the unit is so designed that the feedback current is proportional to the input volume. For accurate results it is essential that the meter be terminated by an impedance equal to its own input impedance, which is nominally 3900 ohms, that is resistance Ra and Rb must have a total resistance of 3900 ohms. In practice Rb is variable to compensate for differences in the impedance of individual meters. Volume indicators of this type are fitted to all first in racks of the physical programme line equipment described previously.

Compandors

Compandor (28) is the name applied to a system comprising two complementary pieces of apparatus, the compressor and the expander. The purpose of its use is to increase the signal to noise ratio in the transmission medium, and thus enable a greater volume range to be transmitted on the programme circuit. This is achieved by compressing the volume range to the transmitting terminal and expanding it again at the receiving terminal.

The amount of compression is governed by a compression law, which is generally of the form:

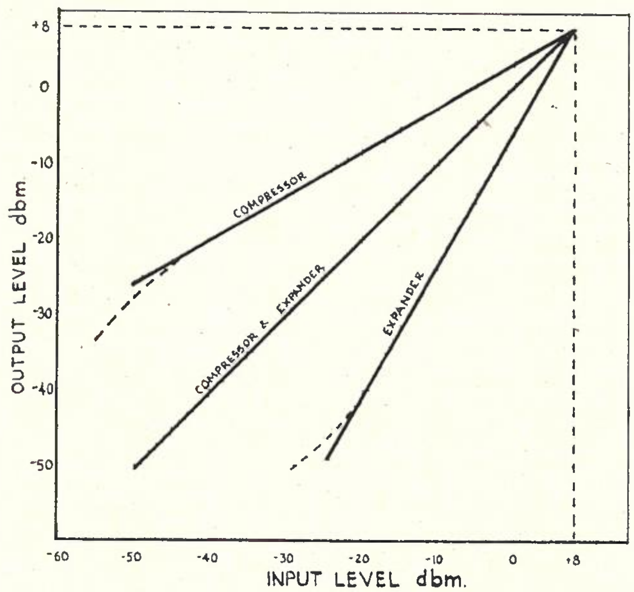


Fig. 33.—Compandor Characteristics.

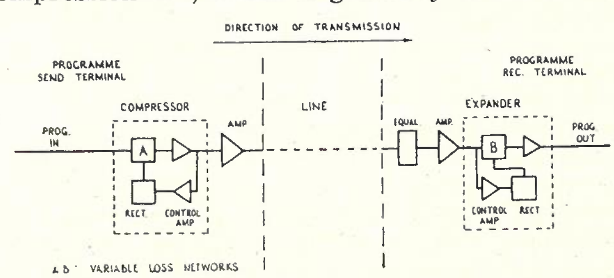


Fig. 34.—Compandor Block Diagram.

$$\log V_1/V_2 = k \log v_1/v_2$$

where v_1 and v_2 are input voltages and V_1 and V_2 corresponding output voltages. If $k = 1$ no compression or expansion is obtained, that is, it indicates a linear amplifier. When $k < 1$ compression is indicated while $k > 1$ indicates expansion. The usual value of k for a compressor is $\frac{1}{2}$, while that for an expander, which must be complementary to its associated compressor, is 2. This is indicated in Fig. 33, which shows the output/input characteristics of a typical compandor. It will be seen from the compressor characteristic that a volume range of, say, 50 db is compressed to a volume range of 25 db, while the expander characteristic is inverse to this, an input volume range of 25 db being expanded to 50 db at the output. Thus when the compressor and expander are used together the output level from the expander is equal to the input level to the compressor, which is the desired condition for distortionless transmission. As a result of the transmission of higher levels from the compressor, an increase in signal to noise ratio must be obtained. It should be noted that no compression or expansion takes place at the maximum transmitting level (+8 dbm).

The essential elements of a compressor and an expander are shown in Fig. 34. These are a variable loss network, the loss of which is controlled by the output level in the case of the compressor and by the input level in the case of the expander, a linear amplifier, and a control amplifier and rectifier. The positions of the compressor and expander in the overall circuit are also shown in Fig. 34. Compandors may be used with any type of programme circuit, either carrier or physical.

Operation: The operation of the compressor may be followed by referring to Fig. 35, which is a simplified schematic of a typical compressor. The programme material impressed upon the compressor is fed through the variable loss network and the linear amplifier to the input of the programme circuit. A portion of the signal voltage at the output of the linear amplifier is fed through the control amplifier, rectified, and the direct current so obtained is used to control the loss of the variable loss network. The loss in the variable loss network, which is a network having varistors as the shunt arm, increases with an increase in rectified current and, therefore, with an increase in signal level. Consequently the loss in this network will be high for high signal levels and low for low signal levels. Low signal levels will, therefore, be boosted much more than high signal levels, and will be transmitted at a consequent higher level.

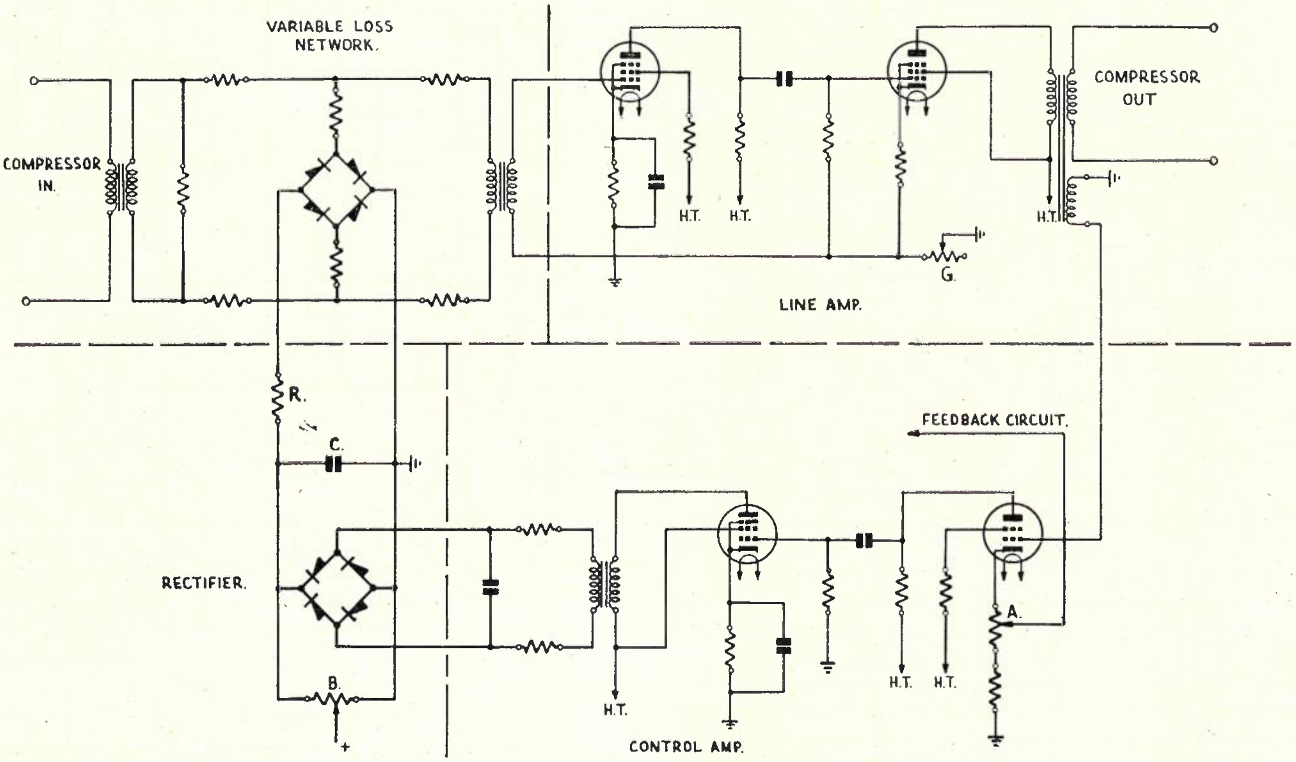


Fig. 35.—Compressor Schematic.

In the expander, a simplified schematic of which is shown in Fig. 36, the operation is much the same. However, it will be seen that the control signal is obtained from the input of the expander, and that the varistors form the series arms of the variable loss network. As a result the loss of the variable loss network will be low for high signal levels and high for low signals. The characteristics of this variable loss network are so chosen that the level at the output of the

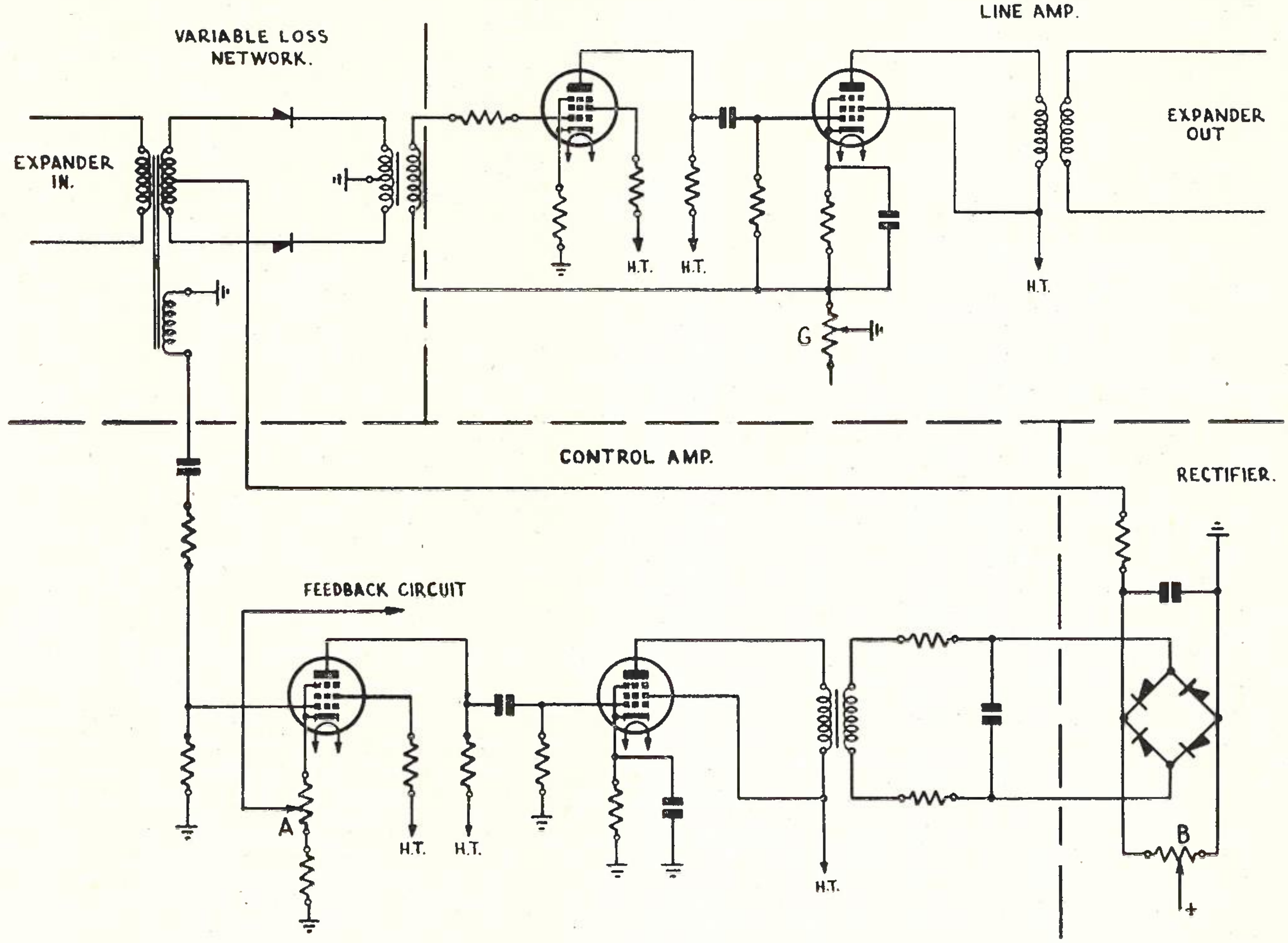


Fig. 36.—Expander Circuit.

expander will equal that at the input of the compressor. In particular it should be noticed that the loss in the expander is a maximum when no signal is present, which means that the noise level at the output will then be a minimum. It is obvious that this is a desirable condition.

The various level variations which occur for different input levels at different parts of the system are shown in Fig. 37. The increase in signal to noise ratio which is obtained, is clear from this diagram. It is also obvious that no improvement in signal to noise ratio will be obtained where the source of noise is before the compressor, as the compressor cannot discriminate between signal and noise at comparable levels.

Requirements and Limitations: There are several important conditions which must be fulfilled by various circuit elements if satisfactory operation is to be obtained, and various performance limitations exist where these conditions cannot be met. The requirements applying to the line and control amplifiers are those applying to any programme amplifier, but in particular it is necessary that the amplifiers be linear over the volume range which they are expected to handle. This requirement is also applicable to the rectifier in the control circuit.

The main requirement of the variable loss networks is that the varistor networks in the compressor and expander have and maintain charac-

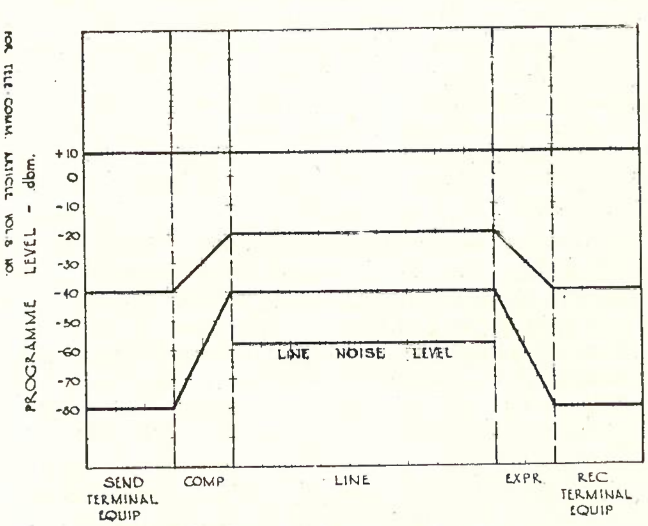


Fig. 37.—Effect of Campandor Operation.

Table 2.—Probable future application of various types of programme equipment.

Class of programme equipment	Type of bearer circuit		
	Open-wire	Cable (carrier type)	Cable (V.F. type)
Audio frequency	This will be most generally used type of equipment, although it will be displaced by carrier equipment on major circuits where improved performance is necessary.	Unlikely to be used on physical circuits. It will probably have extensive use by transmitting over phantom circuits.	Will be used extensively on 10 kc/s loaded pairs.
Carrier (for use with broad-band systems)	Will have extensive application where performance of audio transmission not satisfactory. It will be used with compandors to reduce crosstalk.	Will be used extensively.	
Open-wire carrier	Use of existing type of equipment restricted to non-J routes. Gradually being replaced. Limited use of new types of system for special applications.		
Split-band systems	Use will be restricted to emergency circuits. Application is very limited.		

teristics which will ensure that the action of the two networks is always complementary. To achieve this in practice, the varistors are often mounted in controlled temperature ovens to hold the varistor characteristics constant. The varistors also impose the principal limitation against achieving the theoretical overall performance. This is because the resistance of the varistors is a linear function of the control voltage over only a limited range, and, consequently, this imposes a limit to the volume range over which compression and expansion are effective. The dotted curve in Fig. 33 shows the variation from the theoretical characteristic which occurs in practical compandors.

It is important that the programme line, on which a compandor is used be equalised accurately, as a 1db variation in frequency response will appear as a 2db variation at the output of the compandor. To allow for variations in the compandor equipment, and to permit operation over circuits having various input and output level requirements, three controls, A, B and G, in Figs. 35 and 36, are provided. These enable the maximum transmitting level, the top of the companding range, and the slope of the compressor and expander characteristic to be fixed.

Timing Characteristics: One of the most important requirements of compandor design is the choice of a suitable operating time. The operating time is defined as the time taken for the loss or gain of the compressor or expander to reach 80% of the final value when the input level is changed suddenly.

The operating time of the compressor (which should be that of the expander) may vary between two limits. The lower limit is fixed by the period of the lowest frequency which has to be transmitted. It is essential that the operating time be long compared to the period of the lowest frequency signal as otherwise the wave shape will be altered during transmission. The ear fixes the upper limit of the operating time. It is necessary to make the operating time less than about 70 milliseconds to prevent the ear from detecting the changes. It is desirable that the operating time be as short as possible to prevent transient signals from momentarily overloading amplifiers.

The operating time of the compressor shown in Fig. 35 is determined by resistance R and condenser C. Condenser C also integrates the rectified signal currents, thus making the control current proportional to the power of the programme material.

Application: Through the use of compandors, improvements in the signal to noise (including crosstalk) ratio of up to 25db may be obtained. This improvement allows compandors to be used on programme circuits to obtain one of two results. Firstly, they may be used on circuits which are otherwise unsatisfactory for programme working because of high noise or crosstalk levels existing. Secondly, they may be used on existing circuits to enable a greater volume range to be transmitted, thus permitting the effective transmission of higher class programme material. It is likely that compandors will have extensive application for both purposes in the future.

CONCLUSION

A brief outline of transmission requirements of programme circuits, and details of various types of programme equipment, has been given. To sum up, as far as performance of programme circuits is concerned, the trend is towards improved performance, although there is no evidence of any move for near perfect transmission the obstacles against achieving this being economic rather than technical. The probable trends as far as equipment usage is concerned are set out in Table 2, while, in addition, the use of compandors is likely to become widespread on all classes of permanent programme channels.

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FLUORESCENT LIGHTING

A. F. Hall

Introduction

Artificial lighting is of vital importance in many of the activities of mankind, and the correct application of lighting has a direct influence on personal well-being. Modern developments in the lighting field, when properly employed, have provided the means for improving conditions in practically every branch of human endeavour. One of the most outstanding contributions of science to lighting has been the development of the electric lamp. The fluorescent lamp is the most modern example of that development, and it is the purpose of this article to describe briefly some of the more interesting features associated with this device, which has found such growing application in lighting for communication activities as well as in industrial and commercial lighting in this and other countries.

General

Before considering the fluorescent lamp it is well to introduce briefly the historical development of light sources generally in order to appreciate certain advantages which fluorescent lighting may have over commonly accepted standards.

Luminous Flame Sources. Since before the dawn of recorded history man has made use of the luminous flame to extend the period of his activities beyond the hours of daylight. More than half of the world's inhabitants still rely on flame sources for illumination although this method of lighting reached its peak with the gas flame and the incandescent mantle, first introduced about 1885.

Incandescent Electric Sources. The incandescent electric lamp, comprising an evacuated or gas-filled glass bulb enclosing a filament which is raised to a high temperature, has had a relatively short history, the first commercial lamp being produced in 1881. Since that time many improvements have been effected, and the gas-filled tungsten filament lamp in its many sizes and types is in general use today. Limitations imposed by the materials and principles of operation of these lamps make it extremely unlikely that any further improvements of a major nature will be possible.

Luminous Discharge Sources. Illumination produced by electric discharge was first applied commercially by means of carbon arcs in 1852, and, although this system was doomed by the rise of the incandescent light source, the application of electric discharge followed further development in the Cooper-Hewitt mercury vapour lamp, and later in the modern mercury vapour and sodium discharge lamps now applied increasingly to highway lighting. The neon sign lamp is also in common use, and much experimental work has been devoted to other types of gaseous discharge sources. The fluorescent lamp has developed directly from the gaseous discharge lamp, but employs the principle of luminescence to produce its luminous flux.

Luminescence is the term used for the phenomenon whereby visible radiation is generated without the application of heat. There are several types of luminescence. In the type known as photo-luminescence, visible radiation is produced by a body, not a light radiator under normal conditions, when excited by certain stimulating radiations not necessarily visible in themselves. If the emission of light continues for some time after the exciting agent is removed the phenomenon is called phosphorescence. Should the emission of light cease immediately the stimulating radiation is withdrawn, the phenomenon is termed fluorescence. It is an interesting natural law, discovered by Sir Gabriel Stokes, and hence known as Stokes' Law, that the wavelengths of the emitted fluorescent and phosphorescent radiations are always greater than that of the exciting radiation. The visible spectrum ranges from wave lengths of approximately 2800 Å (1) (violet) to about 7600Å (red) as indicated in Table No. 1.

Colour	Wave lengths (Angstrom units)	Frequencies (10^{12} cycles/sec.)
Violet	3900-4300	770-700
Blue	4300-4700	700-640
Blue green	4700-5000	640-600
Green	5000-5300	600-565
Yellow green	5300-5600	565-535
Yellow	5600-5900	535-510
Orange	5900-6200	510-480
Red	6200-7600	480-390

Table No. 1

Infra-red radiation, therefore, cannot be usefully employed in lighting applications as an exciting agent for these phenomena, and hence ultra-violet, violet, blue or green radiations are utilised.

Fluorescent Types. There are two general classes of fluorescent lamps, termed respectively "cold cathode" and "hot cathode." The former operate at high voltage, require no preheating and therefore "strike" immediately the circuit switch is closed. The latter operate at mains voltage, and hence require preheating, which may introduce slight delay in "striking" after the circuit is completed. Each type may be further subdivided according to operating characteristics. The cold cathode tube is employed to a very limited extent in the Postal Department and consideration will be restricted to the hot cathode type.

Excitation and Colours. In the modern fluorescent lamp, a low pressure mercury arc discharge is used as the exciting medium. It produces a very considerable radiation of one particular wavelength, namely 2537 Å and phosphors are selected and blended to respond efficiently at that wavelength. By proper selection a precise degree of control may be exercised on the colour of the light emitted by the fluorescent powders. This is important, because the direct production of coloured light without the use of absorption filters gives greater efficiency. The lamps are designated in several ways. One method is by specifying the absolute temperature (in Kelvins) to which a black body would need to be raised to produce a similar appearance. Peach, white (3500°K), natural (4200°K), daylight (4500°K), daylight (6500°K), blue, green and red are readily available in this country, although several of these may be obtained only in imported tubes. From the foregoing it will be obvious that the fluorescent powder behaves as a frequency changer, converting the energy of excitation from the almost invisible wavelength of 2537 Å to the visible range 2800 Å-7600 Å according to the particular phosphors selected.

The 48 inch 40 watt tube.

The 40 watt hot cathode fluorescent lamp consists of a glass tube having a $1\frac{1}{2}$ inch diameter, with a nominal length of 48 inches. Into each end of the tube is sealed a heavy filament, termed a cathode, coated with active material of barium and strontium oxides, the function of which is to provide copious electrons when heated. Certain additives, such as zirconium oxide, may be used and these may have a pronounced effect on lamp life by reducing end blackening and by conserving active material on the cathodes. The ends of each filament are brought out to a pair of pins in each cap. Sometimes antenna-like electrodes are associated with the cathodes, their object being to absorb part of the electron bombardment each half cycle and so reduce the evaporation of active material from the cathodes. Recent experiments have indicated that the anodes may be omitted in certain circumstances without affecting lamp life. On the inner surface of the tube during manufacture, a thin layer of adhesive is deposited by forcing a wet sponge through the tube under compressed air. Fluorescent powder is poured in and an evenly distributed coating of powder adheres to the transparent adhesive. The total weight of coating on a 40 watt tube is approximately one-tenth of an ounce. The particle size is extremely small (.0008 to .0002 inches in diameter). Until recently the most commonly used powders were zinc beryllium silicate and magnesium tungstate in different proportions to give the types of tubes 6500°K daylight, 4500°K, 3500°K white and soft white. The use of beryllium compounds, which are toxic, introduced some slight hazard if the powder should enter an open wound or be inhaled, and special precautions are desirable in disposing of used tubes. Latterly the use of halo-phosphors, such as calcium halophosphate has removed this

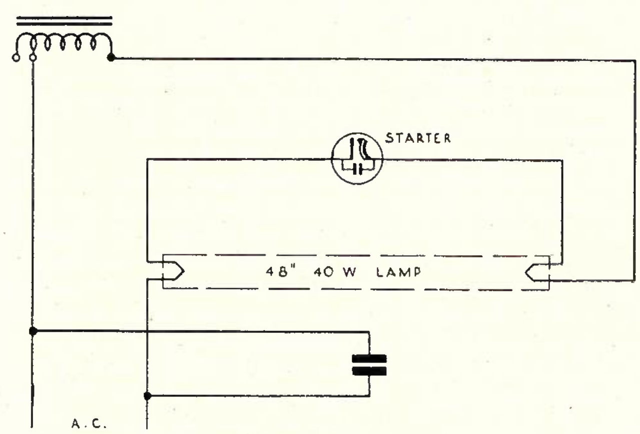

Fig. 1.—Typical Single Fluorescent Lamp Circuit.

(1)—1 Ångstrom Unit (Å) = 10^{-8} Cm.

hazard and most tubes now available are non-toxic. Mention should be made also of the fact that ultra-violet radiations can produce very serious injuries to the eye, but in the case of the fluorescent lamp these radiations are within the glass tube. The glass acts as an effective filter of injurious radiations so that no harm can be occasioned to eyes from this cause.

The tubes must be subjected to very close control during each phase of manufacture. Within the tube is a tiny drop of mercury and a small amount of argon gas. Argon is used because of its electrical conductivity at relative low voltage. A fluorescent lamp operating normally has a mercury vapour pressure of 10^{-5} atmospheres. If the gas pressure is slightly high the tube will be hard to start; if too low the lamp depreciation is accelerated.

A typical standard circuit showing the connection of a fluorescent tube is indicated in Fig. 1, and several items of equipment other than the tube will be noted. A brief description of each is given in the following.

Lamp Ballasts. In common with all gas discharge lamps the fluorescent tube has a negative resistance characteristic, that is, as the tube rises in temperature the resistance of the discharge path decreases. For this reason a current limiting device must be included in the circuit. This device is generally termed the ballast and limits the flow of current in a 48 inch 40 watt tube to a value between 370mA and 415mA. Occasionally a resistance is employed to limit the current either as a plain resistance or, more often, as an incandescent lamp of suitable characteristics. Considerable

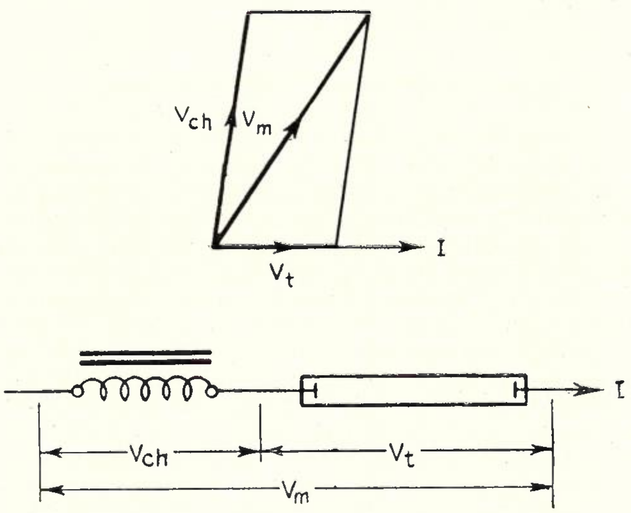

Fig. 2.—Typical Vector Diagram 220/230 V. Circuit—Lagging Ballast.

additional losses are introduced when a resistance is used and an iron-cored choke, wound with copper wire, is the most common type of ballast. It is generally referred to as a "lagging" ballast since its introduction will reduce the power factor to approximately 0.6. When this ballast is used a power factor correction capacitor is added in parallel with the lamp and ballast to restore the power factor to approximately 0.9. On a 50 c/s AC supply the discharge is actually extinguished and re-established at twice supply frequency. Where two tubes are used in a fixture in locations where the stroboscopic effect may be undesirable, a "tulamp" ballast may be used. Such a ballast consists of two choke sections—the normal "lagging" ballast and a second choke section with which is associated a series capacitor to give a leading angle to the current of the associated tube. The respective resultant voltages are phase displaced reducing the stroboscopic effect. The "tulamp" ballast components are enclosed in one can. The capacitor should be a high grade manufacture as a faulty capacitor may cause failure

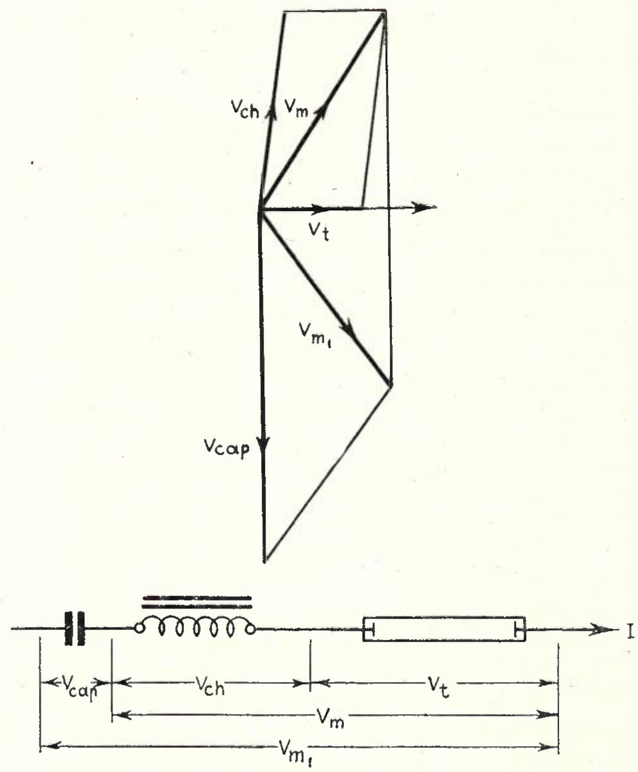

Fig. 3.—Typical Vector Diagram 220/230 V. Circuit—Leading Ballast.

of ballast and tubes. The consequent cost of replacement indicates that separate ballasts would be a better solution, and that the use of leading ballasts should be restricted to places where it is essential to avoid stroboscopic effects as much as possible. Vector diagrams are indicated diagrammatically in Figs. 2 and 3.

The Glow Starting Switch. A starting switch is shown in the circuit. Its function is momentarily to close and then open the cathode circuit and so provide suitable conditions of electron flow to ionize the gas and "strike" the lamp. A common type of starting switch is the two terminal glow starter. The internal elements comprise a small glass bulb containing neon and/or argon. Enclosed in the bulb are a fixed contact and a U-shaped bimetal strip with a movable contact. External to the bulb is a small radio frequency suppression capacitor connected across the contacts. A variation of this starter, termed the "Watchdog" type, employs an additional bimetal strip which will operate to open the circuit should abnormal conditions cause repeated unsuccessful attempts by the starter to "strike" the lamp. An external push button is provided for resetting purposes. The sequence of events during starting is:—

1. When the control switch is operated a glow discharge occurs in the starter switch bulb. Due to the warmth generated, the contacts quickly close and the glow discharge ceases.
2. Full starting current flows through the lamp cathodes which are heated and emit electrons freely.
3. A mercury discharge glow appears around each cathode. The ultra-violet discharge from this glow excites the fluorescent material producing the end glow.
4. The glow switch contacts now open owing to the cooling of the bimetal strip. The capacitor in the starter switch sets up oscillations which increase the duration of the ballast choke surge when the switch contacts open.
5. The collapse of the magnetic field in the choke creates a voltage surge which ionizes the mercury-argon gas between the electrodes within the tube. The ionization initiates a glow discharge principally at 2537 Å, completing the excitation of the phosphors and producing visible light. (Should the tube not "strike" the above sequence is repeated, giving the blinking effect.)
6. The current rapidly reaches the final operating value and the arc centres on the most active spot on each electrode raising the temperature of that spot to red heat, thus providing sufficient thermionic emission for continued lamp operation.

Owing to the voltage drop between the cathodes the voltage available at the glow starter switch terminals is insufficient to produce the glow discharge and the starter contacts remain open while the tube is in operation.

Light source	Luminous flux (Lumens)	Temperature °C.	Efficiency Lumens/watt
Candle	6-13	1450	0.1-0.2
Kerosene lamp	150-200	1600	0.3
Inverted gas burner with mantle	200-1000	1750	1.4-1.7
Acetylene flame	70	2500	0.7
Carbon filament lamp	50-500	1850	2.5-3.5
Tungsten lamps 25w	255	2262	10.2
40w gas filled	440	2437	11.0
100w gas filled	1430	2527	14.3
500w gas filled	9800	2692	19.6
Carbon arc lights (Blondels carbon)		3500-4000	31.5 (D.C.)
Mercury vapour discharge			
250w	9000		36
1000w	40,000		40
Sodium discharge			
100w	6100		58.1
150w	9600		58.2
Fluorescent (hot cathode)			
40w White (3500°K)	2320		46 overall
Natural			
(4200°K) .. .. .. (4500°K)	2100		42
(6500°K)	1920		38.5
30w Blue	780		22.3
Green	2250		64.4
Pink	750		21.4
Gold	930		26.5
Red	120		3.4

Table No. 2

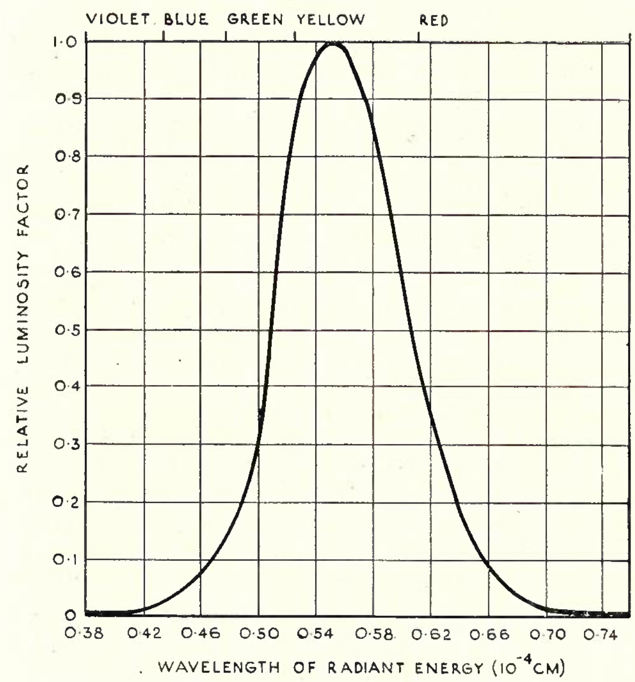

Fig. 4.—Relative Visibility Curve.

Operating Features

Lamp Life. Since the cathodes are raised to a high temperature during each attempt to start, lamp life is, to some extent, adversely affected by frequent starting. Some tubes appear to be affected less in this regard than others of different manufacture and lamp life up to 7000 hours has been obtained on groups of lamps in local tests with three switchings a day. Deterioration in lumen output at the end of that period had not exceeded 38 per cent. These tests are tests to destruction, and it is not suggested that, in service, a depreciation of 38 per cent. due to deterioration in lamp output alone should be permitted. Certain fluorescent lamp manufacturers give an unconditional guarantee of 3500 hours service, and indications are that at least this period of service may be satisfactorily attained. It is important to note that the crest factor of the ballast (the ratio of peak to R.M.S. current) has a very considerable effect on lamp life. The crest factor of either lagging or leading ballasts should not exceed 1.58 if the lamp life is not to suffer.

Eye Response and Luminous Efficiency. The visible portion of the frequency spectrum is tabulated in Table No. 2. The human eye is not uniformly responsive to all colours, being less sensitive to violet and red, but most sensitive in the yellow-green band of the spectrum and to wavelength of approximately 5560 Å. The typical relative visibility curve is indicated in Fig. 4. The visibility figures hold true for brightness usual with artificial and daylight illumination. If all the energy supplied to a light source could be converted into light of wave length 5560 Å the luminous efficiency of that imaginary light source would be 670 lumens per watt, and this is the theoretical maximum luminous efficiency. The maximum attainable efficiency of any white light source with its output distributed uniformly with respect to wave lengths within the visible region is approximately 200 lumens per watt.

Relative Efficiency of Light Sources. In Table 2 the light output of a number of sources is listed as well as the respective luminous efficiency. The 40 watts of input energy supplied to a fluorescent lamp is said to be dissipated in 24.9 watts of visible light directly from the discharge in ultraviolet excitation, 60% of which is concentrated at 2537 Å and 15.1 watts in heat. The 24.9 watts of excitation produce from the fluorescent powders 8.2 watts in light and 16.7 watts in additional heat. Although the efficiency is low when compared with the theoretical maximum, the lamp is approximately four times as efficient as the incandescent lamp of similar wattage.

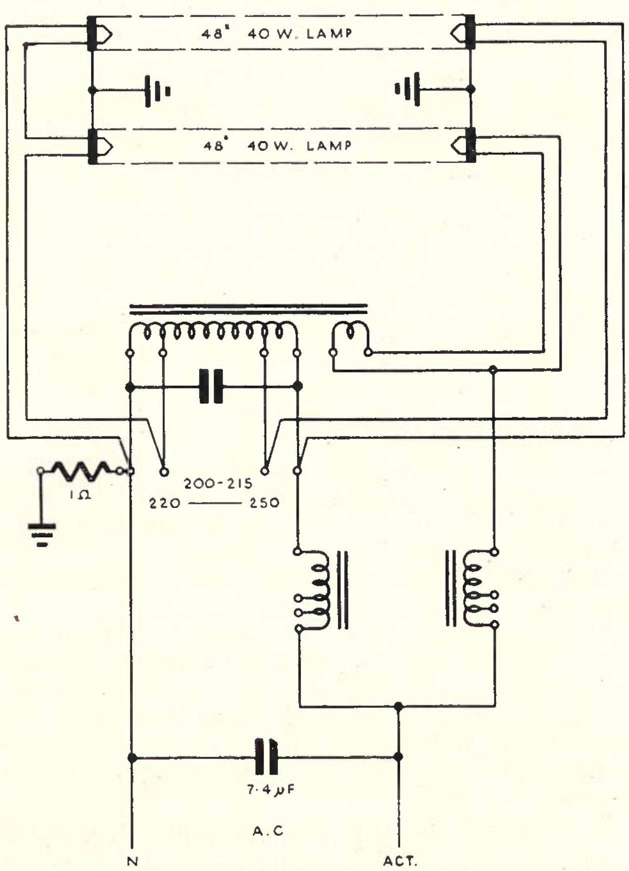

Fig. 5.—Typical Instant-start Circuit.

Disadvantages in Application. Notwithstanding the advantages of the fluorescent tube in efficiency, in decrease in heating effect, in lamp life and in reduced surface brightness, some disadvantages also attend its application to lighting. Colour rendition is somewhat different from that produced by incandescent sources. This effect applies particularly towards the red end of the spectrum, the light output of fluorescent tubes being somewhat deficient in red, and the effect differs for tubes of different colour temperature gradings. A second disadvantage is in initial cost. The auxiliary equipment and also the physical dimensions of the light source necessarily increase cost of manufacture. The auxiliaries introduce greater fault liability and the clearance of faults requires a higher degree of skill and experience. The delayed starting and flickering during the starting period are also disconcerting and objectionable. The ballast is designed on the assumption that the increased current at starting will flow for a short period only and if, for any reason, the tube should fail to strike or should the starter switch contacts fail to open, the temperature of the ballast may in time rise to the point of failure. An attempt to meet these circumstances has been made in the "watchdog" starter referred to previously, but these starters are not now available on the Australian market. It is indeed remarkable that the glow starter switch, so ingenious in operation yet so relatively cheap, should perform as well as it does. It may be said, however, that most failures of ballasts and a fair proportion of tube failures may be traced to the defective operation of the associated starter.

Quick Start Operation. In order to avoid the use of the starter switch the so-called "quick start" or "instant start" circuit has been developed and is shown in Fig. 5. There are a number of variations of the circuit, but in general the lamp cathodes are supplied with current from special heater windings on a high reactance transformer, the primary of which is connected in series with the lamp control ballast. The lamp will not strike until the cathodes reach a suitable temperature, and when the strike occurs the cathode current is reduced to about two-thirds of the preheat value. This reduced current flows through the cathodes during the entire time the lamp is in operation, but is of sufficiently low value not to affect the cathodes adversely. Tube life at least equal to that when used in a standard circuit is claimed. Since the tube is required to strike at mains voltage, striking conditions are more critical and at present specially selected tubes, known as quick-start graded tubes, are recommended for reliable starting in these circuits. An important point also is that an electrostatic field is necessary for reliable lamp operation, and this is provided by an earthed strip from end to end of the tube and within ¼ inch of its surface. Under conditions of extreme humidity a film of moisture may be deposited on the surface of the tube and this may prevent the striking of the lamp under quick-start operation. An additional precaution may be taken in the manufacture of the tubes to reduce this effect by coating the surface of quick-start graded tubes with an invisible water repellent which causes the moisture film to form into droplets. It is interesting to note, however, that one local manufacturer is now producing quick start equipment which gives reliable starting under adverse conditions using standard tubes.

Conclusion

The introduction of fluorescent lighting into this Department has brought about improved working conditions without a correspondingly great increase in power consumption. Although many lighting problems, particularly in respect of maintenance, have yet to be solved the wider application of this method of lighting, particularly where long burning hours are expected, will be of undoubted advantage.

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MANUAL C.B. MULTIPLE EXCHANGES AND SLEEVE CONTROL TRUNK SWITCHBOARDS. PART 3: TRUNK LINE CIRCUITS

J. S. Silvester, A.M.I.E. (Aust.), M.I.R.E. (Aust.)
and J. L. Harwood, M.I.R.E. (Aust.)

General

In the two articles which formed parts 1 and 2 of this series (see Vol. 8, Nos. 1 and 3) the physical design, construction, certain operating procedures and the circuit description were detailed. This article describes the circuit operation of the trunk line circuits. Reference should be made to the table of circuits and operating sequences involving the various classes of trunk circuits, Fig. 3, on page 148 of Vol. 8, No. 3, when reading the circuit functions described in the following.

Generator Signalling Trunk Line Circuit—2 wire. Fig. 20 (C.E. 371, Sheet 1).

Incoming calls from these lines are answered on the terminating positions. Calls for subscribers within the unit fee area are completed on these positions, but calls for other trunk lines are completed via the through trunk positions. Bothway jacks with guard lamps are provided with multiple appearances on both terminating and through positions. The call lamps appear on the terminating positions while the transfer lamps (call for through connection) appear on the through positions.

Incoming Call. Relay L operates on the incoming ringing current and operates relay LL. LL locks under the control of CB or DR. LL also connects the engaged test battery to the sleeves of the through position jacks, lights the guard lamps on all positions, the call lamps on the terminating positions, closes the N.A. circuit, prepares the flicker earth circuit and connects earth to the P wire from the trunk selector multiple.

The telephonist on a terminating trunk position answers by inserting the "trunk" plug in the B/W line jack. Relay S operates, followed by SS. Relay CB operates and takes over the busying functions of the LL contacts. The calling lamps are extinguished. Relay CB also disconnects the line termination as a cord circuit is now connected to the line.

The operation of relay SS connects DR to the sleeve of the line jack. The windings of DR are connected in opposition and, due to the telephonist being connected to the line, the current in the windings is unbalanced and DR operates. The contacts of relay DR short circuit relay LL which releases.

If a re-ring signal is received relays L and LL re-operate. Relay LF is connected to flicker earth and LF intermittently earths both sides of relay DR. As a result the cord circuit supervisory lamp flickers as an indication that the circuit requires attention. When the telephonist answers the windings of relay DR again become unbalanced, and while LF is released, DR operates and releases LL.

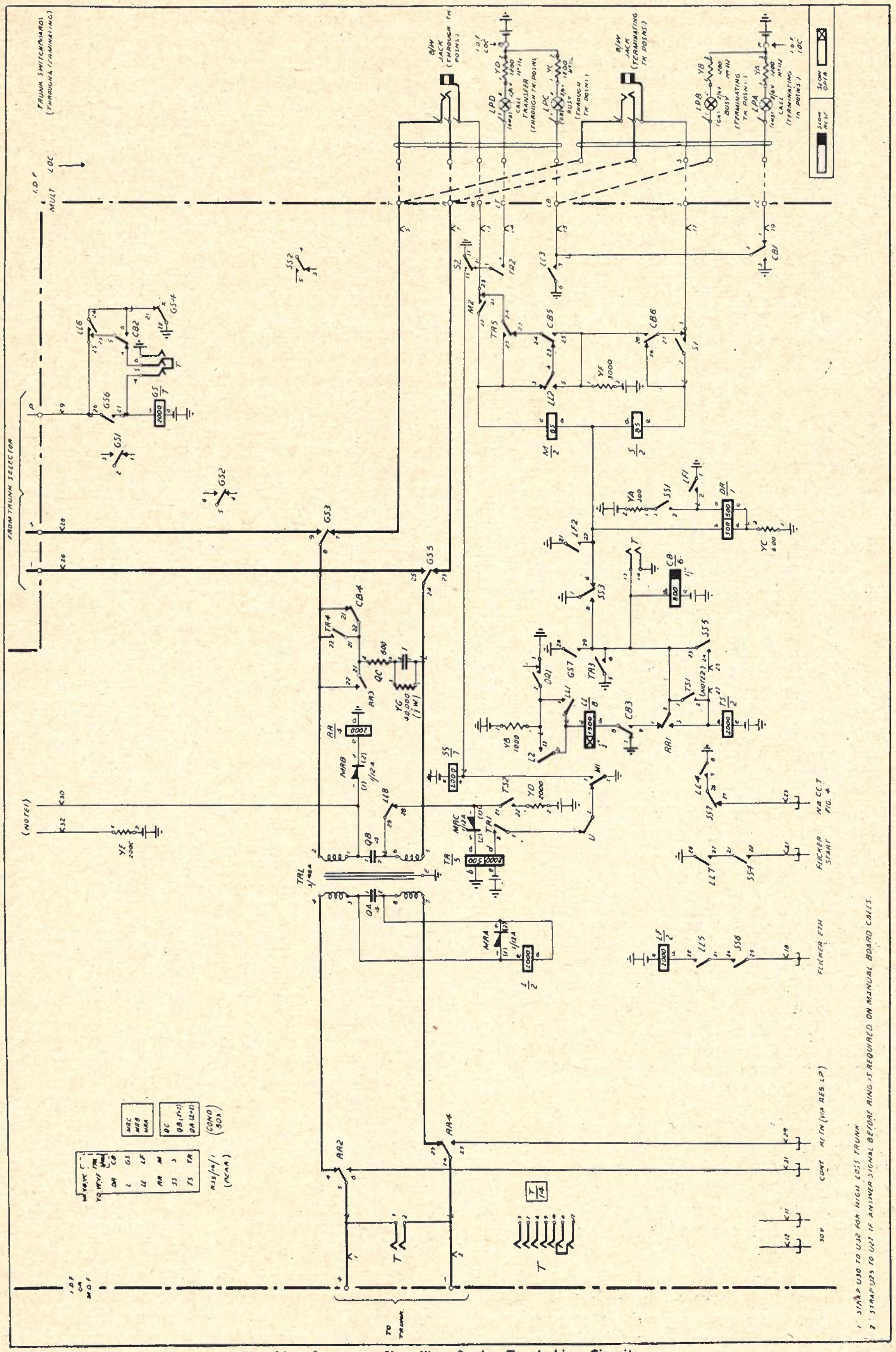


Fig. 20.—Generator Signalling 2-wire Trunk Line Circuit.

To ring in the reverse direction (to recall the distant operator) relay RR operates from positive battery connected from the telephonist's position circuit, and connects continuous ringing to the trunk negative and positive lines. When the position ring key is released relay RR is de-energised and the ringing current is disconnected.

If the call is for another trunk line, R.A.X., or automatic exchange outside the unit fee area, the call after being answered by the telephonist on a terminating trunk position, is transferred to the through trunk positions for further action. With the speak key operated the transfer key is thrown to connect positive battery to the ring side of the trunk. Relay TR operates and provides an alternative holding earth for CB, reconnects the 600 ohm termination, and provides an operating circuit for relay M. The telephonist on the terminating trunk position then removes the plug. Relay S releases, followed by SS, and the transfer lamps light on the through positions. Relay S now reconnects the engaged test potential to the sleeves of the terminating position jacks.

When the telephonist on a through position answers, relay M operates and operates SS and opens the circuit of relay TR. TR releases and extinguishes the calling lamps. The operation is then as described previously for calls answered by a telephonist on a terminating position.

Outgoing Call. The insertion of the calling plug into the line jack operates relay M or S, according to the type of position from which the call is made. SS operates, followed by CB, which marks the circuit busy. RR operates when the operator rings and operates TS, if not already operated by SS. TS locks and connects battery to the R conductor of the cord as an answer supervisory signal to an incoming circuit on the other side of the cord circuit. The cord circuit is divided at this stage and the answer supervisory is therefore inoperative until the cord circuit is coupled.

When L and LL operate on the ring off signal from the distant end the answer supervisory battery is removed from the R side of the line and the flicker earth is connected to LF. The cord circuit supervisory lamp now flashes. When the calling plug is withdrawn relay M (or S) releases, followed by SS. After a short lag CB releases and the circuit is free. Should LL be operated when the plug is withdrawn it will release when SS releases (in the releasing time of relay CB).

Outgoing Call from Trunk Selector (when installed). The trunk selector tests in on the P wire and operates relay GS, which operates relay CB to mark the circuit busy to the manual board. FW operates and extends the network pair to the trunk selector in the case of a 4-wire trunk line circuit.

The distant telephonist now rings and RR operates on positive battery connected to the tip side of the line. Ringing current is connected to the trunk. TS operates and connects the answering supervisory battery to the ring side of the line and RR releases when the calling telephonist ceases ringing.

A ring back from the called end operates relay L, followed by LL. LL signals to the distant calling telephonist by disconnecting the answering battery from the R side of the line. The calling telephonist may either disconnect, terminate the connection (if the ring was a "ring off" signal) or re-ring. The operation of RR in the latter case releases LL and restores the answering supervisory battery to the R side of the line.

When releasing, the trunk selector removes earth from the P wire and GS releases, followed by LL (if operated) and TS. CB then releases slowly and the circuit is free.

Generator Signalling Trunk Line Circuit—4 Wire. Fig. 21. (CS.371, Sheet 2.).

These circuits are for use with amplified lines or carrier channels on which generator signalling to and from the switchboard is employed. These lines may be switched on a 4-wire basis with auxiliary cord circuits on the through positions (net cords). The method of operation is similar to that described above for 2-wire generator signalling trunk lines, except that for through calls to other 4-wire trunk lines, net cords must be used to reduce the overall transmission loss.

Circuit Operation. The circuit operation is similar to that described in the foregoing for 2-wire generator signalling trunk line circuits, but with the addition of the 4-wire switching and pad control circuit elements. Relay FW will operate in both circuits when the net plugs are inserted. Relay FW will release if the telephonist enters the connection due to relay DR operating and the connection then reverts to two-wire working. When the telephonist leaves the connection DR releases and 4-wire switching is restored by the re-operation of FW.

If the line cord is taken down before the net cord the release of relay SS will connect the low resistance winding of relay FW to the sleeve of the net jacks. The net cord pilot lamp will light as an indication to the telephonist that the net cord should be taken down. Relay CB holds under this condition.

If the trunk is of low loss the PC relay will be connected, with FW normal, to the negative line only. PC will only operate if the trunk becomes connected to a 2-wire high loss circuit (that is, in excess of 3 db from switchboard to switchboard), and will remove the 3 db pads but leave the 4-wire circuit connected on a 2-wire basis. PC operates from negative battery supplied over the tip side of the net cord (200 + 200 ohm feed coil). PC releases whenever the telephonist enters the connection, due to the operation of relay DR.

When in the idle condition both line and net pairs are terminated in 600 ohms. The line termination is removed whenever the circuit is in use and the net termination when relay FW is

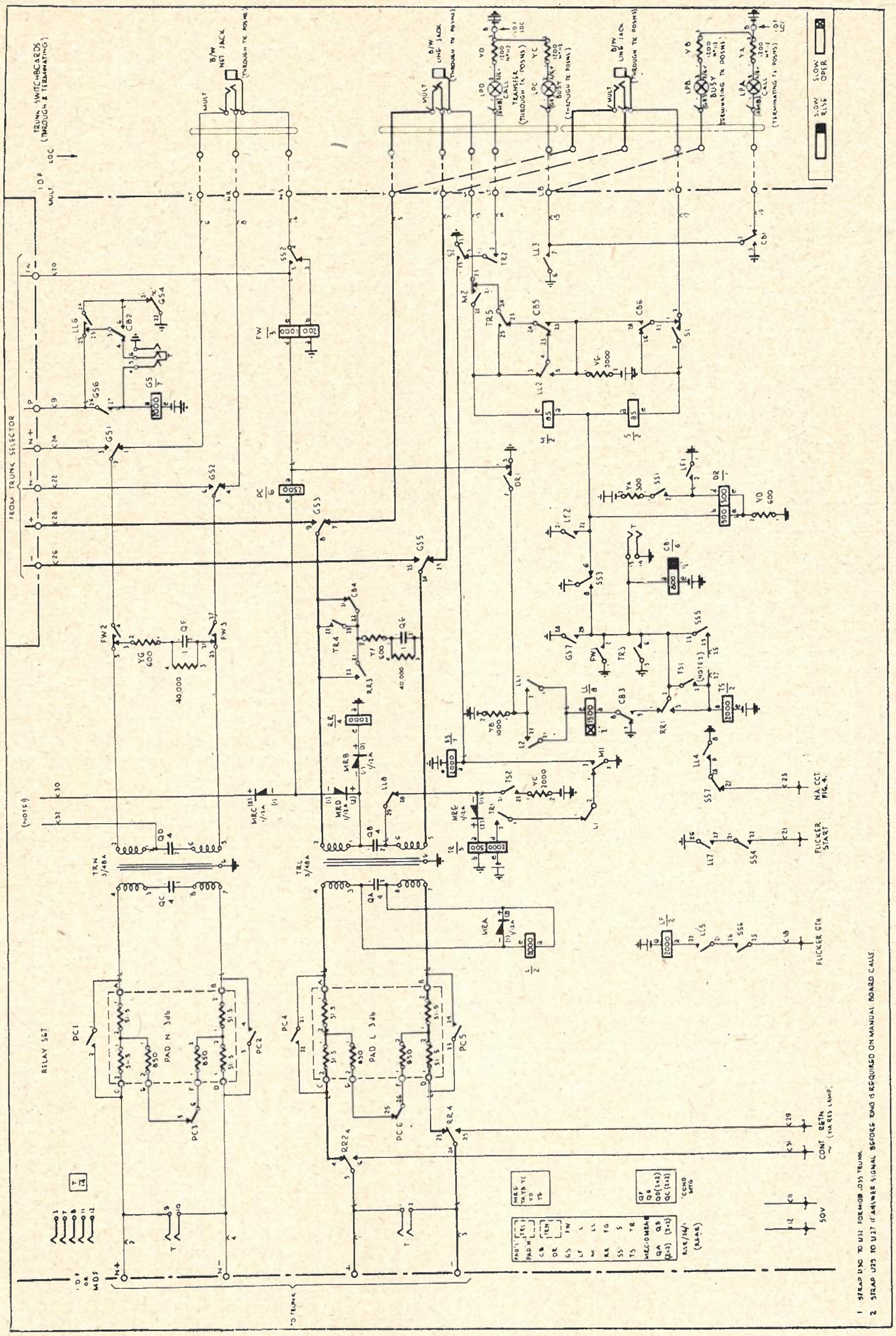


Fig. 21.—Generator Signalling 4-wire Trunk Line Circuit.

operated. In the case of connection between two 4-wire trunks either or both pad control relays may be operated to effect an improvement in transmission. This is determined by appropriate shelf jack strappings.

Trunk Line Circuit to Automatic Exchange or R.A.X.—Fig. 22, (CE.371, Sheet 3.)

This circuit is for use for bothway working between the trunk switchboard and an automatic exchange or R.A.X., outside the unit fee area. The circuit can be adapted for unidirectional working if required. Incoming calls are handled by the terminating trunk positions for connection to local C.B. subscribers or other exchanges in the unit fee area. Incoming calls for other trunk lines are transferred to the through positions by the operation of the transfer key in the terminating trunk telephonist's position circuit.

Circuit Operation—Incoming Call. The incoming ring operates relays L and LA which lock via contacts SR. LA operates relay SA, connects 3,000 ohm resistance (YE) to the jack sleeves of the trunk line multiple appearances on the through positions for the engaged test, lights the busy lamps in multiple on all positions, lights the call lamps on the terminating trunk positions, and closes the N.A. circuit (if switched on). Relay SA prepares the holding bridge circuit.

When the telephonist answers, negative battery on the sleeve of the cord operates relay S. S1 closes relay SR and S2 switches relay S direct to the sleeve circuit. Relay SR operates and provides an alternate earth to light the busy lamps, connects 3,000 ohm battery (YE) to the multiple sleeves for the engaged test on the through positions (in lieu of LA contacts), breaks the circuit of relay LA which releases, holds SA via its contacts, connects the bridge loop, including relay D, across incoming line, removes 600 ohm termination and disconnects relay L.

The incoming ring is tripped by the loop. Relay LA releases and opens the circuits of the calling lamps and the night alarm. Relay D operates and connects the 2,000 ohm resistance (YC) and negative battery to the ring side of the connection for the supervisory signal circuit and operates relay Z. Relay Z will remove the earth shunting the 5,000 ohm resistance (YF) in the sleeve circuit to increase the sleeve resistance and dim the supervisory lamp in the cord circuit. Z will also lock itself and prepare an operating circuit for relay LF.

If the call is to be connected to a local subscriber or exchange in the unit fee area the telephonist on the terminating trunk position completes the call with the subscriber's cord. If the call is for another exchange outside the unit fee area, the telephonist transfers the call to the through positions by operating the transfer key in her position circuit. This applies positive battery to the ring side of the cord and trunk line circuits, operating relay TR which locks via TR1 to earth at M1. TR prepares a circuit for lighting the call lamps on the through positions after the plug is removed by the telephonist on the terminating trunk position and removes the battery engaged test from the sleeves of the through position jacks. TR also reconnects the 600 ohm termination across the line, holds relay SR when the plug is removed, and short circuits 5,000 ohm resistance (YF) increasing the current in the sleeve circuit to light the supervisory lamp in the cord circuit. The telephonist now removes the plug and releases relay S, which lights the call lamps on the through trunk positions and connects the engaged test battery YE to the sleeves of the terminating trunk position jacks.

When the telephonist on the through position answers, relay M is operated to earth at TR6. M opens the holding circuit of TR and provides a holding circuit for relay SR.

If the call is released at the automatic exchange battery is reversed in the line and relay D releases. D will remove 2,000 ohm (YC) battery from R side of other trunk circuit, connect relay LF to the flicker earth and will close the flicker start circuit. Relay LF impulses and intermittently shunts the 5,000 ohm resistance YF in the sleeve circuit, causing the supervisory lamp in the cord circuit to flash until the telephonist takes down the cords.

Circuit Operation—Outward Call to Automatic. Calls can be made from the through or terminating trunk positions, the trunk cord (rear) being used to make the call from the terminating positions. Either cord may be used on the through positions. The telephonist plugs in, operating relay M or S, according to the position from which the call is being made. Relay SR operates and connects the engaged test battery via YE to the other position sleeve circuit. YE is disconnected from the sleeve circuit of the corresponding positions. SR also disconnects relay L from the line and connects the line through, prepares the flicker start circuit, prepares operating and locking circuit for relay Z, lights the busy lamps, and removes the 600 ohm termination. The supervisory lamp on the cord circuit glows via earth at Z2.

The telephonist now operates the dial key with the speak key open and positive battery is fed over the tip side of cord to operate relay DC. Relay DC locks via DC3 to earth at SR5. DC also connects the line through clear of the transformer TRL, opens the locking circuit of TR to prevent TR locking up if flicked up before DC2 opens, disconnects earth from the sleeve at Z2 and connects the sleeve circuit through relay SA to earth at SR5. The increased resistance (3,000 ohms) in the sleeve of the position circuit whilst the dial key is operated prevents relay SA from operating.

Dialling is thus carried out over a clear loop, and when the dialling key is restored battery is increased on the sleeve circuit and relay SA operates and locks with both windings in series via SA4 to earth at SR5. SA also opens relay DC

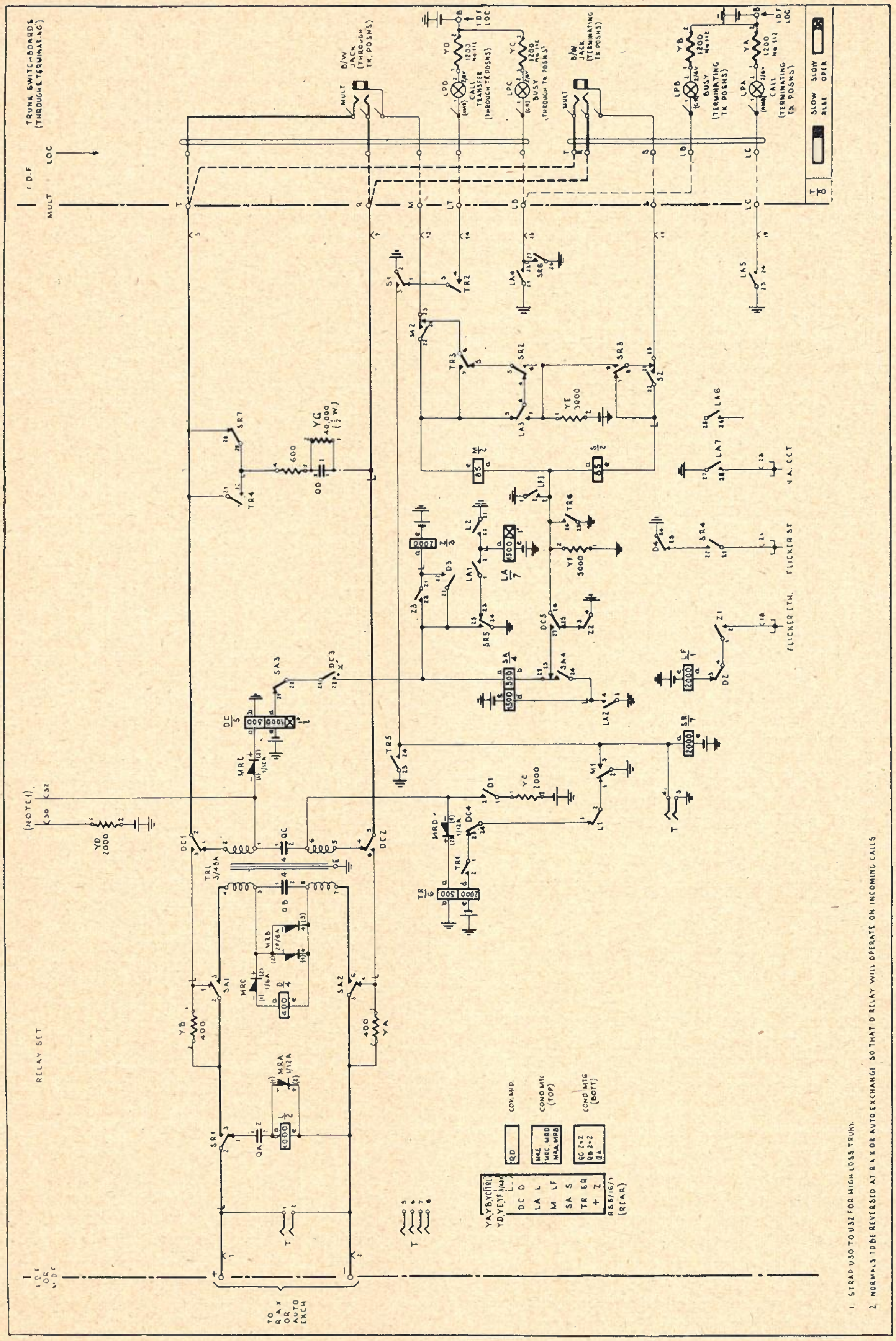


Fig. 22.—Trunk Line Circuit to Auto Exchange or R.A.X.

which releases and reconnects the line to the transformer TRL. SA contacts re-connect the line side to the transformer. The 400 ohm resistors YA and YB prevent the dial short circuiting relay D, whilst DB and DK are releasing in the position circuit.

The selector at the automatic exchange is held by the rectifiers across relay D until the called subscriber answers. Relay D then operates to reverse battery and operates relay Z. Z locks to earth at SR5 and Z2 removes the shunt from the 5,000 ohm resistance YF in the sleeve circuit. The supervisory lamp in the cord circuit is dimmed, and Z1 prepares the circuit for the LF relay to flicker earth.

When the called party clears, battery is reversed again on the line causing the release of relay D. D removes battery via YC (2,000 ohms) from the R side of the line, closes the circuit of relay LF to the flicker earth and closes the flicker start circuit. Relay LF pulses from the flicker earth and intermittently earths the sleeve circuit causing the supervisory lamp in the cord circuit to flash. All relays release when the cords are taken down.

2 VF Trunk Line Circuit—Fig. 23 (CE.371, sheet 4.)

General. This circuit may be used for through connections (routed automatically via selectors or manually) as well as for terminating traffic. Both-way working is catered for and this may be automatic and/or manual in either direction, but the circuit may be used for unidirectional working if required.

Manual working conforms to the standard sleeve control trunk exchange procedure as previously described. Incoming calls are at present routed to the local manual board but may be routed, when the necessary equipment is provided, as follows:—

(a) To the local automatic area.

(b) To branch 2VF signalling trunks via trunk selectors and without passing via the manual board.

(c) To branch generator signalling trunks via trunk selectors without passing via the manual board.

(d) To branch DC signalling trunks or junctions via trunk selectors without passing via the manual board (for example, R.A.X. junctions).

(e) All of the foregoing also via the local manual switchboard.

Outgoing calls are derived from:—

(a) The local manual board.

(b) 2VF signalling trunks via the trunk selectors without passing through the manual board (when the necessary equipment is provided).

When two 2VF signalling circuits are switched together via the trunk selectors the tandem switching circuits involved (one in the incoming and one in the outgoing condition) are switched into a condition whereby all VF signals pass right through the switching centre without causing any action other than, of course, the signal which releases the connection. When such circuits are connected via the manual board VF signals do not pass right through but are relayed through the cord circuit on a DC basis at the same time giving the manual operator supervisory indication of the condition of the call.

Four Wire Switching and Pad Control. If the exchange has branch trunks capable of four-wire switching, the circuit will cater for such conditions. Network jacks will be required at the same rate of provision as the line jacks on the "through" positions. The circuit will be switched to a four-wire condition when the network cord has been put up between the two trunk circuits concerned or when a similar connection has been established via the trunk selectors. Reversion to two-wire working occurs if the operator throws the speak key associated with the line cord. Connection must, of course, be established via the line cord before putting up the net cord.

3 db pads are equipped on circuits of all types and are switched as follows:—

Type of Circuit	Switched to Trunk	Pads
4-wire high loss	4-wire high loss	Out
4-wire high loss	4-wire low loss	Out
4-wire low loss	4-wire high loss	In
4-wire low loss	4-wire low loss	In
4-wire high loss	2-wire high loss	Out
4-wire high loss	2-wire low loss	In
4-wire low loss	2-wire high loss	Out
4-wire low loss	2-wire low loss	In
2-wire high or low loss	Any class of circuit	Out

V.F. Signalling. Each 2VF trunk line circuit has associated with it a 2VF receiver. This receiver incorporates two relays termed X and Y. The X relay operates when 750 c/s tone is received (X tone) and Y when 600 c/s tone is received (Y tone). Oscillators provide 600 c/s and 750 c/s current for signalling purposes. When these tones are being sent the 2VF receiver associated with the sending circuit is disconnected as it is not required to function on any but received signals. Certain signals sent by the circuit are repeated. A relay interrupter provides the control for these repeated pulses and also pulses for stepping a signal sending uniselector.

V.F. Signalling Code. The following is a list of the VF signals used, together with their function. The order of their occurrence during calls is described later under headings for particular types of call.

1. Pick up Call: 750 c/s: 50 ms minimum, 100 ms maximum, single pulse. Establishes a calling condition on incoming calls by preparing the circuit for impulsing. Prepares the distant end for impulsing on outgoing calls.
2. Impulsing: 750 c/s: 67% of impulse length (nominal). On incoming calls is used to position local selectors. On outgoing calls selects the wanted party at the distant end.

3. Answer: 600 c/s: 350-400 ms on 350-400 ms off. Repeated until acknowledged. Sent on incoming calls when called subscriber answers or when circuit without supervision is engaged. Received on outgoing calls when distant subscriber answers. Extinguishes supervisory lamp.
4. Answer acknowledge: 600 c/s: 250-350 ms single pulse. Received on incoming calls when answer signal has registered at the distant end and causes the repetition of the answer signal to cease. Sent on outgoing calls when answer signal pulse has been received and caused repetition of answer signal from distant end to cease.
5. Clear back: 600 c/s: 350-400 ms on 350-400 ms off repeated. Sent on incoming calls when subscriber hangs up, rings off or operator withdraws answer plug. Ceases if subscriber removes receiver. On out-going calls is received when called subscriber hangs up. Lights supervisory lamp steadily for duration of signal reception.
6. Ring forward: 750 c/s: length dependent on operation of ring key. On incoming calls the signal flashes the supervisory lamp on calls via the manual board. On calls via the trunk selectors the signal passes right through on VF-VF connections but causes a generator ring to be sent out on VF-magneto trunk connections. The signal causes the circuits to revert to the pre-answered state. On outgoing calls it is sent when the attention of the distant operator is required.
7. Clear forward: 600 c/s: 1400-2500 ms on 450-550 ms off 6000-7000 ms on second pulse sent only when release signal is not received during pause.

   On incoming calls to manual board it lights supervisory lamp indicating that call has finished. It initiates circuit release. On calls via trunk selectors it prepares for release of connection on its cessation. On outgoing calls the signal is sent when the call is terminated.
8. Release: 600 c/s: 450 ms minimum single pulse: Is an acknowledgment of the clear forward signal. On incoming calls is sent until the circuit is completely released. On outgoing calls is received until the distant end is normal.
9. Re-route: 750 c/s. 100-300 ms single pulse: Is sent on an incoming call on main trunks used as alternative routes when the selected branch 2VF signalling route is congested. It causes the release of the connection to be initiated from the distant end as alternative routing cannot be effected.

Distant busy: 600 c/s: For period of condition. A signal applied only to a free trunk for engaging the distant end without calling. Used mainly for maintenance work or routine testing.

Splitting. Received signals cause a line splitting action to occur after the signal has been received for between 160 and 210 ms. (Except on tandem switched 2VF calls. where signals go right through without splitting.) This action prevents more than the foregoing amount of tone from escaping past the 2VF circuit. In certain cases, as when a signal is received as an acknowledgment of one transmitted, the lines will be already split by the prior action of transmitting.

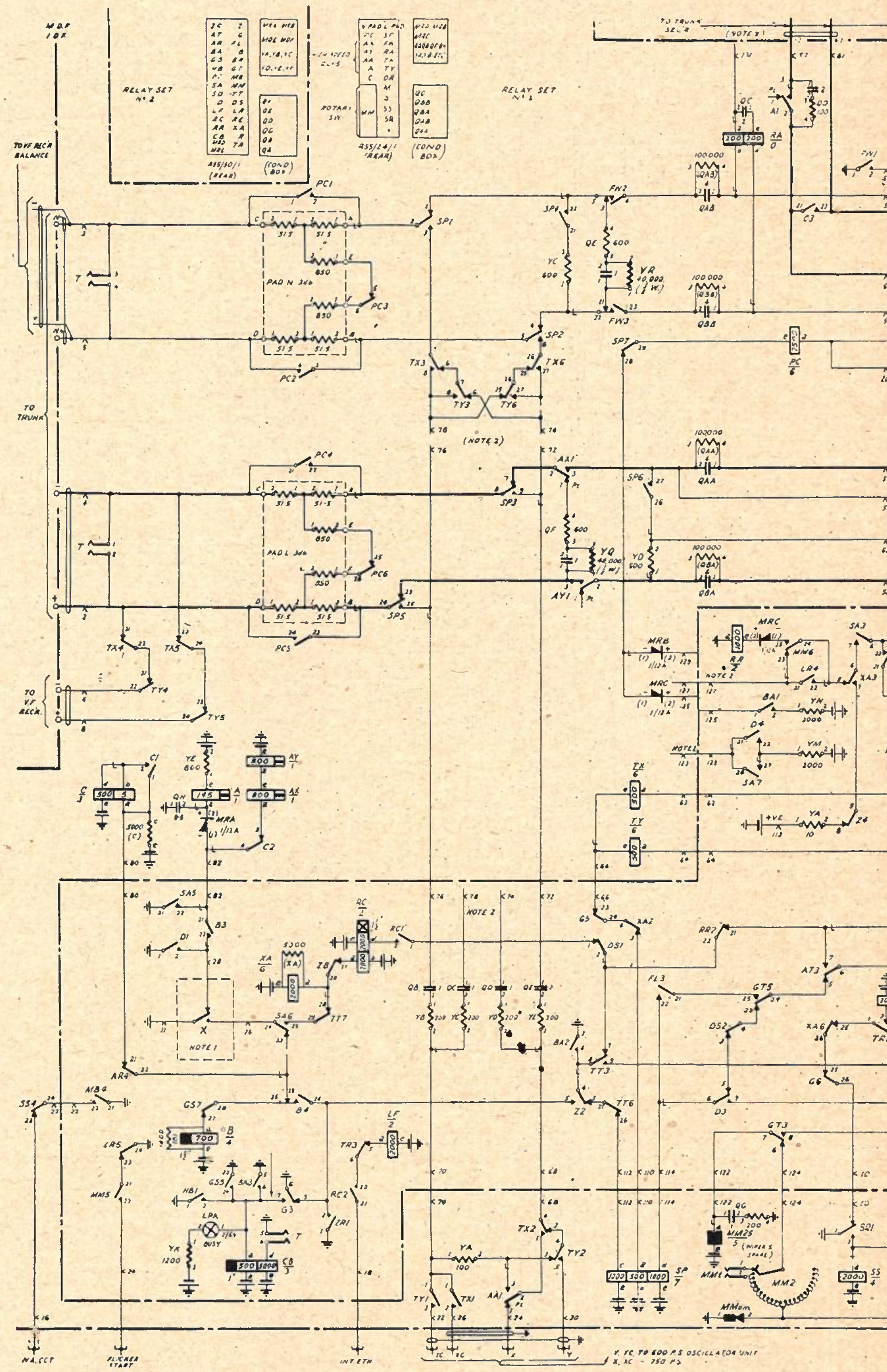
Guard Pause. When a signal has to be sent its transmission is prevented for a period between 100 and 150 ms after the cessation of any received signal. This prevents the application of two signals to the line at a time from its two ends.

Incoming Call to Local Auto. The call signal prepares the circuit and associated trunk selector for impulsing. The engaged lamps on the manual switchboard light to mark the circuit busy. The first train of impulses steps the trunk selector which then searches in the level for a free junction in the local area. Subsequent trains of impulses select the required local subscriber.

When the called subscriber answers a pulse of Y tone is sent (the answer signal). If this is accepted at the far end an answer acknowledgment pulse of Y tone is received and stops further transmission of answer signal pulses. If the first answer signal pulse is not accepted, further pulses are sent until an acknowledgment is forthcoming. During the transmission of these pulses the called subscriber is disconnected from the trunk. When the acknowledgment pulse ceases the called subscriber is re-connected to the trunk and conversation can commence.

If the called subscriber replaces the receiver the clear back signal is sent for as long as the subscriber is off the line or until the call is broken down. If the called subscriber comes on the line again the clear back pulsing ceases and conversation conditions are re-established. When the originating end breaks down the connection the clear forward signal is received. This commences the release of the local auto connection. When the signal ceases the circuit transmits the release signal, after the guard pause, until complete release of the circuit has occurred, which period is made sufficiently long by means of slow releasing relays to adequately guard the release of local switches.

Incoming Call to Branch Magneto Trunk via Selectors. The branch trunk is selected in the same manner as a junction to the local area. Following selection of a trunk the back bridge conditions of the 2VF circuit are changed from a loop "auto" condition to one suitable for leg signalling. No further impulsing will follow. To attract the attention of the called exchange the originating telephonist must ring. On receipt of the ring forward signal the 2VF circuit converts this to a positive battery leg signal and passes it forward to the magneto trunk line circuit, where it is converted into 17 c/s ringing. The ring continues for as long as the calling telephonist sends the ring forward signal. When the ring ceases the magneto



1 CONTACTS OF 2VF RECEIVER SHOWN FOR EXPLANATORY PURPOSES ONLY

2 STRAPPING - I/C MANUAL ONLY. STRAP JACK PT 106 TO JACK PT 104 (R S Nº 2) TRUNK SELECTOR WILL NOT BE FITTED
O/G MANUAL ONLY - - PTS 119 & 121 TOGETHER (R S Nº 2).
4 WIRE WORKING - - - 72 & 74, 76 & 78 (R S S Nº 1 & 2) AND 23 & 31 (R S. Nº 1).
4 WIRE HIGH LOSS TRUNK, STRAP JACK PTS 125 & 127, 129 & 131 (R S Nº 1)
2 WIRE HIGH LOSS TRUNK. - - 125 & 121 (R.S. Nº 2)
2 WIRE TRUNKS. - - - 123 & 125 (R.S. Nº 1)
B/W MANUAL. STRAP AS FOR I/C AND O/G MANUAL

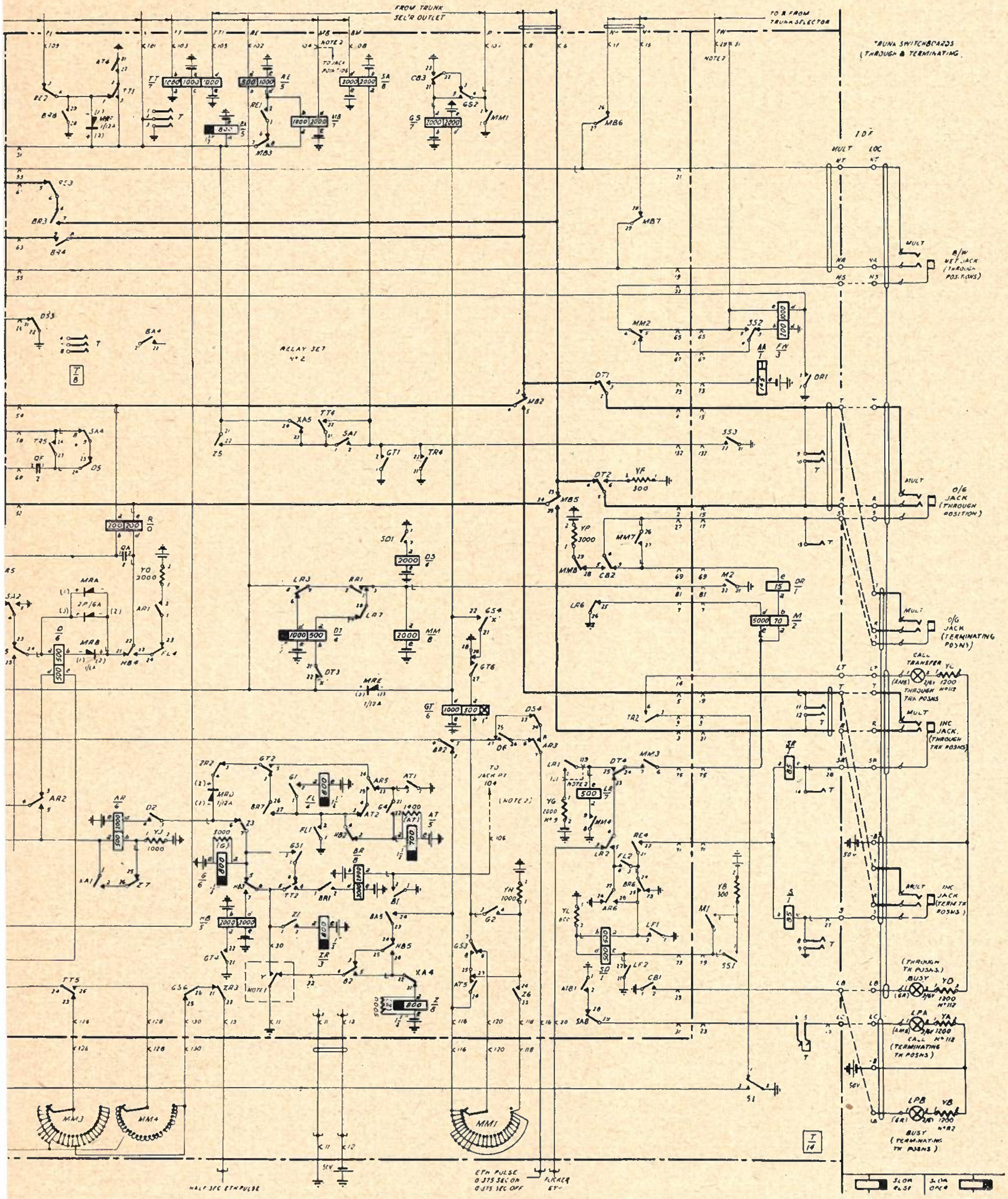


Fig. 23.—2 V.F. Trunk Line Circuit.

trunk line circuit returns an answered condition to the 2VF circuit. The answer signal sequence follows as previously described.

If the called exchange (or magneto subscriber) rings back, either to attract attention or as a clear, the magneto trunk line circuit will remove the answered condition and the 2VF circuit sends out the clear back signal to light the originating telephonist's supervisory lamp. The calling telephonist must ring forward if she wishes to speak again to the called party. The ring forward signal restores the entire connection to the pre-answered condition. When the ring forward signal ceases the answer signal sequence occurs again, following which speech conditions are re-established. When the originating telephonist breaks down the connection the clear forward signal is received. This starts to release the connection, and when the signal ceases the circuit transmits the release signal until complete release of the circuit has taken place.

Tandem 2VF Connection via Trunk Selectors. If the selected branch trunk is equipped with 2VF signalling the following occurs: When the two trunks have been joined together the two trunk line circuits switch themselves into a condition in which all signals are allowed to pass right through the switching point without causing any action, except the clear forward signal, which, by virtue of its being longer than any other Y tone signal, brings about the release of the connection.

The clear forward signal registers at the incoming 2VF circuit, but is allowed to pass right through the tandem switching point. When the signal ceases the connection to the outgoing 2VF circuit is dropped immediately. Following the guard pause the incoming circuit sends the release signal until released. The outgoing circuit when dropped by the incoming circuit should receive a release signal from the distant end and will release if this is received. If the release signal does not arrive within about 50 ms a 6 second clear forward pulse is sent, after which the circuit will release whether or not a release signal has been received.

Congestion on Trunk Selector. If the selected route is congested the trunk selector will drive to last contact and busy tone will be connected to the line. The originating telephonist will break down the connection in the usual way. In those cases where the route is an alternative route, automatically selected, congestion causes the trunk line circuit to send the re-route signal. This signal informs the pulse sending circuit at the originating exchange that connection cannot be made via the alternative route due to congestion at the switching point. The result is that the connection is released in the usual way and the call re-routed.

Incoming Call to Manual Switchboard. When the digit for selecting the manual board is received the trunk selector is released and the calling lamps light on the terminating trunk position switchboard. The back bridge is changed from the usual loop condition to one suitable for standard sleeve control conditions. When the telephonist inserts the answer plug the calling lamps are extinguished and the call is then extended as required. If the call is for another trunk line, the call is transferred to the through position.

The called subscriber answering (or equivalent) results in a battery being received via the cord circuit and the answer signal sequence is started. If the called subscriber hangs up the battery via the cord circuit is removed and the clear back signal is sent out, but ceases if the telephonist comes on the line. A ring forward signal changes the circuit condition back to the pre-answered state but may also occur before any answer signal has been received. The signal is relayed through the cord circuit as a positive battery pulse to call in any other telephonists party to the call. The answering supervisory lamp is flickered until extinguished by the telephonist entering the connection by throwing the speak key. If the called subscriber is still on the line the answer signal sequence will occur again when the ring forward signal ceases. If the clear back signal was being transmitted the ring forward signal causes this to cease so that conversation between the telephonists can follow.

When the connection is broken down the receipt of the clear forward signal lights the answer supervisory lamp, indicating to the telephonist that the call has finished. The release signal is sent when the clear forward signal finishes and continues for a minimum period if the answer plug has been removed or else until it is removed.

Incoming Call to Manual Board Only. If selectors are not fitted all calls will terminate on the manual board and the calling lamp will light without impulsing being necessary. Strapping arrangements on the relay set cover the provision of this facility.

Outgoing Call via Trunk Selectors. When the trunk selector tests in the circuit is marked busy to the manual switchboard and the call signal is sent out. The circuit is then switched to the tandem VF condition and functions as previously described in the appropriate section in the foregoing.

Outgoing Call from Manual Board. The call signal is sent when the telephonist plugs in to the outgoing jack. The signal engages the distant end and prepares it for impulsing. The call supervisory lamp in the cord circuit flickers, indicating to the telephonist that the trunk is a dialling circuit. When the dial call key is thrown the flicker ceases and the circuit is prepared for translating loop impulses from the position circuit to X tone impulses on the trunk. The telephonist restores the dial key when impulsing ceases and this changes the circuit back from the impulsing to the usual condition.

The answer signal is received when the called subscriber answers and after the guard pause the answer acknowledgment signal is sent. The call supervisory lamp in the cord circuit is extinguished and a battery answer signal is applied to the line to signal back through the cord to a circuit connected to the other side of the cord circuit. The clear back signal will be received when the called subscriber hangs up. This signal lights the cord circuit call supervisory lamp and disconnects the answer battery passed back through the cord circuit. The telephonist can attract the attention of a distant telephonist (when the call has not been dialled direct to the subscriber) by operation of the ring key before or after the called subscriber has answered. If the answer signal has been received the action of sending the ring forward signal restores the circuits at both ends to the preanswered condition. If the clear back signal is being received this will, of course, cease.

The clear forward signal is sent when the telephonist withdraws the call plug. The first (and shorter) pulse of this signal will be effective in most cases and the release signal will be received during the pause. The second pulse will not be sent and when the release signal ceases the circuit will be free. Should the first clear forward signal pulse fail to register at the distant end, as might occur if the call has been routed to N.U. tone, the release signal will not appear during the pause and the second and long pulse will be transmitted. The release signal should be received following the long pulse, but if not forthcoming the circuit will release itself after a short pause.

Distant Exchange Manual Only. In this case impulsing will not be required and strapping arrangements are provided so that the circuit can be made to assume the condition usually obtained after dialling, immediately the call plug is inserted.

Four-Wire Switching. If the trunk connected to the circuit is capable of being switched 4-wire such switching will take place when the circuit is connected to another trunk also capable of 4-wire switching. The switching of the net pair is automatic on calls established via the trunk selectors. On calls via the manual board the net pairs are joined through when the telephonist puts up the net cord. The circuit is held engaged until both line and net cords are taken down. If the net cord is left up alone a pilot lamp in the cord circuit lights as an indication to the operator to withdraw the plug.

Distant Busy. This signal (continuous Y tone) is received when the circuit is idle and makes it busy to outgoing calls. The signal may be sent by inserting a U link in the test jack. The distant end of the trunk will be marked busy.

Unidirectional Working. Temporary unidirectional working can be obtained by inserting a U link in the test jack. The circuit is marked busy to outgoing calls.

Test Jacks. Test jack points are provided at various parts in the circuit for maintenance purposes.

Measurement of Pulse Lengths. Measurement of transmitted pulse length and response to pulses of minimum and maximum length can usually be made over the trunk line from the regional centre trunk exchange which is equipped with a special tester for this purpose.

Conclusion

The expense and complexity of the equipment involved in providing comprehensive operating aids are more than offset by the improvement in the grade of local and trunk line service achieved. The larger keyshelves provide greater space for docket handling, etc., and the installation of cord circuit call timing, key sending and efficient supervising facilities enable telephonists to assume greater control of traffic than hitherto possible under magneto working conditions. This results in a much greater occupancy of expensive trunk circuits and raises the effective load per operator.

ERRATUM

Vol. 8, No. 5, Page 297. The last line in column 1 is misplaced, and should be read as the third last line.

SOME TRANSMISSION DEVELOPMENTS—QUEENSLAND*

P. M Hosken, B.Sc., A.M.I.E. (Aust.)

Introduction: This paper will deal with two types of carrier telephone systems which have been in use overseas for some years, and are now to be introduced into this country, namely the Two-Band and the Active-Inert single channel systems. These systems have been designed primarily to provide improved transmission on certain classes of trunk circuit.

In order to appreciate the application of these systems to the Australian trunk network, it is first necessary to consider the general transmission plan which has been designed to allow any two subscribers in this country to converse satisfactorily with one another.

Transmission Performance Standards: A minimum standard grade of transmission performance has been defined both for transmission between the subscriber and the local exchange, and also for the overall transmission between any two subscribers. The overall transmission standard requires that any exchange can be connected to any other exchange with a maximum loss of 15 db. Trunk exchanges have been divided into the following classifications:—

(a) **Main Trunk Centre:** In general corresponds to the capital city of each State.

(b) **Primary Trunk Centre:** A centre of major trunk switching importance within a large district (e.g., Toowoomba, Rockhampton).

(c) **Secondary Trunk Centre:** Switches for terminal exchanges and minor trunk centres (e.g., Dalby, Kingaroy).

(d) **Minor Trunk Centre:** Switches only for terminal exchanges (e.g., Nanango, Yarraman).

(e) **Terminal Exchange:** Performs no "through" switching (South Nanango, Blackbutt).

To achieve the 15 db limit between any two trunk exchanges:—

(i) Trunks between Main Trunk Centres must have zero loss.

(ii) The total loss between any trunk exchange and its Main Trunk Centre shall not exceed 7.5 db (includes 1.5 db for switching losses). The total line loss is therefore limited to 6 db.

The connection of any trunk exchange to its Main Trunk Centre frequently consists of three links (Terminal Exchange to Minor Trunk Centre, Minor Trunk Centre to Secondary Trunk Centre, Secondary Trunk Centre to Main Trunk Centre) and sometimes four links (where Secondary Trunk Centre switches via a Primary Trunk Centre). In practice this necessitates zero loss links:—

(1) Main Trunk Centre to Primary Trunk Centre.

(2) Main Trunk Centre to Secondary Trunk Centre.

(3) Primary Trunk Centre to Secondary Trunk Centre.

A typical arrangement is shown in Fig. 1. In general, the 6 db loss will all be absorbed in the final link to the Terminal Exchange but, where possible, the 6 db applies from the Terminal Exchange through the Minor Trunk Centre to the next Trunk Centre of higher switching order. It will be seen that in many cases, in addition to the zero loss links previously mentioned, a zero loss link will be required from a Minor Trunk Centre to its next higher switching centre.

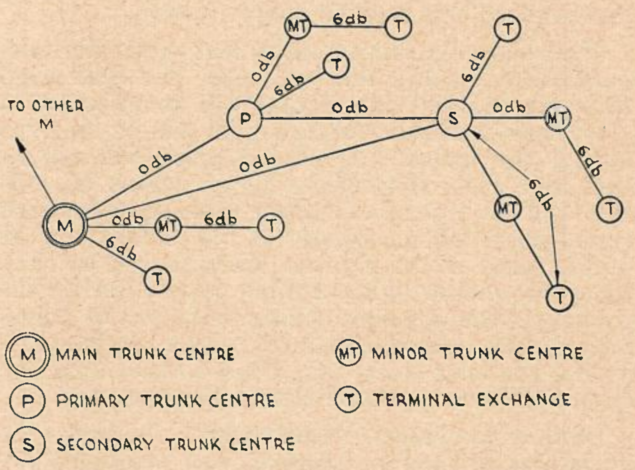


Fig. 1.—Basic Element and Trunk Network showing Switching Centres and allocation of Transmission Loss.

Manner of Provision of Links: Standard trunk lines consist of 100 and 200 lb. per mile copper conductors having a 1000 c/s wet weather attenuation of 0.118 and 0.069 db/mile respectively. In general, all trunk lines are equipped with a transformer at each end. The loss introduced by each transformer is 1 db so that the allowable line loss for a 6 db circuit is 4 db, which is the loss of approximately 35 miles of 100 db. or 65 miles of 200 lb. copper circuit (see Fig. 2). Offices tapped across a circuit introduce a further loss and reduce the allowable length of line accordingly. Using V.F. amplifiers on a 2-wire basis, a trunk line cannot be operated at an equivalent of less than 6 db, the stable working equivalent being more usually about 8 db. For all trunk links requiring zero equivalents, 4-wire operation, either V.F. or carrier, is therefore necessary.

Main to Main, Main to Primary and Primary to Primary links are, with few exceptions, already provided by standard carrier channels.

A fair proportion of Main to Secondary and Primary to Secondary links still consist of 2-wire physical circuits, although many will be replaced

*Paper delivered on 27/8/51 to The Telecommunication Society of Queensland.

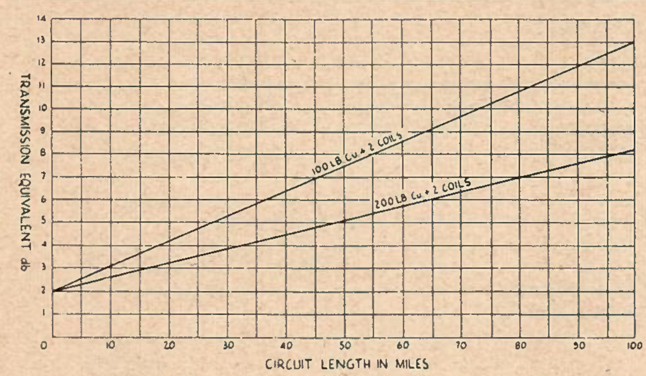


Fig. 2.—Circuit Loss v. Length of Aerial Trunk Line.

by standard carrier channels over the next few years. It will be necessary, however, to retain a number of physical pairs free of encumbrances over carrier repeater sections for carrier bearers and part-time programme channels. To use effectively the V.F. band over these pairs to provide links of zero loss, it is necessary either to use two pairs to provide a 4-wire V.F. amplified circuit, or split the V.F. band into two halves and use one in each direction. This principle of splitting the V.F. band is utilised in the two-band carrier system.

Two-Band Carrier System

A block schematic is shown in Fig. 3. Terminals are identical, a simple wiring alteration being necessary to convert an "A" to a "B" terminal.

"A" Terminal Operation: The "A" terminal transmits the carrier band and receives the speech band. Speech from the switchboard divides at the hybrid, half being blocked at the output of the receiving amplifier and the other half passing, via an attenuator, to the modulator (modem). Carrier current at a frequency of 5.4 kc/s is also fed to the modulator, which is of the double balanced metal rectifier type, in which both voice and carrier components are suppressed. The two predominant components of modulation are the sum and difference of the voice and carrier frequencies, that is, the upper and lower sidebands respectively. The modulator is followed by a low pass filter, which allows the lower side band to pass with little or no attenuation to the input of the transmitting amplifier. The upper side band and other unwanted products of modulation are severely attenuated. The amplified lower side band (3.05-5.1 kc/s) then passes, via the high pass directional filter and the 5.6 kc L.P. line filter to line.

On the receive side the speech frequency band (300-2350 c/s) from the remote "B" terminal, passes through the L.P. line filter to the directional filters. It is blocked at the T.D.F., but passes with little loss through the receiving D.F., thence via the receiving attenuator to the receiving amplifier. The amplified speech divides at the hybrid, half being absorbed in the balance network and half passing to the switchboard.

"B" Terminal Operation. The "B" terminal transmits speech and receives the carrier band. Speech from switchboard passes via the hybrid, attenuator, transmitting amplifier, L.P. directional filter, L.P. line filter to line.

In the receive direction the lower sideband frequencies from the remote "A" terminal pass through the L.P. line filter, the H.P. directional filter and attenuator to the modem, which now acts as a demodulator. The same carrier frequency 5.4 kc/s is fed to the modulator, and the speech frequency components derived from the sideband pass freely through the L.P. filter to the receiving amplifier, other products of demodulation being severely attenuated. The amplified speech band then passes via the hybrid to the switchboard.

Signalling: A ringer oscillator panel is included in the system which converts 17 c/s ring from the switchboard to 17/1000 c/s interrupted V.F. cur-

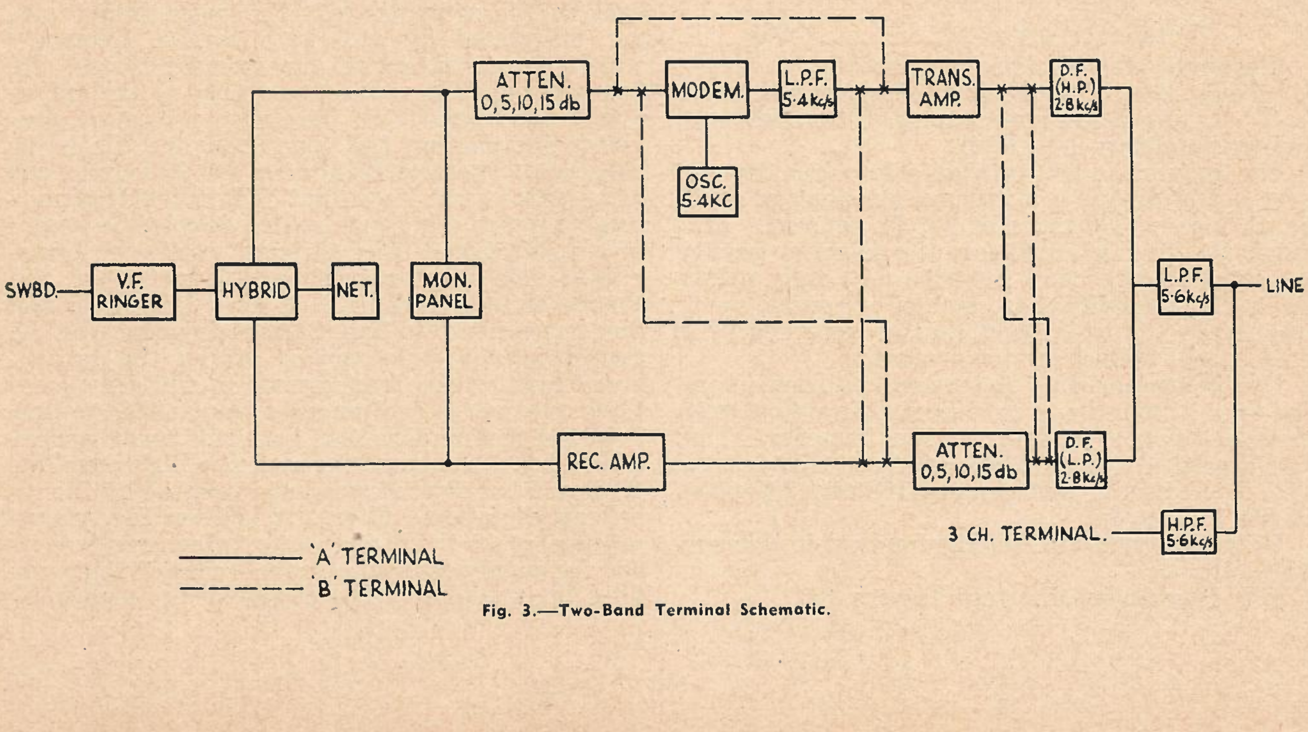


Fig. 3.—Two-Band Terminal Schematic.

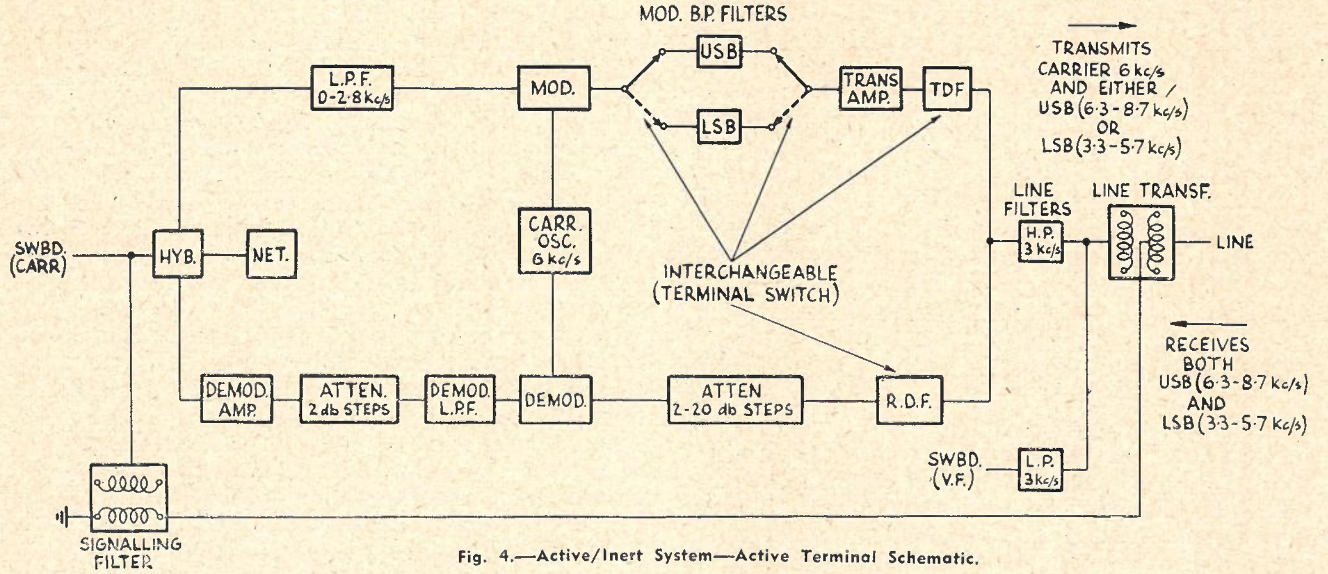


Fig. 4.—Active/Inert System—Active Terminal Schematic.

rent at the transmitting end, and reconverts this to 17 c/s at the receiving end.

Testing and Monitoring: Test jacks are provided for monitoring and transmission test points. A monitoring telephone is provided, and may be connected to any part of the audio circuit. Ringing and speaking facilities are also available.

Power Supplies: Standard 24 V. and 130 V. supplies are used generally. Alternatively 154 V. high tension may be used by suitable connection of 24 V. and 130 V. supplies. This allows a higher output level to be transmitted. Separate rectifier units are being provided in some cases.

Mechanical: Each terminal comprises four standard 19″ panels of the following widths:—

Ringer oscillator panel	$5\frac{1}{4}$″
Frequency changer panel	7″
Monitor and Amplifier panel	$10\frac{1}{2}$″
Directional filter panel	$3\frac{1}{2}$″
Total rack space	$26\frac{1}{4}$″

Electrical: The electrical characteristics are:— Maximum gain of transmit and receive amplifiers is 33 ± 1 db. Maximum output of transmit and receive amplifiers is $+ 20$ db.

The equipment will provide a zero loss channel over a line having a maximum attenuation of 30 db at 5 kc/s (300 miles of 200 lb. copper). Provided the line is equalised, the channel quality (effective speech band 300-2350 c/s) falls within the C.C.I.F. specification, but is, of course, much inferior to the wide band channel provided by a modern 12-channel carrier system.

Use in Queensland: A system has been in use for over 12 months to provide a Cairns-Cooktown channel using a repeater at Mt. Surprise. This was described in a previous article in this Journal (1). The repeater sections are 168 and 296 miles of 200 lb. copper.

Other systems are coming forward in Queensland for:—

(P) Hughenden-Charters Towers (S).
(M) Brisbane-Warwick (S).
(S) Gympie-Murgon (S).
(S) Gympie-Goomeri (MT).

Many more systems are planned to provide similar low-loss links in the next few years.

Active-Inert Single Channel Carrier System

To assist in the provision of 6 db links to terminal exchanges, and to make full use of available line plant in outlying areas, a simple type of single channel carrier system, one terminal of which does not require a power supply, is to be brought into use. This is known as the Active-Inert single channel carrier system, and a block schematic is shown in Figs. 4 and 5.

Active Terminal Operation: Voice from switchboard passes via the hybrid and 2.8 kc/s L.P. filter to the metal rectifier bridge type modulator. The L.P. filter prevents carrier leak and unwanted products of modulation from being fed back to the switchboard. The voice frequencies are modulated by a 6 kc/s carrier frequency which is suppressed in the modulator, and the two side bands pass via a 15 db pad to the appropriate band pass filter. Two such filters are provided, one passing the upper and one the lower side band. The desired filter is selected by means of a switch, and its output fed to the transmitting amplifier. The same switch selects the appropriate directional filter through which the transmitted side band passes to a transformer and thence through the H.P. 3 kc/s line filter and line transformer to line. Carrier frequency at the appropriate level is applied across the switchboard side of the transformer in the directional filter unit and is continuously transmitted to line.

In the receive direction, both side bands are received from line, pass through the high pass line filter and the desired side band selected by the receiving directional filter. It is then fed, via an attenuator, to the demodulator, which receives its carrier supply from the same oscillator that supplies the modulator. The output of the demodulator is passed through a low pass filter which suppresses carrier leak and unwanted demodulation products, and thence via an attenuator, amplifier and hybrid coil to the switchboard.

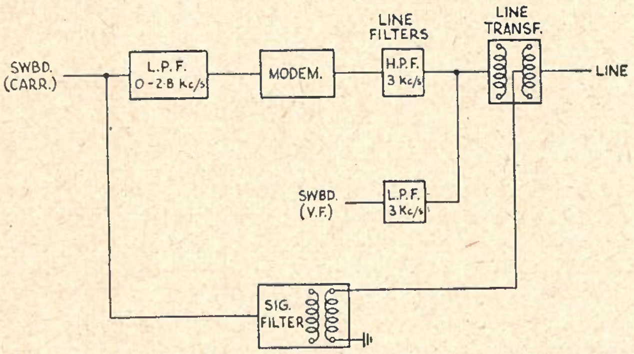


Fig. 5.—Active/Inert System—Inert Terminal Schematic.

Inert Terminal Operation: Voice from the switchboard passes through a 2.8 kc/s low pass filter to the "modem" where it is modulated with the 6 kc/s carrier frequency continuously fed over the line from the active terminal. Both side bands are then fed via the high pass line filter and line transformer to line.

In the receive direction, the carrier frequency and the upper or lower sideband pass through the line transformer and the high pass line filter to the "modem," where the sideband is demodulated with the carrier. The voice frequencies are thus recovered and separated from other products of demodulation by the low pass filter through which they pass to the switchboard. The "modem" acts as both modulator and demodulator.

Signalling: 17 c/s ringing current from the switchboard is tapped off the circuit by the signalling filter. The output transformer of this filter has one end of the secondary winding connected to earth and the other end is connected to the centre tap of the line winding of the line transformer. It is thus transmitted over the cailho leg of the bearer circuit to the receiving terminal, where it passes through the signalling filter to the switchboard. The necessity for the cailho leg for signalling prevents the use of the system in some cases, as quite often all cailho legs are in use for telegraph purposes.

Levels: Active terminal transmits the carrier frequency at a level of + 25 db (maximum) and the sideband at a level of + 15 db. The receive gain at the active terminal is 27 db.

Quality: The quality is reasonably good, and is approximately C.C.I.F. standard.

Range: Line losses should not exceed 14 db at 9 kc/s (150 miles of 200 lb. copper, or 100 miles of 100 lb. copper), and under this condition will give a 5 db channel.

Power Supplies: Either A.C. mains or standard 24 V. and 130 V. batteries may be used.

Approximate Dimensions: The terminals are mounted on standard 19 inch racks, the active terminal occupying a space of 3 feet and the inert terminal a space of 1 foot.

Application: Owing to crosstalk difficulties, these systems will in general be used only on minor routes where other carrier systems are not employed.

Typical locations for which Active-Inert carrier systems are coming forward in Queensland are:—

(S) Cloncurry-McKinlay (T), 67 miles.
(P) Hughenden-Tangorin (T), 67 miles.
(P) Toowoomba-Crow's Nest (T), 29 miles.

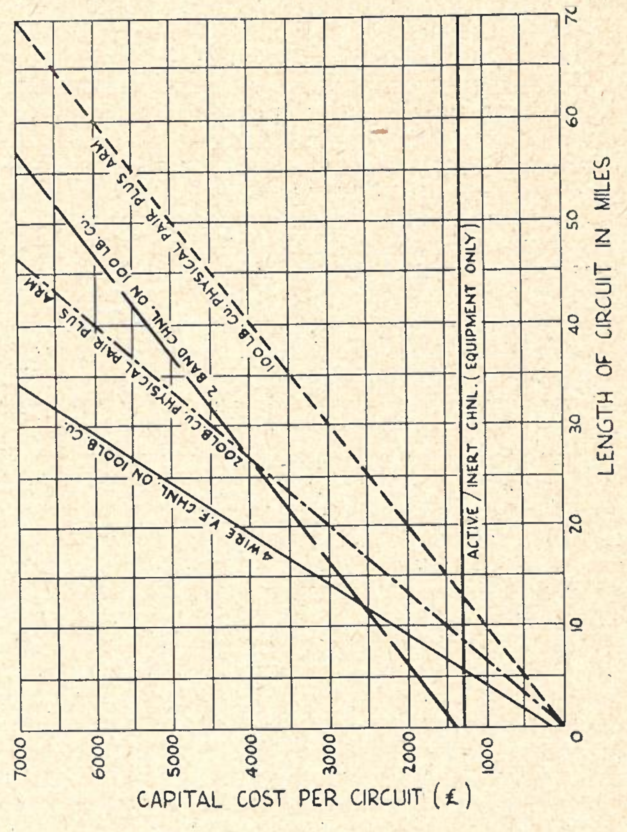


Fig. 6.—Channel Cost v. Circuit Length.

Economics of Channel Provision

The approximate costs of provision of the various types of channel under discussion are indicated in Fig. 6. £30 per mile has been allowed on the open wire costs for arming, which, of course, may not be necessary.

The installed cost of a Two-Band system is approximately £1400, and that of an Active-Inert system is approximately £1300. Considering capital costs only, a 6 db channel could be provided economically by means of an Inert system rather than the erection of 100 H.D.C. wires over a distance of 15 miles if arming were necessary, or 20 miles if arming were not necessary.

Bibliography

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AN "IMMEDIATE APPRECIATION" TECHNIQUE FOR RATING THE PERFORMANCE OF TELEPHONE TRANSMISSION SYSTEMS

D. A. Gray, B.E.E., A.M.I.E. (Aust.)

Introduction

In the past, the effectiveness of telephone transmission has, for practical engineering purposes, been judged by the overall "volume efficiency" of the circuit, that is, by the capability of the system to produce a sufficiently intense signal at the receiving end. On this basis, a Commonwealth Transmission Plan was set up to ensure that any two telephone subscribers in the Commonwealth could be connected together via the telephone network with an overall volume efficiency not less than a certain standard. This transmission plan is described in reference (1). Because of the attenuation distortion and nonlinear distortion in existing types of telephone instruments, it is possible to obtain substantial improvements in the effective transmission of ideas from speaker to listener, via the telephone circuit, without increase in the loudness of the received signal. Similarly, improvements in the sidetone performance of telephone instruments, by their psychological effect on the masking of received speech by room noise, can improve the effectiveness of telephone transmission without any change in the overall attenuation of the circuit (2). For these and other reasons, "transmission performance" ratings of telephone circuits have replaced "volume efficiency" ratings in the British Post Office (3), and a transmission performance standard for the Australian Post Office has been laid down. The circuit representing the Australian standard is shown in Fig. 1. All telephone connections within the Commonwealth should have a transmission performance equal to, or better than the transmission performance of this circuit.

The terms "transmission performance" and "transmission performance rating" have been defined by the British Post Office as follows:—

The Transmission Performance of a telephone circuit used for transmitting and reproducing speech, is the effectiveness of the circuit for transmitting and reproducing speech in the circumstances in which it is used. (Note: "effectiveness" is the quality of being fit for service.)

The Transmission Performance Rating is a transmission performance measure which is obtained by any specified method, and is expressed as an amount of equivalent loss or gain, in decibels, equal at all audible frequencies.

It is the object of this paper to describe the "immediate appreciation" technique of subjective testing of telephone transmission systems, to discuss its application to the determination of transmission performance ratings, and to give results of such a test on the circuit representing the Australian transmission performance standard. The tests described in this paper were carried out in the Research Laboratories of the Postmaster General's Department as part of a programme of investigation and evaluation of various methods of measuring transmission performance ratings by means of subjective tests. No particular method of subjective measurement of transmission performance has yet been standardised by the Department.

The Need for Subjective Tests

In arriving at a transmission performance rating for a communication circuit, consideration must be given to psychological factors as well as purely physical factors. It is possible, however, to calculate from the physical properties of a circuit the effect on the transmission performance rating of that circuit of some small change in certain of its parameters; for example, the effect of changes in line length and attenuation, and of changes of a much lesser extent in frequency response and sidetone characteristics (2). Transmission performance calculations for a given telephone circuit are related to a comparison between the circuit under consideration and a "reference

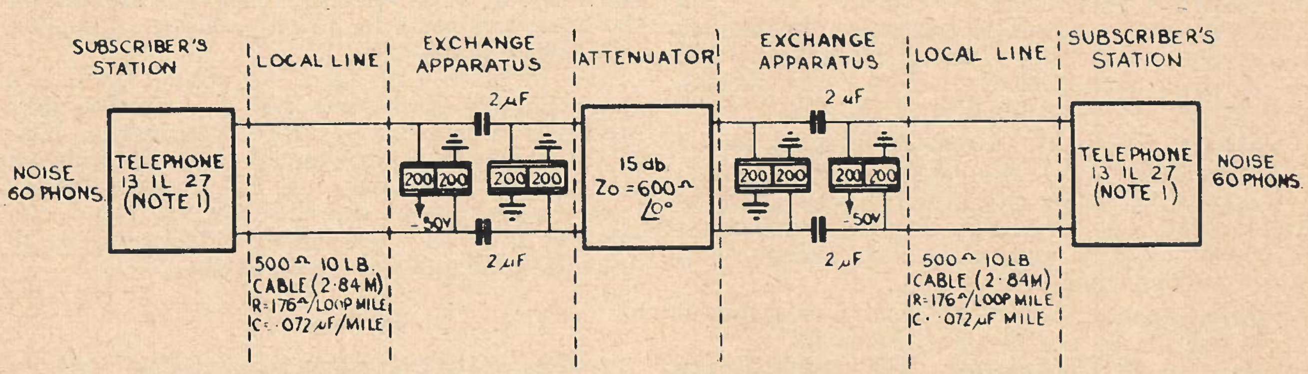

Fig. 1.—Circuit Representing the Overall Transmission Performance Standard.

Note 1.—Telephone 13. 1L. 27 refers to handset type telephone having the following transmission components. Transmitter Inset, No. 13. Receiver Type, 1L. Anti-Sidetone Induction Coil, No. 27.

circuit." The transmission performance rating of the former circuit is given as the amount of non-reactive attenuation it is necessary to add to or remove from the reference circuit, in order that both circuits shall give the same transmission performance.

It does not appear to be possible, with present techniques, to calculate precisely the effect of non-linear (harmonic) distortion on the transmission performance rating, and the effect of large changes in frequency response or sidetone can only be estimated. Therefore, subjective measurements are necessary to obtain transmission performance ratings in such cases. A change in the design of the electro-acoustic transducers in the telephone circuit, for instance, will usually require subjective tests in order to determine the new transmission performance rating. Various techniques of subjective testing have been considered for the evaluation of transmission performance. The most important techniques are:

(a) **Repetition Rate Tests.** Ordinary telephone conversations are monitored and the number of requests for repetitions recorded. The "repetition rate" is usually expressed as the number of requests for repetitions per 100 seconds of actual conversation time.

(b) **Articulation Tests.** Meaningless syllables (called "logatoms"), usually of the form consonant-vowel-consonant, are transmitted over a circuit by a trained talker, and a listener (or listeners) at the far end records the sounds heard. The "syllable articulation" is the percentage of syllables correctly received; the "sound articulation" is the percentage of sounds correctly received.

(c) **Intelligibility Tests.** This test is similar in form to the articulation test, but short sentences or commonly used words are transmitted instead of logatoms. The listeners record the words or sentences heard. The number of words or sentences correctly received is known as the "word intelligibility" or "sentence intelligibility."

(d) **Judgment Tests.** Judgment tests may take many forms, but in general selected observers are asked to converse over a test circuit and then to express an opinion as to whether it is better or worse than a standard reference circuit in some carefully defined performance aspect. A suitably planned test is capable of giving quantitative results (4), (5).

(e) **Immediate Appreciation Tests.** The "immediate appreciation" test is a laboratory test in which a speaker reads out a series of short, unrelated sentences. The listener or listeners record, usually by a tick or a cross, whether they have, or have not, understood the sentence without the necessity to review its meaning after reception. It is not necessary that the listener receive the correct meaning but that he should be immediately satisfied with the impression he receives.

History of "Immediate Appreciation" Tests

The "immediate appreciation" test was first described by W. H. Grinsted (6), of Siemens Bros., Woolwich, England, in January, 1937. In the tests described a number of short sentences read from a newspaper were transmitted over the test circuit, and listeners were asked to record the number of sentences "immediately appreciated." The final result of the measurements was not a transmission performance rating, but a statistical table showing the percentage of telephone connections in actual service which could be expected to have an immediate appreciation score better than a given value. Measurements were made with various values of room noise at the listening end and with varying values of attenuation in the junction line. Using a volume meter, speakers adjusted their speaking level to give, as nearly as possible, "C.C.I. normal speech volume," and therefore sidetone effects at the speaking end had no effect on the results of the test. A further paper, by J. R. Hughes (7), in November, 1938, described the testing technique in greater detail and introduced an improved method of statistical evaluation of the test results.

A further development of the technique was described by J. R. Hughes (8) in December, 1942. In the modified technique, the speaker's talking level was not controlled and room noise was introduced at the speaking end. Measurements were made systematically with a number of combinations of values of speaking end and listening end room noise. The "natural speaking level" of each speaker taking part in the test was measured separately and allowed for. The result obtained from the measurements, after allowing for the statistical distribution, in normal service, of room noise levels and subscribers' talking level, was a graph of junction line attenuation versus the percentage of total calls made in normal service which could be expected to enjoy an immediate appreciation exceeding a given value.

Immediate Appreciation Test Procedure Used in Research Laboratory Tests.

While the basic principles described above have been adopted in tests in the Australian Post Office Research Laboratories, the objective is normally the measurement of transmission performance rating of one communication circuit relative to a reference circuit. Tests are, therefore, usually carried out with a fixed room noise sound level (60 db) at both ends of the circuit. The room noise is of the uniform continuous spectrum type, generated by amplifying the Johnson noise present in a resistor at room temperature. The noise level is measured by means of an American (General Radio) sound level meter, using the 70 db weighting network.

Usually the speakers' talking level is allowed to find its normal level under the particular conditions of the test, and sidetone effects are allowed full play. As normal routine measurements are comparison tests, involving similar systems, it is not necessary to know the absolute value of the talking level. In tests of a more absolute nature, a sufficiently large number of speakers is used to ensure that the mean of all speakers' levels approximates to the mean value observed in the service. Grinsted (6) deduces from published data that the distribution of service speaking levels is roughly that of the statistical "normal" or gaussian distribution, and has a standard deviation of 6 db. The standard deviation in the mean of the talking levels of a group of N speakers selected at random is therefore approximately

$$6/\sqrt{N} \text{ db}$$

In recent laboratories' tests, a junction splitting amplifier has been used at the receiving end of the junction line, represented by the 15 db attenuator in Fig. 1, so that up to four listeners may listen simultaneously. The gain of this amplifier is adjusted to be 0.0 decibel, and identical exchange feeding bridges and local line circuits can be connected to each output channel. Thus all listeners receive simultaneously the same speech volume level, and are subject to the same sidetone conditions as apply for one listener when the splitting amplifier is not used.

The use of a multi-channel listening circuit reduces the time required to make a test and, as a result, increases the reliability of comparison tests. The reliability of comparison tests of the receiving rating of two different local line circuits or subscribers' instruments may be improved by connecting each instrument to a separate receiving channel and listening to a common speaker, the listeners being interchanged systematically from instrument to instrument.

Statistical Analysis of Test Results

"Pure Chance" Variations. With practical telephone systems, one hundred per cent. immediate appreciation of a group of sentences is recorded only on infrequent occasions, and as the transmission performance is degraded, for example by increase of circuit loss, the average immediate appreciation score decreases relatively slowly from a high value to zero. For this reason it is necessary to base the transmission performance rating of a given system on observations taken under conditions where the immediate appreciation is less than 100 per cent., for example, the 95 per cent. level is frequently chosen.

The factors which cause a failure of immediate appreciation to be recorded are factors which vary in an unpredictable manner, for example, variations in speaking level, difficulty of sentences, the random nature of continuous spectrum noise and variability of sensitivity of carbon granule telephone transmitters. As a result of this, the mean immediate appreciation scores obtained from a number of replications (that is, replicas of the first tests) will not be the same for each replication.

The distribution of the various replications means about the overall mean, due to purely random factors, will be that of the binomial distribution considered in elementary statistical theory. (9). It is therefore possible, on the assumption that the probability of failure to receive a sentence remains the same from sentence to sentence, to predict the standard error, that is, the standard deviation of replication means, resulting from such factors. This is given by the following expression:—

$$S = \sqrt{p(100-p)/n}$$

where S is the standard error (root mean square deviation of replication mean from the overall mean),

n is the number of sentences in each replication, and

p is percentage "immediate appreciation" obtained over an extended period.

Under the usual test conditions, when n is large, the distribution of group means is very nearly gaussian, and this fact may be used to simplify the estimation of the confidence limits to be placed on the results of a test in which only random factors influence the result.

For example, in the tests described by Grinsted (6), 120 sentences were read for each set of test conditions. In a typical case where the average immediate appreciation score was 95%, the standard error of the 120 sentence mean estimated from the above expression is 2.0% and the 95% confidence limits based on gaussian distribution are approximately 4% above and below the average, that is 91% and 99%. It is to be noted, however, that the assumption of a gaussian distribution is not essential, and it merely simplifies the calculation of approximate confidence limits.

Other Variations. In addition to variations due to minor unassignable causes, there are factors due to the speaking and hearing characteristics of crew members which, on the average, tend to remain constant or change slowly from test to test. For example, one crew member may naturally speak at a level a few decibels higher than the other crew members. Such factors do not necessarily affect the accuracy with which two communication systems may be compared, but they do increase the variance of the immediate appreciation scores obtained on a group of sentences. If the overall mean square deviation of individual observations from the general means is S_o (see reference (10)), we can write:—

$$S_o = S_1 + S_2 + S_3 + \cdots + S_r$$

where S_1, S_2, etc. are the mean square deviations contributed by certain assignable causes, and S_r is the residual mean square deviation contributed from unknown sources, and which, in a well conducted test, will be a simple function of the standard error due to pure change dealt with in the previous section. The statistical technique of determinating $S_1, S_2, \ldots S_r$ from which the corresponding variances V_1, V_2, V_r may be calculated, is known as the analysis of variance and is described in standard texts on statistical theory, and in reference (11).

In a comparison test, the residual variance is normally the only one which determines the in-accuracy of the comparison. Since this may be estimated beforehand from the binomial distribution, it is possible to calculate the minimum amount of testing work necessary to carry out a given test. For example, suppose that two communication systems are to be compared under conditions which cause the immediate appreciation to be 90% and that the uncertainty in the overall means is not to exceed $\pm$ 1%. If the 95% confidence limits to the overall mean are taken as 89% and 91%, then the standard error of the overall mean must not exceed 0.5%. Using the relation $S = \sqrt{p\,(100-p)/n}$ we put $S = 0.5$ and $p = 90$ and calculate n, the total number of sentences to be used in the test on each system. It is found that $n = 3600$ sentences, and this is the minimum number of sentences to be spoken over each system if the overall mean is to have the required degree of precision. The testing rate, including rest periods, is about 300 to 400 sentences per hour, and in this particular case, a total testing time, assuming no multiple listening arrangements, is 18 to 24 hours.

Application of Immediate Appreciation Test to Check Subscribers' Local Line Limits

As an example of the application of the immediate appreciation test technique, a series of measurements on the overall transmission performance standard circuit shown in Fig. 1 will be described. This test was originally planned as an absolute measurement, and not as a comparison measurement, that is, the final objective was the production of an immediate appreciation versus junction attenuation graph, and for this reason a large crew was used. The test also provided a basis for the study of the immediate appreciation technique as little previous experience of this type of test had been gained.

Selection of Observers. As it was decided to use untrained and untried observers in these tests, preliminary checks were made to detect those having abnormal speaking or hearing characteristics.

(a) **Speaking Tests.** A telephone circuit using 300 type C.B. telephones was set up between two rooms, using continuous spectrum room noise (60 db sound level) in both rooms. Provision was made for simultaneous reception at the listening end by four persons experienced in subjective testing of telephone systems. Each speaker read a list of 100 English words, which were written down by the listeners. The average word articulation score was 62.0% (mean of 277 observations) and those speakers for whom the listeners obtained an average score of less than 40% were rejected as unsuitable. The 40% rejection level was determined after a few tests had been made, and was largely an arbitrary figure.

(b) **Listening Tests.** Two sets of listening tests were carried out; the first set followed the same procedure as for the speaking test, except that the person being tested formed one of the listening crew of four. At a later date an audiometer was set up using laboratory components and a calibrated moving coil receiver; with this apparatus the hearing loss of crew members was measured. The results of these measurements are shown in Table No. 1. Despite the fact that all crew members gave satisfactory results in the speech tests, it was found that high frequency deafness was quite pronounced among the older men. The figures given in the table apply to a group of 29 persons, including three women.

Organisation of Crews. When the studies reported herein were undertaken, no satisfactory apparatus was available for multiple listening, and the observers available for the tests were

Test tone frequency c/s	Hearing loss—decibels			
	Mean	Standard deviation	Minimum observed	Maximum observed
200	+ 1.6	7.1	— 10	+ 20
300	— 4.7	6.5	— 17	+ 12
400	— 5.8	5.7	— 14	+ 10
500	— 6.4	6.2	— 19	+ 10
800	— 8.7	6.2	— 18	+ 11
1000	— 7.9	5.5	— 19	+ 7
2000	— 7.1	7.0	— 20	+ 25
3000	— 2.9	14.1	— 18	+ 51
4000	+ 2.9	16.6	— 20	+ 60

Table No. 1.—Hearing Loss Measurements on Immediate Appreciation Crews used in Tests on the Overall Transmission Performance Standard.

1.—The datum for hearing loss is that of the Western Electric 2A audiometer (see Steinberg, Montgomery and Gardner, "Results of the World's Fair Hearing Tests", Bell System Technical Journal, Vol. 19, October, 1940, page 533.)

2.—The subjects of the hearing tests numbered 29 persons, including three women. Both left and right ears were measured.

split up into crews of three. The test programme provided for one crew member speaking, another listening, and the third resting at any time. Larger crews would have meant a larger number of observers disengaged at any time and the cost of the tests would have been increased accordingly; such considerations outweighed the advantages which would have been obtained as a result of the larger number of crew combinations (speaker-listener) which result from the use of a larger crew.

The selection of crews was made so as to cause the smallest amount of disorganisation to the other sections of the Laboratories from which the individual observers were drawn. In all, eleven different crews of three participated in the tests. Only six crews produced sufficient results to enable their use in this paper.

Attempts were made to organise equal numbers of male and female crews, but these were not successful due to the rapid replacement rate experienced with female employees. Insufficient data was obtained from any group of women to enable satisfactory comparison of the results obtained by it with the results obtained by the men. No female crews produced sufficient results for consideration in the test results given in this paper. The tests extended over a period of ten months, from September, 1948, to July, 1949. Because of difficulties of organisation, this period is much too long, and in subsequent tests of this kind, the maximum possible use of multiple listening arrangements has been made.

Test Procedure. The overall transmission performance standard circuit shown in Fig. 1 was set up in two rooms connected by a junction line into which a 600 ohm variable attenuator was connected. Networks representing lengths of 20 lb., 10 lb. and 6½ lb. subscribers' cable were made up and connected into the circuit as required. Details of these networks are given in Fig. 2; the lengths of cable which they represent were estimated, by means of a suitable calculation method, to give an overall transmission performance equal to the Department's standard. Each speaker reads a group of 20 sentences, taken with minor modification to suit Australian idiom, from the sentence list published by Fletcher and Steinberg (12). All of the six possible combinations of speaker and listener were used and the tests were repeated with a number of different values of junction line attenuation, set up in random order.

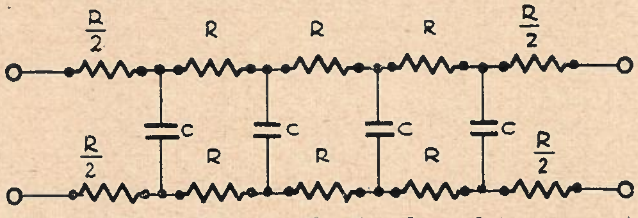

Fig. 2.—Circuit diagram of network used to represent Subscriber's cable. The values of C and R are:—

Type of Cable	6½ lb	10 lb.	20 lb.
Length (miles)	2.22	2.84	4.54
Loop Resistance, ohms	600	500	400
R, ohms	75	62.5	50
C, μF	0.03975	0.05325	0.08515
Insertion loss in db at 1000 c/s between 600Ω impedance	4.12	3.86	4.35

Test Results. The average scores for the six crews which completed the series of tests, expressed as percentages, are plotted as graphs of immediate appreciation versus junction attenuation in Fig. 3. The curve for 10 lb. cable crosses

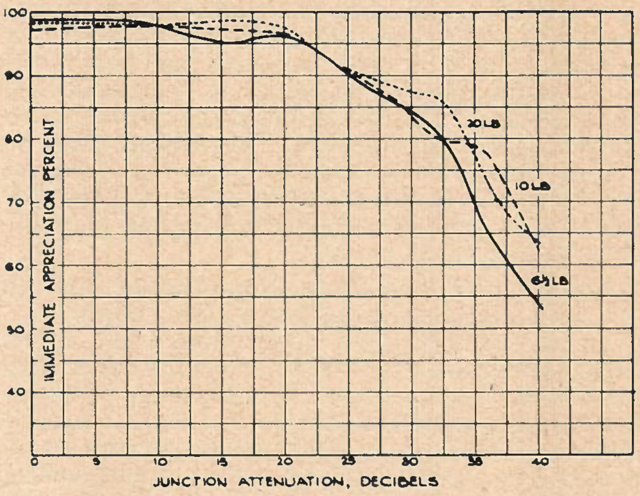

Fig. 3.—Comparison of Subscribers' Local Line Limits.

the 15 db junction attenuation line at 97%, and this represents the immediate appreciation result obtained with the circuit constants shown in Fig. 1. It is seen that the calculated lengths of 6½ lb. and 20 lb. subscribers' cable give very similar immediate appreciation scores to that obtained with 10 lb. cable over a wide range of junction attenuations. The deviations which do appear are mostly at junction attenuations exceeding 25 db, well in excess of the maximum of 15 db set down in the overall transmission performance standard.

An analysis of variance has been made for the test results obtained on the 6½ and 10 lb. cables at a junction attenuation of 32 db. The results are given in Table No. 2, and they are calculated from the scores obtained by each crew combination from 20 sentence groups. The overall or grand mean of the tests providing the data for Table No. 2 was 16.22 or 81.11 per cent.

The variance figures given have been obtained from the mean square deviations (from the overall mean) due to the various sources listed, and the number of degrees of freedom. In the case of crew combinations, line conditions and replications, the number of degrees of freedom is one less than the number of variables, for example, there are 36 crew combinations of speaker and listener and hence 35 degrees of freedom in calculating the variance. The number of degrees of freedom for the interaction terms are the products of those for the two principal sources of

Source of variation	Degrees of freedom	Variance	Variance ratio	Degree of significance (See Note 1)
Crew combinations	35	94.7	5.25	Highly significant
Line condition ($6\frac{1}{2}$ or 10 lb.)	1	21.2	1.175	Not significant
Replications	4	74.4	4.12	Highly significant
Interactions				
Replications and crew combinations	140	10.14	0.562	Not significant
Line conditions and crew combinations	35	16.60	0.920	Not significant
Line conditions and replications	4	14.58	0.808	Not significant
Residual	140	18.04	—	—

Table No. 2.—Results of Analysis of Variance.—Comparison of local line limits for subscribers' $6\frac{1}{2}$ lb. and 10 lb. cable. Junction attenuation, 32 db.

1.—Variance ratios greater than those lying on the 1% significance level are designated "highly significant"; those lying between the 5% and 1% levels "significant"; and those less than the 5% level, "not significant." The variance ratio corresponding to the different significance levels depend upon the number of degrees of freedom; the actual values may be found from tables given in standard tests on statistics.

variation concerned, and the number of degrees of freedom for the residual term is the product of those for all three principal sources of variation.

The "variance ratio" is the ratio of the variance due to the source listed to the residual variance. The residual variance is that due to all unassignable causes, as discussed under statistical analysis of test results. If the variance ratio is high, then it is fairly certain that the source of variation concerned is a significant one; if the variance ratio is low, then it is possible that the variance attributed to a particular source is a result of random sampling effects only. Statistical tables (for example, those of reference (9) and the graphs in reference (11)) show, for various degrees of freedom, the probability of a given variance ratio being due to random sampling effects. The value of variance ratio, which for a given number of degrees of freedom can be expected to occur only once in a hundred times as a result of "chance," or random sampling, is called the 1% significance level. Variance ratios less than that on the 1% significance level occur more frequently as the result of random variations and are therefore less significant; they will lie on a significance level between 1% and 100%. Similarly, variance ratios greater than that of the 1% significance level will occur less frequently as a result of pure chance and will be a more significant pointer to some other source of variation. These variance ratios will lie on a significance level between 0% and 1%. If the variance ratio calculated for a given source of variation exceeds the 1% significance level, that source of variation for the purposes of this report, is arbitrarily designated "highly significant." Variance ratios lying between the 5% and 1% levels are designated "significant," and variance ratios less than that corresponding to the 5% probability are designated "not significant" and are assumed to arise from the same source as the residual variance.

In Table No. 2 the residual variance is 18.04, corresponding to a standard deviation of $\sqrt{18.04} = 4.25$ or 21.25 per cent., since the scores refer to 20 sentence groups. The value of the standard error estimated from binomial theory (see the section dealing with Statistical Analysis of Test Results) for a probability of success $16.222/20 = 0.8111$, is 8.75 per cent. Thus, in this case, the variability of the test results, after allowing for known sources of variation, is much greater than would be obtained from a simple test in which the probability of success remained constant. It is quite possible in a well-designed test to obtain residual variances close to the theoretical values and an example is given in a subsequent section of this paper.

The "analysis of variance" table shows that the variance due to crew combinations is highly significant and it is therefore concluded that the absolute values of the results of immediate appreciation test of the type described in this paper is of little value unless a fairly large crew is used. (The test results are nevertheless valuable as a comparison between different local lines.) In the present case, 36 crew combinations were used and the variance due to crew combinations, from Table No. 2, is 94.7, corresponding to a standard deviation of $\sqrt{94.7} = 9.74$, or 48.7 per cent. The standard error in the overall mean as a result of crew combinations is $48.7/\sqrt{36}$, or 8.1%. To achieve, in this test, a standard error of 1% in the overall mean due to crew variations, the number of crew combinations would need to be increased to about 2370. The number of individuals required to provide this number of combinations depends upon the multiple listening arrangements made, but at least 50 would be necessary.

It is of interest to determine whether the variance due to crew combinations arose from differences between speakers or from differences between listeners, or from both. This could only be determined accurately if each speaker spoke to all listeners, which was not so in the present case. However, by taking the mean score for each observer as a speaker and as a listener, the speaker means were found to have a standard deviation of 15.7 per cent. and listener means a standard deviation of 13.8 per cent. Although this indicates that slightly more variation arises from speakers than from listeners, use of statistical tests show that the difference between 13.8 and 15.7 per cent. is not significant, and such a difference would occur due to chance variations six times in every ten trials.

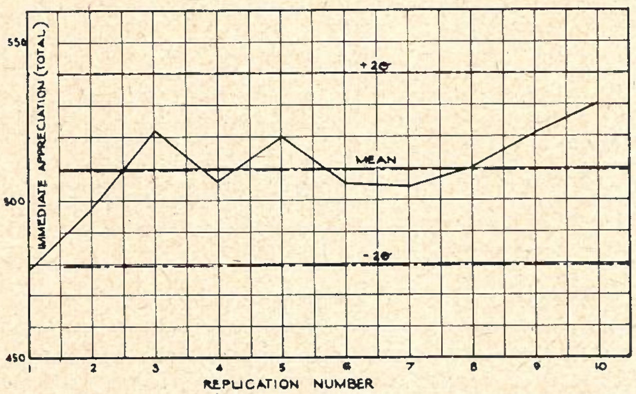

Fig. 4.—Total Immediate Appreciation Score Vs. Replication Number.

After crew combinations, the largest source of variation is in replications, that is, in repetitions of the same test. It is of value to determine whether this arises from random variations or as a result of some systematic variation, such as might arise as a result of observers becoming accustomed to a certain type of distortion and obtaining higher scores at each trial. The crew totals for the first ten tests at a junction attenuation of 32 db were averaged, and the overall replication means have been plotted in graphical form in Fig. 4. It will be seen that a rise in immediate appreciation was experienced after the first test and there was also a gradual increase during the last tests. It appears, therefore, that there is some evidence of a "practice effect" but of rather different nature to that observed in syllable articulation tests (12).

Application of Immediate Appreciation Test to Compare Two Telephone Instruments

Test Procedure. In Research Laboratory Report No. 3333 (13) comparative tests on two different telephonist's telephones were described. Portion of the results obtained in the speaking tests are given here to show that a more satisfactory test than that described previously for subscribers' local line limits may be made when multiple listening arrangements are provided. In these tests a splitting amplifier at the receiving end allowed four observers to listen simultaneously to each speaker. A crew of five could then be used effectively and a large number of results obtained in a comparatively short time. The crew used consisted of two men and three women.

Test Results. The test results obtained for a junction attenuation of 15 db are given in Table

A.P.O. Telephone

Listener No.	Speaker No.					Totals
	1	2	3	4	5	
1	(17.7)	20	19	20	17	93.7
2	18	(20)	20	19	16	93
3	18	20	(20)	20	17	95
4	17	20	19	(19)	15	90
5	17	20	20	20	(16.3)	93.3
Totals	87.7	100	98	98	81.3	465.0

Belgian Manufacture

Listener No.	Speaker No.					Totals
	1	2	3	4	5	
1	(19.75)	20	20	20	20	99.75
2	17	(18.1)	20	19	16	90.1
3	19	20	(20)	19	19	97.0
4	18	18	19	(17.1)	14	86.1
5	17	16	20	16	(15.4)	84.4
Totals	90.75	92.1	99.0	91.1	84.4	457.35

Table No. 3.—Comparison of A.P.O. Telephonist's Telephone and a New Telephonist's Telephone of Belgian Manufacture—Number of sentences "immediately appreciated" in a total of twenty.

Source of variation	Degrees of freedom	Variance	Variance ratio	Degree of Significance
Telephones	1	29.27	1.697	Not significant
Speakers	4	390.8	22.7	Highly significant
Listeners	4	159.3	9.25	Highly significant
Interactions				
Telephones and speakers	4	73.82	4.28	Significant
Telephones and listeners	4	82.44	4.78	Significant
Speakers and listeners	11	31.48	1.827	Not significant
Residual	11	17.42	—	—
Total	39			

Table No. 4.—Comparison of A.P.O. Telephonist's Telephone and a new Telephonist's Telephone of Belgian Manufacture:—Results of Analysis of Variance.

1.—Variances given above were calculated from the immediate appreciation scores given in Table No. 3, expressed as percentages.

No. 3. There is inevitably a series of "missing values" in a table of this kind, due to the fact that no observer can speak and listen simultaneously. The missing values in Table No. 3 have been estimated by means of the technique described in reference (11) and are enclosed in brackets () to distinguish them from the actual test results. Calculations of the missing values is a necessary preliminary to the analysis of variance, the results of which are shown in Table No. 4. The most important result of the test is that there is an insignificant difference between the sending performances of the two telephones. It is of interest to note that there is a significant interaction between telephones and speakers, and between telephones and listeners, but no significant interaction between speakers and listeners. The greatest source of variation is the difference between speakers, and it is considered that this is mainly due to differences of speech volume. It is, of course, advantageous to use controlled speaking volumes in tests where this action would not affect the final result, for example, in cases where the effects of sidetone at the sending end are not to be included in the test.

The residual variance of 17.42 (calculated on percentage scores) gives a standard error of 4.15%, which compares favourably with the value of 6.0% estimated from the overall mean by use of known properties of the binomial distribution theory. It is, therefore, concluded that the test procedure is efficient, and more so than in the test discussed previously, where the actual standard error was approximately 2½ times the estimated value.

Calculation of Transmission Performance Ratings from Immediate Appreciation Test Results. The definition of transmission performance rating adopted for this paper has been given in the introduction. Proceeding from this definition it is obvious that the transmission performance rating of a circuit relative to a reference circuit may be obtained by measuring the length in decibels of the intercept between the junction attenuation versus immediate appreciation graphs for the two circuits, such intercept being drawn along a line of constant immediate appreciation.

Examination of the shape of typical graphs indicate that the transmission performance rating obtained in any given case depends upon the value of immediate appreciation chosen for the intercept. Grinsted (6) used a value of 95%; however, cases arise frequently in which an intercept at this level is unsatisfactory. Such a case exists when one or both curves do not reach a value of 95% at any value of junction attenuation. In other cases, the 95% value may be reached, but the slope of one or both graphs may be very small at this level, and in such a case large errors in transmission performance rating may result from small errors in immediate appreciation scores.

On the other hand, the use of an intercept at a low level cannot be justified because the standard error of immediate appreciation scores increases as the immediate appreciation average falls (see the reference to "pure chance" variations under Statistical Analysis of Test Results), and, further, such a procedure may result in a rating being obtained which was only applicable when the transmission performance of the circuit was commercially unsatisfactory.

Due to the fact that the immediate appreciation scores obtained by one crew are not necessarily repeatable by any other crew, it is undesirable to choose an invariable value of immediate appreciation for the evaluation of transmission performance rating. It may be suggested that the relative level may be chosen at a level corresponding to, say, 90% of the maximum average value of immediate appreciation obtained during the test, but this is still open to the objection that the inferior system may not reach a sufficiently high level of performance to make an evaluation possible at the value of immediate appreciation so calculated. To overcome these and other difficulties, it is suggested that the transmission performance rating might be calculated from the area enclosed between the immediate appreciation junction attenuation graphs of the test and reference systems, the rating so determined being dependent upon circuit performance over a range of junction attenuations.

Similar suggestions to this have been made by Pocock (14) in relation to articulation tests, with the object of obtaining better correlation between ratings determined by such tests and those determined by repetition—rate tests. Although the method of determining transmission performance rating suggested above has the possible advantage of resulting in better correlation with ratings determined from repetition rate tests, it is suggested here mainly for the purpose of ensuring that ratings determined by subjective tests will be satisfactorily repeatable. A definite recommendation as to the method of calculating transmission performance ratings for general use from immediate appreciation scores cannot be made until further experience has been gained in subjective testing, particularly in repetition rate tests.

Conclusion

The Immediate Appreciation Test. The immediate appreciation test has the important advantage over articulation tests, that crew members require only a minimum of preliminary training. The checking and calculation of immediate appreciation scores is a relatively straightforward matter, as compared with the work involved in calculating the results of syllable and sound articulation scores.

To obtain results which have useful absolute values, crews larger than can be assembled in the Research Laboratories are required, and hence normal laboratory tests are organised and carried out on a comparative basis only. The use of multiple listening arrangements such as have now been installed, makes it possible to complete tests of satisfactory precision in a much shorter time than was possible previously.

Use of Immediate Appreciation Test Results for Calculation of Transmission Performance Ratings. Various methods of calculating transmission performance ratings from immediate appreciation test results have been discussed in this paper, but no satisfactory recommendations can be made at this stage. The problem is very similar to one which has been considered by the C.C.I.F., namely, the determination of A.E.N. ("Affaiblissement Equivalent pour la Netteté" or Articulation Reference Equivalent) ratings from articulation tests.

Use of Statistical Techniques in Connection with Immediate Appreciation Tests. It has been shown that statistical techniques enable the minimum amount of testing required to achieve a given result to be estimated. The analysis of variance procedure is an invaluable tool in the evaluation of the test results.

Transmission Performance of Standard Reference Circuit. Laboratory tests have indicated that a satisfactory value of immediate appreciation is obtained with the "overall transmission performance standard" circuit adopted by the Department. Comparative tests on lines representing the lengths of 6½ and 20 lb. subscribers' cable calculated to give equivalent performance to that of the standard circuit, are shown to give the expected performance.

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PLASTIC MOULDING IN THE MELBOURNE WORKSHOPS

H. J. Lewis

Introduction

Since early historical times man has cast his requirements in metals, clays and resins. The gradual introduction of artificial materials such as phenol formaldehyde (Bakelite), polystyrene, cellulose acetate (Celluloid), and polyvinyl chloride (P.V.C.) are only the extension of the age-old casting practice by modern chemists to give the better physical, chemical and electrical properties now required in materials and products. The first step in the introduction of the present form of plastics was probably the treatment and compounding of rubber. Ebonite was one of the first plastics produced in this way which has found common use in communication equipment. Although still in use today ebonite is quickly being outmoded as it lacks the electrical properties of the modern artificial materials and has a tendency to distort and crack with ageing. However, it was useful in the development of much of the present communication apparatus, and was a very good material in its day. Glass can also be considered one of the most useful plastics, and although not generally malleable, it has very good electrical properties, and has yet to be superseded in its special uses. New compounds of its main element, silicon, have been prepared recently and are known as the "silicone" group. These products include artificial oils, greases, rubbers and films. The latter form is most interesting as it provides a plastic with very good electrical properties which is non-combustible and non-fusible at temperatures up to 2000°C.

The first common plastic was phenol formaldehyde, prepared by Dr. Baekeland, of Holland, about 1908. This material was most useful in the development of the internal-combustion engine during the First World War, and also proved to be of great value in the Second World War in communication equipment. It was introduced into the Melbourne workshops during the latter period to form the main insulant of the equipment then being made for the armed forces, such as morse keys, telegraph relays, terminal blocks, plugs and strips. Other plastics, such as polystyrene, polyvinyl chloride and cellulose acetate, although discovered during the nineteenth century, did not gain recognition as communication engineering materials until recent years, although cellulose acetate was used for toys from about 1911 onwards. These materials have been introduced into the Melbourne workshops only in post-war years, but have proved to be very useful due to their high production rates, very good electrical properties, and stability during moulding.

Types of Moulding Process

The plastics used at present in the Melbourne workshops may be subdivided into the following two main groups insofar as the moulding processes are concerned.

Thermo-setting. These include phenol-formaldehyde, urea formaldehyde and melamine formaldehyde materials, the first two of which have been the chief ones used to date. The term "thermo-setting" explains their character in that they are moulded by the application of heat and pressure to a set state. During the application of the heat and pressure the powder undergoes a chemical change called "curing," and after this change they cannot be retreated or reprocessed. The moulding process for small parts takes from one to ten minutes, depending on the thickness of the moulding.

Thermo-plastic. The chief types of this material used for communication equipment, so far, have been polystryene and polyvinyl chloride. Polyester (nylon) and methyl methacrylate (perspex) are other important plastics of this type which have miscellaneous uses, but these are not moulded. This type of material is injected in a molten state into the die and is characterised again by its name, in that it becomes plastic on the application of heat, and provided critical temperatures are not exceeded it can be reformed, as there is no chemical change during its moulding cycle, which is usually of a duration of up to one minute.

Early Moulding Methods and Present Equipment

About 1932, due to the persistance and enthusiasm of some technicians, a small thermo-setting press was produced from scrap parts and set up in the workshops, and for several years laboriously turned out some quite good mouldings. This eventually paved the way for the purchase of two 60-ton hydraulically operated vertical presses, which provided for most of the requirements during the recent war. These presses were rather slow due to their dependence on gravity for their opening, and operation from manual pumps was laborious. They have since been replaced and are at present used as glue presses in the carpenters' shop.

The first step towards installation of the modern type of power operated hydraulic press was taken in 1948, when two Johns 40-ton automatic vertical presses were installed. These operate from a common electric oil pump and are electrically heated in both platens. Opening of the press is provided by additional hydraulic rams and ejection of the moulding accomplished either by the "up" stroke of the press or manually. These presses are still in operation and have proved very reliable, speedy and efficient. The moulding plant was further supplemented with two 100-ton Johns presses, shown in Fig. 1, of design similar to the

40-ton type. The old hand-operated presses were removed from service at this stage. These presses are capable of exerting a pressure of 100 tons, and cover the requirements of most plastic manu-

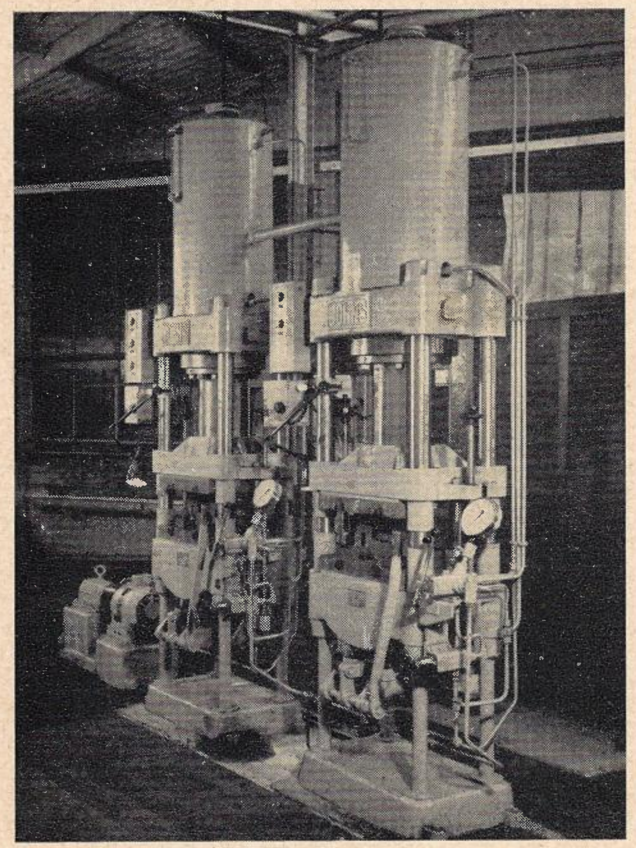


Fig. 1.—100 ton Thermosetting Machine.

facture for communication purposes. They have several features not included in the smaller machines, and although operating from a common oil pump, have independent pressure adjustments between the proportions of 3 : 2. Individual electronic timing is provided on each press, and the platens are fitted with "chase plates" which permit the forward withdrawal of the die during loading, cleaning and moulding removal. These 100-ton presses are also giving good service. They are very convenient to operate and occupy a minimum of floor space, and although not fully automatic, as are the more recent models installed in the Sydney workshops, they are just as efficient. Due to the diversity of work carried out in the workshops, in most cases it is not possible to have one operator attending many presses, and the additional virtues of the automatic presses cannot be fully exploited.

The first injection moulding machine was installed in 1948 and this opened the field for experience in moulding polystyrene, for which many new uses have been found in the last three years. This machine is of the horizontal hydraulic type of press, and is shown in Figs. 2 and 3. It is capable of making mouldings from up to 500 pounds of moulding powder in an eight-hour day and occupies comparatively more floor space than the thermo-setting presses, but its high production rate removes the present need for more than one press and offsets the space disadvantages. This machine has two hydraulic rams, one to close the dies by large locking toggle arms, and the other to inject the molten plastic into the dies after closure. The pump and die closing ram can be seen in the illustration on the left hand end of the press. The injection ram is at the other end of the machine in a similar position.

The machine can be arranged for fully automatic operation, but as there is a risk of costly damage to the dies in the event of a moulding not ejecting cleanly, an operator is usually in attendance to work the press under semi-automatic conditions. This has little effect on the cost of the mouldings due to the high production rate of the machine, and is a very cheap insurance for constant trouble-free manufacture.

A small half oz. capacity hand-operated injection moulding machine is now being installed to cater for small quantity production and "jobbing"

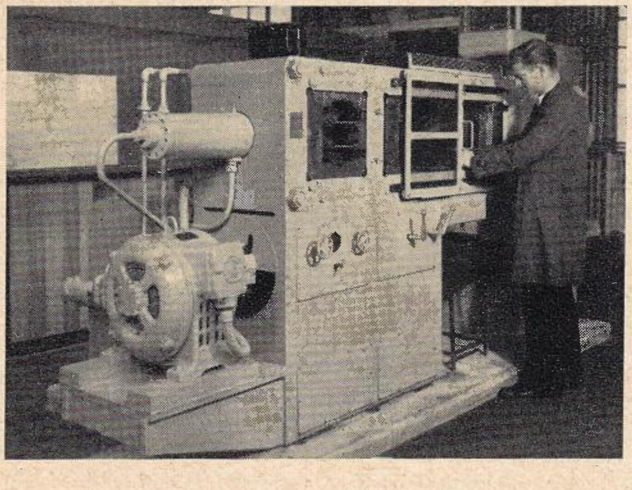


Fig. 2.—Injection Moulding Machine.

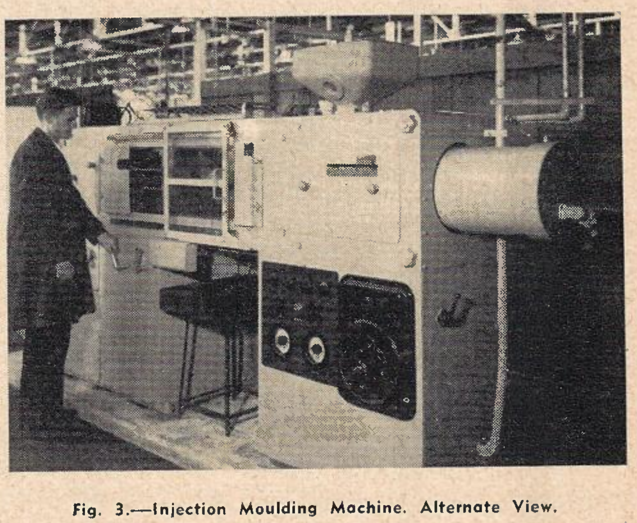


Fig. 3.—Injection Moulding Machine. Alternate View.

work, as it has been found that even for quantities of 50,000 off, the die cost can be between 80 and 90 per cent. of the total cost, and it is thus not an economic proposition to make a die to mould up to 1,000 off a small article in the large machine. The dies for the small machine will cost approximately one-sixth of the four-oz. machine dies and enable the small quantity and size mouldings to be economically and quickly produced.

Manufacture of Moulding Dies

This is probably the most important and certainly the most critical portion of the whole process, and much credit is due to the tool designers and tool makers for their perseverence, which has resulted in trouble-free manufacture of accurately dimensioned and high quality mouldings. Much progress has been made throughout the world during recent years in the design of machines and dies, and to take advantage of the improved methods and materials it has been necessary to carry out many experiments, some of which required weeks of concentrated trial, but which in turn rewarded their triers with success and a saving many times the experimental cost. All moulding dies are designed and manufactured in the workshops, as past experience, when pressure of other work forced the sub-letting of die manufacture to commercial contractors, proved this commercial manufacture unsuccessful. This was mainly due to the inability of the contractor to "run-in" the die and correct any errors before handing the die over for the production run.

The dies are designed by a skilled tool designer, who follows their manufacture and assists the toolmakers with any doubtful points that may arise. Only one toolmaker is normally used to make each die, and this individual arrangement of designer and toolmaker encourages a personal pride and interest in the work that pays dividends in the finished tool. The toolmaker is responsible for the initial set-up, trial and proving of the die and to assist him in obtaining the best results, a small sample stock of each type, brand and grade of moulding powder is held in the toolroom. The results with each powder are recorded after examination, and from a combination of data and sample, the most suitable powder is selected for production. This information is recorded on the "master production schedules" and "die history card," and forms a permanent record to avoid future troubles.

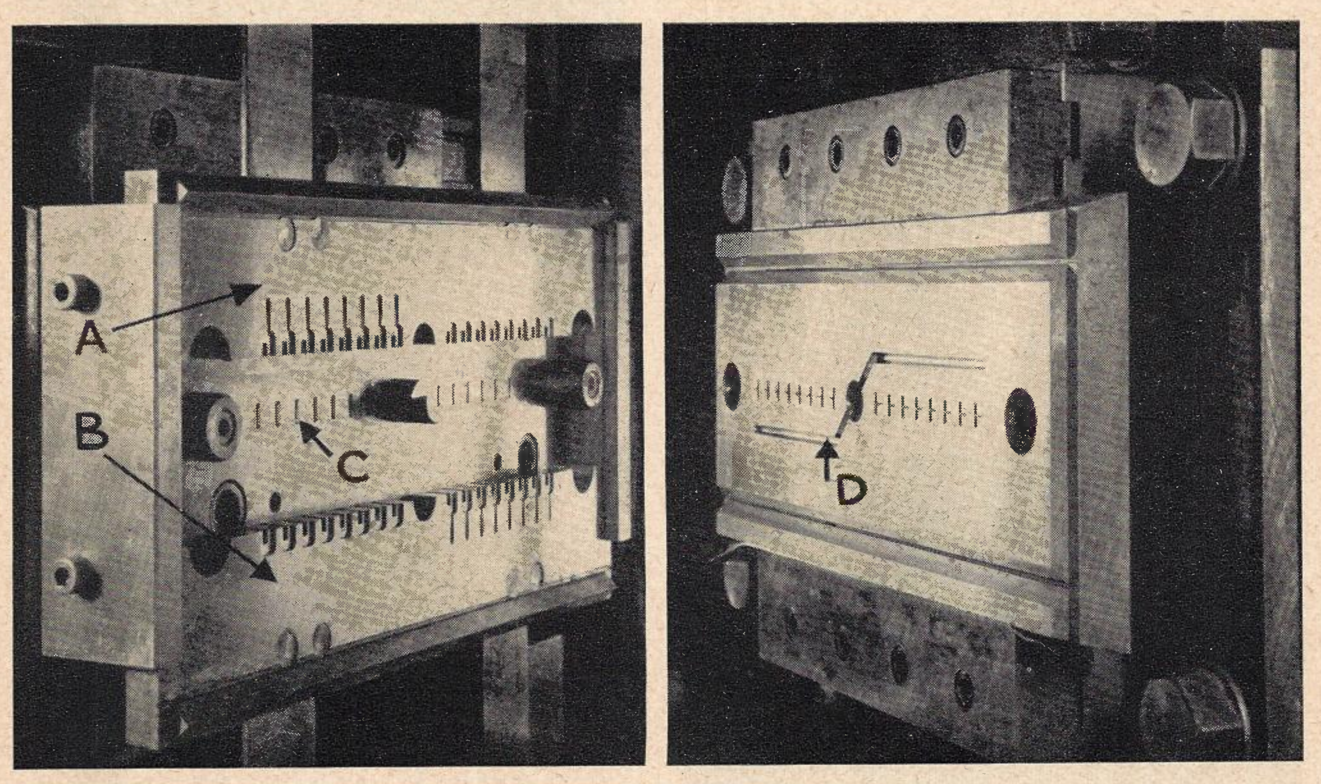


Fig. 4.—1 L Receiver Bobbin Dies.

With the injection moulding machine, only one grade of polystyrene is used, and it is therefore necessary only to record the injection times, die temperature and heating temperature. A standard nickel chrome steel of high quality is used for all dies. This standardisation simplifies die manufacture in that the design, toolmaking and heat-treatment became standard, and this limits the variations which would otherwise occur if different steels were used. It is quite possible to ruin a die completely during heat-treatment due to faulty steel or incorrect treatment, and the policy of purchasing a very good quality, one brand, standard type of steel for these dies, has proved well worth while. This will readily be appreciated when it is realised that the material cost of the dies is usually only 10 per cent. of the total, and even doubling the cost of the steel only adds 10 per cent. to the overall cost.

After initial machining, allowing for shrinkage during heat treating and grinding to finished sizes, the dies are sent to the heat treatment section where one toolmaker, who has been specially trained in the work, carries out the necessary treatment. This is again a very skilled process, and the resultant distortion and life of the die is entirely in the hands of the artisan, and is the reason for employment of one expert solely for heat-treatment. After hardening the dies have to be hand fitted and ground to a high finish, and great care is necessary at this stage to ensure a good finish on the moulding and freedom from "sticking" during the moulding process. Most thermo-setting dies are then chrome-plated as this finish provides a very fine surface on the moulded articles and acts as a lubricant to assist in their release from the dies.

Two good examples of the die-makers' art can be seen in Figs. 4 and 5. The I.L. receiver bobbin die (Fig. 4), is shown with the dies apart. On closing, the two halves of the left hand die, A and B come together and inserts C protrude through

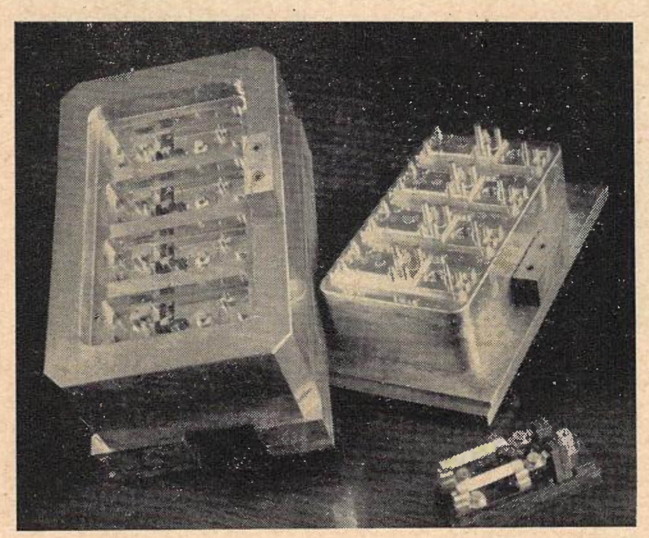


Fig. 5.—Protector No. 1 Base Moulding Die.

the body of the bobbin into the slots in the right hand die to form the cores of the bobbin. Channel D in the right hand section of the die provides the feed or runner for the injected molten polystyrene, from where it flows into the cavities via the small channels in the left hand side of the die, appearing as "spade handles" in the illustration. When the die opens, the resulting moulding "strips" on the hook in the centre of the left hand die and this is clarified by examination of the product in Fig. 6.

The protector No. 1 die in Fig. 5, is a four-cavity thermo-setting die of conventional type. Ejection of the part from the female die is made by raising the insert pins and thus forcing the moulding from the cavity. An assembled protec-

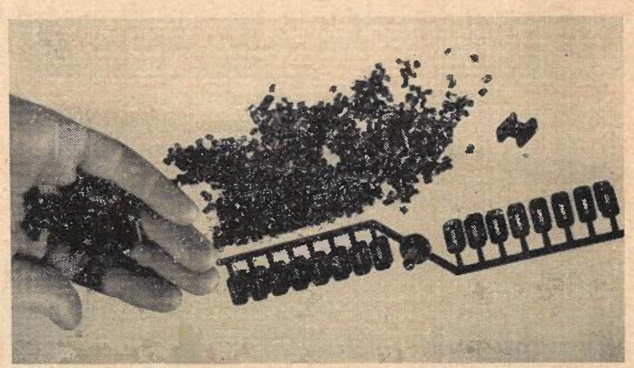


Fig. 6.—I L Receiver Bobbin Spray and Polystyrene.

tor appears in the right hand lower corner of the illustration. This die has been chrome plated, and as the photograph was taken after the die had produced many thousand mouldings, the excellent condition of the die faces is indicative of the benefit to be gained from this form of finish.

Manufacturing Procedures

Figures 7, 8 and 9 give the schematic principles of each type of moulding and will assist in the explanation of the process.

The thermo-setting press, Fig. 7, is of conventional design, and almost self-explanatory. The main ram is above the platens and brings the top force down into the loading well to compress the powder and force it into the lower die cavities. Both platens are electrically heated and thermostatically controlled, and, after closing, the dies

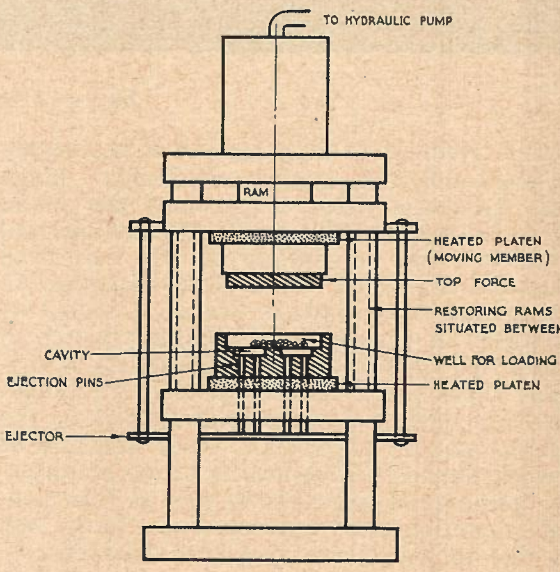


Fig. 7.—Typical Thermo Setting Moulding Press.

are held in this condition for a predetermined time to allow the "curing" and solidifying process to occur. It is sometimes found necessary to "breathe" the dies by momentarily opening them for a few seconds after full pressure has been applied. This allows the initial gases to escape and helps to overcome blistering of the mouldings. On completion of the curing time, the main ram and top force rise under pressure from the restoring rams and bring the ejector pins up through the bottom section of the die to lift the mouldings clear of the cavities.

Loading of the powder into the well is accomplished by a simple discharge fixture. During the curing period the operator weighs out the correct quantity of powder and loads it into the fixture. On removal of the completed moulding, it is then a quick process to reload the well by sliding out a shutter in the bottom of the fixture to permit the powder to fall into the well. Another simple and clean method of loading is to preform the the powder into pellets; the operator then places the required number of pellets evenly in the well. It is essential for small mouldings in multi-cavity dies that the powder is evenly distributed in the well as it has little opportunity to move from cavity to cavity.

After each moulding cycle it is often necessary to clean out the "flash" around the rim of the loading well and top force, and this is readily accomplished with a jet of compressed air. Where long "draws" occur in deep articles, it is necessary also to lubricate the die faces, and this is executed quickly by using a small compressed-air spray gun to apply a thin film of paraffin or olive oil. This has to be applied sparingly to avoid "graining" the face of the mouldings. A new silicone mould emulsion is now available in America which is supposedly a superior die lubricant, and it is hoped to use this fluid in the near future to further perfect the moulding production.

Fig. 8 shows a variation of a thermo-setting die arrangement where the loading well is separate

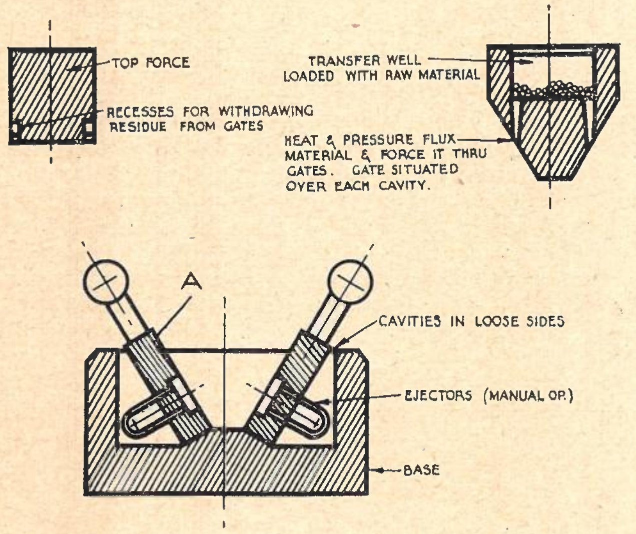


Fig. 8.—Typical Transfer Moulding Die Schematic.

from the lower die and the cavities of the die are removable. This type of die is essential where small metal inserts are being included in the moulding, and is the arrangement used in the Melbourne workshops to mould the terminal blocks for both drop and eyeball indicators. The powder is loaded into the transfer well and the top force enters this when the press closes to flux the powder and force it in the molten state into the cavities in the die blocks. On opening the press after the curing period, the two die blocks A are lifted out and another similar pair inserted, the transfer well refilled and the moulding process continued. The removed die blocks are then cleared of their mouldings by driving the ejectors out with a small mallet, and then these die blocks are cleaned and prepared for replacement in the base as soon as the current moulding cycle is completed.

This type of die is very costly to make, but has a high production rate to offset this, and ensures consistently good mouldings without damage to the fragile terminal pins moulded therein. It is necessary to remove the waste moulding from the transfer well gates, and this is achieved by hooks in the top force which pull the residue out on opening the press. One precaution that must be taken during manufacture is to keep the powder dry and clean. This is accomplished by storing it in sealed containers prior to loading into the dies.

Fig. 9 shows the arrangement of the horizontal injection moulding press and again is fairly self-explanatory. On closing the safety gate on the front of the press the moulding cycle automatically completes its course. The die-closing ram receives pressure and locks the two dies together at a high pressure. The powder from the hopper is metered automatically into the injection chamber. There it is heated, melted and forced by the rams into the cavities of the die, where it solidifies to form the required mouldings. The press then opens and the moulding is forced out of the cavities by ejector pins and falls into a container beneath the press.

Although the dies are stated to be "cold," it has been found that much better mouldings and faster moulding cycles are obtained by having them at a temperature of approximately 150°F., which is about 50° below the softening point of polystyrene. This heating of the dies is achieved by hot water circulation through the main plates on which they are mounted. The temperature of water is thermostatically controlled at the dies, and high pressure circulation ensured by a rotary water pump. This additional equipment has also permitted a change in die design, and where formerly it was necessary to provide a substantial section in the runners as shown in Fig. 6, it is now possible to restrict the opening into the cavity to a "pin point" and the practice is known at "pin-point gating." This has several advantages, the chief of which is the inflation method by which the cavity fills, which tends to limit the stresses that otherwise appear with dies at ambient temperatures using large runners. The required moulding is also more readily detached from the waste runner, and a further plate can be introduced between the main die blocks to automatically "degate" the moulding as the press opens.

Moulding in this machine is very fast and thus requires constant attention from a competent operator to ensure that there are no blockages that would damage the valuable dies if the press was allowed to close in that condition. The I.L. receiver bobbin die has a moulding cycle of 7 seconds, which gives a production rate of over 6000 an hour. It is interesting to compare this figure with the production rate of the old fabricated bobbins which took about 4 minutes each to manufacture.

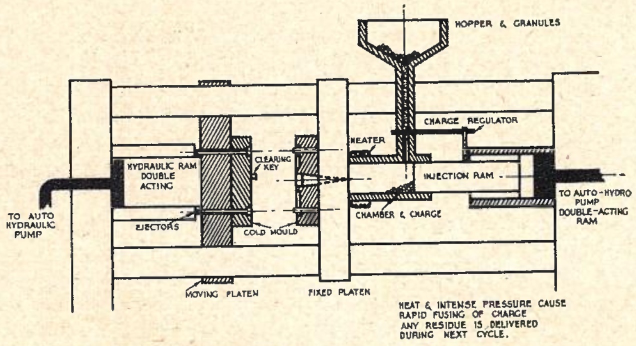


Fig. 9.—Typical Injection Moulding Press Schematic.

Plastics as a Substitute for Other Materials

From this title it might appear that plastics were being used as a makeshift for other unobtainable materials. However, although shortages of other materials often lead to the substitution by plastics, usually it is found that an improvement in cost, manufacture, and performance is obtained, provided the correct design and type of material is chosen. Plastics lend themselves very well to the development of odd-shaped articles which are difficult to fabricate, and many improvements in Departmental equipment have originated in the workshops as it is at the point of manufacture that the possibility of these changes is most apparent. The transmitter No. 13 base shown in Fig. 10 is a good example of this. Previously of pressed brass, it was very difficult to develop and suffered from insulation breakdowns on the internal surfaces as these were only sealed with enamel coating. Moulding this case in polystyrene has reduced the manufacturing costs and removed the pressing difficulty as well as banishing the insulation problem.

The eyeball indicator coil was originally wound on a bobbin assembled from sheet materials, the end cheeks being fibre with rivetted terminals and the core cover varnished cotton cloth. This was a clumsy and unreliable assembly which was expensive to make, and did not provide high insulation to the frame of the indicator. The bobbin is now made from two mouldings, one cheek and the core cover being moulded directly on to the core in polystyrene, and the other cheek of phenol formaldehyde carrying the moulded-in terminating tags is locked into position with mating splines by a tight fibre washer. The complete bobbin is cheaper, easier to manufacture, and provides a high insulation surface for the winding which is free from corrosive chemicals likely to attach to fine copper winding wire.

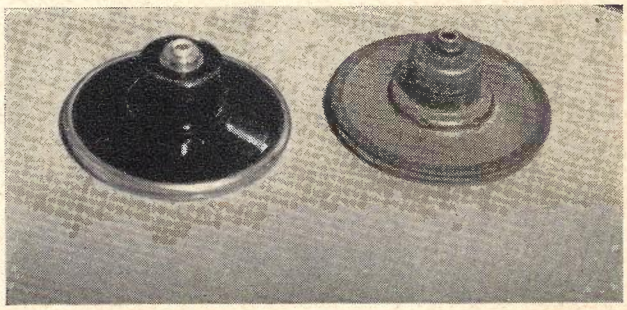


Fig. 10.—Transmitter No. 13 Base. Plastic Type on the Left, Brass on the right.

Use has also been found in the workshops for the plastic adhesives for both repair and production purposes, but as this item is large enough for a separate article it will be sufficient to say that they are supplanting all other forms of adhesive, as they are both faster-setting and stronger, and provide better electrical properties than animal derivative glues. Experiments have been made with electronic heating as a curing medium, and it is hoped to introduce this method of glueing into the woodworking section of the workshops at an early date.

Conclusion

It has been impossible to cover all of the interesting points and experiences encountered in the plastic moulding section of the workshops as the subject is a vast and varying one, which is becoming one of the major industries and manufacturing methods of the world and for which the future is still very rosy. With the constant interest and enthusiasm shown by those concerned with its progress in the Department, it is certain that many years of achievement and success are yet to come.

A CABLE MEASURING MACHINE

J. Mead, Dip.E.E., A.M.I.E. (Aust.)

Wherever cable is manufactured, or in stores where large quantities of cable are handled and issued, the need exists for some simple means of measuring the cable. In the Department, various methods have been adopted, such as using a tape, or pulling the cable off the drum and measuring between markers set out along the ground.

In locations where space is restricted, or where cable is being measured continuously, a simple method is necessary. A machine for measuring cloth has been developed, and consists essentially of a pair of rollers between which the cloth passes. By counting the number of revolutions of the rollers and using a suitable set of gears, the actual length of cloth passed through the rollers can be measured. This principle has been applied to measuring cables and wires, and many types of commercial machines have been manufactured for this purpose.

One of these machines has been in use in the Stores Branch, Perth, for some time, and in the following a general description of the machine is given, and also some details of its use. A view of the general set-up is shown in Fig. 1, and two views of the actual measuring machine are shown in Figs. 2 and 3. The larger wheel, which has a

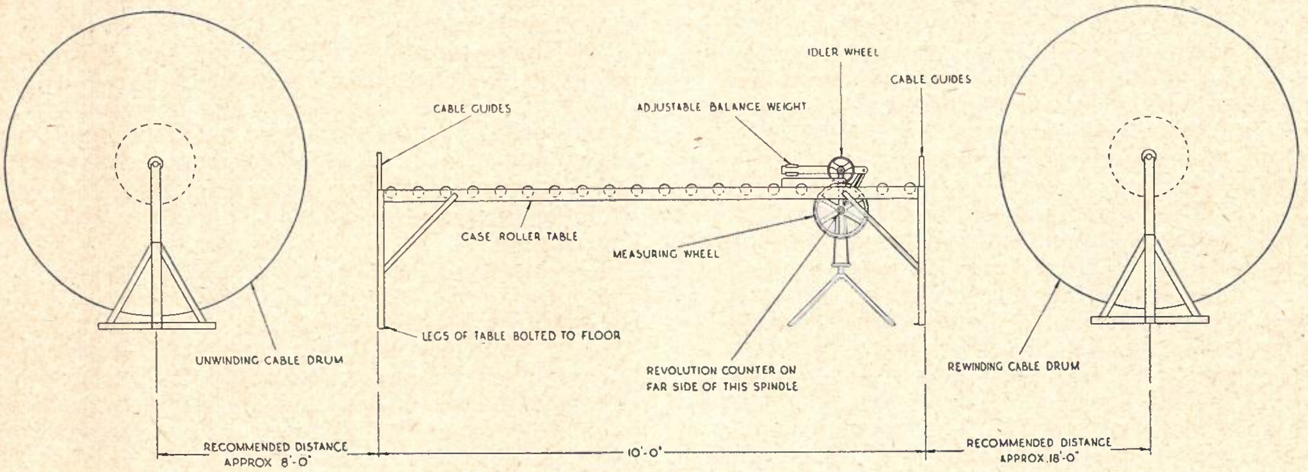


Fig. 1.—General View of Cable Measuring Machine.

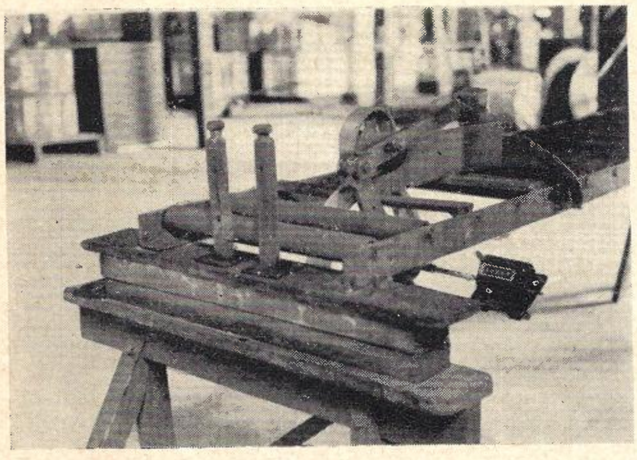


Fig. 2.—Front View of Measuring Unit, showing Counter.

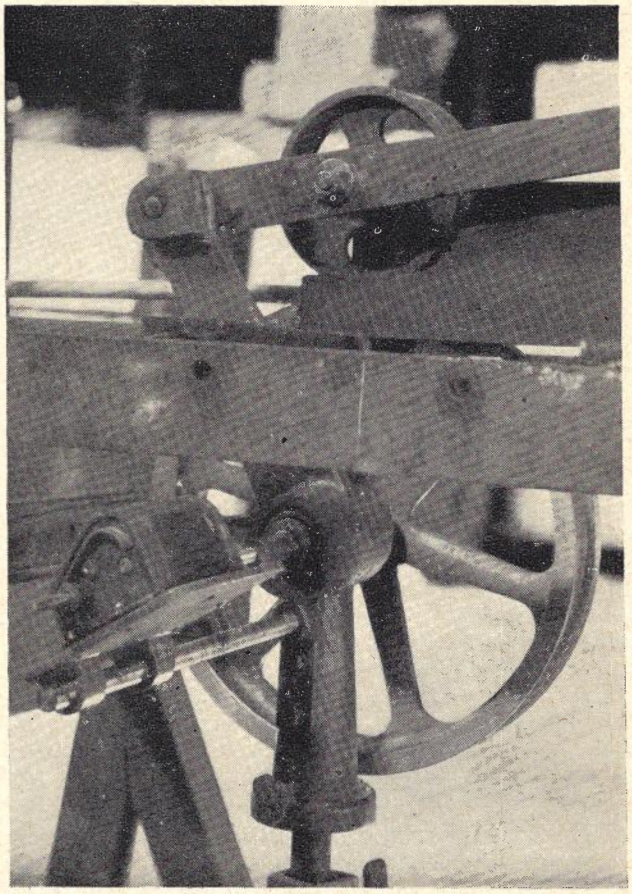


Fig. 3.—Side View of Measuring Unit, showing Measuring and Idler Wheels.

lip around each edge, is exactly one yard in circumference, measured in the section between the lips, and is geared directly to a revolution counter. The cable is passed over this wheel and kept pressed against it by a small idler wheel, the pressure being applied by an adjustable balance weight.

A roller table three feet high was constructed by using approximately ten feet of a commercial case roller mounted on angle iron legs. Three rollers are removed at one end to allow the measuring machine to be placed in position. The machine is mounted on an angle iron tripod at such a height that the top of the measuring wheel is in line with the rollers of the table. Shorter tables could be used where the machine is used in confined areas.

When the machine was first received it was fitted with a circular guide through which only small cables could be fed. The guide was removed and two ferrules fitted on the table to keep the cable on the measuring wheel. The ferrules consist of pieces of piping placed over two bolts, and will turn freely if touched by the cable when passing. The revolution counter spindle was also extended so that the number of yards rolled off, and indicated on the revolution counter, could be easily seen by the officer turning the receiving drum.

Two other ferrules are fitted at the other end of the roller table to prevent the cable rolling off the table. These are set at the sides of the table, so that the cable can be easily taken off the drum without excessive bending.

As indicated in Fig. 1, the drum containing the cable is mounted on jacks approximately 8 feet from one end of the table, and the receiving drum approximately 18 feet from the other end. The cable passes from the drum along the rollers of the table, over the measuring wheel, between the two ferrules set close together, and is finally wound on to the receiving drum. To prevent the larger cables from slipping out from between the wheels, a spiral spring, as shown in Fig. 2, is fitted to increase the tension applied by the balance weight.

The machine readily accommodates cables up to approximately 1¼ inches in diameter, which corresponds to a 54 pair 10 lb. tape armoured cable, or a 200 pair 10 lb. unarmoured cable. It has been used extensively in the Stores Branch, and in the near future additional machines will be installed in main line depots where large quantities of cable also are handled.

USE OF DDT FOR THE PROTECTION OF LEAD CABLE SHEATHS AGAINST TERMITES

F. R McNicoll, B.Sc.

Many faults in underground cables in the past have been caused by termites (white ants) gnawing through the lead sheathing and allowing moisture to enter the cable. These faults have been experienced mainly in districts where termites are more than usually prevalent and voracious, such as in the Northern Territory and parts of Queensland and South Australia. During 1945, in Adelaide, approximately 20% of over 400 cable faults which occurred were found to be due to the attacks of termites.

Prior to 1947 few effective means for combating the depradations of termites in the Department's underground cable installations had been available, but the advent of DDT solutions and their efficacy, even in weak concentrations, appeared to offer some positive solution to the difficulties formerly experienced in the eradication or prevention of the termite nuisance.

DDT is the common name for the organic compound Dichlorodiphenyl trichloroethane. It is a white crystalline powder with a slight smell, having a specific gravity of 1.6 and melting point of 107°-108° C. It is insoluble in water, but dissolves readily in the aromatic solvents benzol and toluol and also in kerosene and such liquids. It is generally used in a diluted form, a few per cent. of the finely powdered material being added to many commercial insect powders.

DDT solutions have been largely used for such purposes as insect sprays, in which a liquid solvent, such as deodorised kerosene is mostly employed. In addition to such methods of dilution the preparation of such emulsions in water has been found to be a much more economical method of using the material, as only a concentrated base, in a form suitable for preparing an emulsion, is required for purposes of transportation.

Of preparations containing a DDT emulsion base manufactured in Australia, that which promised to offer the most effective and practicable deterrent to termite attacks on the Department's cable plant was a water soluble DDT base known as Rucide, a product of Taubman's Ltd. This is a buttery looking material which contains 50% DDT. To prepare an emulsion it is slowly heated until melted, and then poured into a suitable quantity of water with constant stirring. This produces a milky-coloured watery liquid which may be readily sprayed.

A 1% solution of DDT is obtained by mixing 1 lb. of "Rucide" in 5 gallons of water, but even weaker solutions would probably be equally effective in some instances for the particular applications referred to. A minimum toxic concentration in the soil has not been determined, but it is possibly quite low, and field tests to date have not yet been sufficiently extensive to enable definite conclusions in this regard to be reached.

Extensive trials of Rucide emulsion have been made in Queensland and South Australia, with such favourable results that extension of the treatment to other States, in districts where termite activity might be expected, was arranged. The results of these trials have been most encouraging, and reports indicate that the Rucide emulsion is not only reasonably effective in combating termites where attacks are being made on cable sheathing, or where termite activity is to be expected, but is probably the best repellent that has so far been used.

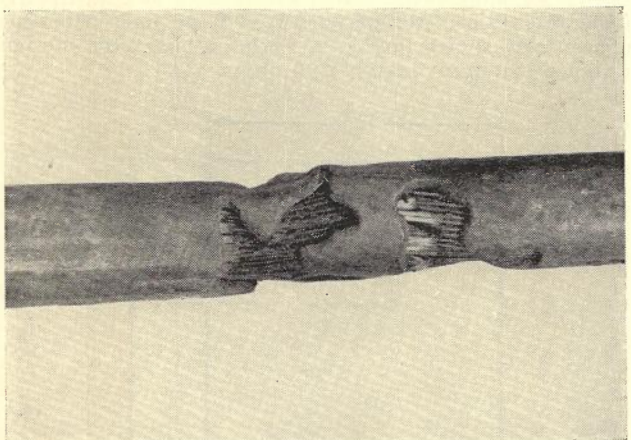


Fig. 1.—Typical Termite Attacks on Lead Cable Sheathing.

The DDT emulsion has the effect of causing the termites to transfer their activities elsewhere. There is some possibility of the insects resuming their activities at a later stage, and repetition treatment may, in some cases, be necessary, although experience has shown that the effects of the DDT treatment are longstanding, and only in isolated cases where DDT has been used to date has any re-appearance of termites been experienced.

On one or two instances where the DDT emulsion has been used during the installation of cable, termites have subsequently made their appearance, but this has occurred, as far as is known, only in the Northern Territory, where the termite species, Mastotermes Darwiniencis, a particularly large and voracious type, is prevalent. In each of these cases, however, the DDT concentration used was only a little over 0.5%, whereas it now appears probable that a 1% concentration may be considered the desirable minimum strength. Fig. 1 illustrates typical termite damage to cable sheathing and conductor insulation.

The extent of the application of DDT emulsion and the methods used are largely dependent upon the nature of the cable installation and the circumstances of the particular case. Where treatment with Rucide is considered to be practicable, the adoption of suitable practices presents little difficulty. For the treatment of soil in the vicinity of buried cable, a watering can with a flat spout or spray of limited angle may be used during the laying process. The liquid may be applied after a layer of soil has been put over the cable, or, if considered desirable, a preliminary spray can also be applied before laying the cable in the bottom of the trench. Impregnation of the soil for only a couple of inches around the cable is all that should be necessary.

Where a cable-laying plough is used, a suitable means of applying Rucide through the tube into which the cable is fed, in sufficient quantity to saturate the earth in the vicinity of the cable, can be adopted.

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 TRANSMISSION SECTION 2—RADIO AND BROADCASTING

Q.6 (i)—Develop an expression for the anode circuit efficiency of a linear radio-frequency amplifier in terms of the D.C. anode supply voltage and the minimum anode voltage at peaks of anode current. The tube is assumed to be biassed to cut-off, and anode voltage/anode current curves are assumed to be linear.

(ii) A tube operates at a D.C. supply voltage of 10,000 and the anode voltage falls to a minimum of 5,500 volts. An output of 5 kilowatts is required.

(a) What is the anode circuit load impedance?

(b) What is the anode circuit efficiency?

(c) What is the minimum anode voltage at peaks of 100 per cent. modulation?

A (i)—The anode circuit waveforms for a linear radio-frequency amplifier are shown in Q.6, Fig. 1.

With the conditions of grid bias and input voltage which exist under Class B operation, the plate current waveform is in the form of half sinusoid and zero current half cycles, as shown.

The average value of such a waveform represents the steady D.C. plate current and is—

$$I_B = i_{max}/\pi$$

Also, the fundamental frequency component of such a plate current waveform may be shown to have a maximum value—

$$i_{fm} = i_{max}/2$$

The R.F. power output is the product of the effective voltage and effective current at fundamental frequency—

$$P_0 = (E_{max}/\sqrt{2})\,(i_{rm}/\sqrt{2})$$
$$= [(E_B - E_{min})/\sqrt{2}]\;[i_{max}/2\sqrt{2}]$$
$$= E_B \cdot i_{max}/\pi$$

The plate circuit efficiency is thus

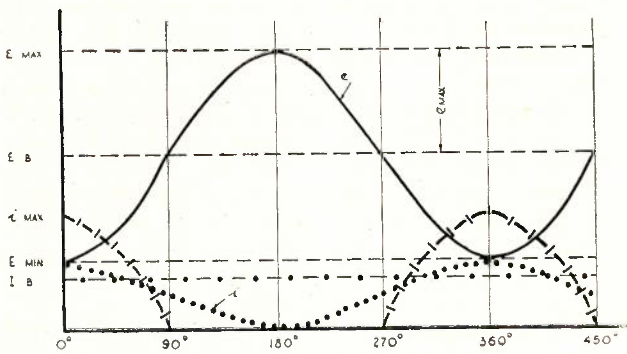
$$= P_0/P_I \times 100\%$$
$$= [(E_B - E_{min})\, i_{max}/4]\;[\pi/E_B\, i\, max]\; 100\%$$
$$= (1 - E\, min/E_B)\;(100\,\pi/4)\,\%$$

(ii) (a)

$$P_0 = (e_{max}/\sqrt{2})^2/R_L$$
$$= [(E_B - E_{min})/\sqrt{2}]^2/R_L$$
$$R_L = [(E_B - E_{min})/\sqrt{2}]^2/P_0$$
$$= [(10000 - 5500)^2/2]/5000$$
$$= 2025 \text{ ohms}$$

(ii) (b)

$$\eta = (1 - 5500/10000)\;(2200/28)\,\%$$
$$= 35.4\,\%$$



Q.6, Fig. 1.

(ii) (c) at 100% modulation the value of e_{max} is doubled and

$$e_{min} = E_B - 2\,e_{max}$$
$$= 10000 - 2 \times 4500$$
$$= 1000 \text{ volts}$$

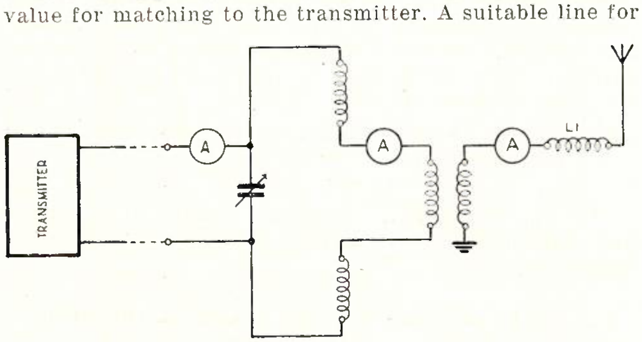
Q. 7 (i)—A medium-frequency vertical aerial is required for use with a broadcast transmitter and is located some hundreds of feet from the transmitter building. Describe a system of feeding the aerial from the transmitter—

(a) When the transmitter is designed to operate into a balanced load impedance of 600 ohms;

(b) When the transmitter is designed to operate into an unbalanced load impedance of 200 ohms, one side of which is earthed.

(ii) Explain the criteria for correct line-up of each system, enumerate the testing equipment necessary and briefly outline any measurements which must be made to ensure that the line-up is correct.

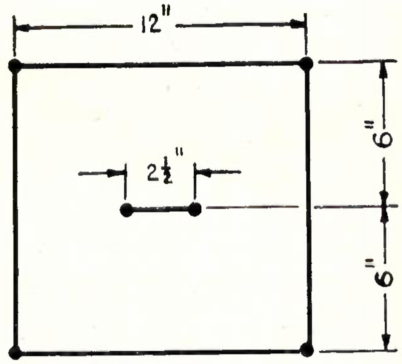
A. (i) (a).—The transmitter output may be connected directly to a balanced two-wire line, which has a characteristic impedance of about 600 ohms, the correct value for matching to the transmitter. A suitable line for powers up to 10kw would consist of two 300 lb. H.D. copper wires spaced 10" horizontally, mounted on insulators carried on poles. The line must be terminated in a coupling circuit which matches the unbalanced aerial impedance to the balanced line. One suitable circuit is shown in Fig. 1.



Q.7, Fig. 1

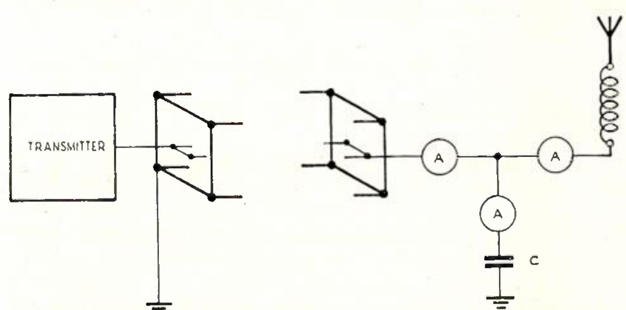
The aerial reactance (assumed to be capacitive) is balanced by the inductance L1 in series with the aerial. The condenser C1 is usually made adjustable by using a number of mica condensers of different capacitances in parallel. The inductances are air-cored helices of silver plated copper tube, with tappings for inductance variation. A rotating short-circuited turn inside each coil is used for fine adjustment. Thermocouple type ammeters A, are inserted in the circuit where shown, with knife switches by which they may be shorted out.

(b) An unbalanced six-wire line may be fed directly from the transmitter output. This is an open-wire line of the form shown in Fig. 2, having a characteristic impedance of approximately 200 ohms.



Q.7, Fig. 2.

Using $^7/_{16}$ stranded wire, and dimensions as shown, the line will handle up to 50 kw. The four outer wires are earthed at both ends and the two inner wires in parallel form the live conductor. The connections of the line and coupling unit are shown in Fig. 3.



Q.7, Fig. 3

The coupling circuit may be of the T or L type. The L network shown in Fig. 3 is suitable for most cases, but could not be used with an aerial of resistance greater than the line characterictic impedance, such as a vertical aerial very near a half wavelength in height. The inductor L may be thought of as two inductances in series, one tuning out the aerial reactance (which is here assumed capacitive) and one forming part of a matching network. The circuit components are as described in (a).

(ii) For correct line-up in both cases the correct load impedance must be presented to the line at the coupling unit and to the transmitter output. In this case the ratio of the aerial and line currents, fixed by their impedances, will be correct, and there will be no standing waves on the line. If an artificial aerial of impedance equal to the characteristic impedance of the line is connected to the transmitter, then it should be possible to change over to the line without disturbing the transmitter final stage currents.

The testing equipment required includes:—

(a) R.F. bridge, or resistance box and thermal milliameter.
(b) R.F. oscillator.
(c) Wire loop and thermal ammeter loosely coupled to line for standing wave measurements.
(d) Artificial aerial if available.

For both types of coupling unit, the aerial resistance at the operating frequency is measured either with an R.F. bridge or by the added resistance method. From this the desired aerial current at normal power input is obtained. The desired line current is obtained similarly from the line characteristic impedance.

In the mutual inductance type of circuit, the secondary circuit must then be tuned to resonance. The circuits are then tuned to give the correct values of line and aerial current when normal power is applied. This may be checked by using the three ammeter method at the coupling unit input, which should show that line current and condenser current differ 90 degrees in phase. The input current to the line should be measured and readings taken along the line with the sliding loop. The absence of standing waves is shown by the equality of the currents at the ends of the line and constancy of the loop readings. Finally, a check should be made with an artificial aerial, if one is available, as indicated above.

References:—

Telecom Journal—

Vol. 3, No. 1, June, 1940, p. 12. Transmission Line to Aerial Coupling Circuits for Broadcasting Stations. A. J. McKenzie.

Vol. 7, No. 4, June, 1949, p. 247. Answer to Examination Question (Senior Technician—Broadcasting). N. S. Smith.

Vol. 7, No. 5, October, 1949, p. 318. Answer to Examination Question (Engineer—Transmission, Section 2). E. J. Wilkinson.

Q. 8.—Write brief specifications for any two of the following units:—

(a) A line amplifier for use on an open wire programme transmission circuit.
(b) A microphone pre-amplifier for studio use.
(c) A filament transformer for a high-tension thermionic rectifier.
(d) An anode supply transformer for a three-phase, full-wave, high-tension thermionic rectifier.

A. 8 (a) Brief specifications of a line amplifier for use on an open-wire programme transmission circuit.

1. The gain shall be 30 db ± 1 db.
2. Provision shall be made for an attenuator to vary the gain in 2 db steps from + 30 db to − 10 db.
3. The power capability shall be 240 milliwatts.
4. The ratio of the output to harmonic distortion shall be not less than 34 db, for all values of power less than 50% of the power capability of the amplifier, in the frequency range 60 to 5000 cycles per second.
5. The frequency response shall be ± 0.5 db from 35 to 10,000 cycles per second.
7. The input impedances shall be 600 ohms ± 20%.
8. The load impedance shall be 600 ohms ± 20%.
9. The output impedance shall be 600 ohms ± 20%.
10. The unweighted signal to noise ratio shall be not less than 75 db when measured with an output of 120 milliwatts and a gain of 30 db.
11. The amplifier shall be required to operate from a direct supply voltage of 130 volts and 24 volts.

(b) Brief specification of a microphone pre-amplifier for studio use.

1. The amplifier shall be suitable for amplifying the output of high quality microphones.
2. The gain shall be 30 ± 1 db.
3. The power capability shall be 100 m. watts.
4. The ratio of output to harmonic distortion shall not be less than 34 db for all values of power less than 50% of the power capability of the amplifier, in the frequency range 60 to 7,500 cycles per second.
5. The frequency response shall be within ± 1 db from 30 to 15,000 cycles per second at 10 db below the full power capability, and ± 2 db at 40 db below.
6. The input impedance shall be suitable for matching to microphones having an impedance of 50 ohms.
7. The input transformer shall be multi-shielded to minimise the effects of external electro-magnetic fields.
8. The input tube shall be of the low noise non-microphonic type.
9. The load impedance will be 600 ohms.
10. The output impedance shall be 600 ohms ± 20%.
11. The unweighted signal-noise ratio shall be not less than 95 db when measured with an output of 100 m. watts and a gain of 30 db.
12. The amplifier shall be required to operate from a power converter providing a D.C. supply voltage of 300 volts 20 m.amps. and an A.C. supply of 6.3 volts 1.0 amps.

(c) Brief specifications of a filament transformer for use with a high-tension thermionic rectifier.

1. The transformer shall be suitable for operation at 230 primary volts, 50 cycles per second.
2. Voltage taps shall be provided in 10 volt steps from 210 volts to 250 volts.
3. The secondary voltage shall be 30 volts for an input of 230 volts and load current drain of 100 amps.
4. The temperature rise under the above conditions shall not exceed 55°C.
5. The insulation between the secondary to primary windings and to the transformer case shall withstand 10,000 volts.

(d) Anode Supply transformer for a 3-phase full-wave high tension thermionic rectifier.

1. The transformer is intended for service as the supply transformer in a 3-phase full-wave rectifying system using thermionic valves, the rectifying system being capable of supplying continuously a D.C. power of 15 Kilowatts at a D.C. voltage of 10,000 volts.
2. The primary winding shall be suitable for operation from 3-phase, A.C. supply mains of 415 volts 50 cycles per second, and shall be provided with voltage taps at 10 volt intervals from 400 volts to 450 volts.
3. Under the continuous load given in paragraph 1 the temperature rise of the windings shall not be greater than 55°C. when operating in an ambient room temperature of 25°C. for a continuous operating period of 24 hours.
4. The efficiency of the transformer shall not be less than 98% at full rated load.
5. The insulation between windings and between windings to frame shall be capable of withstanding a peak voltage of 12,000 volts.

Q. 9 (i)—Discuss the relative merits of the undermentioned bands of radio-frequencies for use in the establishment of a radio-telephone service between a central station and cars operating throughout a city and its environs:—

Medium frequencies (300 to 3,000 kilocycles/sec.).

High frequencies (3 to 30 megacycles/sec.).
Very high frequencies—
(a) (30 to 60 megacycles/sec.).
(b) (60 to 300 megacycles/sec.).

(ii) State the approximate band of frequencies you consider most suitable for this class of service, giving your reasons.

A. 9 (i).—The main factors effecting the choice of a frequency for an urban mobile radio-telephone system are set out below:—
(a) Radio noise level.
(b) Aerial efficiency.
(c) Number of channels available.
(d) Propagation characteristics.
(e) Efficient usage of frequencies.
(f) Other factors.

These will be discussed separately in relation to the various frequency bands.

(a) **Radio noise level.** In urban areas man-made noise is predominant over other sources, including first circuit receiver noise, over all bands from 300 kc/s to 300Mc/s. Its level is greatest at the lower frequencies and decreases as the frequency increases. From the point of view of noise then the medium frequencies are the least attractive and the V.H.F's from 60 Mc/s to 300 Mc/s the most.

(b) **Aerial efficiency.** As the radiating and receiving efficiency of aerials of fixed dimensions varies directly with frequency, it follows that for a car installation where the aerial size is limited, the greatest aerial efficiency is possible with the highest frequency. This condition indicates the use of the V.H.F. band 60 Mc/s to 300 Mc/s.

(c) **Number of channels available.** As it is certain that a service such as this would have to share a band with other mobile and fixed services working in the same area, it is important to have a large number of separate frequency channels available. The number available is directly proportional to the total frequency space available. Thus medium frequencies would yield a very limited number, high frequencies considerably more and V.H.F's the greatest number. Alternatively or concurrently the wide spectrum available at V.H.F's allows greater bandwidth per channel to be employed. This makes possible the use of F.M. with deviation ratios greater than unity and an increase in received S/N ratio results for the same radiated power. F.M. also discriminates against noise to a greater degree than does A.M.

(d) **Propagation characteristics.** Both medium and high frequencies give good coverage of the required service area, but they also propagate over very great distances outside this area, thus precluding the use of the same frequency within hundreds of miles or even anywhere in the world in the case of H.F's. The V.H.F's do not give as good coverage in the service area because of shadow effects, which become more marked as the frequency rises, but this can be offset by the use of more fixed stations. V.H.F's do not normally propagate much beyond line-of-sight but intermittent long distance ionospheric propagation occurs above 30 Mc/s and persists up to 70 Mc/s on rare occasions, due to sporadic E layer reflection. The band 60-300 Mc/s is, therefore, most suitable from this point of view.

(e) **Efficient usage of frequencies.** Medium and high frequencies, because of their long distance propagation characteristics, are far too valuable for broadcasting, international radio-telephone, etc., to be used for mobile radio-telephone services. This factor alone would completely preclude their use. Likewise the 30 Mc/s-60 Mc/s band is suited for point-to-point services operating near or slightly beyond line-of-sight and for rural mobile services which require greater range than city services.

(f) **Other factors.** R.F. circuit components are smallest at the highest V.H.F. frequencies which allows more compact and lighter units. Countering this is the fact that more tubes are necessary in V.H.F. transmitters because the frequency has to be multiplied more times from the original crystal controlled generator to the output. R.F. power generation is less efficient at higher frequencies and this combined with the greater number of tubes, requires more battery drain for the same power output as the frequency increases.

(ii) The band of frequencies most suitable is probably 150 Mc/s-200 Mc/s for the following reasons—
(a) Low noise level.
(b) High aerial efficiency.
(c) Sufficient frequency spectrum to give a large number of channels and also allow use of F.M.
(d) Practically no long distance propagation.
(e) Small R.F. circuit components.

Frequencies above 200 Mc/s have all the above advantages but special tubes and circuit techniques are necessary and at the present state of the art their use is not economical.

Q. 10.—With the aid of a block schematic diagram describe the main items of equipment in the transmission channel, plus monitoring and supervisory equipment, between the termination of the programme transmission line (assumed to be cable) and the radio-frequency transmission line, of a typical standard medium frequency broadcasting station. The functions of each unit of equipment should be stated.

A.—Fig. 1 illustrates in block schematic form the general arrangements for the transmission channel plus monitoring and supervisory equipment of a standard M.F. broadcasting station.

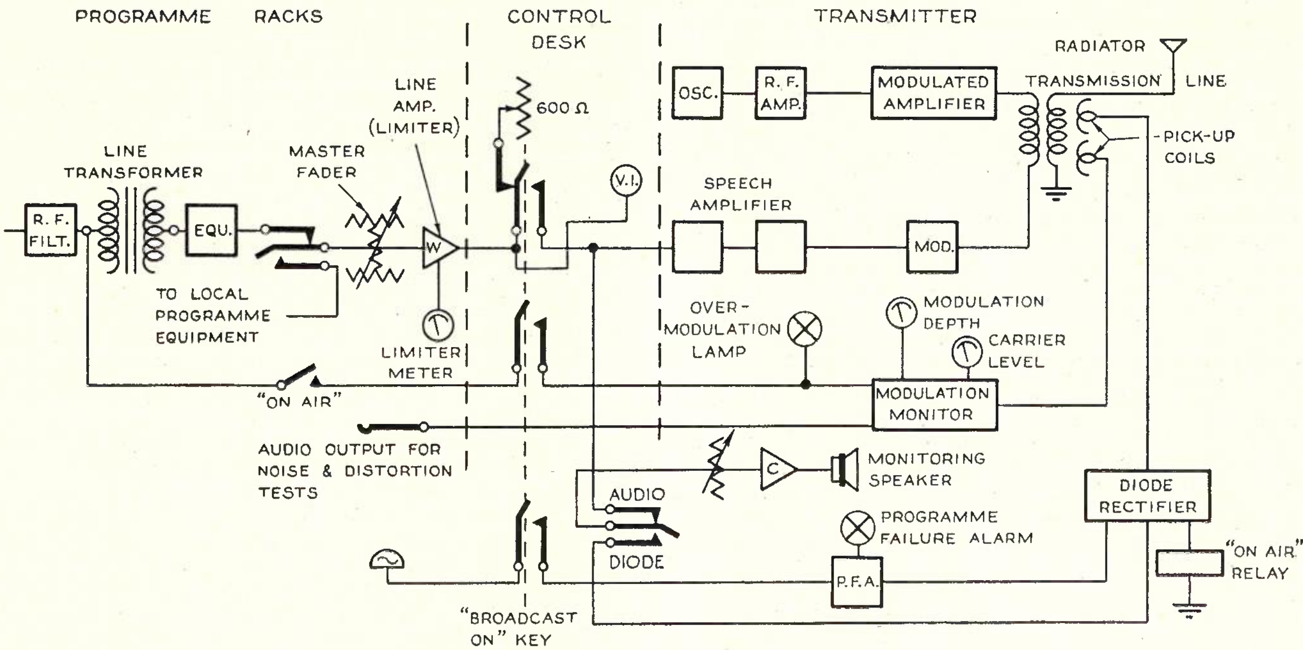
A Radio Frequency filter is connected to the incoming line as it enters the speech equipment racks, the filter being used to remove R.F. currents induced in the line by the high power transmitter circuits. The presence of R.F. currents in the low-level speech equipment can result in severe distortion and possible oscillations.

The R.F. filter is followed by a 1:1 ratio line transformer in order to break the line to D.C. and longitudinal currents and to enable the use of the line for "ON AIR" or over-modulation indication back to the studio in a cailho circuit using the transformer centre-tap.

The transformer is followed by an individually designed equaliser having a frequency response curve the converse of that of the line, which, together with the line, will give a uniform attenuation over the transmission band.

The Master Gain Control is of the balanced H type, and is used to adjust the input level to the following line amplifier and the transmitter. The Line Amplifier is a push-pull amplifier with a gain of 60 db, and its output adjusted to +8V.U. Its function is to overcome the attenuation of the line and equaliser and supply the correct level to the transmitter speech amplifiers. The amplifier is of the peak limiting type and as such prevents peaks of programme from overmodulating the transmitter.

A Broadcast On key in the transmitter control desk serves to connect the programme line to the transmitter, the line being terminated in 600 ohms when the transmitter is not connected. It should be mentioned that all



Q.10, Fig. 1.

the programme equipment has input and output impedances of 600 ohms. A Volume Indicator across the transmitter input indicates the programme level being supplied to the transmitter.

The transmitter is of the high level plate modulated type using several speech amplifiers; a cathode coupled stage driving the Class B modulator. The single-sided R.F. channel employs a crystal controlled oscillator, buffer or isolator stages, R.F. class C amplifiers and a plate modulated Class C output stage feeding the radiator by an unbalanced line such as an 80 ohm co-axial cable or 200 ohm 6-wire line.

Monitoring and Supervisory equipment consists of a Modulation Monitor, Programme Failure Alarm, audio monitoring from the programme input or diode, as well as the supervisory system for the transmitter control circuits.

A pick-up coil, coupled to the output of the transmitter feeds R.F. current to the Modulation Monitor, where it is rectified and the carrier level is indicated on a meter and adjusted to a reference level.

The adjusted level of rectified carrier, that is, the audio output is applied to another diode V.T.V.M. circuit to indicate modulation depth on either positive or negative peaks, and gives a flashing lamp indication of over modulation peaks in excess of any predetermined modulation level. Both the meter and lamp may be extended to a remote point. In some cases the flashing lamp indication is extended by the programme line caihlo to the studios. The carrier level meter indicates the stability of the carrier during modulation. The Modulation Monitor also provides a high quality audio output for Noise and Distortion tests.

A Cathode Ray Oscilloscope is shown connected to the pick-up coil and this provides for visual inspection of the modulation envelope. At the present stage the C.R.O. is not always provided.

A pick-up coil and diode rectifier are provided to operate the Programme Failure Alarm, Diode Monitoring, and "On Air" Relay. The P.F.A. is arranged to give a visual and key-controlled audible alarm when the programme level drops 15-20 db below 100% modulation and remains below that level for a predetermined time, usually one minute.

The "On Air" relay is operated by rectified carrier and the "on air" signal is transmitted to the studio by the programme line caihlo and controlled by the "Broadcast On" key.

Audio Monitoring is provided by a diode unit feeding a monitoring amplifier and speaker or by switching the amplifier to the input programme.

EXAMINATIONS Nos. 2854 and 2855—TECHNICIAN TELEPHONE INSTALLATION AND MAINTENANCE

Q. 1.—A relay having a resistance of 50 ohms and an inductance of 12 millihenries is connected across a 10 volt 800 cycle supply. Calculate the value of the current in the relay coil, given $\omega = 2\pi f = 5000$ radians per second (approximately).

A.—

Relay current $I = E/Z$ where E is applied Voltage and Z is the circuit impedance. $E = 10$ volts.

$Z = \sqrt{R^2 + (2\pi fL)^2}$ ohms

$= \sqrt{50^2 + (5000 \times 12/1000)^2}$ ohms

$Z = \sqrt{50^2 + 60^2}$ ohms $= \sqrt{6100}$ ohms

$Z = 78$ ohms approx.

$I = 10/78 \times 1000$ milliamps $= 128$ milliamps approx.

Answer—128 milliamps approx.

Q. 2.—In what way do the characteristics of a voltage amplifying valve differ from those of a power output valve?

A.—Typical characteristics—

	Voltage Amplifier	Power Amplifier
Amplification factor	30	3.5
Anode resistance	150,000	1500 ohms
Anode current	0.2	36 m.f.
Transconductance	200	2000 micromhos
Load resistance	20,000	2000 ohms
Power output	0.02	2 watts

Voltage amplifying valve: Large finely meshed grid close to cathode, anode well separated from and smaller than grid. Grid voltage variations produce relatively large voltage variations across anode load.

Power amplifying valve: Wide mesh grid smaller than anode. Small separation of cathode, grid and anode for low impedance. Grid voltage variations produce relatively large variations of anode current.

Q.3.—Draw a block schematic diagram of one channel of any multi-channel carrier telephone terminal with which you are familiar. Briefly explain the function of each filter in the circuit.

A.—The block schematic is one channel of a type SOS 3 channel system.

The Mod. Band filter suppresses all frequencies present in the modulator output except those of the sideband desired.

The transmitting and receiving directional filters separate the send frequency group from the receive frequency group.

The Demod. Band filter selects the band of frequencies appropriate to the particular channel demodulator and suppresses all other frequencies.

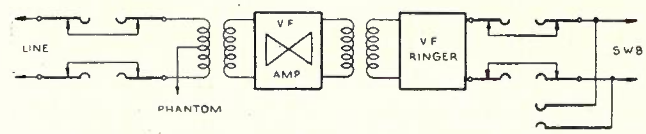
Q. 4.—A physical trunk line terminating on a toll test board is reported faulty. Briefly detail the preliminary tests you would make to determine the nature of the fault.

A.—Assume a physical trunk circuit as shown in sketch.

Preliminary tests:

Listen at listening jacks for noise, permanent ring, induction, etc.

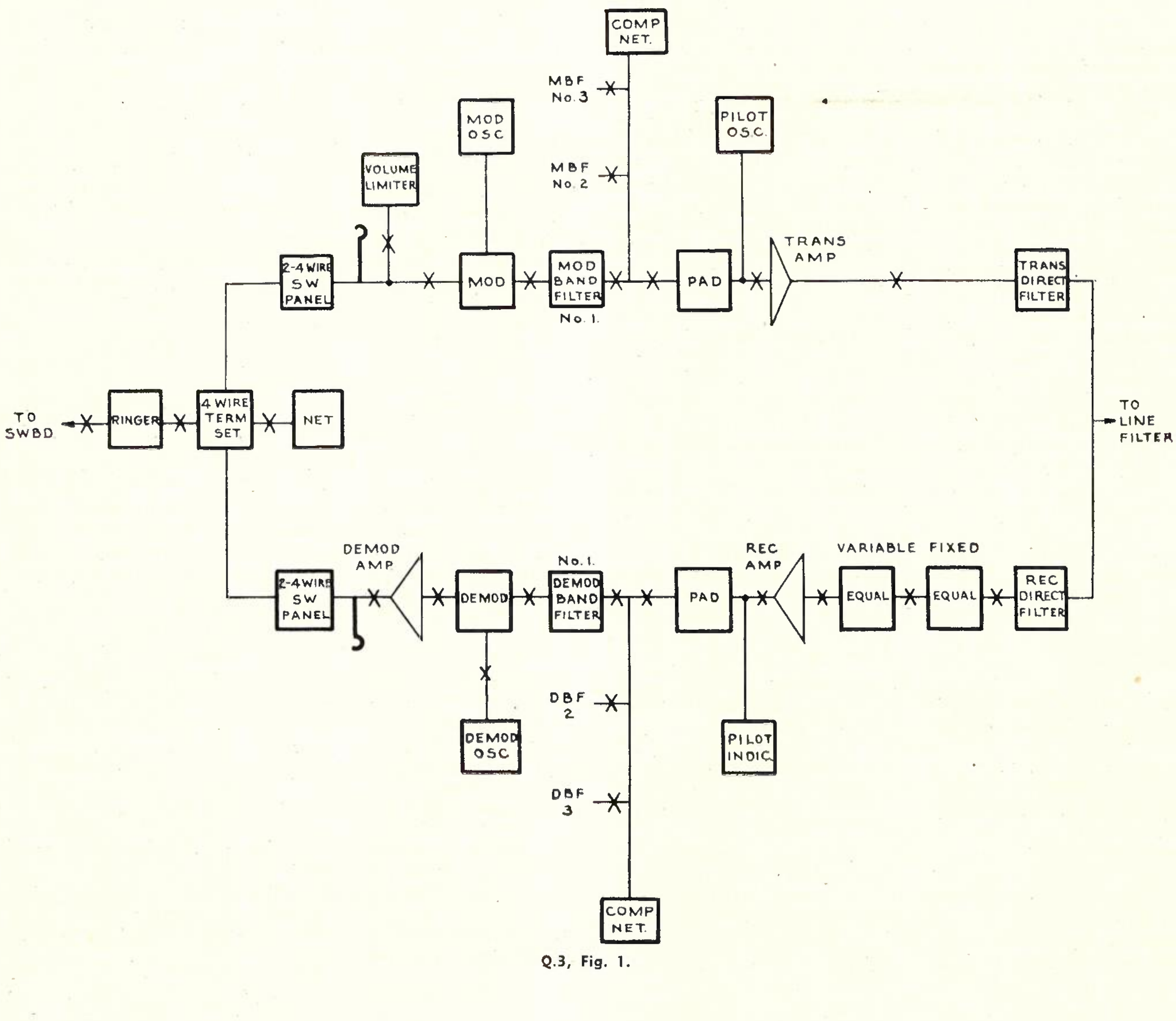
If noisy, prove trouble on drop or drop equipment side by plugging into appropriate test jacks. If tests indicate that the fault is on the drop equipment side, listen on other circuits that are derived from the physical concerned and compare results. If line appears to be normal, make signalling and speaking tests in each direction from drop and drop equipment jacks. If successful, an operator to operator check is made with the testing officer observing at the listening jacks.



Q.4, Fig. 1.

In many cases, other circuits appearing on the test panel may be derived over different sections of the faulty line, and failure of these circuits will give an indication of the faulty section. A further check helpful for later fault location is to listen on other physicals on the same pole route for contact faults, etc.

Where no derived circuit trouble is in evidence and the fault is out from drop equipment jacks, the terminal amplifying and signalling equipment should be tested in both directions before "calling in" intermediate or distant terminal stations for further test.



Q.3, Fig. 1.

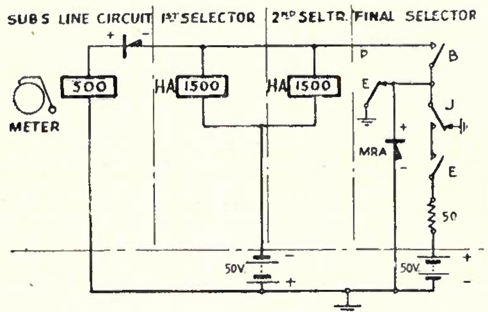
Q. 5.—(a) Draw the circuit of a 300 type automatic or magneto telephone and briefly explain its operation.

(b) List two major improvements which have been incorporated in the 300 type telephone as against earlier types of handset telephones used by the Department.

A.—See article Vol. 5, No. 5, page 298, for both automatic and magneto telephone type 300.

Q. 6 (a)—Draw the elements of the positive battery metering circuit employed in 2,000 type final selector switches, and briefly describe its operation.

(b) Indicate one advantage which the positive battery metering system has over the booster battery metering system.



Q.6, Fig. 1.

A. (a)—Prior to the called subscriber answering, the B and J relays in the final selector are operated.

The hold windings of relays H.A. etc., have circuit via B contact to the E and MRA earths. The meter is earthed on both sides.

When the called party answers, relay E operates and opens the slow releasing J relay. During the slow release of J (300 milliseconds) the 50 volt positive metering battery is applied to operate the calling subscriber's meter via the metal rectifier in the M wire. During the metering pulse HAs, etc., are held via the MRA earth.

When J releases, it cuts the metering pulse and the meter restores to normal. With J normal, earth is re-applied to replace that formerly provided by E.

As a precaution against re-operation of the meter, the J relay in the final selector is locked out of circuit until the call is finished.

(b) Compared with booster type metering, the advantages of positive battery metering are:—

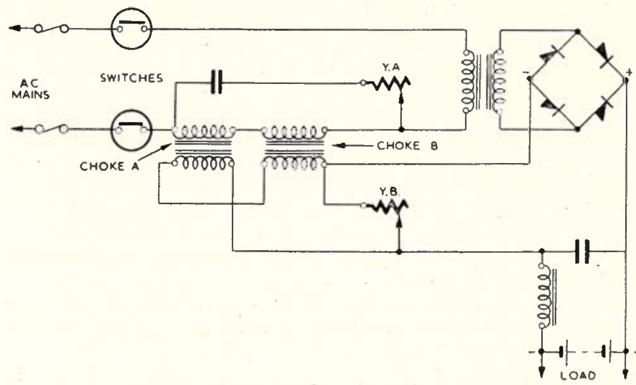
(1) Critical marginal adjustments and operation is eliminated. Normally there is no potential difference across the meter, current flows only for the duration of the metering pulse.

(2) Use of change-over, instead of make before break contacts to apply the metering battery to the circuit, eliminates the momentary short circuiting of the battery and consequently, contact wear.

(3) The operation and release characteristic of the metering arrangement makes the circuit readily adaptable to multiple or repeat metering if such arrangements are required in the future.

Q. 7.—In the "floating" method of supplying power to Departmental equipment a rectifier equipped with a means of automatic voltage control is sometimes used. Describe with the aid of a sketch the operation of such a rectifier.

A.—The transrector is an A/C mains operated battery charger which automatically varies its charge rate in accordance with the condition of the battery. This regulation is accomplished by means of a special choke, the primary winding P of which is connected in the



Q.7, Fig. 1.

AC input circuit, and the secondary winding S in the rectified DC output circuit. The impedance offered by the primary winding depends on the degree of magnetic saturation of the core, which depends in turn on the current value of the rectified output flowing in the secondary. If the output current is high, the choke impedance is low, and vice versa. Assuming a charged battery and negligible load, the transrector would supply a trickle charge, as a result of the high choke impedance under this condition. If the load is increased, the battery voltage falls and causes an increase in rectified output. This causes a decreased choke impedance and, therefore, an increased A/C input to the transformer, sufficient to balance the increased output. Further load increases will decrease the choke impedance up to the saturation point for maximum transrector output. As the load decreases the output current will fall in value and the choke impedance will rise, reducing the AC input. This will continue with decreasing load until the charge is once more reduced to a trickle.

The YB resistance is to regulate the choke saturation corresponding to any particular DC output. That is the value of battery voltage at which trickle charge begins to rise.

The YA resistance regulates the proportion of AC current which can be controlled by the choke. Reducing YA raises the trickle charge.

To eliminate AC ripple in the output, the choke secondaries are connected in opposition.

Q. 8.—(a) List the facilities provided by C or CA unit type PABX's.

(b) State two differences between C and CA unit type PABX's and other types used by the department.

A.—(a)

1. Extension to extension calls dialled direct.
2. Direct dialling to public exchanges after call prefix Y.
3. Barred direct exchange access. Exchange calls can be routed via manual switchboard.
4. Incoming calls received on manual switchboard and routed to extensions by telephonist.
5. Extensions can gain access to manual board by dialling 9.
6. Outgoing exchange calls can be set up by telephonist and routed to extension.
7. A busy extension may be offered an exchange call, a warning tone being provided to advise the extension that the telephonist is across the circuit.
8. Where special press button equipment is fitted to the telephone, an extension may hold an exchange call and dial another extension. If necessary the exchange call may be transferred to the extension without calling the manual board.

9. Exchange calls are night switched to predetermined extensions.
10. Camp on busy extension facility with cut through when the extension clears.
11. Through clear and automatic release on extension to exchange calls routed via the manual switchboard.
12. On exchange to extension calls routed via the manual switchboard, the telephonist may speak to either party without the other hearing.

(b) 1. The C unit PABX (4 Exchange lines, 25 Extensions) can be extended by the addition of a similar unit to 8 Exchange, 40 Extensions. The unit is known as a CA and is not capable of further extension.

Other departmental PABX's, such as the line finder and uniselector types can be extended to three figure working. The uniselector type, in particular, can be extended indefinitely.

2. The C, CA types have a small table mounted cordless type manual switchboard, with key setup of extension cables and standard dialling on Exchange lines. Each exchange line is used for incoming or outgoing calls.

All other types of PABX's (except Siemens Halske pe) require a floor pattern cord-type board with jack-nded Exchange and extension lines. Separate incoming and outgoing exchange lines are generally used.

The Call Back and transfer facility is not provided on other than C, CA and Siemens Halske PABX's.

EXAMINATION No. 3101—SENIOR TECHNICIAN TELEPHONY II. SECTION I

Q. 1—(a) Define the "decibel."

(b) A current of 2 milliamps is sent into a 600 ohm line. What is the power sent to line? If the attenuation of the line is 6 db and it is terminated in a 600 ohm load at the distant end what is the value of received power in db relative to 1 milliwatt? ($\log_{10} 2.4 = 0.4$).

A.—(a) The decibel notation is used to specify the relative magnitude of powers at two different points in a network of lines or apparatus. When the common logarithm of the ratio of any two quantities of power is unity the difference in level between them is defined as one bel. The practical unit, the decibel, is one tenth of this unit. The difference in level in decibel between two powers, P1 and P2, is given by:—

$$\text{decibel (db)} = 10 \log_{10} P1/P2.$$

If the impedance at both power levels is the same then the difference in level can be obtained indirectly,

$$= 10 \log_{10} (E_1^2/R)/(E_2^2/R)$$
$$= 10 \log_{10} (E_1/E_2)^2$$
$$= 20 \log_{10} E_1/E_2 \text{ db}$$

where E1 and E2 are the respective voltages.

A similar relationship holds when the respective currents are used.

(b) Power $= I^2R$ watts
$$= (.002)^2 \times 600$$
$$= 2.4 \text{ milliwatts}$$

$$\text{db} = 10 \log_{10} P1/P2 \quad \text{where } P_1 = 2.4 \text{ mW and } P_2 = 1 \text{ mW}$$
$$= 10 \log_{10} 2.4/1$$
$$= 10 \times 0.4$$
$$= 4 \text{ db}$$

$\therefore$ Power sent to line = 2.4 milliwatts = +4 db on one milliwatt.

Since attenuation of line is 6 db and the transmitted power is +4 db on 1 milliwatt, the received power ± +4–6 = –2 db below 1 milliwatt.

Q. 2—(a) What do you understand of the terms "near end" and "far end" crosstalk?

(b) Two Carrier Systems operate over the same pole route between adjacent repeater stations. What effect will be noticed if the systems are lined up to different transmitting levels?

A.—(a) All electrical circuits set up fields which extend into space, and these fields can cause interference in the form of noise or crosstalk in neighbouring circuits. The fields set up by an electrical circuit are electromagnetic and electrostatic in nature, and unless circuits (particularly those near one another) are properly co-ordinated these fields cause interference by induction.

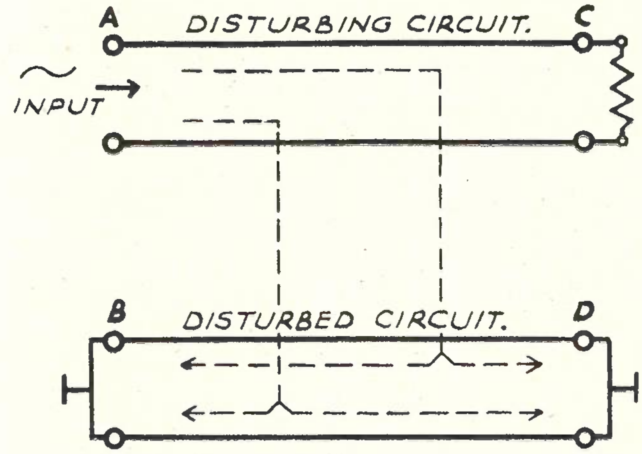


Fig. 1.

Cases arise where one end of a circuit is noisy, or where the crosstalk level is high, whilst the other end of the circuit is relatively silent. Under such conditions, it is necessary to specify the end of a circuit to which a crosstalk level refers.

"Near end" crosstalk is the crosstalk heard at the end of the disturbed circuit adjacent to the input end of the disturbing circuit.

"Far end" crosstalk is the crosstalk heard at the end of the disturbed circuit furthest from the input end of the disturbing circuit.

In Fig. 1 the crosstalk at B is referred to as near end crosstalk, and that at D at the far end of the circuit as far end crosstalk.

(b) If two carrier systems are lined up to different transmitting levels, the effects of crosstalk from the system at the higher level into the second system will be increased by the difference in transmitting levels. The effects of far end crosstalk are reduced by arranging that the transmitted currents from parallel systems pass a given point on the pole route at the same level.

Q. 3.—What is a volume limiter? Where is it used and why?

A.—A volume limiter is a device which is included in a speech transmission circuit to limit the peak voltage passed through the circuit. Two types of volume limiter

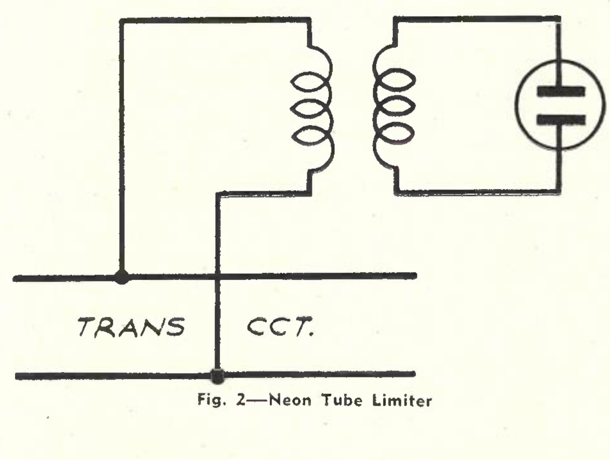


Fig. 2—Neon Tube Limiter

are in general use; they are of the neon tube and dry plate rectifier types, and are illustrated in Figs. 2 and 3.

The general principle of volume limiters is that at voltages lower than the pre-determined level the limiter appears as a high impedance across the transmission circuit, but to voltages in excess of that level its impedance is very low thereby introducing a loss which tends to limit the voltage.

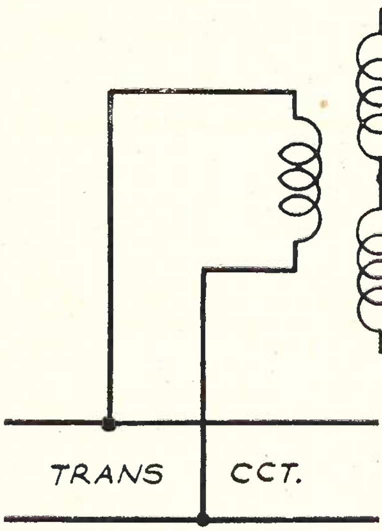


Fig. 3—Metal Rectifier Limiter.

Volume limiters are connected at the input of the metal rectifier modulator circuit in each channel of a carrier telephone system. The characteristics of metal rectifiers used as modulators require that the voice input voltage shall be low in comparison with the applied carrier voltage. Thus the volume limiter keeps the audio voltage input to the modulators from exceeding a predetermined value, regardless of the level delivered by the subscriber.

Volume limiters can also be usefully employed in preventing overloading of amplifiers and oscillators.

SECTION II

Q. 1.—You are required to install a single-channel terminal in an office equipped with 130V and 24V batteries. What wiring would be necessary and what type would be used for each connection?

A.—Since the office in which the single channel terminal is to be installed is equipped with 130 volt and 24 volt batteries, it is assumed that the office is a main carrier terminal and/or repeater station. In this case the miscellaneous apparatus racks to accommodate 3 or 5 Kc/s line filter groups, line transformers, voice frequency ringers, etc., together with the trunk test boards will be in situ and cabled to a common I.D.F. All cabling between these racks and the I.D.F. is in braided quad 20 lb. cable. The wiring of the filter racks is in screened wire.

Power distribution to the apparatus rack bays is made via a copper bus-bar network.

When installing a single channel system in this office wiring would be required as follows:—

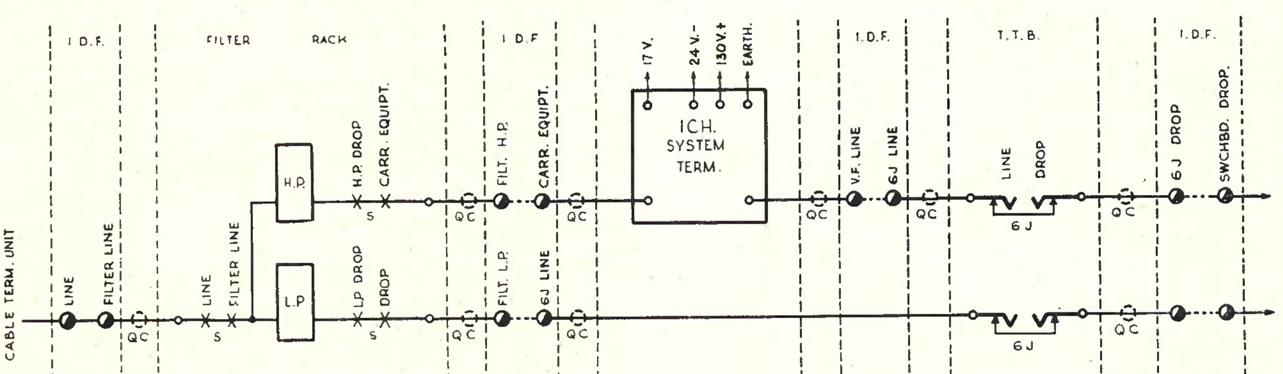
(a) from carrier line of system to H.P. drop of line filters.
(b) from V.F. line of system to switchboard. (It is assumed that the signalling equipment is included as part of system—this is usual practice with single channel systems.)
(c) for alarm lead and patch trunk or speaking circuit to T.T.B. as required.
(d) from 17 cycle input on system to station ringing distribution. This wiring should be in a separate cable to prevent interference to speaking circuit.
(e) power cabling for 24V and 130V battery supplies.

A braided quad 20 lb. cable is provided between the I.D.F. and the system tag block to provide for a, b and c connections. Interconnection between the appropriate equipment is made at the I.D.F. The connection between the bus-bar sub-distribution panel and the system power input terminal is made with V.I.R. cable of size suitable for current to be carried and allowable voltage drop. Three leads are required, one each for 24 volt negative, 130 volt positive and earth. A diagram illustrating how various items of equipment should be wired together is shown in Fig. 4.

Q. 2.—A physical trunk line terminates in an office and the following facilities must be provided:—

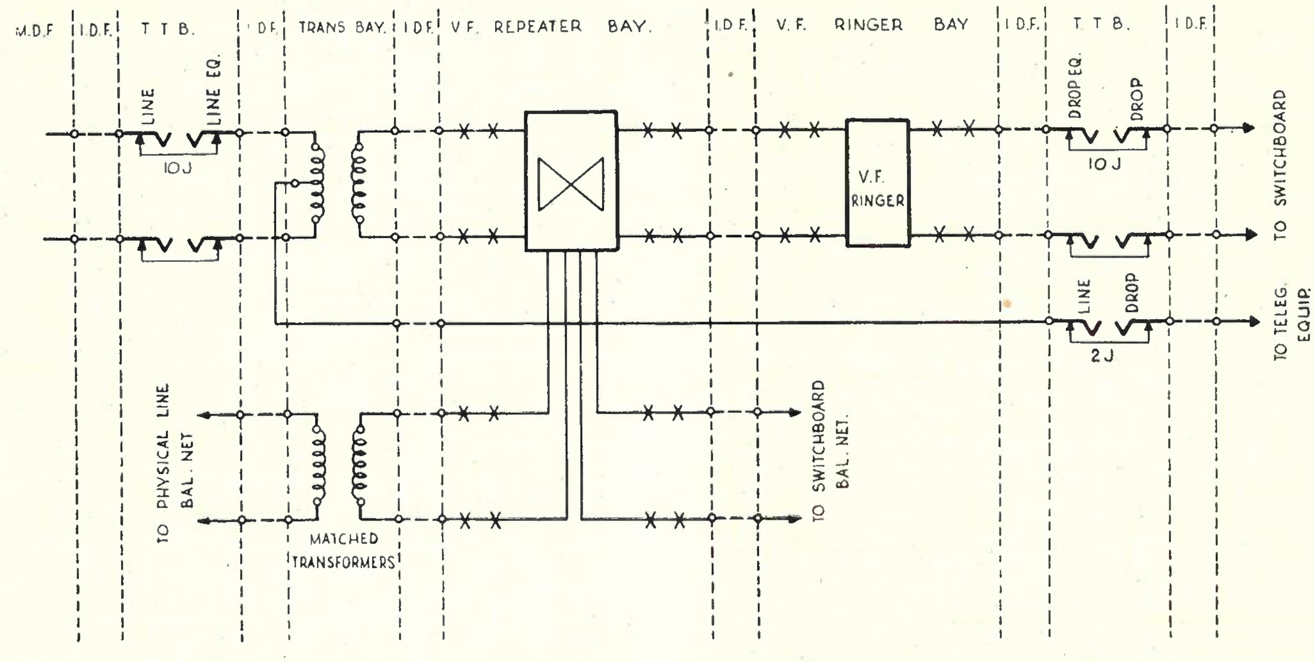
(a) A Cailho telegraph circuit;
(b) A physical telephone circuit;
(c) A voice frequency telephone repeater on the physical telephone circuit;
(d) necessary trunk signalling equipment.

Draw a schematic circuit showing how all the office equipment is connected and indicate what points would be jacked on the trunk test board.



QC — QUAD 20 LB. CABLE
S — SCREENED WIRE
—o— TERMINALS OF BLOCKS ON EQUIP. RACKS
● TERMINALS OF BLOCKS ON I.D.F.

Fig. 4.



—X—X— DENOTES JACKS SIMILAR TO THOSE SHOWN FOR T.T.B.

FIG. 5.

A.—The various items of equipment in the office to provide the required facilities on the physical trunk line and the method in which they should be wired together are shown in Fig. 5.

It will be seen that each piece of apparatus is wired to the I.D.F. to provide a fully flexible arrangement. Alterations to the circuit at a later date would be carried out at only one point, namely, the I.D.F.

Q. 3.—(a) **What is carrier leak?**

(b) How would you adjust a 3-channel carrier system to correct excessive values of carrier leak and what value would you regard as satisfactory?

A.—(a) In carrier telephone systems the modulators employed are designed as a balanced circuit to suppress the carrier frequency. When any unbalance exists between the two halves of the modulator circuit some of the carrier frequency current appears at the modulator output jacks. This unsuppressed value of carrier frequency current from each channel modulator is termed "carrier leak" and is most conveniently measured at the transmitting amplifier output jacks.

(b) The method of adjusting a 3-channel carrier system to correct excessive values of carrier-leak is as follows:— (Refer to Figs. 6 and 7.)

Remove pilot frequency current from input to the amplifier during tests if system is equipped with A.G.C. equipment.

Insert 600 ohm plugs in the "Mod. In" jacks of all three channels of system under test.

Patch from "Trans. Amp. Out" jacks to the Rec. Jacks of a T.M.S. set at Loss with range switch at +20 db.

Insert 600 ohm plugs in "M.B.F. In" and "Mod. Out" jacks of the two channels not under test.

Set the transmitting amplifier potentiometer to maximum gain with all input pads out of circuit.

Adjust the balancing potentiometer P1 in the modulator circuit so that minimum carrier leak is measured on the T.M.S.

The carrier leak should not be less than 38 db. below the relative test level. If the transmitting level of the 3-channel carrier system is +18dbm for a correct input test level at the hybrid line jacks with the transmitting amplifier gain set as above, then the carrier leak measurement should not exceed −20 dbm for each channel.

Note: The three channels of the system must be out of service to permit making these tests.

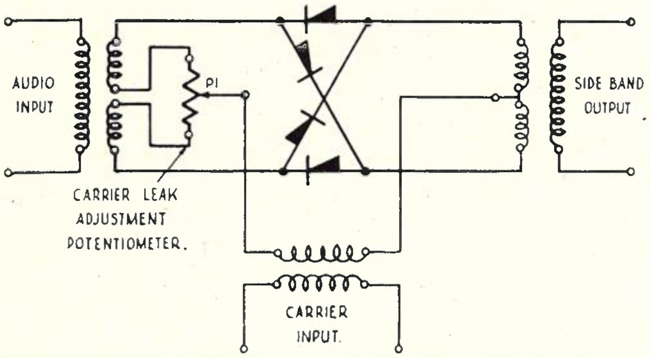


Fig. 6—Balanced Copper-Oxide Rectifier Modulator

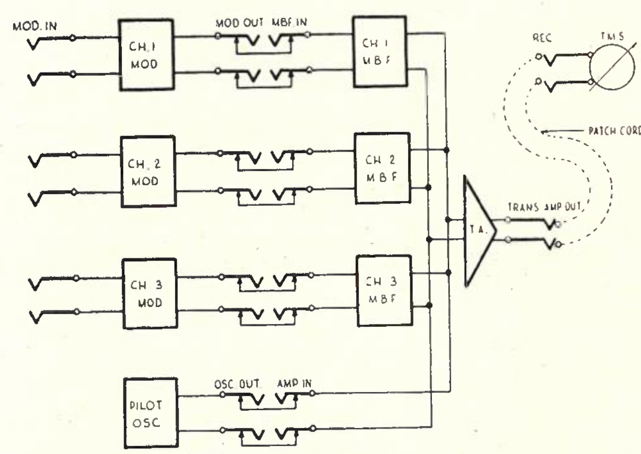


Fig. 7—Carrier Link Adjustment.

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