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Telecommunication Journal of Australia

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TRIGGER CIRCUITS IN TELEGRAPH REPEATERS AND CARRIER TELEGRAPH SYSTEMS

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Experience with conventional relay telegraph repeaters and carrier telegraph systems suggests a need for improvement in both these devices and in similar equipment using conventional telegraph relays. Theoretically, the introduction of relay repeaters on long physical telegraph circuits enable higher signalling speeds to be maintained, but in practice there is a tendency to endeavour to work long distances without them. There are, doubtless, many reasons for this state of affairs, which appears to be a correct statement in some instances, if not in all. Treating telegraph transmission theory on the same general lines as telephone transmission shows that the practice of working long circuits without repeaters, i.e., by using abnormally high sending levels (currents) is fundamentally unsound since the amount of power required at the sending end is so large that cross-fire into adjacent circuits becomes a major problem. The problem is exactly analogous to the telephone problem, where, if voice frequency repeaters were not used at regular intervals, the sending power would need to be of the order of kilowatts if a very long circuit were to be usable. The practice, in telephone circuits, of using repeaters at intervals is so well established and both the theory and practice are so well understood that there must be some good reason to account for the reluctance to use telegraph repeaters at frequent intervals. Some of the reluctance is because telegraph repeaters require skilled telegraphists to look after them and the question of staffing costs is important.

One of the reasons for disliking repeaters is that the relays available in the past have not been reliable for continuous use on high-speed circuits. For a long time the relays were poor in performance and for this reason the faulty performance of the relays outweighed the advantages of introducing repeaters. The introduction of the 215 type and later the 209 type relays improved matters considerably, but even with these relays the performance was far from perfect and it was not uncommon for "bounce" at the contacts to cause trouble. The question of bounce at relay contacts has received a good deal of investigation and need not be stressed except to state that many attempts have been made to solve the problem, sometimes by using light moving springs of low inertia and sometimes by using heavy tongues and strong driving forces to ensure a single firm contact at each movement. The B.P.O. polar relay, the 215, 209, and lately the new model Creed relay all represent endeavours to design a sensitive relay, suitable for high-speed signals and free from bounce, etc. An interesting suggestion is the possible use for telegraphy of the Siemens high-speed relay used in conjunction with the motor uniselector, for example, in the new Melbourne Trunk Exchange. This relay has small and light moving parts.

At first sight, it would appear that the design of a relay suitable for modern telegraph practice should be an easy problem in view of the extensive use of relays in automatic telephone exchanges, some of which are good for perhaps five million operations before failure. On telegraph circuits, where a circuit may run continuously on teleprinter or multiplex basis for days on end with practically no shut downs, it does not take long to reach five million operations of a relay where dots are being transmitted at from 15 to 50 per second. No relay in an automatic exchange is called on to operate under similar conditions.

It is thought that the problem of the telegraph repeater and relay will not be solved until use is made of new principles, such as the use of thermionic valves. A relay is nothing more or less than a device to amplify telegraph signals and there is no fundamental reason why ordinary valves cannot perform the required functions. Relays are being replaced by valves in many important industrial applications, ranging from exceedingly delicate jobs such as operation from photoelectric cells to the very large size valves used for controlling electric welding sets. They are used also to replace commutators in electric motors and it is interesting to note that a commutator on a motor is really just a pole-changer type of relay.

In the succeeding pages there are described some endeavours made in Adelaide to replace relays by valves, first in the carrier telegraph systems, where the receiving relay has now been replaced successfully, and in Appendix IV. there is described a possible use of valves to replace relays in a C.T.O. or in a physical telegraph repeater. The latter is only in the stage of having theoretical possibilities at present, but the former has been in actual use for nearly a year.

TRIGGER CIRCUITS IN CARRIER TELEGRAPH SYSTEMS

Trigger circuit is the name given to a circuit in which a small electrical impulse releases, suddenly, a comparatively large amount of electrical energy, the amplitude of the latter being independent of that of the controlling impulse. The action is analogous to that of a trigger of a gun, hence the name. The trigger circuits can be devised in a number of ways, including mechanical and electrical, but the most useful for carrier telegraph systems are those embodying various arrangements of thermionic valves. Trigger circuits have received a great deal of attention from various investigations in recent years and now provide an amazing variety of novel circuits for unusual application, such as counting and recording impulses of different types, for replacing mechanical devices such as scanning wheels in facsimile and television systems, sweep circuits for oscillographs, etc. Therefore, it was quite natural that attempts should be made to utilize trigger circuits in both ordinary and carrier telegraphy. In carrier telegraph systems, there is a great deal of scope for the future use of trigger circuits, particularly in improving the maintenance conditions. In most telegraph systems, for example, it is necessary to use, at various parts of the system, mechanical devices, including electro-mechanical relays in their many varied types (see Fig. 1). While a mechanical device in itself is not necessarily objectionable and is frequently more reliable and easier of adjustment than a corresponding electrical device, it is generally found that there is a broad distinction between the equipment of a purely mechanical nature, as exemplified in the typical telegraph office and the equipment of a purely electrical nature as exemplified in the typical voice frequency repeater, carrier telephone system, etc. This broad distinction is carried right through the general arrangement of equipment, method of wiring, etc., into the staff itself. Thus, while the typical telegraph office must place great emphasis on the easy accessibility of every part of the equipment, the carrier telephone equipment can be placed in a small, compact space because it does not need the room which moving parts would necessarily require. The staff engaged in maintenance of equipment also seems generally to fall into two distinct types, the young man concerned showing a preference for one or the other before completing his training. The typical telegraph mechanic is a man skilled and keen on the type of work generally associated with typewriter and similar mechanisms, while the carrier telephone mechanic is a man not so keen on mechanical devices, but instead is specially interested in types of circuits such as are generally associated with radio and valve equipment. The first man deals with equipment in which the cause and effect of each change in the state of the equipment can often be seen, heard and even felt by hand, whereas the second man deals with equipment in which cause and effect are often detectable only by indirect means, some of them being difficult to follow. While the above broad distinctions of equipment and staff have many exceptions, the distinction is sufficiently clear in the majority of cases to warrant the assumption that it embodies an important general principle. On this assumption, the ordinary carrier telegraph system can be considered as falling midway between the above two types (see Fig. 2). It embodies all of the general features of radio and carrier telephone systems and at the same time it must furnish the means for control of the mechanical devices in the telegraph office. There is thus raised a problem in the design of the equipment as regards the general form and assembly of the apparatus, and also a problem in the choice of staff to maintain it. The most difficult part of the problem is that point where the telegraph office equipment actually connects to the carrier equipment. It is at this point that the transition from purely electrical to electro-mechanical functions occurs. In carrier telephone systems the whole of the equipment (with the possible excep-

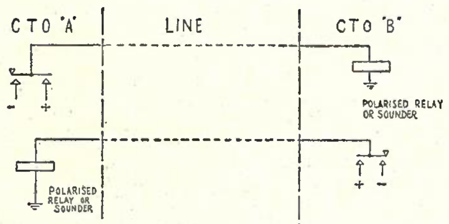

Fig. 1.—Simple Telegraph Circuit.

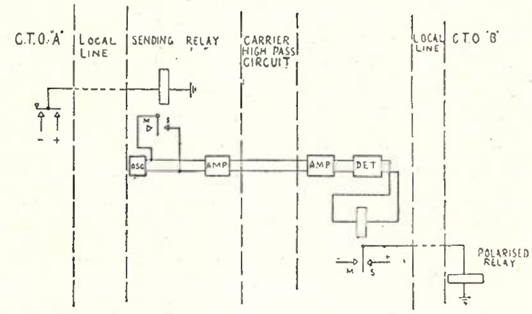

Fig. 2.—Simple Carrier Telegraph Circuit (one way).

tion of the comparatively simple ringing circuits) is of a static nature, there being no devices with moving parts to wear or require attention. In carrier telegraph systems, in the early types it was necessary to use an electro-mechanical relay to translate the electrical impulses of the carrier system itself into a form suitable for the use of the telegraph operator. A sending relay was used to enable the C.T.O. to send signals over the carrier system and a receiving relay was used at the other end to enable these signals to control the distant C.T.O. apparatus. For duplex working, four relays were required for each channel. Consideration of the problem will show that these relays need to be always slightly better than the mechanical devices in the C.T.O. to ensure that the working margin of these latter devices is not reduced by failure of the carrier relays. The relays were expensive in design and construction and had to be delicate to meet the necessary high-speed operating requirements imposed by modern printing telegraph practice, the high speed necessarily requiring light moving parts. In the past few years, many different types of relays have been suggested and tried out for carrier telegraph systems. When carrier channels are joined in tandem, using sometimes four channels in series, cumulative errors of the eight relays placed in circuit will reduce the working margin of the telegraph equipment unless the relays are of superlative type and always maintained in good order. Relays which would meet the requirements mentioned were costly and took more time in maintenance than the rest of the equipment forming the carrier telegraph channel. The fact that relays were in circuit and could be out of order gave rise to a tendency to regard them with suspicion, particularly at intermediate points on long built-up circuits. In the aggregate, relays were responsible for many hours' stoppages per annum through direct and indirect causes. In an endeavour to ensure good adjustment of these relays, many kinds of testing devices were used, but it was difficult to design a test circuit which would ensure that the relay was in the best possible adjustment to reproduce faithfully the type of signals being transmitted on a particular channel. One school of thought tended to the belief that the test table should subject the relay to high-speed test signals, whereas another believed that slow-speed test signals were best. It was by no means certain that a particular adjustment of a relay would be equally satisfactory for, say, teleprinters, multiplex or hand speed signals. Therefore, efforts were made to replace these relays by devices with no moving parts, which would be equally suitable for any type of signal and would require no adjustments. The sending relay was first considered, since it was the least satisfactory. The use of the static modulator in place of the sending relay was successful. There is a number of types of static modulators from which to choose, but the two most commonly used are described in detail in Appendix II. The static modulator consists of simple and fixed devices such as transformers, resistances and metal rectifiers. These are fixed on installation and require no subsequent adjustments. The static modulator is capable of handling with equal efficiency any kind of telegraph signal, slow speed or high speed and of any character, whether of the dot-dash variety or the special characters associated with teleprinters or multiplex codes (see Fig. 3).

The replacement of the sending relay by the static modulator has reduced by half the number of intermediate points at which mechanical repetition of signals takes place and has substantially reduced the stoppages. It has reduced the cost of telegraph carrier maintenance by eliminating the time spent on testing and adjusting sending relays and by eliminating requests for changing of relays at intermediate points.

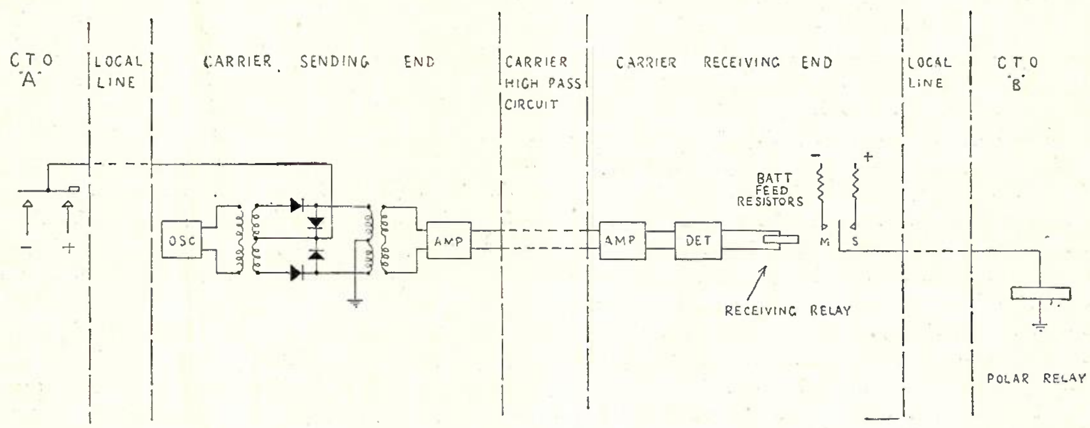

Fig. 3.—Carrier Telegraph System with Static Modulator Sending Device.

The replacement of the receiving relay by a static device has not been easy. Many circuits have been tried in an endeavour to find a satisfactory solution. The receiving relay is the one remaining item of a partly mechanical nature which has to be provided and maintained by the carrier staff among associated plant the operation of which is entirely electrical. If a satisfactory solution to this problem can be found, the carrier telegraph stoppages will be reduced considerably. Carrier telegraph stoppages on the whole are actually quite a small percentage of total traffic time and are considerably below those of a correspondingly long physical telegraph circuit with conventional telegraph relay repeaters. But with the modern trend for high-speed reliable telegraph service, stoppages of only a few minutes' duration are intolerable, especially in the case of multiplex systems on long built-up circuits. So far as intermediate stations, such as Adelaide on the Sydney-Perth circuit, are concerned, direct connections might be made between the Melbourne-Adelaide and the Adelaide-Perth carrier channels at Adelaide by using valve amplification only, assuming that the carrier frequencies are identical, but one objection is, that unless the incoming signals are demodulated and converted back to direct current signals before being repeated to Perth, the C.T.O. Adelaide and the carrier maintenance staff cannot monitor the signals passing through. Although this is not an insuperable difficulty, it is better to allow for standard telegraph practice if possible, as it facilitates dealing with faults, traffic congestion, etc.

The main essential in a device to replace a receiving relay is that it shall be of a static nature, requiring little or no periodical adjustment. It must be equally suitable for low-speed or high-speed morse signals and for teleprinters or multiplex characters. It may contain within itself automatic gain control features to compensate for changing attenuation of the high frequency carrier line, but this is not essential and may be provided for in some other part of the circuit. The receiving device should, if possible, deliver to the C.T.O. exactly the same voltage and current values for marking and spacing as does a receiving relay. It should be suitable for connecting into a standard C.T.O. receiving loop (in which positive and negative impulses are sent to the C.T.O. on one wire of the loop through the C.T.O. equipment and back to the ground at the carrier panel over the mate wire of the pair, the pair of wires being an ordinary twisted cable pair to minimize cross-fire into other circuits). It should be suitable for sending signals into a single wire telegraph circuit which is grounded at the distant end. This need arises in the case of a carrier channel being extended by a physical telegraph circuit without a conventional telegraph repeater interposed at the junction. The device should, if possible, function also as a wave-shaping device or telegraph signal regenerator, i.e., it should operate on distorted incoming signals in which the square-topped impulses have been rounded off by inductance, capacity or tuned circuit effects and it should restore these to a square-topped shape and deliver these to the C.T.O. It should operate on standard voltages, such as 24 volt for filament supply, and 130 volt positive and negative for signalling. The necessity for delivering double current signals to the C.T.O. and also being suitable for operating direct into a single wire grounded telegraph circuit has been found to impose difficult conditions in the design of circuits. The number of circuits available for some of the functions is almost unlimited, but it has proved to be difficult to find a circuit combination capable of meeting all of the desired conditions. If the C.T.O. is close to the carrier panel, for example, it is possible to use certain circuits, but these are unsuitable for use where the C.T.O.

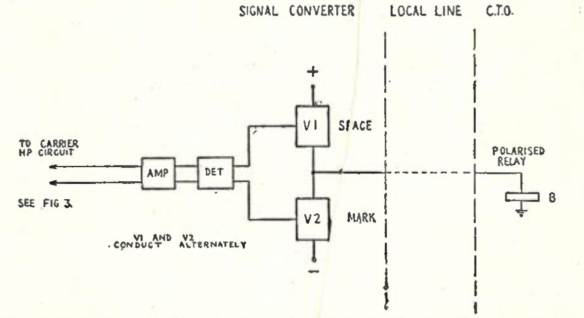

Fig. 4.—Carrier Telegraph System with Static Receiving Device.

is some miles from the carrier panel. By persistent effort, experiments carried out in Adelaide over a number of years have yielded results which promise general solution of the problem. A number of circuits have been tried out on a laboratory basis and actual field trials have been made of two of the circuits. One of these (see Fig. 4) has now been in use on a 300-mile long 4-channel carrier telegraph system, Adelaide to Mount Gambier, since May, 1941, and has

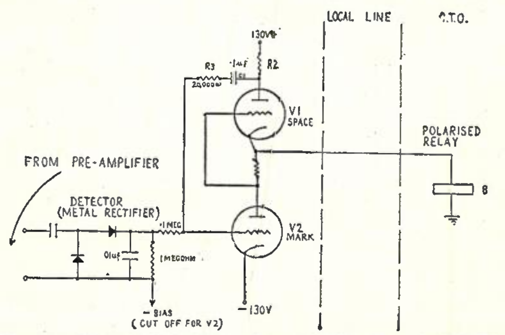

Fig. 5.—Details of Detector and Static Receiving Device of Fig. 4.

given satisfactory results. This system is unique in that it is the first system to have no moving parts, and it thus requires no periodical checking and adjustment of the apparatus of electro-mechanical type previously used. The system is similar to a carrier telephone system and operates on standard telegraph loops or legs and involves no change in the long-established telegraph circuits and lining-up procedure (see Fig. 5). The sending device is a static modulator to which reference has already been made. The receiving device was developed in Adelaide and it delivers the usual 25 mA. positive and negative current into a 1000 ohm telegraph loop for spacing and marking respectively. The device consists essentially of two valves, one known as the marking valve and the other known as the spacing valve. These valves, in effect, take the place of the receiving relay. The device delivers reasonably square-topped waves to the C.T.O. while itself operating on distorted incoming signals. It operates on standard 130 volt, positive and negative batteries. It contains a simple trigger device to provide the square-topped output from distorted input signals (see Fig. 9). It is simple in circuit arrangement and should provide long life and reliable performance. Experience to date has been very satisfactory. It does not contain automatic level control in the receiving device itself, but this is provided in an earlier part of the associated pre-amplifier valve circuit (see Figs. 6 A and B). The complete receiving portion of a channel comprises a receiving tuned circuit of conventional design, two high frequency amplifying valves, metal rectifier to convert the incoming carrier signals to direct current and the receiving device proper, consisting of two valves in a trigger circuit. The adjustments provided are "receiving gain" and "bias control." The receiving gain control alters the gain of the amplifying stages, while the bias control enables a change to be made in the relative amplitudes of marking and spacing currents in the loop. This latter device is not intended to be used frequently and is actually a screwdriver slot type of control. It was provided for emergency use to compensate for any unforeseen

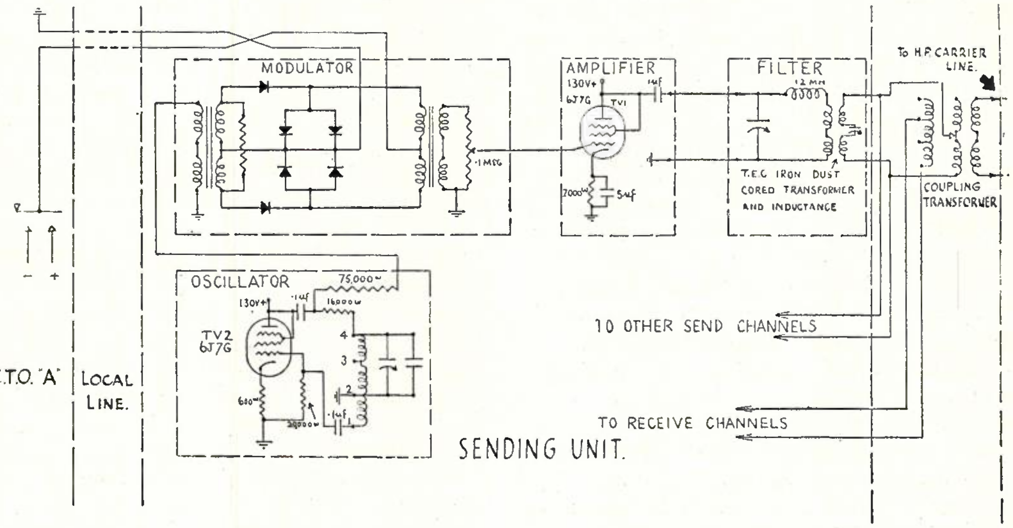

Fig. 6A.—Complete Circuit of Sending Unit of Carrier Telegraph System, No. 1 channel shown in detail.

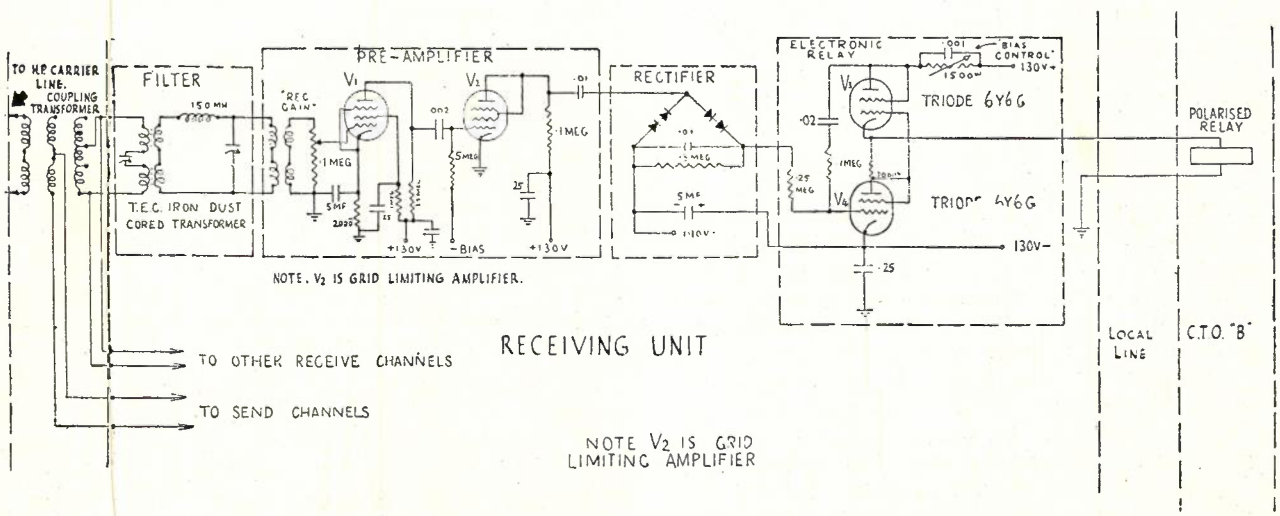

Fig. 6B.—Complete Circuit of Receiving Unit of Carrier Telegraph System, No. 1 channel shown in detail.

source of bias, such as would occur if the distant end sent biassed signals into the system and it was not desirable to shut down a channel for a fresh line-up. The circuit details are given in Appendix I.

The system has recently been improved so far as the automatic level control feature is concerned by altering the connections to those shown in Fig. 20. This also eliminates a rather awkward bias voltage problem, no bias on the trigger valves being necessary in Fig. 12 as discussed in Appendix I.

APPENDIX I.—DEVELOPMENT OF TRIGGER VALVE RELAY

It will be noted from Fig. 1, which covers the simplest type of telegraph circuit, that signals are sent from A to B by the manipulation of the morse key at A, which sends either positive or negative battery to the line, thus either operating or releasing a polarised relay at the distant end. All the moving parts necessary are in the telegraph office, there being no mechanical devices of any kind in the channel itself which links the two telegraph offices together. Fig. 2 shows the next stage in the ordinary carrier telegraph system where the signals from the C.T.O. control the sending relay at the carrier panel. The sending relay contacts control the flow of carrier current over a high-pass circuit to the distant end, where the carrier currents are first amplified and then converted back into direct current to operate the carrier receiving relay. The tongue of this relay then sends positive or negative signals to the C.T.O. In a carrier telegraph system of this type there are thus added two mechanical devices to the complete channel with obvious fault liability. In the next development, shown in Fig. 3, the sending relay at the carrier panel has been replaced by the simple static modulator. The static modulator controls the flow of carrier current to line just as effectively as does the sending relay, but the fault liability is considerably below that of the best sending relay. Further consideration of Fig. 2 shows that the function of the receiving relay is to open or close the flow of current from the positive and negative batteries alternately to the local C.T.O. It follows that any device that can start and stop the flow of current can take the place of the tongue and contacts of the receiving relay. There are many such devices, but the electron valve has obvious possibilities in this regard. The flow of current from the plate to the cathode of a valve can be switched on and off instantly by the application of a suitable potential to the grid electrode. Instead of deriving direct current from the receiving end of the carrier system and applying it to the coils of an electro-mechanical relay, the magnetic effect of which will swing the tongue from one contact to the other, the direct current from the carrier panel can be utilized to change the potential on the grids of suitable valves to switch the plate currents on and off as required. The power required from the carrier panel is in the form of voltage to control grid circuits rather than in the form of current to operate coils of relays. There is no difficulty in deriving the required voltage from suitable valve and/or metal rectifier circuits. The two valves which are required to take the place of the tongue and contacts of the receiving relay are shown in block schematic form in Fig. 4. If it is assumed that circuit arrangements are such that V1 and V2 conduct alternately under the control of the incoming carrier signals, positive or negative potentials will be impressed on the local line to the C.T.O. just as they would be by the tongue of a receiving relay. There is a difference between the valve and the relay, in that the resistance between the tongue and the contact, in the case of the relay is zero, or it should be so, if the relay is in good condition, whereas no type of valve exists in which the resistance between the plate and the cathode is zero. The nearest approach to this condition is in the case of the gas-filled valves such as the 885, OA4G and similar types. While the use of such gas tubes is quite feasible, they have disadvantages which make their use difficult at the present stage of development. It is a fortunate circumstance that in practice it is not necessary to use a valve whose internal resistance is zero. It will be noted in Fig. 3 that the positive and negative battery supplies are fed to the contacts of the receiving relay through battery feed resistances. These resistances are used to minimise risk of damage to the contacts of the relay should the tongue happen to touch both contacts simultaneously, due to the relay being out of adjustment. The standard practice has been adopted of using a higher voltage than is strictly necessary and reducing the current to the required figure by the use of comparatively high battery guard resistances. The normal internal resistance of a valve might function as this battery guard resistance and simple readily available types of valves can be used for the purpose. The valves V1 and V2, which are designated "spacing" and "marking" valves respectively, are effectively connected in series between the positive and negative 130-volt batteries. The leg to the local C.T.O. is connected to the junction of the two valves and if both valves are conducting simultaneously the midpoint will be at zero potential above ground, and this corresponds to the condition with the receiving relay where the tongue is between both contacts. When V1 conducts, the leg to the C.T.O. receives a positive potential while, if V2 conducts, it receives a negative potential. To make use of the "valve relay," as it may be called, it is necessary to design circuits in which V1 and V2 conduct alternately for spacing and marking conditions respectively. There is a great number of circuits which could be used to achieve this object and the circuit shown in

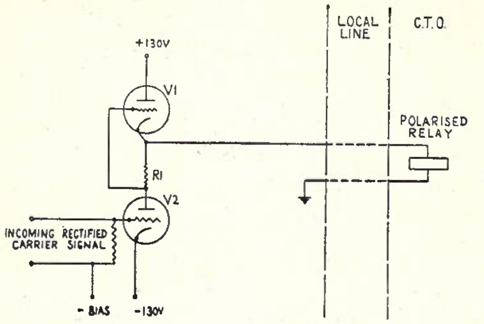

Fig. 7.—Thermionic Receiving Relay providing double current signals (no trigger action).

Fig. 7 is probably the simplest. In the normal condition, i.e., where no carrier current is being received from the distant end, the valve V2 is biassed to cut-off, i.e., the plate current is zero. In this condition the bias on V1 is zero, since there is no current flowing through resistance R1. The valve V1, therefore, conducts and positive current flows from the 130-volt positive battery, through the plate to cathode path of V1, to the telegraph leg and through the C.T.O. equipment to ground. The current will be determined by the valve characteristics and by the resistance of the receiving leg and other equipment in the C.T.O. By suitable choice of valve and other constants the current can be fixed at the required value to hold the C.T.O. polarized relay or other device on the spacing side, with adequate margin. When carrier current is transmitted from the distant end, it is selected by the tuned circuit of the particular channel, amplified as required and then rectified to produce direct current. The D.C. voltage produced across an appropriate resistance is applied to the grid of V2 in such a direction as to swing the grid from the cut-off value to zero. The valve V2 now conducts and the flow of current through R1 immediately biasses V1 to cut-off. Current now flows from ground, through the C.T.O. equipment, receiving leg, through R1 and V2 to 130-volt negative battery. The current in the C.T.O. relay is reversed and by suitable choice of valve and other constants the marking current will be the same value as the previous spacing current. The simple device, thus shown, operates on the incoming dots and dashes of the carrier current signals (after rectification), and applies standard double current telegraph signals through the receiving leg to the C.T.O.

The transition from the spacing to the marking condition in the simple device shown, would be gradual, i.e., the current through V1 would die down as the current through V2 built up. It is desirable to make the transition from one condition to the other as sudden as possible; in other words, to reduce the transit time which corresponds to the travel time of the ordinary relay. It is at this point that the trigger circuit principle has application. The trigger circuits in their many various forms make use of circuit devices which can be applied, for example, to the speeding up of the operation of a normal valve. It is this possibility which enables trigger circuits to be used for recording and counting very high-speed signals. The problem is analogous to that of reducing inertia of mechanical devices. The Gulstad circuit overcomes the inertia of conventional telegraph relays by arranging that the relay, without control, normally pulsates backwards and forwards from spacing to marking at a rate which can be set as required to be somewhere near the speed at which incoming signals are expected. A similar principle can be used with the two valves V1 and V2 if they are arranged so that in the absence of a control signal they will oscillate, first one and then the other conducting alternately and thus delivering to the C.T.O. a steady stream of reversals at a rate corresponding to the normal signals expected to arrive. By adding a small control voltage the normal tendency to oscillate can be overcome so that, at rest, a spacing current is sent to the C.T.O. Then, when the incoming signal arrives, it overcomes the control voltage and forces V2 to conduct. The trigger circuit, which is normally trying to make V1 and V2 oscillate, comes into play just at the transition from spacing to marking and it accelerates the transition from one condition to the other. In practice, the use of a relaxation oscillator, which is a name often applied to this general circuit, presents difficulties, e.g., the speed at which V1 and V2 are normally tending to oscillate must bear some relation to the incoming signal speed. This tends to call for a different adjustment when the channel is used for different types of telegraph equipment. The same objection applied, to a certain extent, to the Gulstad relay device. It is found in practice that relaxation oscillator condition need not be set up with the two valves, but a compromise can be made wherein the two valves will never actually oscillate, but, where, nevertheless, the speed of transition from spacing to marking is made very high.

In the type "B" carrier telegraph system, the movement of the tongue of the receiving relay is accelerated by the use of a kick transformer. A similar kick transformer can be used as shown

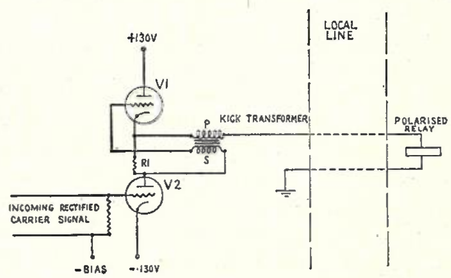

Fig. 8.—Thermionic Receiving Relay fitted with kick transformer providing double current signals to C.T.O. and including trigger action.

in Fig. 8 to accelerate the transition from V1 to V2. If the transformer design and the connections are suitable, an E.M.F. will be induced in the secondary whenever the current in the primary changes and this E.M.F. will be in such direction as to accelerate the transition. Thus, if V1 is conducting and then an incoming signal arrives, V2 will begin conducting. This will cause the current through V1 to begin to decrease. The positive current in the receiving leg will begin to decrease and an E.M.F. will be established in the secondary of the kick transformer in such a direction as to make the grid of V1 still more negative. The effect will be cumulative and the current in V1 will die down at a very rapid rate. Similarly, the current through V1 will increase at a rapid rate when the incoming carrier ceases. The kick transformer can be replaced by a condenser C1 and an appropriate resistance R2 as shown in Fig. 5.

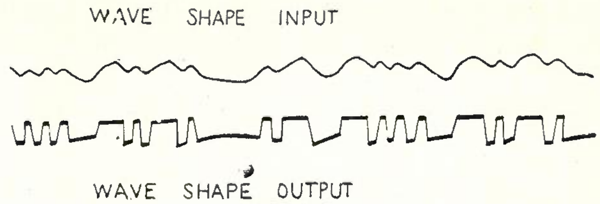

Fig. 9.

of the trigger circuit is shown in Fig. 10, which illustrates an electronic receiving relay which utilises only one valve instead of the two or four valves which are referred to in Figs. 5 and 19 respectively. This new circuit, using only one valve, provides—

(a) Double current signals to the C.T.O. of the normal values of 25 mA. positive and 25 mA. negative for spacing and marking respectively;
(b) Trigger action to secure square-topped wave shape in the output circuit;
(c) Automatic level control over a range of 8 to 10 db.

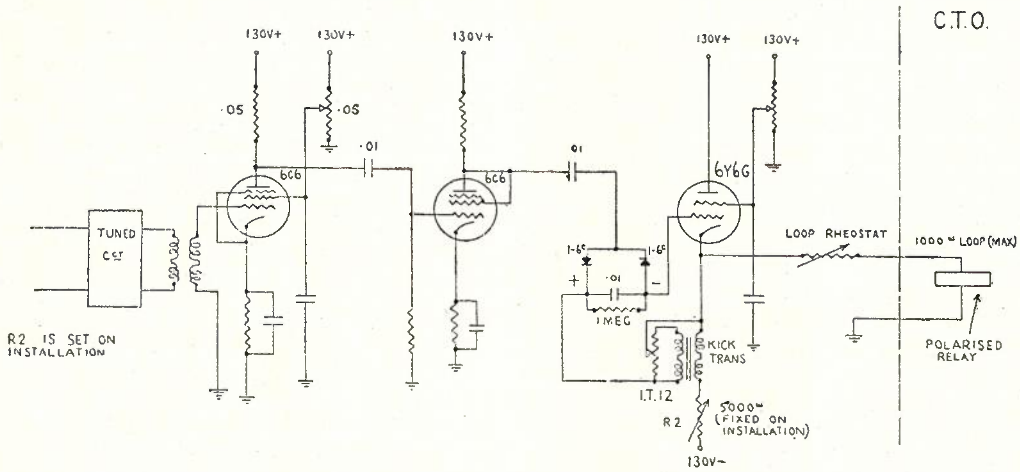

Fig. 10.—Trigger Circuits using only one valve.

In this case, the trigger effect is achieved by voltage change rather than by current change (as is used in Fig. 8) the polarities in Fig. 5 being such that the transition from V1 to V2 and vice versa is made very rapidly due to the feedback voltage from the plate of V1 to the grid of V2 (through the condenser C1). The resistance R3 is included to control the amount of this feedback and limit the tendency to relaxation oscillator effect which might have the effect of sending a stream of reversals to the C.T.O. unexpectedly if any fault occurred in the carrier channel itself. The resistance R3 damps out the tendency of V1 and V2 to oscillate, but it permits sufficient trigger effect to achieve the desired object, i.e., the high-speed transit from spacing to marking and vice versa. The values of resistance and condensers will depend upon the valves and other components in use.

Fig. 9 illustrates the beneficial effect of the trigger circuit in restoring signals (which have been rounded off by tuned circuit effects, inductance or capacity) to the desirable square-topped shape. Further development in the practical use

The complete receiving end of a carrier telegraph system using this later development requires a total of only three valves, assuming that two pre-amplifier stages are necessary, together with a metal rectifier.

In the spacing condition the valve is conducting, there being no bias on the grid and the plate current being limited by the screen grid potential and by the other circuit constants. Approximately 55 mA. flows from 130 volts positive through the plate to cathode of the tube and at this point the current divides, 25 mA. flowing through the C.T.O. receiving loop, on the assumption that it is about 1,000 ohms total resistance and the remainder flowing through the fixed resistance to the 130-volt negative battery. When an incoming signal arrives it is selected by the tuned circuit and amplified in one or two stages, rectified by a metal rectifier assembly and applied to the grid of the trigger tube in such a polarity as to reduce the plate current.

Providing the minimum input signal is sufficient to bias the tube to cut off, an automatic level control feature is present, since signals in excess of this minimum can have only the same effect on the plate current. When the plate current is reduced to zero, the flow of current through the C.T.O. receiving loop will be reversed. The marking current will be negative and will be equal to the spacing current previously flowing. The trigger action which makes the transition from spacing to marking at a very high rate is secured by means of the kick transformer.

As the current begins to change from spacing to marking and vice versa the E.M.F., which is momentarily established in the secondary of the kick transformer, results in the potential on the grid of the valve being changed in such a direction as to accelerate the change which is taking place. The improvement in performance due to this transformer is generally similar to that shown in Fig. 9. If the E.M.F. from the kick transformer is too high, the valve will oscillate steadily and send a stream of reversals to the C.T.O. In practice, the E.M.F. can be fixed to give ample trigger action without any danger of oscillation.

The valve required for this circuit is one which is designed to carry up to 60 mA. plate current continuously while operating on 130-volt supply. Such a valve is the 6Y6G, which is a beam tetrode designed for a plate current of 58 mA. continuously under Class "A" conditions with a 135-volt anode supply.

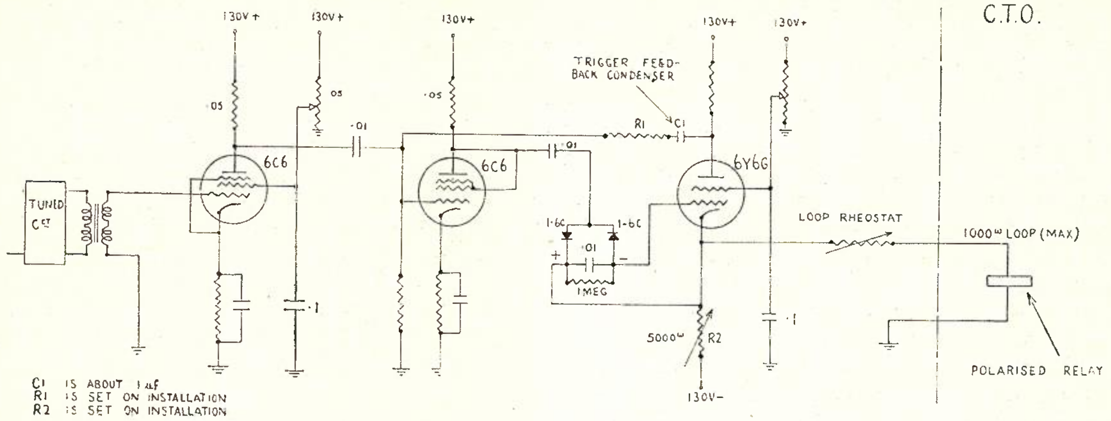

Fig. 11.—Trigger Circuit using one valve and feedback circuit.

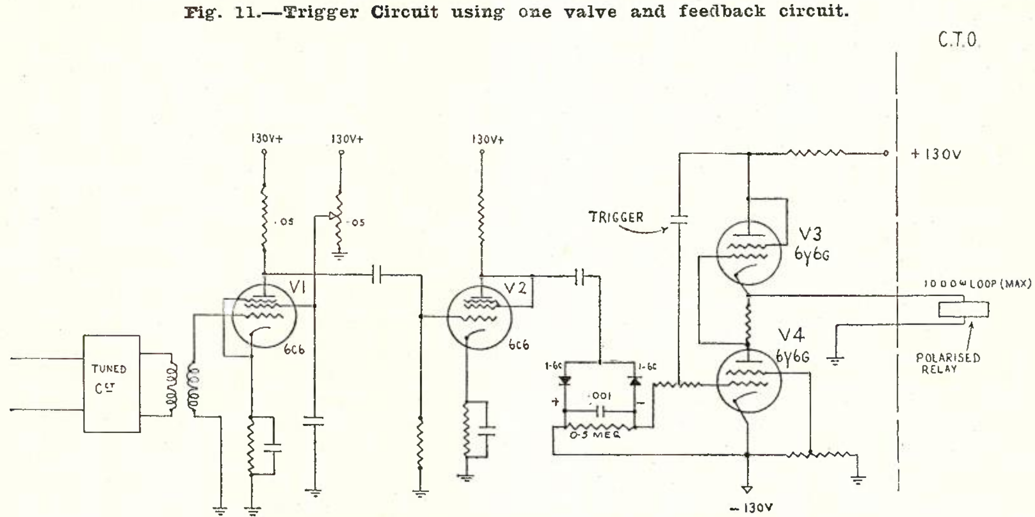

Fig. 12.—Electron Valve Receiving Relay with automatic level control—used Adelaide-Mt. Gambier circuit.

A still further variation of this one-tube trigger relay is shown in Fig. 11. The kick transformer of Fig. 10 is replaced by a kick condenser which feeds back a voltage of suitable phase and value to the grid of the amplifier stage preceding the metal rectifier to raise and lower the effective grid bias of that tube as required to accelerate the transfer from spacing to marking and vice versa. Suitable choice of circuit constants gives the desirable square-topped output from the trigger tube without danger of oscillation at signal frequency.

The automatic level control feature of Figs. 10 and 11 can be employed to considerable advantage in conjunction with the 2-tube electronic relay of Figs. 4, 5 and 6. To utilize this method of level control it is necessary to reverse either the sending loop or the receiving loop, in order to preserve the convention that negative to C.T.O. represents marking and positive represents spacing. If this convention is not considered important, no change need be made in the sending or receiving loops. The arrangement in Fig. 12 shows a very useful circuit, which appears the best evolved to date. This circuit—

(a) Provides double current signals to C.T.O.
(b) Provides automatic level control over a range of 10 to 15 db.
(c) Provides signal regeneration or wave shaping.
(d) Requires no grid bias supply.
(e) Is very simple and easy to adjust.

The essentials are shown in the figure and assuming that no signal is being received, V4 will be conducting, there being no bias on the control grid. (The plate current is determined by the screen grid potential, which is fixed to permit 25 mA. to flow under this condition.) The anode current of V4 will bias V3 to cut off and so the loop current to the C.T.O. will be 25 mA. negative.

When an incoming signal arrives, it is amplified in two stages (V1 and V2) rectified by metal rectifiers and the resulting direct current signal is applied to the control grid of V4 to bias it to cut-off or beyond. (Hence the automatic level control feature for all signals above a minimum amplitude.)

The trigger action is secured by means of a simple condenser/resistance combination as shown. When V4 goes to cut-off, V3 of course conducts fully and the loop current is reversed to 25 mils. positive. As no carrier current corresponds to negative loop current, the need for reversing either the sending loop or the receiving loop will be apparent. A simple reversal in the C.T.O. would suffice, except for the obvious advantages of retaining standard conditions on all loops for testing, etc.

The condition of no carrier current to line for spacing is generally accepted as the conventional standard condition. This does not mean that carrier current will normally be off for the greatest period of time since, for example, many telegraph systems, when idle, transmit marking condition. Certain teleprinter circuits and also circuits extended by half Toye repeaters to simplex omnibus circuits transmit marking when idle. From this point of view, which affects overload point of carrier telegraph repeaters, for example, there is little to choose between a system which transmits carrier current for marking and one which transmits it for spacing, since the actual conditions depend so much on the telegraph instruments and circuits to which the carrier channels are connected at a particular time. It seems that the reversal of the sending loop in order to make use of Fig. 12 would provide the simplest solution. Carrier current would flow for spacing condition and the valve V4 would be biassed to cut off for spacing. There would be no change in the C.T.O. receiving loop, spacing being positive as usual.

The advantages of automatic level control of Fig. 12 and the fact that no grid bias supply is required, make this circuit attractive. It does not involve the use of valves capable of very high plate currents, so that a number of types of valves can be used for V3 and V4. This circuit is giving excellent results on the Adelaide-Mount Gambier circuit, which was originally wired to Fig. 6, but altered later to Fig. 12 to improve the automatic level control feature. The actual test figures obtained by means of an S.T.C. Cathode Ray Telegraph Distortion Measuring Set are as shown in Table 1.

TABLE I.
TELEGRAPH DISTORTION TESTS

ADELAIDE-MOUNT GAMBIER SYSTEM—USING VALVE RELAYS.

Two (2) channels looped in Tandem, including carrier repeater at Bordertown (total length, 600 miles).

	Test	Speed in Bauds	Total Distortion over 2 Channels	Speed in Bauds	Distortion over 2 Channels
Carrier normal line-up conditions	1 : 1	50	3%	80	8%
	2 : 2		2		10
	5 : 1		1		6
	5 : 1 reversed		4		12
	Paris		4		8
	Paris reversed		5		10
Line attenuation decreased 3 db	Do.	50	4	80	10
			5		6
			2		12
			6		15
			6		15
			6		15
Line attenuation decreased 6 db	Do.	50	5	80	15
			2		10
			2		8
			5		20
			5		20
			4		20
Line attenuation decreased 10 db	Do.	50	8	80	20
			7		20
			4		15
			7		20
			8		20
			10		20

NOTE.—Total distortion, including fortuitous distortion, etc., is included in above figures.

APPENDIX II.—STATIC MODULATORS

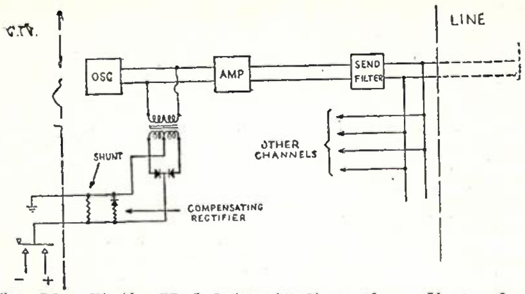

Fig. 13.—Static Modulator in lieu of sending relay.

The first type of static modulator used to replace a sending relay is shown in Fig. 13. This consists of a transformer and an assembly of metal rectifiers. The metal rectifier, in addition to possessing the property of conducting current much better in one direction than in the other, has the useful property of having a resistance which depends on the impressed E.M.F. In the direction in which the rectifier is conductive, if the E.M.F. is very small, the resistance of the rectifier will be very high. As the E.M.F. is increased, the current will increase, not only in accordance with Ohms Law, but at a much higher rate, because the resistance of the rectifier falls as the E.M.F. is increased. The characteristic curves of typical half-wave metal rectifier units are shown in Fig. 14 and 15.

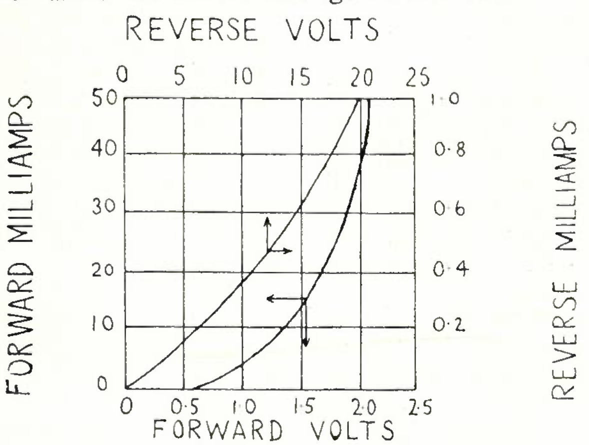

Fig. 14.—Copper Oxide Rectifier. Typical voltage-current curves.

In the circuit arrangement shown in Fig. 13 the transformer has a primary winding which is of very low D.C. resistance, but fairly high number of turns of wire, thus possessing a high value of inductance. The secondary winding is closely coupled to the primary, both windings being on a common iron core. The primary is connected across the output of the oscillator for the particular channel concerned, where it connects to the associated sending amplifier. The secondary is connected to metal rectifiers and to the sending loop from the C.T.O. If the C.T.O. loop is open, so that neither positive nor negative D.C. voltages are impressed on the rectifiers, the resistance of the rectifiers will have a definite value dependent on the type and size of the elements. The secondary of the transformer will be loaded with this value of resistance. The

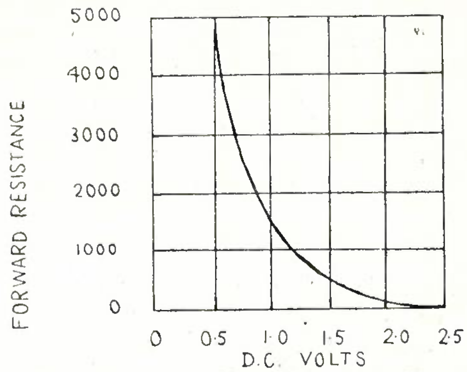

Fig. 15.—Copper Oxide Rectifier. Typical resistance-voltage curve.

voltage output from the oscillator, acting through the primary of the transformer, will induce a voltage in the secondary of the transformer which will cause currents to flow through the resistance of the metal rectifiers. The current through the secondary winding will set up a magnetic flux which will oppose that due to the primary current. This lowers the effective inductance of the primary winding, so permitting greater current to flow from the oscillator. This loads the oscillator and reduces the carrier frequency E.M.F. driving the amplifier. Under this condition, with no signal from the C.T.O., the carrier current to line will have a certain value, say, 1 mA. When the C.T.O. loop is closed and marking potential (negative) is impressed on the rectifiers by depressing the morse key, the D.C. E.M.F. acting on the rectifiers is in such a direction and of such a value that the resistance of the rectifiers rises to high values. The rectifiers, under this condition, are not only high resistance to the D.C. signal currents from the C.T.O., but also to the superimposed A.C. from the secondary of the transformer. The secondary current is reduced and due to the consequent reduction in the effect of this secondary current on the magnetic flux in the core, the primary inductance of the transformer rises substantially. The loading across the oscillator output is reduced so that the voltage driving the amplifier rises. The current to line now rises, say, to 2 mA., the normal marking current value.

If the C.T.O. key is released, sending positive current to the rectifiers, their resistance will fall to a low value. This will permit a comparatively heavy current to flow from the secondary of the transformer. As a result, the primary inductance falls to a low value and consequently the load across the oscillator output becomes heavy, so that the driving voltage to the amplifier becomes low, practically zero, if the various circuit constants are properly chosen. Thus, the static modulator permits the C.T.O. key to control the flow of carrier current between zero and, say, 2 mA. to line. It is suitable for the operation of any kind of telegraph system, morse, teleprinter or multiplex.

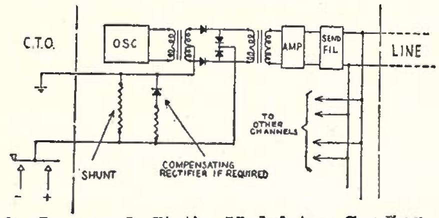

Fig. 16.—Improved Static Modulator Sending Device.

The second type of static modulator is shown on Fig. 16 and consists of two transformers and four half-wave metal rectifiers. The complete assembly is inserted between the oscillator and the amplifier valve for the particular channel concerned. The circuit makes use of the same property of the metal rectifier as is used in the first type. With one polarity from the C.T.O. the series rectifiers are high resistance while the shunt rectifiers are low. In this condition the rectifier assembly acts as a pad of very high insertion loss to the carrier current so that the output of this particular channel, under this condition, is zero or practically so. When the polarity of the current from the C.T.O. is reversed, the series rectifiers become low resistance while the shunt rectifiers become high resistance. This is equivalent to a pad of low insertion loss and, under this condition, the carrier current to line is a maximum.

In both the above types of static modulators, the desirable feature is that the carrier current for marking conditions should be 30 or 40 db. greater than the value for spacing. The difference between the two levels of carrier current is referred to as the discrimination of the static modulator and tests are made periodically to ensure that this is maintained at a satisfactory figure. This is the only test that need be made with static modulators and actual experience has shown that the faults in and the replacement costs of static modulator units are negligible.

The static modulators both tend to take more D.C. current from the C.T.O. for one condition than the other and this tends to give a false indication of bias on a centre zero meter in the sending loop. This can be corrected by shunting another set of rectifiers across the loop with suitable resistance in series and connected in such a manner that it has the opposite characteristic to the assembly used in the static modulator itself. The rectifiers operate on very small currents and for convenience the full 25 mA. marking and spacing are transmitted from the C.T.O. The bulk of this current is shunted in resistances which by-pass the metal rectifiers. These resistances tend to swamp the effect of the rectifiers mentioned above so that, in many cases, the compensating rectifier assembly is not required.

APPENDIX III.—TRIGGER CIRCUITS—GENERAL TYPES

The "Eccles-Jordan" trigger circuit shown in Fig. 17 is described in the general literature on the subject, but the following brief description may be of interest:—

There are several possible variations, but one typical type using the simplest arrangement of battery supply is shown in Fig. 17. With suitable constants for the various resistances, etc., a condition can be arrived at where normally valve V1 will be conducting. Under this condition the grid bias on V2 will be such that the plate current of that tube is reduced to a minimum. If anything is done which tends to reduce the plate current of V1, the grid bias on V2 will begin to decrease, allowing the plate current of V2 to increase. This increased plate current of V2 will immediately change the bias on V1 towards the negative end so that the plate current of V1 will decrease still further. This will result in a still further increase in the plate current on V2 with the net result that there is a rapid decay of plate current in V1 and a correspondingly rapid rise of current in V2, until finally V1 is reduced to a minimum and V2 reaches the maximum dependent on the valve and circuit constants. If at this stage anything is done which tends to decrease the plate current of V2, the reverse action will occur.

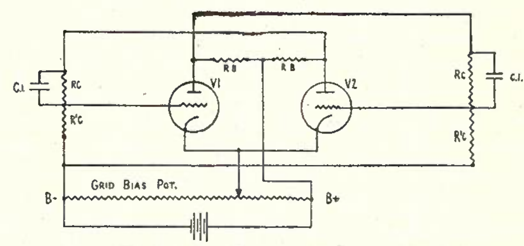

Fig. 17.—Eccles-Jordan Trigger Circuit.

With proper adjustments a condition of stable equilibrium is obtained normally, but the introduction of a very small signal voltage, for example, in series with one of the grids, will cause the plate current to change rapidly from one valve to the other. The amplitude of plate current reached in each tube is independent of the amplitude of the incoming control voltage provided the control voltage is above the minimum figure required to cause the trigger action. This gives rise to the condition that the wave shape of the plate current pulses in each tube is square topped, even if the wave shape of the control voltage is rounded. The condensers, C1, are required in certain cases if the speed of reversal from one tube to the other is required to be fairly high. The condenser improves the trigger action in practically all cases.

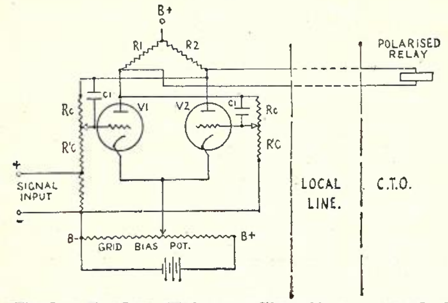

Fig. 18.—Eccles-Jordan Trigger Circuit arranged for use as a Carrier Telegraph Receiving Device.

Fig. 18 shows the Eccles-Jordan trigger circuit arranged for use as a carrier telegraph electronic receiving relay, the loop to the C.T.O. being joined across the two plate circuits. Under normal conditions, with no incoming signal, by setting the potentiometer connected to the grid of V1 at the proper setting, it can be arranged that V1 is not conducting and V2 conducting. Under this condition, the flow of current to the polarised relay in the C.T.O. will be in such a direction as to correspond to spacing.

The incoming telegraph signal, after amplification and rectification in a suitable circuit, is applied to the grid circuit of V1 and it initiates the trigger action resulting in a very rapid transfer of plate current from V2 to V1. The current through the C.T.O. relay is, therefore, reversed. On the decay of the incoming signal, a reverse rapid transfer of current from V1 to V2 occurs. The wave shape of the rectified signal coming in, may be as shown in the upper curve of Fig. 9, while the wave shape of the E.M.F. applied to the C.T.O. loop is shown in the lower curve of Fig. 9.

The circuit shown in Fig. 18 has been used for continuous operation over a month on the Adelaide end of a Melbourne to Adelaide Murray Multiplex carrier channel. It has the disadvantage that the circuit conditions looking into the carrier channel from the C.T.O. are somewhat different to those normally encountered and thus involves changes in testing procedure, etc., from the C.T.O.

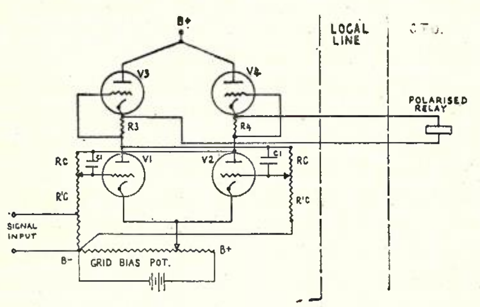

Fig. 19.—Trigger Circuit using four valves to increase current through receiving loop.

Modification to this circuit is shown in Fig. 19, in which the resistances R1 and R2 of Fig. 18 have been replaced by two additional tubes. This increases the efficiency of the tubes and makes it easier to secure comparatively high currents through the receiving loop from conventional receiving type valves. It has the disadvantage that four tubes are used plus a metal rectifier and two pre-amplifier stages in the complete receiving circuit.

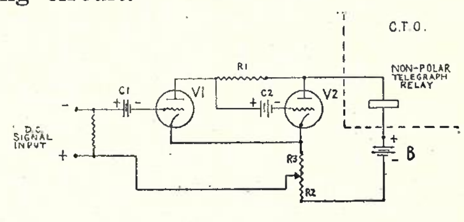

Fig. 20.—The Evans Trigger Relay.

The "Evans" trigger relay, which is described in P.O.E.E. Paper No. 136, is shown in Fig. 20, and this is another variation of the general trigger circuit. Under normal conditions V1 is conducting while V2 is non-conducting since the drop of potential over R1 caused by the plate current of V1 will be biassing V2 to cut off. The neutral relay in the telegraph office is, therefore, at spacing. If an incoming signal with the polarity shown is applied to the circuit, V1 will begin to decrease in plate current and this will lower the bias of V2, causing its plate current to begin to rise. The resulting rise in the drop of potential over R3 will tend to make V1 decrease more rapidly, which will again cause the plate current of V2 to rise more rapidly. There will be a very rapid change over from V1 to V2 so that the telegraph relay is now brought rapidly to the marking position. The general effect of this circuit is similar to that described in the other diagrams and the improvement in wave shape due to the trigger action is shown in Fig. 9.

APPENDIX IV.—VALVE RELAYS IN PHYSICAL TELEGRAPH CIRCUITS

The theoretical and practical work described shows that valve relays have at least theoretical possibilities in physical telegraph circuits both in the terminal equipment and in repeaters. Fig. 21 shows a possible arrangement for a duplex terminal telegraph set which has no moving parts other than the morse key and sounder. The sending pole changer has been replaced by two valves which are similar in principle to the receiving valve relay described earlier. No trigger action is necessary and a simple valve arrangement suffices. The arrangement is, that with the morse key spacing, the valve V2 is biassed to cut off and consequently positive potential is applied to the line through valve V1. When the morse key is depressed the bias potential at V2 is removed and this valve conducts fully. Valve V1 is driven to cut off by the drop of potential over R1. The potential applied to the line is reversed and is now negative.

On the incoming side of the duplex bridge, the receiving relay is replaced by a static modulator. When marking current is sent from the distant end the static modulator will permit the tone frequency from the local oscillator to flow to the amplifier and to the rectifier, where a direct current is produced which will hold down the neutral sounder. When the distant end goes to spacing, the reversal of polarity across the static modulator causes this to cut off the local oscillator and consequently the output from the rectifier is reduced to zero and the neutral sounder is released.

The duplex connections are similar to the conventional type and with proper adjustment of the artificial line the "sent" signals will not influence the static modulator. The low pass filter in the sending leg may be necessary to limit the transmission of unnecessary harmonics to line and minimise radio interferences, etc.

By an extension of the above principle a duplex telegraph repeater using no moving parts at all may be constructed and this is shown in Fig. 22. The operation should be obvious from the above description and preceding pages.

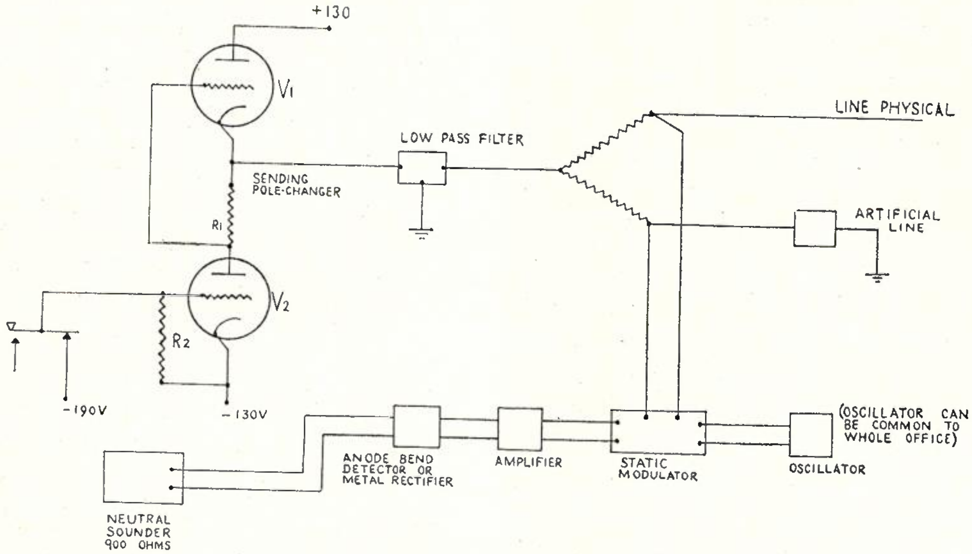

Fig. 21.—Duplex Telegraph Set using valve relays.

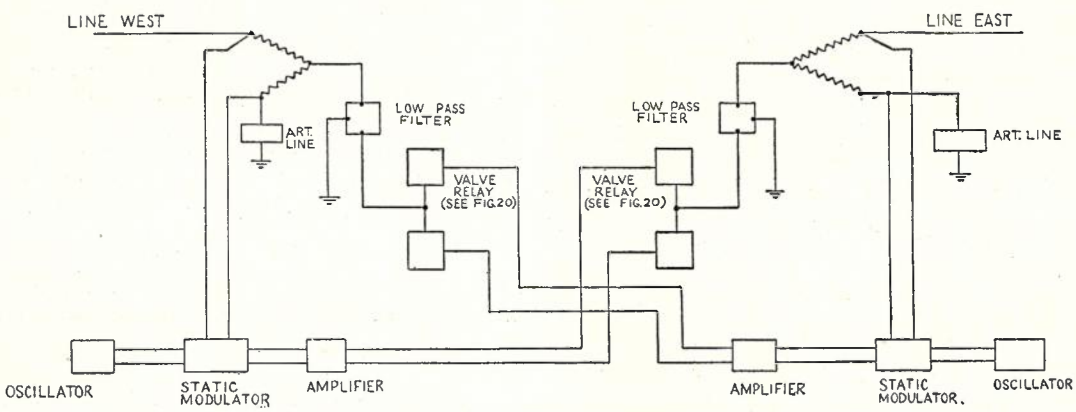

Fig. 22.—Duplex Telegraph Repeater using valve relays.

The above circuits embody more actual parts than the existing telegraph devices, but it often pays to use more parts provided the annual charges over all are less and providing always that the performance is better. The above duplex repeater, for example, could be assembled on a standard rack exactly similar in appearance to a carrier repeater. The routine tests and adjustments required would be on a similar basis to those used for carrier and voice frequency repeaters. The complete absence of moving parts and of contact trouble make the repeater attractive.

Although long physical telegraph lines are rapidly being replaced by carrier systems, there are still quite a large number of telegraph repeaters in use in terminal offices for such applications as the extension of carrier channels to local loops and for inter-connecting various networks of telegraph circuits together. The possibilities in the use of valve relays are quite extensive and it will be interesting to see the future trend in this direction.

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SHORT-WAVE RADIO TRANSMISSION

N. S. Smith

Short-wave broadcasting in Australia during the last two years has received an impetus which can be attributed to war conditions. The term "short-wave" as used here applies to that portion of the frequency spectrum between 3 megacycles and 30 megacycles, corresponding to wave lengths between 100 metres and 10 metres.

Prior to the commencement of hostilities, our main contributions to overseas listeners were from the National Short-wave Stations VLR, Melbourne, Victoria, and VLW, Perth, Western Australia, each rated at 2 kilowatts power.

Amateur stations played their part in obtaining radio-recognition for Australia, but since the advent of war, amateur licences have been suspended. An additional transmitter, VLG, of 10 Kw power, has recently commenced service at Lyndhurst, near Melbourne, and plans for the near future include several short-wave transmitters having a nominal rating of 100 kilowatts. These transmitters will place Australia in a better position to counteract propaganda from overseas. The present transmitters are doing good work, but their low power relative to that of overseas transmitters tends to make reception of the Australian transmissions less satisfactory. How insidious the influence of the high-powered foreign broadcasts can be, has been well demonstrated and any measure taken to minimise its effect is worth while.

The Department of Information established a Short-wave Broadcasting Division to conduct the broadcast of Australian news and viewpoints. The programme drawn up by them was too extensive to be provided by the National Short-wave Stations alone, so two 10 Kw transmitters at Sydney have been used for the broadcasts to supplement the National transmitters. The number of transmissions and the countries served have varied considerably since the inauguration of the service, and Table 1 shows the services operating in July, 1941.

TABLE 1.

Transmission	Transmitter	Countries Served	Australian Eastern Time
1	VLQ	New Caledonia, French Oceania	6.25 p.m.- 7.25 p.m.
2	VLQ2	Japan, China, Hong Kong	9.40 p.m.-10.15 p.m.
3	VLQ5 VLG5	North America, Eastern States	9.20 p.m.-10.05 p.m.
4	VLQ VLW2 VLG5	Malaya, Dutch East Indies, Indo-China	11.10 p.m.- 1.00 a.m.
5	VLQ VLG5	North America, Western States	1.25 a.m.- 2.10 a.m.
6	VLG6 VLQ2	North America, Western States	3.55 p.m.- 4.40 p.m.
7	VLQ2	Middle East	3.00 p.m.- 3.30 p.m.
5A	VLQ	Central America, Mexico, Panama Zone	12.50 a.m.- 1.15 a.m.
6A	VLG5	Middle East	2.20 a.m.- 2.50 a.m.

In providing these services at suitable listening times, numerous problems peculiar to the propagation of high frequency signals are encountered. In general the problem as related to the Department of Information broadcasts resolves itself into effecting a compromise between provision of a programme at reasonable listening hours and transmitting it at a time favourable for propagation. These periods do not always coincide.

It is the intention of this article to outline briefly the theory of ionosphere radio transmission—as short-wave transmission over distances is now generally termed—and to indicate the lines of investigation being followed to enable conditions to be predicted with reasonable accuracy. Satisfactory reception of medium-frequency transmission (550 Kc-1500 Kc) is mainly dependent on the "ground" wave. Outside the service area of this wave, fading occurs due to interaction of the "ground" wave and the "sky" or reflected wave. These two waves are out of phase due to the different distances they have travelled to the receiver. Fig. 1 illustrates this point.

On the other hand, this reflected wave makes possible communication over long distances, using frequencies between 3 megacycles per second and 30 megacycles per second approximately. Frequencies higher than 30 Mc/s appear to penetrate the layers and are not useful for regular communication, and frequencies below 3 Mc/s are subject to high attenuation and severe fading at long distances.

The term "reflected" has come into common use, when referring to what is actually a process of continued refraction, and so the word "reflection" will be used throughout this article. As long-distance communication is made possible by the reflection of radio waves from ionised (electrically conducting) layers in the upper regions of the earth's atmosphere, it is termed "ionosphere transmission."

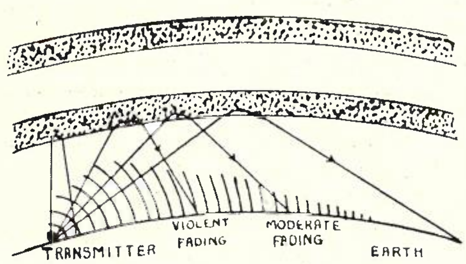


Fig. 1.—Representation of Fading.

Ionosphere transmission is discussed under the following broad subdivisions:—

(a) Reflecting Layers.

(b) Characteristics of the Ionosphere.

(c) Variations of characteristics.

(d) Determination of virtual heights of ionosphere layers.

(e) Graphs relating (d) to maximum usable frequencies, distances and times of transmission.

(f) Concluding notes.

Reflecting Layers.—As far back as 1902, Kennelly and Heaviside independently advanced the theory of reflecting layers in the upper atmosphere to account for otherwise unexplainable phenomena in connection with the propagation of radio waves. These layers were arbitrarily termed E and F, as it was considered there might be other layers below these. The existence of several layers is now an accepted fact. These layers are formed by the ionization of the air particles in the upper atmosphere. In the high atmosphere above 30 miles (50 Km) the air particles are separated so far that collisions between them are far less frequent than in the lower atmosphere, and when an air particle is ionized by ultraviolet radiation from the sun it remains ionized for a considerable time. Therefore, at any given time, a large proportion of the air particles are in an ionized condition. This does not occur much below about 30 miles (50 Km) because the ionizing radiations from the sun are largely absorbed in the higher regions of the atmosphere. Likewise, there is not very great ionization density above about 250 miles (400 Km), because the air is so rare at such heights that there are not enough atoms to provide for great ionization density. The region in which the ionization is great enough to affect radio wave transmission is thus between 30 and 250 miles (50 and 400 Km) above the earth's surface, and this region is called the ionosphere.

The ionization in the ionosphere is not uniformly distributed with altitude, but is stratified, and there are certain definite layers in which the ionization density is such as to reflect radio waves. These layers do not always remain the same as to height and ionization density, but vary diurnally, seasonally and otherwise. There may be several such layers at a given time. There are two principal ones, called the E and F layers. The E layer is at a height of 55 to 90 miles at different times, usually about 70 miles. The term F-layer is ordinarily reserved for the other layer as it exists at night; in the daytime, during most of the year, the F layer divides into two layers which are called the F1 and F2. The night F layer is at a height of about 110 to 250 miles; the F1 layer exists in the daytime at a height of about 86 to 155 miles; the F2 exists in the daytime at a height of about 155 to 220 miles or more in the summer, and about 94 to 190 miles in the winter day.

The "virtual" heights, defined later, are somewhat greater than these values, which may be taken as the average height of the layer. The layers possess a certain thickness which causes the virtual height to vary slightly with frequency, but, as will be seen from Fig. 5, the height of a layer is fairly constant, and this is the "height" of the layer referred to above.

The existence of another layer below the E, and called the "D" layer, has been inferred, but direct observations to ascertain its characteristics have not been made.

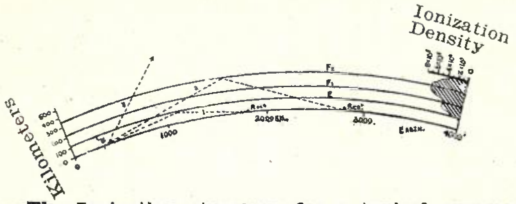


Fig. 2.—The Ionization structure for a typical summer day.

Fig. 2 illustrates in an elementary way the structure of the ionosphere for a typical summer day condition. This drawing is to scale, so the angles of reflection of radio waves from the layers may be estimated correctly. The three layers, E, F1 and F2, are all present and are shown as thin lines for simplicity. The dotted lines 1 and 2 indicate two of many possible paths of radio waves from a transmitter to a receiver as transmitted by reflection from the ionosphere layers. This simple picture represents the basic mechanism of radio wave transmission over long distances, and most of the phenomena of long-distance transmission are completely explainable in terms of the characteristics of the ionosphere. An approximate idea of the comparative density of the layers is shown at the right of Fig. 2.

Referring to this figure, path 1 shows a signal reflected from the E layer, and path 2 is reflected from the F2 layer, whereas path 3 penetrates the three layers. In practice, the frequency of path 1 would be the lowest, e.g., 5 Mc/s; path 2, say, 25 Mc/s, and path 3, 45 Mc/s. If the frequency of path 2 were used for transmission over path 1, it would not be received at the desired point; if the 5 Mc were used to communicate with the receiver R2, it would reach there with two reflections, but it would be preferable to use the one-reflection frequency as the attenuation would be less.

The distance between the transmitter and the first point where the reflected wave returns to earth is termed "skip distance" and within this area any reception (apart from the small area served by the ground wave) will be due to "scattering" and/or freak reflections. The higher the frequency, the greater will be the skip distance and this variation of skip distance with frequency is one of the controlling factors in radio communication by short-waves.

Ionosphere Characteristics.—The principal ionosphere characteristics which determine long-distance radio transmission are the height and ionization density of each of the ionosphere layers. Since each layer has a certain thickness it is necessary to define the sense in which the term height is used. When a ray or train of waves is reflected by a layer, it is slowed down as soon as it starts to penetrate into the layer. The process of reflection thus goes on from the place at which the waves enter the layer until they have been fully turned down and leave the layer. This is true whether the waves travel vertically or obliquely to the ionosphere. Each layer reflects a certain band of frequencies and the last frequency reflected by a layer is termed the "critical" frequency of that layer (referred to later).

Fig. 3 illustrates the path of the electric waves through the ionosphere, and it will be noted that the waves follow a curved path in the layer until they emerge at a vertical angle equal to that at which they entered. The time of transmission along the path BCD in the ionized layer is the same as would be required for transmission along the path BED, that is, if there were true reflection at the point E, if there were no ionized particles present.

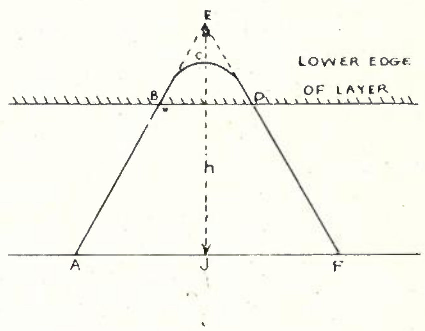


Fig. 3.—The path of a reflected ray.

The height "h" from the ground to "E," the intersection of the two projected straight parts of the path, is called the "virtual height" of the layer. This is the important quantity in all measurements and applications. The virtual height of a layer is measured by transmitting a radio signal from A, and receiving at F both the signal transmitted along the ground and the echo, or signal reflected by the ionosphere, and measuring the differences in the time arrival of the two. The difference between the distance (AE + EF) and AF is found by multiplying the measured time difference by the velocity of light. From this and the known distance AF, the virtual height "h" is calculated.

The effectiveness of the ions in reflecting the waves back to earth depends on the number of ions present in a unit of volume, i.e., ionization density. The higher the frequency, the greater is the density of ionization required to reflect the waves back to earth. It can be shown that for electron ionization the relation for the ordinary ray is—

$$N = 0.0124f^2$$

where N is the number of electrons per cubic centimetre and f is the highest frequency in kilocycles at which waves sent vertically upward are reflected back to earth. Waves of higher frequency than this pass through the layer and are not reflected, while all lower frequency waves are reflected. This frequency "f" is termed the "critical frequency" and the measurement of it is, with the equation just given, a means of measuring the maximum ionization density in an ionized layer. The angle at which the wave is reflected depends on the density of ionization and the frequency of the signal, the index of refraction μ of the ionized gas decreasing with increase of density, and within the range 5 Mc to 30 Mc there exists the following relation between μ and N:—

$$\mu = (1 - e^2N) / \pi m f^2$$

where e = charge of an electron
m = mass of an electron
f = frequency of the wave
μ = index of refraction
N = Number of electrons per cubic cm.

Regular Variations of Ionosphere Characteristics.—There are three principal types of variation of critical frequencies which are fairly regular with time:—

(i) Diurnal variations.
(ii) Seasonal variations.
(iii) Year to year variations with the sun-spot cycle.

The diurnal and seasonal variations of the critical frequencies of the normal E layer are particularly regular. The critical frequencies vary with the altitude of the sun, being highest when the sun is almost nearly overhead. Thus the diurnal maximum of the E critical frequency (F^E) is at local noon, and the seasonal maximum is mid-summer. At night this layer does not usually reflect waves of frequencies higher than about 1000 Kc/sec.

The diurnal and seasonal variations of the critical frequencies of the F2 layer are quite different from those of the E layer. The winter F2 critical frequencies exceed any regular critical frequency found during the summer. In the winter a broad diurnal maximum occurs in the daytime centred round 1 p.m. local time. In the summer a broader diurnal maximum centres about sunset. During the night the winter critical frequencies are usually lower than the corresponding summer values. Thus the highest F2-layer critical frequencies occur during the winter day, and the lowest during the winter night.

The seasonal effects in the ionosphere synchronise with the sun's seasonal position, not lagging a month or two as do the seasons of weather. Winter conditions in the F2 layer obtain during a period April to September and summer conditions from about October to March. Around the equinoxes, which are transition periods, the ionosphere characteristics fluctuate between summer and winter conditions and are thus more erratic than at any other time of the year.

There are important changes in ionosphere characteristics in the 11-year sunspot cycle. From the sunspot minimum in 1933 to the sunspot maximum in 1938, F1 and F2 layer critical frequencies doubled (for most hours of the day) and the E layer critical frequencies became 1.25 times as great. In about 1944 they will return to minimum values.

Ionosphere conditions also vary with latitude, and observation stations have been established at various centres to collect data on this aspect.

The above may be summarised as follows:—

(i) The highest maximum usable frequencies occur during a winter day.

(ii) The lowest maximum usable frequencies occur during a winter night.

(iii) The greater the density of the ionosphere, the higher the frequency that will be reflected. Thus as we approach the period of minimum sunspot activity (1944) the maximum usable frequencies decrease each year.

(iv) Abnormal conditions affect the above conclusions, typical examples of such are:—

(a) Ionosphere storms.
(b) Sporadic E layers.
(c) Scattered reflections.
(d) Prolonged low layer absorption.
(e) Dellinger fade-out.

The effects range from loss of a few frequencies to complete radio blackouts.

Ionosphere Storms.—These are periods of disturbance during which there are great anomalies of critical frequencies, virtual heights, and absorption. Radio transmission is poor (except below 500 Kc, which is sometimes improved) and usually remains so for two or three days. It is usually accompanied by a magnetic storm. The critical frequencies are much lower than usual and the virtual heights much greater.

Sporadic E Layers. — It sometimes happens that waves are reflected by the E layer on frequencies higher than that at which the E layer waves normally disappear and the reflection of waves by higher layers begins. This layer is patchy or sporadic both in geographical distribution and time and most generally occurs in the summer, and more in higher latitudes and equatorial regions. Freak long-distance communication on frequencies as high as 60 megacycles has been attributed to this cause.

Scattered Reflections.—An irregular type of reflection occurs at all seasons and is prevalent both day and night. These reflections are most noticeable in the "skip" zone, or at frequencies higher than those nominally receivable from the regular layers. They are complex and jumpy and, therefore, cause signal distortion.

Sudden Ionosphere Disturbances. — The most startling of all the irregularities of the ionosphere and of radio wave transmission is the sudden type of disturbance manifested by a radio fade-out. This phenomenon is the result of a burst of ionizing radiation from a bright chromospheric radiation from the sun, causing a sudden abnormal increase in the ionization in the D layer (below E layer), frequently with resultant disturbances in terrestrial magnetism and earth currents as well as radio transmission. The radio effect is the sudden cessation of radio transmission on frequencies above about 1500 Kc. The drop of the radio signals to zero usually occurs within a minute. The effects occur simultaneously throughout the hemisphere illuminated by the sun, and do not occur at night. The effects last from 10 minutes to an hour or more. A radio fade-out of this nature, due to the Aurora Borealis, occurred in America, July 5th and 6th, 1941, and European stations East of Great Britain were not receivable for periods of up to 12 hours. A similar fade-out occurred from August 6th to 8th.

Prolonged Periods of Low Layer Absorption.—This phenomena is similar to the sudden ionosphere disturbance in its effect and characteristics except that its beginning as well as its recovery is gradual and it has a longer time duration, commonly several hours.

Dellinger Fade-out.—This usually results in an almost complete wiping out of high frequency communication over lighted portions of the globe. It generally affects low frequencies first, or it may affect all frequencies, depending on the severity, and also diminishes static and atmospherics.

The characteristics of the ionosphere have been treated at some length (though much more could be written about them) because they exert the controlling influence on short-wave radio transmission.

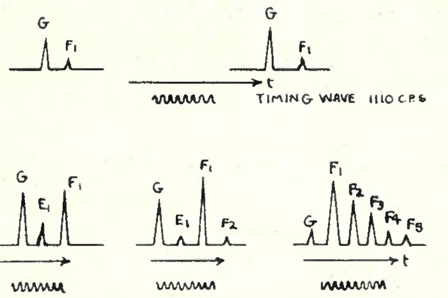
Table 2 summarises the general characteristics and effects.

TABLE 2.
IONOSPHERE RADIO TRANSMISSION CHARACTERISTICS.

Condition of Ionosphere	Cause	Usual Time of of Occurrence	Effect on Transmission
Weak Ionisation.	Lack of energy from the sun.	Every night.	Long skip distance usually resulting in loss of frequencies above 15 Mc.
		Summer day F2 region.	Night conditions as above being found during the day.
	Magnetic storm.	Irregular intervals.	Night conditions at all times on all H.F. bands during the storm with severe fading and/or distortion.
	Minimum sun spot cycle.	Every 11 years—next 1944/5.	Long skip distances on all H.F. bands and loss of usefulness of frequencies above about 26 Mc.
Strong Ionisation.	Considerable radiation from the sun.	Winter day.	Short skip distance up to 14 Mc, and good transmission conditions from 14 Mc to 30 Mc.
	Maximum of sun spot cycle.	Every 11 years—next 1948/9.	Best conditions of transmission for the highest frequency bands with shortest skip distances on all bands.
Daily peak in ionisation).	Rotation of the earth.	Winter at noon. Summer at sunset (F2 layer).	These are the times of day for shortest skip distances and the use of the highest frequency.
Abnormal E layer (very strong ionisation).	Not definitely known.	May occur any time but most often in the spring and summer after sunrise and sunset.	Medium long distance on high and ultra-high frequencies, including 60 Mc.
Dellinger fadeout.	Not definitely known.	Most often at 55-day intervals.	Fade-out of all high frequencies and often as low as 2 Mc.
Temperature gradient in lower atmosphere.	Air mass movements.	Precedes periods of unsettled weather.	50-300 mile transmission of ultra-high frequency signals accompanied by fading.

Virtual Height. — Measurements are made to determine the virtual heights of these ionized layers and from these, graphs are drawn showing maximum frequency which may be used for transmission over various distances by reflection from these layers. Referring to Fig. 2, the E layer may be used for transmission over relatively short distances, whilst the F1 and F2 layers may be used for longer distances. Knowing the critical frequencies for each of these layers, a frequency may be chosen that will be reflected by the desired layer. It is better to choose a frequency that will reach the place of reception with the least number of reflections, i.e., should both the E and F layers be usable for a required transmission the number of reflections from the F layer would be considerably less than from E due to the greater height of F, this would result in less overall attenuation of the signal.

Methods of Measuring Critical Frequencies.—The technique of measuring critical frequencies has been developed to the stage whereby the procedure is automatic. Several stations are in operation under the auspices of the Carnegie



G—original recorded ground wave. E1, F1—echoes returning after a single reflection from E or F. F2 to F5—echoes which have suffered two to five reflections from the F layer.

Fig. 4.—Simplified Echo Record.

Institute, Washington, D.C., U.S.A. The equipment and routine of operation have been standardised so that the observations made in different localities may be comparable.

The apparatus in use comprises a multi-frequency transmitter and receiver and a special camera for making an oscillographic record of the received signals. The frequency band from 516 kilocycles to 16 megacycles is covered in 15 minutes, the average spacing between signals being 1600 cycles.

The same antenna is used for transmission and reception and, in operation, a short pulse of each frequency is transmitted vertically and both the sent pulse and the echoes are received and recorded, sufficient time being allowed between the pulses to enable the echoes to be recorded. A timing wave of 1110 cycles per second provides the necessary reference for calculation. The highest frequency at which an echo is received is termed the critical frequency. There is a critical frequency for each layer—E, F, F1, F2—

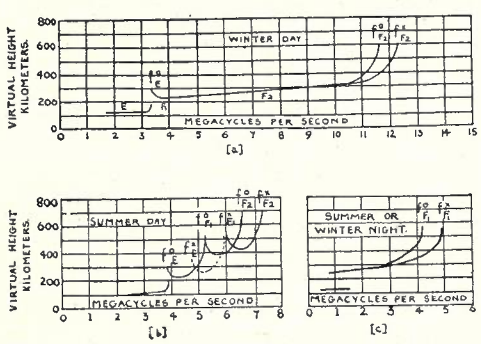


Fig. 5.

and this is determined from the photographic record. Fig. 4 is simplification of the photographic record, and Figs. 5a, 5b, and 5c show the form which the graph prepared from this record takes.

In practice, vertical transmission is the exception and normally the waves are radiated at angles from the vertical, that is, they can be reflected from regions of smaller ionization density. In general, for a given frequency of the transmitted wave, the larger the angle of incidence, the less is the ionization density required for reflection. Thus, if a given layer will reflect waves up to a certain frequency at vertical incidence, it will reflect waves of considerably higher frequencies at oblique incidence.

From the typical results shown in Fig. 5, which are for different times of the year, day and night—starting at a frequency below 2 Mc/s the virtual height is found (in this example) to be about 110 kilometres (70 miles) and remains at this height until about 3.3 Mc/s. The critical frequency of the E layer at the time of this measurement is thus 3.3 Mc/s; all such waves of higher frequency penetrate E and go through to F1. At about 4.6 Mc/s the waves penetrate through the F1 layer and go to F2. In the case illustrated the critical frequency of F2 is about 11.6 Mc/s. The critical frequencies are shown by sharp increases in virtual height.

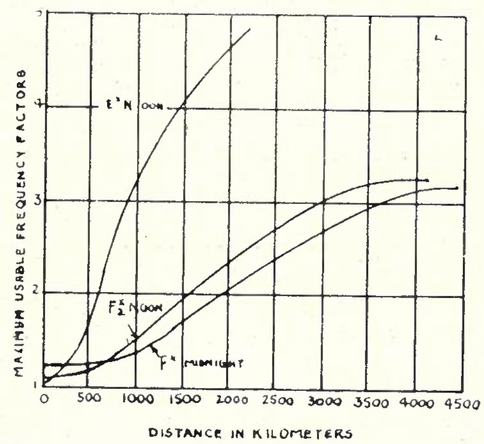


Fig. 6A.

Fig. 6A is a graph giving factors by which the vertical incidence maximum usable frequencies may be multiplied in order to obtain the maximum usable frequencies for transmission over various distances via the indicated layers.

The angle of incidence is the angle between the ray and the normal to the lower boundary

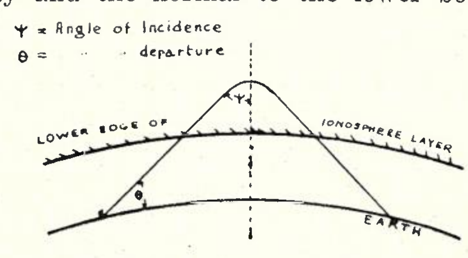


Fig. 6B.

of the ionosphere at the point where the ray enters the layer. The angle of incidence should not be confused with the angle of departure, which is the angle above the horizontal at which the ray is projected from the transmitter. Fig. 6B illustrates this point.

Factors which affect the angle of incidence are:—

(i) The distance of transmission for one reflection from the ionosphere.
(ii) The height of the layer.

Given these two quantities, therefore, the angle of incidence may be calculated. The maximum usable frequency is given, roughly from this angle and the vertical incidence critical frequency, by the following relation, known as the "secant law":—

$$f_1 = f_c \text{ Sec. } \theta_1$$

where f_1 = maximum usable frequency
f_c = critical frequency for the given layer
θ_1 = angle of incidence.

The above law neglects some important factors but is sufficiently accurate for most purposes.

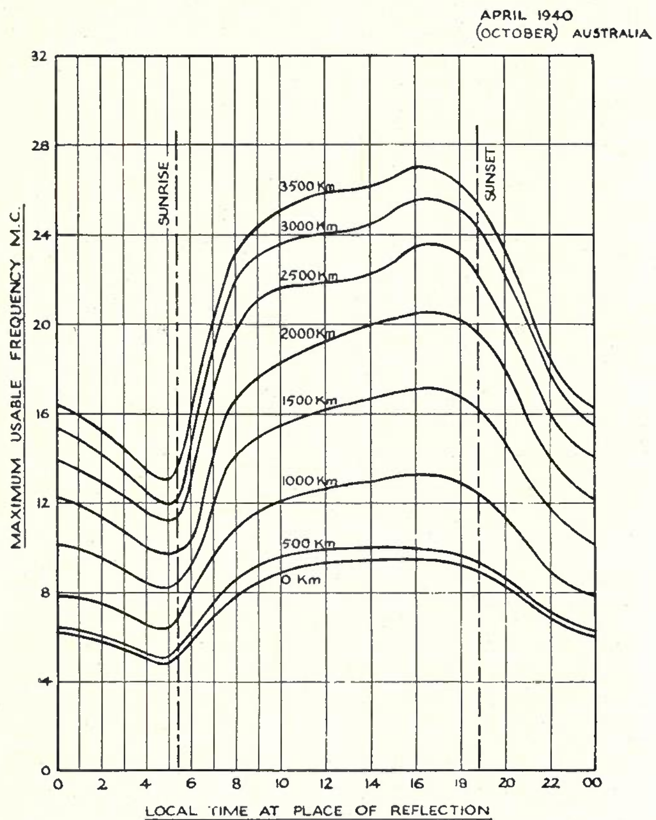


Fig. 7.—Maximum usable frequencies for April, 1940, at Washington, D.C.

Fig. 7 illustrates a useful form of graph prepared from the vertical incidence measurements and shows the maximum usable frequencies for April, 1940, at Washington, D.C., and approximates conditions in Australia for October.

From this graph the following information may be deduced:—

(a) **Skip distance** for any frequency at any time during 24 hours.

e.g., Consider 10 megacycles,
at 2 a.m. it is 1600 Km. (1000 miles)
at 4 a.m. it is 2000 Km. (1250 miles)
at 7 a.m. it is 1000 Km. (625 miles)
at noon it is 500 Km. (312 miles).

Consider 20 megacycles,
before 7 a.m. it is not of much use,
at 7 a.m. skip is 3500 Km. (2200 miles),
at 8 a.m. skip is 2500 Km. (1560 miles),
and by 9 p.m. it is no longer useful.

(b) The maximum usable frequency for any time of day, considered for "one hop" transmission at that time. For example, suppose a 1000 Km. (625 mile) transmission is desired at 10 a.m., then the maximum usable frequency is approximately 12 Mc/s. For 3500 Km. (2200 miles) at the same time we could use about 25 Mc/s, but at midnight for 1000 km. we must use less than 8 Mc/s, and for 3500 Km. about 16 Mc/s. To allow a factor of safety the working frequencies would be taken as approximately 80 per cent. of the above values.

Transmission over distances involving more than one-hop, i.e., more than one reflection from the ionosphere, is not so straightforward, but some idea of the frequency required may be found from this graph, as follows:—

Divide the distance into 3500 Km. (2200 miles) sections and consider that a reflection will take place at the centre of each section. Find the local time at each point of reflection and note the maximum usable frequency corresponding to that time. We now have a series of maximum usable frequencies and our choice will be the lowest of these. If we use a higher frequency than that required for the low frequency hop, we will lose our signal at that section. Thus the maximum usable frequency for multi-hop transmission is governed by that portion of the path requiring the lowest frequency for satisfactory reflection. Many more factors enter into multi-hop transmission, such as the nearness of the path to the Polar Regions, direction of crossing the Equator, local noise level, etc., and any solution is merely a compromise between conflicting factors.

In making the above calculations distances are always considered along the Great Circle Path between the places concerned. Fig. 8 shows the maximum usable frequencies for January, 1940, in Washington (approximately June in Australia) and it will be noted that they are much higher than in Fig. 7. A similar variation exists between the maximum and minimum periods of sun-spot activity, the highest usable frequencies occurring during the period of sunspot maximum.

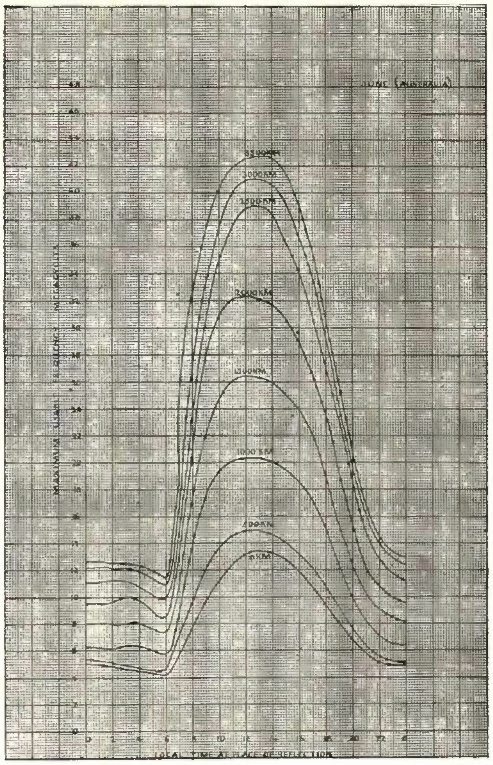


Fig. 8.—Maximum usable frequencies for January, 1940, at Washington, D.C.

Conclusion: Reference only may be made to methods of improving reception of short wave radio transmissions. The development of directive high gain antennas both for transmitting and receiving has materially contributed to improved reception, as has the use of diversity reception applied to the high gain receiving antennas.

One of the latest developments is the M.U.S.A. system (multiple-unit-steerable-antenna) in the application of which as many as 16 rhombic antennas have been used with a single receiver. Investigations of diversity reception had shown that signals arriving at different angles varied in intensity at any instant. It was considered that an antenna system designed for reception of signals at a number of different angles of arrival would enable more consistent reception to be obtained, as there would probably be a good signal intercepted by one of the antennas at any instant. The important point to consider was that there should be no phase displacement between the signals from the various antennas at the receiver input as this would cancel any advantage obtained by the system. This phase difference would be due to the different lengths of lines connecting the antennas to receiver.

This was accomplished by designing phase shifting networks for each antenna and subjecting them to a common control. The operation of this control is governed by the strongest signal being received, and is automatic. The net effect is that no matter which antenna is receiving the best signal, the signals from the other antennas are added to it in the correct phase to increment the input to the receiver.

This article has been necessarily brief and some references for further study are given below:—

(i) Maximum Usable Frequencies for Radio Sky-Wave Transmission—T. R. Gilliland, S. S. Kirby, N. Smith and S. E. Reymer.—Proc. I.R.E., November, 1938.

(ii) Application of Graphs of Maximum Usable Frequencies to Communication Problems — N. Smith, S. Kirby, T. R. Gilliland.—Journal of Research of the National Bureau of Standards, January, 1939.

(iii) Characteristics of the Ionosphere and Their Application to Radio Transmission.—Journal, Research N.B.S., Volume 18, 1937.

(iv) The Ionosphere—K. Darrow.—Electrical Engineering, July, 1940.

(v) The Calculation of Radio Sky-Wave Transmission—K. Maeda, T. Kohno.—Journal, I.E.C.F., Japan, November and December, 1939.

(vi) National Bureau Standards Letter Circular, LC.575.

(vii) Extension of Normal Incidence Ionosphere Measurements to Oblique Incidence Radio Transmission.—National Bureau of Standards Journal, Res., July, 1937.

(viii) Recent Studies of the Ionosphere—Kirby & Judson, Proc. I.R.E., July, 1935.

A C.B. MULTIPLE LAMP SIGNALLING P.B.X.

R. H. Byron

In these days of automatic telephone operation, the requirements of many large subscribers can be satisfied only by the provision of automatic switching equipment for inter-office traffic as well as for exchange service, and this demand is met by the P.A.B.X. However, there are other subscribers—hotels, for example—who require an extensive telephone service; but, with a limited community of interest between extensions, the service is required chiefly for connection to the public exchange network. For this class of service it is often necessary for the subscriber to exercise control of outward traffic in order to ensure that each extension is debited with the cost of the calls. A service of this type can be provided most effectively by a multiple C.B. P.B.X. For many years there was only limited development in this field, but recently some attention has been paid to improvements in circuit and operating features and this article covers the circuit details and general features of two C.B. multiple lamp signalling P.B.X.'s which have been manufactured recently in Victoria. The general construction of the switchboard carcases is on standard lines. There are two panels per position with local jacks and lamps in strips of 10 and multiple jacks in strips of 20, the multiple being repeated every four panels. The resistances for the extension lines are mounted in the back of switchboards, whilst the relays have been rack mounted. The extension line cut-off relays are mounted on fixed bases, 20 per base, whilst the exchange line, miscellaneous and cord circuit relays are mounted on jack-in bases, cord circuits are provided on one circuit per base and exchange lines, two circuits per base. Type 600 relays have been used for extension line cut-off relays and owing to the shortage of 3000 type, it was necessary to use horizontal strowger type relays for exchange line and cord circuits. Each rack is designed to accommodate apparatus for 400 extension lines and four switchboard positions, the exchange and cord circuit relay sets being mounted on a separate rack. An I.D.F. is provided for the connection of the multiple and local cables.

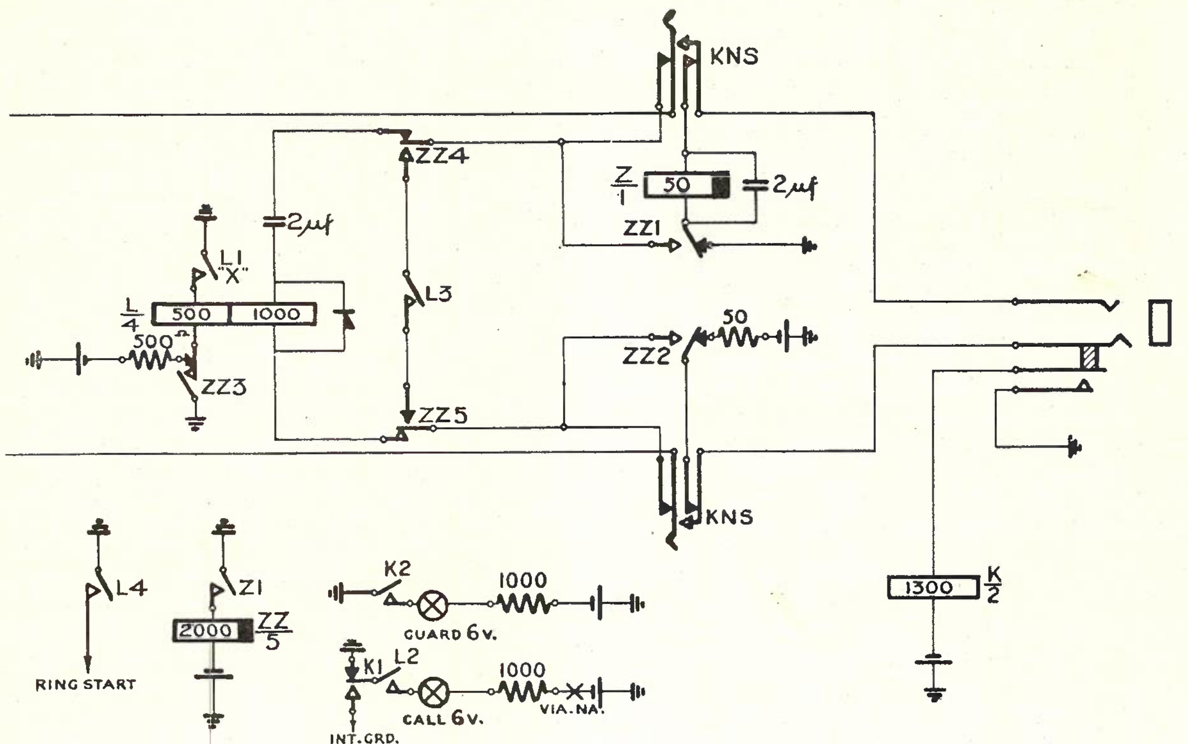


Fig. 1.—Exchange Line Circuit.

The main features of the circuits are:—

(i) Through dialling to an automatic exchange from all extension telephones fitted with dials.

(ii) Through clearing from extensions on both incoming and outgoing exchange calls.

(iii) A trap circuit on each exchange line to recall the telephonist and to prevent the ring going through to the extension if another exchange call is received prior to the clearing of a through connection.

(iv) Use of ordinary cord circuits for night switching.
(v) During dialling, the telephonist can supervise the progress of a call.
(vi) Automatic coupling of telephonists' circuits.
(vii) A voice frequency termination in each cord circuit for exchange calls.
(viii) Automatic ringing.
(ix) Series line lamps for extension lines.

Circuit Operation

Exchange to Extension Calls:—(a) Exchange line circuit (Fig. 1): The exchange ringing current operates relay L in the exchange line circuit. Contact L1 provides a locking circuit, whilst the line lamp circuit is completed by L2. The telephonist inserts the answering plug of a cord circuit (Fig. 2) in the exchange line jack, thereby operating relay Z from the cord circuit A relay loop. Relay ZZ is operated by contact Z1. The exchange line is extended to the cord circuit via ZZ1 and 2 and relay Z is held by line current flowing through the loop provided by relay A in the cord circuit and ultimately by the extension telephone loop. ZZ4 and 5 clear relay L from the exchange line and in association with L3, provide a momentary short circuit to ensure the reliable operation of the ring trip relay of the final selector in the exchange. This is necessary on long lines. The connection of ground instead of battery via the ZZ3 contacts, in effect, short circuits the 500 ohm winding of relay L to provide a release lag to ensure the definite application of the short circuit to the exchange line. Relay K is operated through the make springs associated with the exchange line jack. K1 changes the line lamp circuit (open at L2) from full to interrupted ground, whilst the guard lamp circuit is completed at K2.

The exchange line equipment is under the control of relay Z. When the call is completed and the extension loop is opened, relay Z releases and restores ZZ. If another call arrives before the telephonist withdraws the plug, relay L operates and locks and the circuit of the line lamp is completed to interrupted ground via the K1 contacts. The ring start circuit, which is required to start the ringing equipment to provide interrupted ground pulses, is completed by L4. The flashing line lamp attracts the attention of the telephonist, who withdraws the calling plug from the extension jack and operates the speak key to connect to the new caller. If the answering

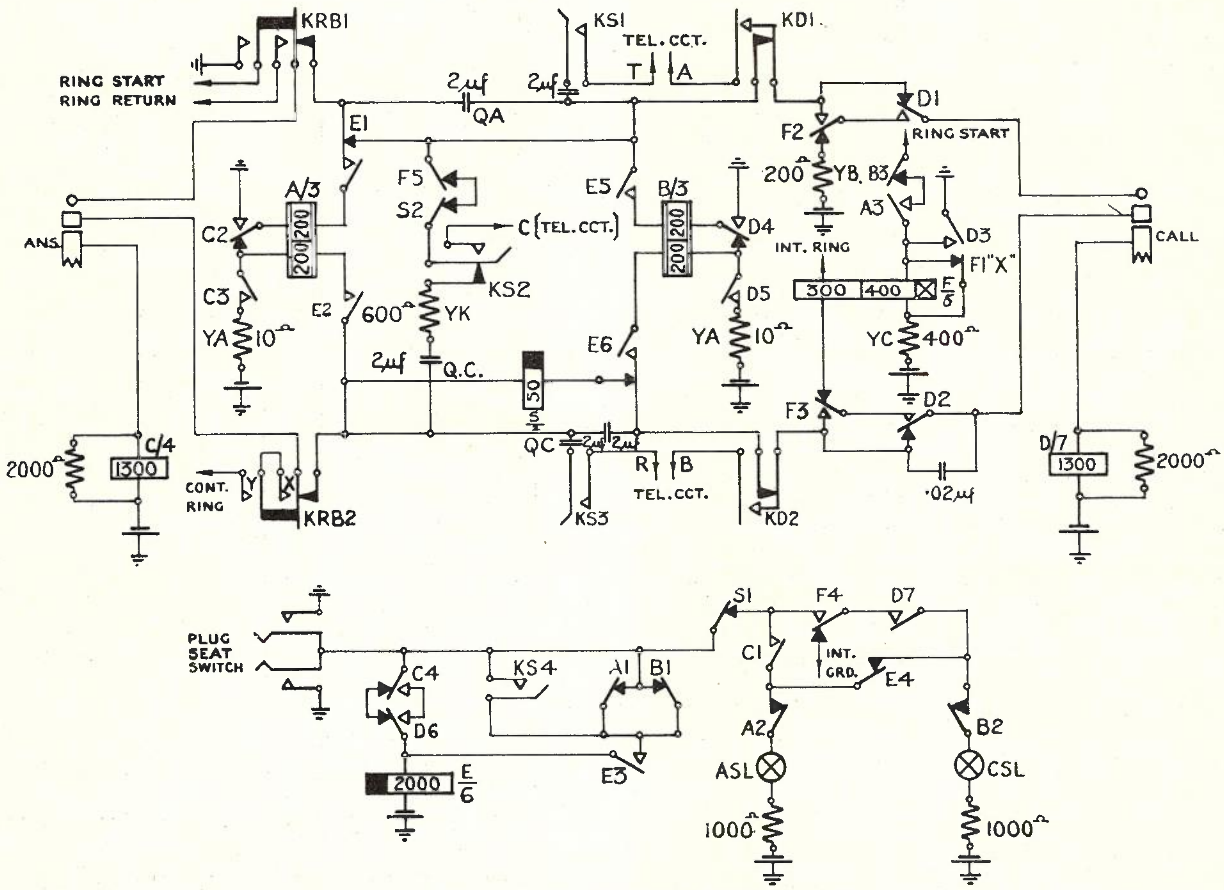


Fig. 2.—Cord Circuit.

plug is withdrawn before the call is answered, the line lamp flash is replaced by a steady glow.

(b) Cord Circuit (Fig. 2): On the insertion of the answering plug in the exchange line jack, relay E operates from ground at the plug seat switch. Contacts E1 and 2 connect relay A across the T and R of the answering cord, whilst E5 and 6 connect relay B across the T and R of the calling cord. E3 prepares a hold circuit for E, whilst E4 separates the ASL and CSL circuits. Relay A operates over the exchange line loop. A1 opens portion of the hold circuit for relay E, whilst A2 opens the ASL circuit and A3 prepares the ring start circuit. The resistance YK and condenser QC provide a VF termination across the exchange line. The telephonist depresses speak key KS, ascertains the extension required and tests the line—tip of calling plug, F5, S2, KS2, to C wire of the telephonist's circuit. If the line is free, the insertion of the calling plug in the extension jack operates relay D from earth via relay K (Fig. 3), which also operates and clears the extension line. D1 and 2 connect the ringing circuit to line, whilst D3 completes the ring start circuit. D4 and 5 connect battery and ground to relay B, D6 is in the operating circuit of relay E and D7 connects interrupted ground to the C.S.L., which flashes in synchronism with the ringing pulses. When the extension answers, relay F operates and locks via F1, which removes the short circuit across F400. The extension line is switched through and the ring cut off by F2 and 3. F4 disconnects interrupted ground from the C.S.L. and F5 opens the V.F. termination. Relay B operates over the extension loop and, at B1, opens the hold circuit of relay E. B2 and 3 open the C.S.L. and ring start circuits. On the release of E the circuits of relays A and B are opened.

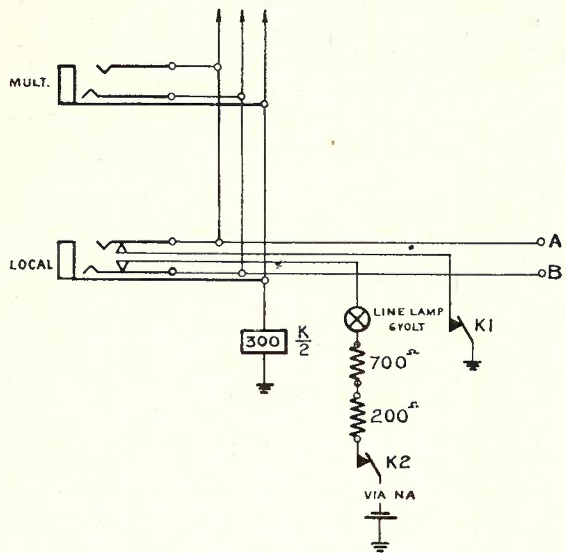


Fig. 3.—Extension Line Circuit.

These relays release and the line is switched through clear of attachments. Condenser QA is short-circuited and QB is shunted by relay S, which operates over the loop. S1 opens the A.S.L. and C.S.L. circuits.

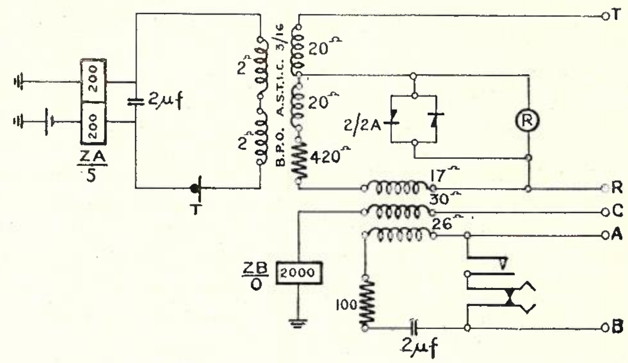


Fig. 4.—Telephonist's Circuit.

On completion of the call, S releases, both supervisory lamps glow, and the line is clear through to the exchange.

Recall by Exchange:—When the telephonist notices the exchange line lamp flashing and both supervisory lamps glowing, she must withdraw the calling plug from the extension jack before answering the second call on the exchange line. The withdrawal of the plug from the extension jack releases relay D, and, as the answering plug is still in the exchange jack, the circuit of relay E is again completed from ground at the plug seat switch via C4, D6, relay E to battery. Relay E again connects relay A as a loop across the exchange line. A in turn operates relay Z (Fig. 1) and switches the call through to the telephonist.

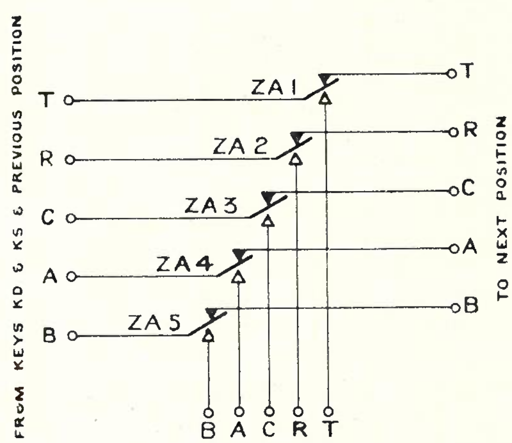


Fig. 5.—Coupling Circuit.

Extension Recalls Telephonist:—The release and depression of the cradle switch in the telephone releases and reoperates relay S, which causes both supervisory lamps to flash. The telephonist comes in on the line and can, if desired, transfer the call to another extension.

Extension to Exchange Calls:—The answering plug is inserted in the extension jack, relays C and E operate and connect battery to the calling extension via relay A, which also operates. The telephonist inserts the calling plug in an exchange line jack, relay B operates via the exchange loop [initially via relay Z (Fig. 1)] and with the restoration of the speak key, KS4, relay E releases and the through circuit is established as for an incoming exchange call. Dialling can be accomplished either by the telephonist or the extension user. On release a through clear is provided and an incoming call, if received prior to the clearing of the cord circuit, will operate the trap circuit in the exchange line and cause the exchange line lamp to flash.

Extension to Extension Calls:—The answering plug is inserted in the jack of the calling extension and relays C, E and A operate as for an extension to exchange call. The telephonist tests the jack of the line required, and, if free, inserts the calling plug. Relay D operates, ringing current is applied and the C.S.L. flashes. When the extension answers, relays F and B operate and the C.S.L. is extinguished. Relay E is held by the operated contacts C4 and D4 and battery is fed to both extensions via relays A and B. On the extensions clearing, relays A and B release and the A.S.L. and C.S.L. glow.

Night Switching:—The answering and calling plugs of a cord circuit are inserted in the exchange and extension local line jacks respectively of the lines to be connected for night switching purposes. The operation of the night switching key (KNS) in the exchange line (Fig. 1) clears the line relay equipment. The power on the P.B.X. is switched off, therefore the cord circuit relays are not operated by the insertion of the plugs in the jacks, and the circuit provides a straight through connection. The extension telephone bell is operated by exchange ringing current and the operation of relay S clears the V.F. termination.

Extension Line Circuit (Fig. 3):—Signalling from each extension is accomplished by means of a 6 V. lamp in series with 700 + 200 ohm resistances. The current limit of 30 to 45 M.A. for operating the 6 V. lamp is adjusted by strapping the 200 ohm resistance.

Telephonist's Circuit (Fig. 4) and Coupling Circuit (Fig. 5):—The telephonist's circuit follows the latest practice for the prevention of acoustic shocks by the addition of two metal rectifiers bridged across the receiver and provides a balanced engaged test. The contacts of relay ZA in the telephonist's circuit are shown in Fig. 5. When the plug of the telephonist's telephone is withdrawn from jack, relay ZA releases and the position is coupled to the adjoining one via the ZA contacts.

A PORTABLE TEST SET FOR COUNTRY MECHANICS

W. King

This test set to Drawing C.1467 has been developed for the use of Mechanics in Country Districts. The necessity for such a test set has been appreciated for some time, and a great deal of thought has been given to the facilities required and to the design and construction of the test set. The complete test set, which is accommodated in a leather carrying case, is illustrated in Figs. 1 to 4, and a schematic circuit of the testing circuit is indicated in Fig. 5. The difficulties associated with the design of a portable test set of this kind will be appreciated when the many facilities required and the necessity to keep the dimensions and weight of the set within reasonable limits are considered.

The various components and the associated keys, etc., are contained in a compact wooden case. A leather carrying case is provided with compartments for the handset, test cords, etc., in addition to the test box. It is considered that all tests should be performed with the test set in the leather case; holes are provided in the case for the insertion of the generator handle, handset plug and test plugs. The test box should be removed from the leather case only when attention to the wiring, battery, etc., is necessary.

Care has been taken in the design of the test set to protect it from damage, and it will be seen from the figures that strengthening light metal plates reinforce the woodwork where there is a danger of warping or shrinking taking place. The testing meter is also protected by a metal cover and the glass face of the meter is protected by a transparent cellon plate. The meter is mounted in a compartment lined with sponge rubber to protect the movement from sudden jolts.

The test set consists of the following components:—

- Universal Avo Minor Meter.
- Hand Generator associated with a voltage doubler circuit for insulation tests.
- Battery, 6 volt.
- Buzzer.
- Handset.
- Fuse and Heat Coil Tester.
- Terminating Resistance Plug, 600 ohms.

Test cords.

Resistor, 100,000 ohms, for calibrating voltage doubler circuit.

Test Keys, etc.

Avo Minor Meter:—This meter is a combined voltmeter, milliammeter and ohmmeter and facilities are provided to read voltages, both D.C. and A.C., up to 500. The various ranges are selected by means of sockets on the face of the instrument, the negative plug (Black) being inserted into the Com. Neg. terminal and the positive plug (Red) inserted into the socket denoting the range it is desired to use. The rotary switch on the face of the meter should be moved to the left when it is desired to use the A.C. voltage ranges. When D.C. milliamps or volts or resistance measurements are to be made, the switch should be turned to the right. The following voltage ranges are provided:—

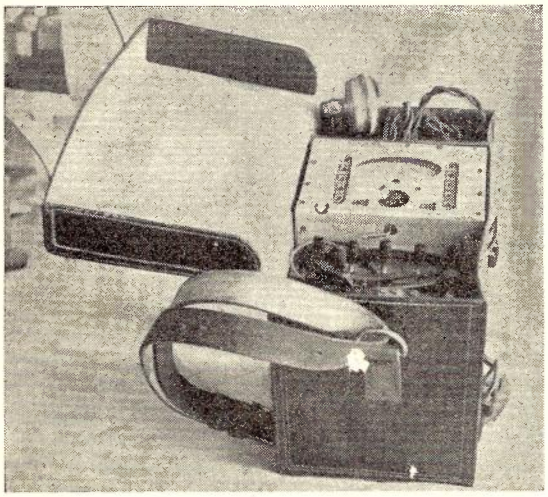


Fig. 1.—Test Set in leather case.

0-5 volts
0-25 ,,
0-100 ,,
0-250 ,,
0-500 ,,

The various ranges in the milliamp scale are selected in a similar manner, the following ranges being provided:—

0-2.5 milliamps
0-5 ,,
0-25 ,,
0-100 ,,
0-500 ,,

For resistance measurements up to 20,000 ohms, use is made of a battery fitted in a small compartment at the back of the Avometer and the Ohms Zero Control in the front of the meter is for the purpose of adjusting the ohms range, should the battery be slightly run down. The adjuster arm should be rotated until the meter reads zero ohms with the test leads short-circuited. Direct readings of resistances up to 20,000 ohms may be read on the meter. In the case of ranges greater than 20,000 ohms the hand generator and voltage doubler circuit is used as for insulation resistances.

Insulation Resistance Tests:—For these tests it is necessary to use the hand generator in conjunction with the voltage doubler circuit. The method of calibrating the Avo-Meter for insulation resistance tests is as follows:—

(a) Connect the Avo-Meter Neg. and Pos. plugs to Com. Neg. and 100 V. sockets, respectively.

(b) Insert the 0.1 megohm resistance in the fuse test clips.

(c) Operate the Avo-Meter and Insulation Keys.

(d) Turn the hand generator handle at normal ringing speed and move the Ohms Zero adjusting lever until the meter needle reads 1000 (i.e., 100,000 ohms) on the ohms scale.

(e) Remove the 0.1 megohm resistance.

Insulation resistance may now be read direct on the ohms scale on the Avo-Meter by turning the generator handle. The reading should be multiplied by 100 (i.e., 10,000 ohms on the scale equals 1 megohm).

The above adjustment is necessary to compensate for the excessive voltage above 100 volts, developed by the generator and voltage doubler circuit, which is approximately 125 volts with the generator handle turned at normal speed. It also serves as a test on the generator and doubler circuit and indicates the speed at which the generator handle should be turned when making insulation resistance tests. With the

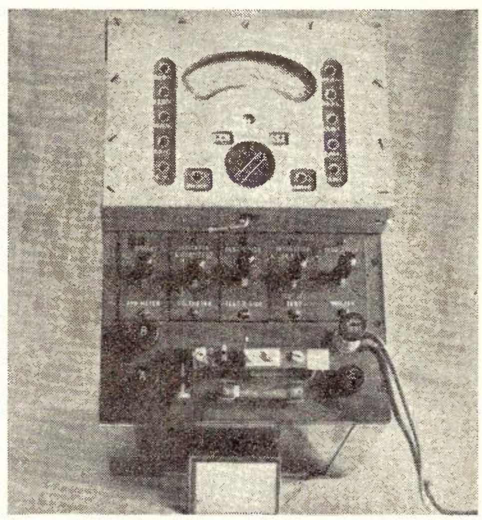


Fig. 2.—Face view of Test Set.

Insulation Key normal the generator may be used for ringing on a line.

Battery:—The 6-volt battery provided is used for the various voltmeter tests, cord and indicator tests, buzzer, etc.

Buzzer:—A buzzer is provided for continuity testing for occasions where a mechanic cannot conveniently see the Avo-Meter.

Handset:—This may be plugged into the test set and is used for speaking and transmission tests when required.

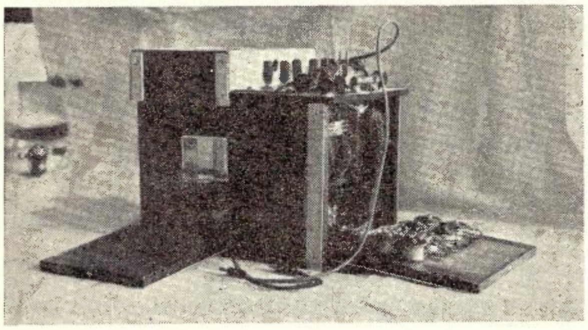


Fig. 3.—Test Set showing front and side compartments.

Fuse and Heat Coil Tester:—Fuse clips are provided for testing standard fuses. A current is passed through the fuse and a deflection obtained on the 100 milliamp scale of the Avo-Meter. Heat coils are tested similarly, but provision is made to vibrate the heat coil during the test in order to detect intermittent opens. The heat coil is inserted in the terminals provided, the locking screw withdrawn and the heat coil plate vibrated by a flick of the finger. A steady deflection should be maintained on the meter. An intermittent open will be indicated by an unsteady reading on the meter.

Terminating Resistance Plug, 600 ohms:—This is provided so that a standard termination may be given when performing transmission tests, etc., on trunk lines.

Test Cords:—A test cord is provided for testing "in" or "out" from the M.D.F. This is fitted with special clips to fit the fuse blocks on one end and switchboard plugs at the other end. The switchboard plugs are designated "In" and "Out" and may be connected to the test set by insertion into the test jack provided at the back of the test set. A cord fitted with spade terminals which may be conveniently connected to the "A," "B" or "E" terminals on the test set is provided for miscellaneous tests, such as resistance tests, continuity tests, etc. Alligator clips are connected to the opposite end of this cord for quick connection to the circuit under test.

Tests:—The following is a list of tests which may be performed with the test set:—

Resistance of Subscribers' Lines.
Insulation Resistance.
Test of Switching Cords.
Test of Calling Indicators.
Tests "In" or "Out" from the Line Fuse Clips, including—
  Loop Tests.
  Tests for Earth or Battery on either leg.
Primary Cell Test by the shunt method.
Direct reading of Voltage.
Direct reading of Current.
Direct reading of Resistance.
Fuse and Heat Coil Test.
Transmission Test.

A description of the various tests is given hereunder. The circuit conditions can be followed readily by reference to Fig. 5; also simplified diagrams of each test condition are available—see Drawing C.1467, Sheet 6.

Resistance of Subscribers' Lines:—

(a) Between A and B sides: With the test cord connected to the test jack, connect the Avo-Meter plugs to the Com. Neg. and 20,000 ohm sockets and operate the Avo-Meter Key. This connects the meter across the test leads. Short circuit the test clips and adjust the Ohms Zero switch until the pointer of the meter reads zero. Connect the test clips to the line under test and read the resistance direct on the meter (ohms scale).

(b) "A" side to Earth (Earth must be connected to terminal "E"): For this test the Avo-Meter and Test "A" Side Keys are operated. This earths the meter on one side, connects the other side of the meter to the "A" test lead and opens the "B" test lead. (Read on ohms scale.)

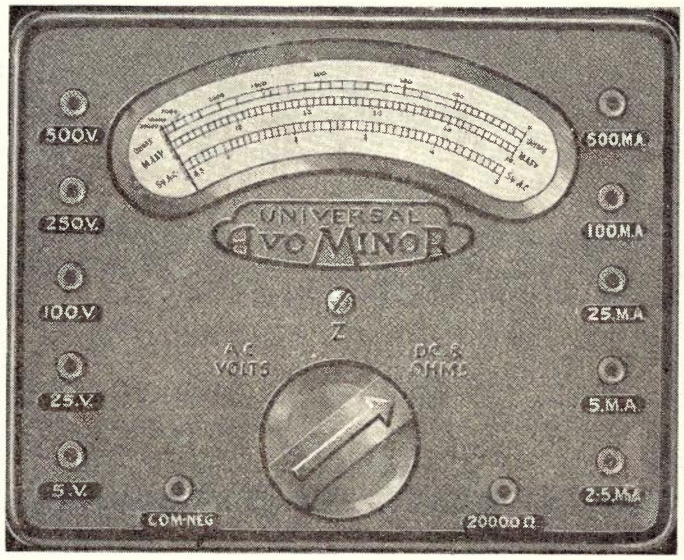


Fig. 4.—Front view of Avo-meter.

(c) "B" side to Earth: With the Avo-Meter and Test "B" Keys operated the conditions indicated in (b) are reversed. (Read on ohms scale.)

Insulation Resistance of Subscribers' Lines:—(See paragraph re calibration.) Connect the Meter Neg. and Pos. plugs to the Com. Neg. and 100 V. sockets respectively. Operate the Avo-Meter and Insulation Keys. This connects the meter and voltage doubler circuit to the test leads. Turn the generator handle and read the insulation resistance on the ohms scale. (Multiply the reading by 100.)

Test Switching Cords:—Plug the cord under test into the test jack of the test set and operate the Cord and Indicator Test Key. Six volts via a 30 ohm resistance is connected across the tip and ring of the cord. The clearing indicator associated with the cord should operate, proving the continuity of the cord conductors and the clearing signal. Operate the Speaking Key associated with the cord under test and shake the cord. Fractured cord conductor strands will be indicated by a scraping noise heard in the telephonist's receiver.

Test of Indicators:—The testing of 1000 ohm and 600 ohm clearing indicators is done in conjunction with the previous test. For testing 100 ohm line indicators, connect the "Out" test plug to the test jack of the test set and operate the Cord and Indicator Test Key and the 100 ohm Indicator Key. Three volts via 30 ohms is connected across the test terminals. By touching the fuse clip end of the test cord on the line terminals at the M.D.F. the calling indicators may be operated.

Test "In" or "Out" from Line Fuse Clips:—

(a) Test "Out," Loop Test: Insert the "Out" plug into the test jack. Connect the Meter Neg. and Pos. plugs to Com. Neg. and 5 volt sockets respectively. Operate the Avo-Meter and Voltmeter Keys. A loop or continuity is indicated by a deflection on the voltage. If an audible indication is required for continuity tests through low resistances, operate the Buzzer Key which substitutes a buzzer for the voltmeter.

(b) Test for Earth on the "A" side: The connections are the same as for (a) above, but in addition the Test "A" Side Key is operated.

(c) Test for Earth on the "B" side: The connections are the same as for (a) above, but in addition the Test "B" Side Key is operated.

(d) To Test "In," insert the "In" plug into the test jack and repeat tests (a), (b) and (c).

(e) Tests for Negative Battery: Connect the Avo-Meter Neg and Pos. plugs to Com. Neg. and 100 volt sockets respectively. (Change the Pos. plug to a lower voltage range if necessary.) To test for negative battery on the "A" side, insert the "Out" plug into the test jack and operate the Avo-Meter and Test "A" Side Keys. The voltage may be read direct on the voltage scale. To test for negative battery on the "B" side, operate the Avo-Meter and Test "B" Keys.

(f) Tests for Positive Battery are made in a similar manner to those indicated for negative battery in (e) above, but the test plugs in the Avo-Meter must be reversed, i.e., the Neg. plug should be inserted in the 100 volt socket and the Pos. plug inserted in the Com. Neg. socket.

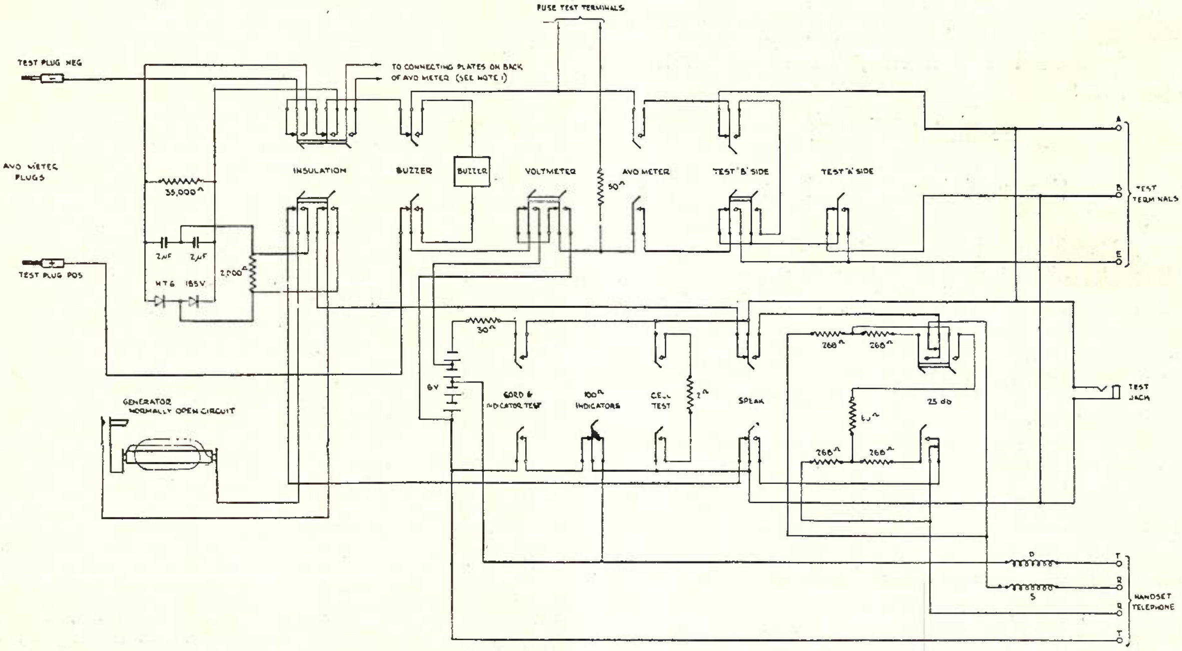


Fig. 5.—Schematic Circuit.

Primary Cell Test:—To perform this test connect the cell under test to the test terminals and connect the meter Neg. and Pos. plugs to the Com. Neg. and 5 volt sockets respectively. Operate the Avo-Meter Key and read the voltage of the cell under test; call the reading V1. Restore the Meter Key and operate the Cell Test Key for 1 minute. This connects a 2 ohm resistance across the cell. Restore the Cell Test Key, operate the Meter Key and again read the voltage of the cell; call the reading V2. The internal resistance R of the cell may be obtained from the equation:

$$R = \frac{S(V1 - V2)}{V2}$$

where S is the resistance used to shunt the battery.

Direct Reading of Voltage or Current:—Connect the Avo-Meter negative plug to the Com. Neg. socket and the positive plug to the desired voltage or current socket. Operate the Avo-Meter Key and read the voltage or current direct on the respective scale.

Direct Reading of Resistance:—Connect the Avo-Meter Neg. and Pos. plugs to the Com. Neg. and 20,000 ohm sockets respectively. Resistance may be read direct on the ohms scale. (Adjust the meter needle to zero by means of the Ohms Zero Control before making a resistance measurement.)

Continuity Tests:—Operate the Avo-Meter, Voltmeter and Buzzer Keys. Continuity will be indicated by the operation of the buzzer.

Transmission Test:—Insert the four-pin instrument plug into the instrument jack at the rear of the test set. Operate the Speak Key. A 25 db pad may be inserted in the test circuit if desired by the operation of the 25 db key.

Fuse and Heat Coil Test:—Connect the Avo-Meter Neg. and Pos. plugs to the Com. Neg. and 100 M.A. sockets respectively.

(a) Fuse Test: Insert the fuse in the fuse clips and operate the Voltmeter Key. This connects 4.5 volts via a 50 ohm resistance across the fuse clips; a steady deflection should be maintained on the meter.

(b) Heat Coil Test: Insert the Heat Coil in the holder and operate the Voltmeter Key. To detect intermittent opens, release the holding screw and vibrate the heat coil assembly. A steady deflection should be maintained on the meter.

It will be appreciated from the above that the facilities provided are comprehensive, and it is considered that the introduction of these test sets should fulfil a long-felt requirement by mechanical officers in Country Districts.

THE MULTIVERSAL TEST SET

C. A. Knight, B.Sc.

The Multiversal Test Set, as manufactured by Elliott Brothers (London), is an instrument designed for the purpose of locating faults in aerial lines and underground cables, and it is used for this purpose at many mechanics' stations where no Toll Test Position is provided. The set is extremely accurate and is very simple to operate.

In principle, it is a form of Wheatstone Bridge possessing the usual two ratio arms R_1 and R_2, and a variable resistance R_3 which can be varied from 1 ohm to 110 ohms in steps of 1 ohm. (See Fig. 1.)

This variable resistance R_3 is usually supplemented by a hundreds unit connected to the side of the instrument by heavy copper connecting straps, thus giving a range for R_3 from 1 ohm to 1110 ohms.

The galvanometer is a very sensitive moving coil instrument having a resistance of 750 ohms and giving a deflection of one scale division for one microampere. It is provided with a constant resistance shunt to vary the sensitivity of the bridge and to protect the galvanometer.

The galvanometer and battery switches are mechanically linked so that the battery circuit is closed before the galvanometer is connected across the bridge. The battery switch is in circuit when an ordinary wheatstone bridge test is being made, but not when a Varley or Murray Loop test is being carried out.

A schematic circuit of the Test Set is shown in Fig. 2. On comparing this with the schematic diagram for the normal Wheatstone Bridge, it will be seen that the ratio arm R_1 and the variable resistance R_3 are interchanged or, what amounts to the same thing, the battery and galvanometer have been interchanged.

This has no effect on the method of operation of the set or the calculation of the resistance so far as the direct measurement of resistance is concerned, but it will be seen later that it makes the calculation of the Varley Loop Test a little more complex.

To measure an unknown resistance x, this is connected across the terminals B and M, a battery of not more than 6 volts is inserted at C and the resistance R_3 is varied until no deflection is noted in the galvanometer when the bridge key is depressed.

The resistance x is then given by the equation:—

$$x = \frac{R_1 R_3}{R_2}$$

Locating an earth fault by Varley's Loop Test. —The faulty wire is first connected to a good line at the distant station. The good line is then connected to terminal B of the set, the faulty wire to terminal M, and the resistance of the loop found by varying R_3 as described above. However, to avoid damage to the galvanometer, begin to balance the bridge with the galvanometer shunt on the 1/300 stud and as a balance is approached reduce the shunt step by step

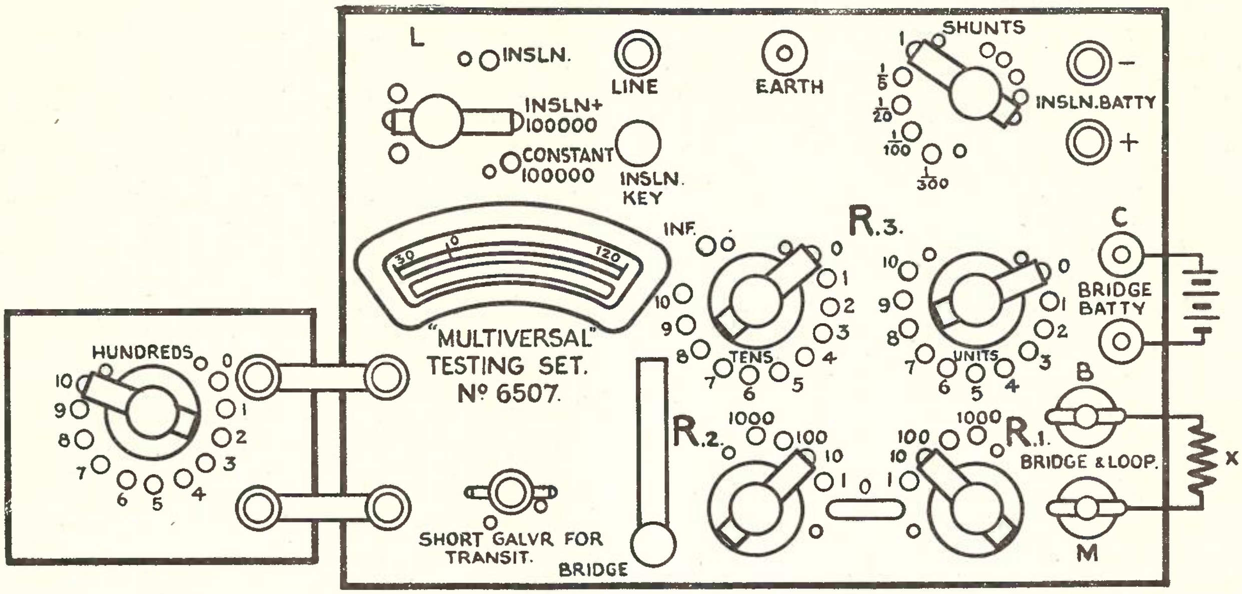


Fig. 1.—Multiversal Test Set.

For this test, ratio arms R_1 and R_2 are adjusted to give the maximum reading with R_3. The loop resistance L is then given by the equation—

$$L = \frac{R_1 R_3}{R_2}$$

The Varley earth test is then made by connecting the battery across the battery terminal C, and an outside earth, and once again varying R_3 until no deflection is observed in the galvanometer. The arrangement of the bridge is then as shown in Fig. 3.

$$\text{Then } \frac{R_2}{R_3} = \frac{R_1 + x}{L - x}$$

$$\text{and } R_2 L - R_2 x = R_1 R_3 + R_3 x$$

$$\text{whence } x = \frac{R_2 L - R_1 R_3}{R_2 + R_3}$$

where L = loop resistance as found in the first test,
x = resistance from the testing station to the fault.

It will be noted on comparing this equation with that shown on page 20 of the handbook supplied with the set that some books have a misprint giving R_1 instead of R_3 in the denominator. This may account for the difficulty some have found in obtaining accurate results with the instrument.

When making this test, use $R_1 = 10$ ohms and R_2 as high as possible. The battery should be connected last as the switch is not in circuit when this earth test is being made.

It may be necessary to increase the battery voltage when making this Varley Earth Test. until a final balance is obtained on the units switch of R_3.

Two points are here worthy of note. If the ratio arms are made equal (i.e., $R_1 = R_2$) the equation reduces to the form—

$$x = \frac{L - R_3}{1 - R_3/R_2}$$

This is a fairly simple form but not so simple as that obtained with the orthodox arrangement of the Wheatstone Bridge. Secondly, with the orthodox bridge when a lineman seeking an earth fault on a line comes through for a check test,

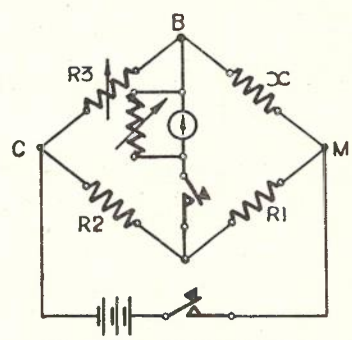


Fig. 2.—Wheatstone Bridge.

it is simple to prove whether he is on the station side of the fault or not (see "Fault Location Tests on Trunk Lines," Vol. 3, No. 1, page 28). With the Multiversal Test Set using the Varley method, a full loop resistance and Varley earth test must be made and the resistance to the fault calculated as in the original fault test. If the resistance to the fault is then equal to L/2 the earth fault is beyond the lineman.

Murray Loop Test.—Fortunately, by using the Murray Loop Test, the calculation of the resistance to the fault and the check test with the lineman become as simple as with the orthodox Wheatstone Bridge.

To make the Murray Test connect the good line to B and the faulty line to M as with the Varley Test, and measure the loop resistance L

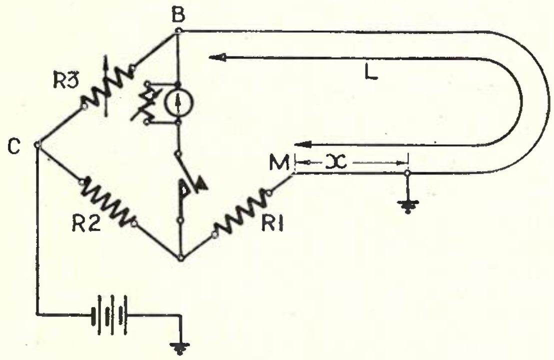


Fig. 3.—Varley Earth Test.

as before. Then connect the battery as for the Varley Earth Test, switch the ratio arm R_1 to the O stud and balance the bridge by means of R_3. The schematic diagram of this arrangement is then as shown in Fig. 4.

The resistance x to the fault is given by—

$$x = \frac{R_2 L}{R_2 + R_3}$$

To make a check test with a fault lineman in order to determine on which side of a fault he is, there is no need to measure L. Simply switch R_1 to zero and balance the bridge to the lineman's short circuit. If $R_3 = R_2$ the fault is beyond the lineman. If R_3 differs from R_2 a full Murray Test must be made to determine the position of the earth fault.

It will be realized that after making a Varley test a very quick check can be made by simply switching R_1 to zero and rebalancing the bridge to give the resistance to the fault by the Murray Test.

Tests for Insulation Resistance.—The Multiversal Test Set has facilities for measuring insulation resistance up to 1000 megohms, potential difference from .75 millivolts to 1200 volts, and current measurements down to 1 microampere. The method of measuring these is described in detail in the handbook with the set and no elaboration is needed. With a 130 volt battery, insulation resistance up to 130 megohms may be measured.

Cable Faults. — In locating cable faults, the procedure is similar to that for trunk line faults. Testing from the exchange or cable distribution point nearest to the fault, use the Varley Earth Test to find the approximate position of the fault. This determines the manhole length in which the fault exists. If it is then necessary to find the exact position of the fault between the manholes open the cable in the manhole on each side of the fault, run out a good wire over this length, and connect it to a faulty cable conductor at the distant manhole. Make the test from the first manhole by connecting the good line to terminal B and the faulty cable conductor to terminal M. Measure the loop resistance and by the Varley Earth test find the resistance to the fault. Say this is x_1 (after the resistance of the lead from terminal M to the cable has been deducted).

Now proceed to the other manhole and make a similar test back to the first manhole. Let this resistance be x_2. Measure the length of the cable accurately from joint to joint (let this be L feet). Then the distance to the fault from the second manhole is—

$$(x_2 \times L)/(x_1 + x_2) \text{ ft.}$$

The points to remember in obtaining an accurate location of a cable fault are:—

(i) In measuring the resistance of the loop use ratios so that the resistance R_3 is as high as possible.

(ii) When making the Varley Earth Test use $R_2 = 1000$ and $R_1 = 10$ if possible.

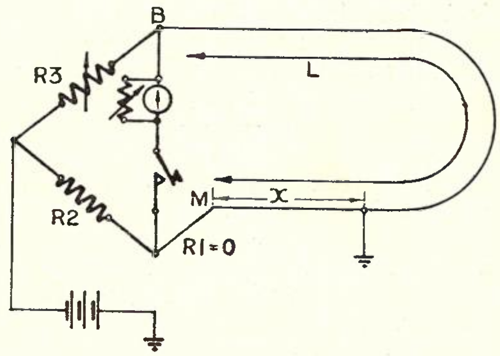


Fig. 4.—Murray Earth Test.

(iii) Do not forget to measure the resistance of the lead from the bridge terminal M to the cable and deduct this from the result to give the resistance of the fault from the cable joint to the fault.

(iv) Do not rely on the resistance per yard of the cable conductor, but make a Varley test from the manhole on either side of the fault and divide the length of the intervening cable as described above.

(v) Do not rely on lengths shown in the cable plan as these are usually from centre to centre of manhole and make no allowance for the cable around the wall of the manhole.

(vi) Keep any rain off the face of the bridge and so avoid surface leakage.

If these precautions are observed no difficulty should be found in locating a fault to within eight inches over a 100 yard manhole length.

A GENERAL SURVEY OF THE TELEPHONE CABLE CORROSION PROBLEM

C. J. Griffiths, M.E.E.

Introduction.—Following a number of years of co-operative treatment of stray current corrosion in the capital cities, it was felt by those interested in the corrosion problem that although a certain liaison existed between the Electrolysis Committees concerned, a firmer basis of Commonwealth wide co-operation was desirable. Being neither a "Plaintiff" nor a "Defendant" in the corrosion problem, and with a suitable organization already established, it was generally agreed that the Council for Scientific and Industrial Research was the best equipped to carry out the work of co-ordination.

In May, 1939, a meeting of representative reticulation and traction Authorities was called by the C.S.I.R. to discuss objectives and procedure. Arising from this meeting it was decided to establish a Soil Corrosion Bureau with similar objectives to those of the Bureau of Standards in U.S.A. Briefly, these objectives were:—

(1) Assembly of information and dissemination to interested authorities.

(2) Extension of the co-operation and interchange of results between investigators engaged on the corrosion problem.

(3) Co-ordination of corrosion investigations and where necessary initiation of research on particular problems.

A two-day conference to provide an opportunity for general discussion of corrosion problems was arranged to follow the Institution of Engineers, Aust., annual conference at Newcastle in October, 1939. Owing to the outbreak of hostilities both of these conferences were cancelled. Although the conference was cancelled, it was agreed to continue with the establishment of the Soil Corrosion Bureau, and to issue papers which would outline the general pattern of the corrosion problem throughout the Commonwealth. The following papers have so far been issued in this series:—

"The Mechanism of Corrosion" — I. W. Wark, Ph.D.

"Soils and Soil Corrosion"—Prof. J. A. Prescott, D.Sc.

"Some Notes on the Fourth (1937) Soil Corrosion Conference held at the National Bureau of Standards, Washington, D.C."—C. M. Longfield, M.E., B.Com.

"Some Aspects of Soil Corrosion in Australia"—A. E. Kelso, M.M., M.C.E., M.I.E.Aust., A.M.-Inst.C.E.

"Survey of the Telephone Cable Corrosion Problem in the Postmaster-General's Department" —C. J. Griffiths, M.E.E.

"Results of Research on Soil Corrosion by the Australian Gas Light Company"—F. A. Gaydon, B.E.

Two information circulars dealing with stray current corrosion from contacts with bridge structures and corrosion of petrol and oil storage tanks respectively are to be issued shortly. Three further circulars on corrosion due to concentrations of acids or alkalis in the ground, contacts between dissimilar metals, and the cathodic protection of structures respectively are in course of preparation.

It is the object of the present paper to outline the more important aspects of the problem in relation to telephone cables.

Analysis of Plant Conditions.—First it is of interest to review in Table 1 the position of the Department in relation to the owners of other reticulations throughout the Commonwealth. Several important points emerge from examination of this table:—

(i) Corrosion of underground systems is primarily concerned with two metals—lead and iron (copper is used to some extent for household water services but its general influence at present is small).

(ii) The Department is the only Commonwealth authority among the principal reticulation authorities.

(iii) A sufficient amount of money is involved in the various installations to make even comparatively small percentage reductions in corrosion worthwhile.

(iv) The wide diversity of authorities who are or should be interested in corrosion and its prevention.

Extent of Problem.—As its name implies, the Soil Corrosion Bureau is primarily concerned either with stray current corrosion or soil corrosion, but in dealing in this paper with telephone cables, all forms of cable damage will be included in order to place cable corrosion in its correct perspective. Table 2 sets out the total number of faults and costs throughout the Commonwealth of the main types of cable failure for the years 1938 to 1941 inclusive. Expressed as a percentage, the distribution (averaged over 4 years) is of the following order:—

Electrolysis	26%
Chemical Corrosion	2.5%
Intercrystalline damage	17.5%
Miscellaneous damage	54%

The cable failures are in general proportional to the mileage of underground cable existing in each State, varied to some extent by the severity of stray current electrolysis influences. Taking one particular year (1940) as an example, Table 3 shows the manner in which the cable failures are distributed between the country and metropolitan networks, and the preponderance of damage in the latter areas.

Fault Analysis.—The preparation of a satisfactory cable fault analysis begins with the initial recording of the fault details by the lines staff engaged on the repair work, and the immediate field examination of causes. A careful check of the circumstances of the fault at the time of occurrence will, in many cases, obviate either an incorrect designation of the cause or lengthy investigations subsequently when the same facilities for examining the fault conditions may not be available. Departmental procedure briefly is as follows: Immediately on the occurrence of a cable failure, advice of all relevant information available is forwarded simultaneously to the Divisional Engineer in charge of the area concerned and to the Electrolysis Engineer of the State. At this stage a fault sequence number is issued and a ready identification provided for the fault record itself as well as other information related to the fault (such as samples, tests, etc.). It is now the responsibility of the Electrolysis Engineer with his specialized knowledge to ensure the collection of adequate data to determine definitely the cause of the failure, to carry out investigations in the field or laboratory, and to consider the application of remedial measures to prevent a recurrence of the trouble. Each month a summary of cable failures is prepared in each State, and this sets out:—

the sequence number,
exchange area,
street location,
cable number,

TABLE NO. 1
SUMMARY OF THE VALUE OF THE UNDERGROUND PLANT IN THE COMMONWEALTH
(Prepared 17/8/39.)

	System	Number of authorities concerned in amount in Column 4	Value of underground plant	Percentage of total	Remarks
1	2	3	4	5	6
1	Water Supply	11	£26,300,000	43.1	Except in the case of 4, these figures do not represent a complete survey of underground plant in any particular subdivision. The total value of all underground plant is estimated to be about £80,000,000.
2	Gas Supply	12	£9,000,000	14.8	
3	Oil Companies	2	£560,000	0.9	
4	Postmaster-General's Department	1	£13,700,000	22.5	
5	Electricity Supply	10	£8,640,000	14.2	
6	Railway	4	£1,850,000	3.0	
7	Tramway	3	£930,000	1.5	
	Total	43	£60,980,000	100.0	

TABLE NO. 2
TELEPHONE CABLE FAILURES — 1938 TO 1941

Year	Electrolysis		Chemical Corrosion		Intercrystalline Fracture		Miscellaneous		Total	
	No.	Cost	No.	Cost	No.	Cost	No.	Cost	No.	Cost
1938	730	£5,611	78	£693	754	£5,743	1884	£12,977	3446	£25,024
1939	1063	£7,132	102	£1,022	965	£6,244	2489	£17,813	4619	£32,211
1940	1424	£7,602	91	£841	666	£3,998	2455	£15,708	4636	£28,149
1941	1924	£9,083	103	£893	694	£4,063	2555	£16,840	5276	£30,879
4 year average	1285	£7,357	94	£862	770	£5,012	2346	£15,835	4494	£29,066

cable size and type,
date and time of fault occurrence,
date and time of cable restoration,
type of conduit or method of cable installation,
cost,

TABLE NO. 3

TELEPHONE CABLE FAILURES—DISTRIBUTION BETWEEN COUNTRY AND METROPOLITAN AREAS, 1940

Area	Corrosion—Electrolysis and Chemical		Intercrystalline Fracture		Miscellaneous Damage		Total	
	No.	Cost	No.	Cost	No.	Cost	No.	Cost
Country	232	£2,150	195	£1,285	1015	£7,190	1442	£10,625
Metropolitan	1283	£6,293	471	£2,713	1440	£8,518	3194	£17,524
Total	1515	£8,443	666	£3,998	2455	£15,708	4636	£28,149

cause,
remarks.

Each State summary is subject to analysis in the Chief Engineer's Branch to provide a basis for unified action in the investigation work and provision of remedial measures and to consider general changes in material and construction methods which may be indicated by the fault statistics. On account of the large variety of causes associated with faults on telephone cables, considerable flexibility in method of segregating the failures is possible. From the point of view of both investigations and the subsequent consideration of preventive measures, the most convenient primary subdivision is that already referred to, namely:—

Electrolysis.
Chemical Corrosion.
Intercrystalline Fracture.
Miscellaneous.

A secondary subdivision of each of these main divisions is made in the following manner:—

Electrolysis.
Earthenware pipes or conduits.
Concrete pipes or conduits.
Iron pipes.
Buried cable.
Manhole and tunnel.

Chemical Corrosion.
Earthenware pipes or conduits.
Concrete pipes or conduits.
Iron Pipes.
Buried Cable.
Manhole and tunnel.

Intercrystalline Fracture.
Conduit—all types.
Buried cable.
Manhole and tunnel.
Cable terminal poles.
Bridges.
Walls.
Aerial cables.

Miscellaneous.
Lightning.
Contacts with power lines.
Mechanical damage by outside authorities.
Due to Departmental workmanship or construction.
Cable terminal boxes.
Termites.
Rodents and borers.
Faulty manufacture.
Unknown.

The two essential details recorded in the analysis are the number of faults and their cost, these two characteristics being plotted against time in monthly intervals with the object of readily determining trends in fault occurrence and any variations which may be co-related with seasonal changes, traction conditions, etc.

Causes of Damage

As a general guide to the classification adopted in the analysis of telephone cable fault conditions, a brief description of the four primary divisions of Electrolysis, Chemical Corrosion, Intercrystalline Fracture and Miscellaneous will be given.

Electrolysis.—Faults under this heading may be due to:—

(1) Stray traction currents.
(2) D.C. supply systems.
(3) Fire alarm systems.
(4) Telephone exchange currents.
(5) Telegraph and signalling circuits.
(6) "Galvanic" or "long line" currents.

Damage due to (1) Stray traction currents, both by its magnitude and the manner of treatment by co-operative committees and the joint application of remedial measures, places this problem in a separate category to the remaining causes. The other sources subdivide into two broad headings covering firstly, conditions where the current flow is due to externally applied potentials, namely, (2) D.C. supply systems, (3) fire alarm systems, (4) telephone exchange currents, and (5) telegraph and signalling circuits, and secondly (6) "Galvanic" currents.

Where telegraph, signalling, and similar equipment operates on earth return circuits, it is necessary to ensure that these operating currents do not pass to earth via the cable sheaths. Only in isolated cases does the problem of fire alarm circuits arise as firstly, the majority of such systems operated on the "open-circuit" rather than the "closed circuit" principle, and secondly, the chance connection of the system to the cable sheath as an earth is rare. Owing to the statutory limitation of one earthing point on the neutral wire of the supply system, the possibility of damage by D.C. supply system is small, although isolated instances of such damage have been recorded, due, generally, to faulty line insulation, but in some instances to intentional earth connections setting up appreciable ground leakage currents.

In the case of "galvanic" or "long line" currents, the provision of trunk cables in recent years involving long lengths of cable passing through widely different types of soils (or electrolytes) has necessitated close attention to this source of damage. Under this heading are listed current sources due to variation in the soil conditions from point to point, variation in oxygen concentration, and differences in electrode conditions such as the connection of the cable to a copper earthing system. In a recent article on the "Causes of Corrosion Currents" (Industrial and Engineering Chemistry, August, 1941, pages 1001-1010) R. B. Mears and R. H. Brown list "Known or Possible Causes" under this heading as—(1) Impurities in the corroding metal, (2) Grain boundaries, (3) Orientation of grains, (4) Differential grain size, (5) Differential thermal treatment, (6) Surface roughness, (7) Local scratches or abrasions, (8) Difference in shape, (9) Differential strain, (10) Differential pre-exposure to air or oxygen, (11) Differential concentration or composition of the corroding solution, (12) Differential aeration, (13) Differential heating, (14) Differential illumination, (15) Differential agitation, (16) Contact with dissimilar metals, and (17) Complex cells. Fortunately, only a few of this list play any important part in the corrosion of telephone cables.

Until recently, electrolysis damage, particularly from stray traction current, was practically all of the anodic type. In recent years, however, and following the extensive introduction of underground cable distribution for house services, using 1 and 2 pair sizes in galvanized or black iron pipe, considerable "cathodic" or "alkaline" corrosion has developed on this type of construction. Although principally occurring in traction "cathodic" areas, cases have occurred in areas remote from traction systems. At present this type of corrosion represents approximately 80% of the total number of faults listed under electrolysis and 60% of the cost.

Chemical Corrosion. — Chemical corrosion represents a comparatively small proportion of the total damage. Typical sources of damage are acetic acid from decaying wood, free lime from insufficiently cured cement, drainage into the conduit system from stables or other contaminated sources. An interesting example of corrosion, and the first of its type recorded on telephone cables in Australia, was recently observed due to microbiological aerobic action. A petrol-alcohol mixture penetrated into the cable duct from a petrol bowser, and action by micro-organisms termed "Mycodermae Aceti" on the alcohol caused fermentation and the development of acetic acid which rapidly attacked the cable. The action of the micro-organisms in this case is very similar to the controlled cultures used to produce "wine vinegar."

This type of corrosion has received considerable attention in recent years; in U.S.A. particularly, following the presentation of a paper, "The Unity of the Anaerobic and Aerobic Iron Corrosion Process in the Soil" by Doctor C. A. H. Von Wolzogen Kuhr, The Hague, Holland, at the fourth conference on Underground Corrosion of the National Bureau of Standards in 1937. Aerobic corrosion refers to bacterial action occurring in the presence of air, whilst anaerobic corrosion requires airtight or water saturated conditions. In the case of iron or steel corrosion experienced on water and oil pipe lines, the damage is of the anaerobic type and is attributed to sulphate reducing microbes ("vibrio desulfuricans" and derivatives).

Intercrystalline Fracture. — In common with most metals, lead is crystalline in formation and liable to inter-crystalline fracture when subject to repeated alternations of stress. The inter-crystalline nature of the attack is shown by the photo-micrograph, Fig. 1. In comparison with steel or aluminium, lead is particularly susceptible to such damage, and its behaviour under such conditions has been the subject of wide investigation. Unfortunately, the number of necessary variable conditions which must be associated with the investigations including the creep conditions, temperature, alloy content, method of test as well as the difficulty of translating the laboratory results in terms of practical cable conditions, leaves a large field yet to be covered before the problem is solved. However, the important features of this type of damage as applied to telephone cable conditions may be summarized in the following:—

The location of the cable in relation to the method of support is of primary importance. For example, the method of handling cables and the provision of adequate support for cables in manholes at the duct entry and along the wall of the manhole are important factors in fault prevention which are very often neglected.

Cables in ducts and buried directly in ground are relatively free from damage and the appro-

Fig. 1.—Inter-crystalline fracture of Cable Sheath. Etched section showing cracks following crystal boundaries.

ximate order of "non-susceptibility" including the distribution of damage due to inter-crystalline fracture for the year 1940 is:—

	Percentage No.	Percentage Cost
Ducts or buried cable	17.9	27.6
Manholes and tunnels	22.7	25.0
Cable terminal poles	29.2	21.0
Walls of buildings	2.4	4.2
Bridges	23.0	15.7
Aerial cables	4.8	6.5

The addition of antimony, tin, cadmium, calcium, tellurium or copper in quantities varying from 0.05% in the case of calcium to 3% for tin, by materially decreasing the grain size increases the resistance of the sheath to intercrystalline fracture. The relative value of these alloy types varies with the investigator and the method of test, but the addition of alloys increases the resistance to fatigue approximately three times that of pure lead. Taking into consideration both cost and resistance to intercrystalline fracture, Departmental practice has provided for an alloy of 0.8 to 0.9% of antimony for cables liable to damage in this manner.

Sun temperatures between 100 deg. and 150 deg. F. play an important part by increasing the crystal size and reducing the resistance to vibration.

Where, due to abnormal conditions, static stress is applied to the sheath, the failure becomes intra-crystalline rather than inter-crystalline, that is, parting of the lead occurs irrespective of grain boundaries. Such failures are classed under Miscellaneous and not Intercrystalline Fracture.

Miscellaneous (see Table No. 4).—The greater proportion of causes under this heading are associated with mechanical damage to the sheath arising from Departmental activities or due to the operations of other authorities or individuals. The mechanical damage may be caused by picks, crowbars, tractors, ploughs, horses' hoofs in soft ground, drills and even by hacksaws in the hands of plumbers preparing to repair a water or gas service. Lightning and power contact faults, although relatively small in number and cost, are important because of the hazards involved to telephone operators, lines staff, and internal equipment. The cable breakdown may be due to lightning or to power contacts on the open wire portion of a route connecting into underground cable. In some instances the breakdown is assisted by incipient low insulation of cable pairs due to previous moisture penetration of the cable insufficient to prevent operation of the telephone circuits. In other cases direct contact of the cable occurs with a heavy current source, and a typical example of this type is the heavy discharge of current on to a cable sheath which occurs when a "flashover" or breakdown of the live wire takes place to a bridge or car sheds with which the cable is in direct contact. Lightning damage tends to concentrate in "susceptible" areas determined principally by the geological structure of the country. For example, such damage is particularly severe in the vicinity of Mounts St. Bernard and Hotham in the Alpine region of Victoria. In this case severe conditions are produced by the cable lying along the top of a very high resistivity rock razorback and thus providing a low resistivity path for the lightning.

Termite damage is more extensive in the dry and warmer areas of the Commonwealth such as Northern Victoria, South Australia, Central and Northern New South Wales and Queensland. Faults are widely distributed and because of the vagaries of the termite in its attack on cables it is difficult to provide comprehensive preventive measures. The damage to the cable is caused primarily by the mandibles of the termite rather than chemical attack from secreted acids. The hole in the sheath is difficult in some cases to distinguish from a nail hole or similar mechanical damage, and can only be confirmed by observation of the mandible marks by a microscope. Fig. 2 shows photomicrographs of termite attack magnified x 4 and x 30 diameters.

Many of the faults under the heading Disposition of Cable in Manhole and Faulty Installation result from the "creep" of the lead sheath under stress. In contrast to intercrystalline failures, the fracture in the case of "creep" is intracrystalline.

Accidental damage includes such causes as fires, collision of vehicles with Departmental plant, etc., and Miscellaneous Departmental causes include such headings as insecure temporary rubber joints, the use of cables as steps in manholes, etc.

TABLE NO. 4

DISTRIBUTION OF MISCELLANEOUS CABLE DAMAGE, 1940

Cause of Fault	Number of failures		Cost	
	No.	Per cent.	Amount	Per cent.
Mechanical Damage by Outside Authorities:				
Councils and Road Authorities	155	6.30	£1084	6.90
Gas Supply	15	.63	£73	.46
Water Supply	55	2.24	£258	1.64
Building and similar Contractors	92	3.75	£340	2.16
Railway, Tramway and Electricity Supply	12	.49	£51	.33
Miscellaneous, including private individuals	425	17.30	£2387	15.18
Sub-total	754	30.71	£4193	26.67
Departmental:				
Disposition of cable in manhole	108	4.40	818	5.21
Faulty plumbing	171	6.97	1370	8.72
Drawing-in or out	88	3.59	534	3.40
Cable boxes and pillars	128	5.22	597	3.80
Faulty installation—				
Pits	74	3.02	319	2.03
Terminal poles	90	3.66	379	2.42
Conduit and buried cable	17	.70	130	.84
Miscellaneous	84	3.42	523	3.34
Sub-total	760	30.98	£4670	29.76
Others:				
Accidental damage	210	8.60	£1624	10.33
Lightning	91	3.70	£787	5.01
Contacts with power lines	26	1.05	£146	.93
Termites	156	6.31	£1547	9.85
Rodents and borers	100	4.07	£531	3.38
Faulty manufacture	88	3.58	£535	3.41
Unknown	270	11.00	£1675	10.66
Sub-total	941	38.31	£6845	43.57
Grand Total	2455	100.00	£15,708	100.00

Faulty manufacture is generally associated with sheath weaknesses caused by "dross" or gas inclusions in the lead during the extrusion process. Fig. 3 shows two typical examples of failures of this type.

Remedial Measures

Interpreted in their broadcast sense, remedial measures commence with the initial planning of the conduit and cable installation. The aim of the telephone engineer and in fact any reticulation engineer is to provide an adequate standard of service with reasonable security of operation at a minimum annual charge. The standard of service will be determined primarily by the class of cable concerned, namely, subscribers', junction or trunk. Security of operation is to a large extent a relative term, and as complete security is economically unobtainable, the setting up of a pre-determined standard of fault occurrence must be primarily on an arbitrary basis and guided largely by experience over many years of construction types, fault statistics and subsequent preventive measures on plant in situ. Apart from the value placed upon the "Security of service" in any particular case, it is evident from the statistics already quoted that an annual fault cost of £25,000-£30,000 on cable and conduit plant valued at over £14,000,000 leaves little scope for any material increase in capital expenditure on construction practices in the direction of further "protection." In the following summary a brief outline is given of the Departmental practices in fault prevention.

Electrolysis.—For dealing with stray traction current conditions, the co-operative committee method has been very successful and such committees are at present operating in Sydney (1933), Newcastle (1938), Melbourne, including Ballarat, Bendigo and Geelong (1927), Brisbane (1939) and Adelaide (1931). These committees include representatives of the traction authorities and principal reticulation owners. In Western Australia (Perth and Fremantle) and Tasmania

(Hobart and Launceston), the equivalent of co-operative committees is operating. The preventive measures adopted are:—

(1) **Applied to the traction system.**

Adjustment of substation feeding conditions.

Improvements in track resistance and track leakage conditions.

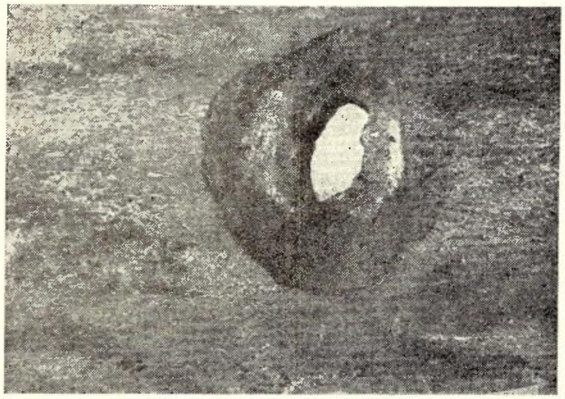


Fig. 2.—Termite attack. Photomicrograph of markings × 4 diameters.

Fig. 2A.—Termite attack. Photomicrograph of markings × 30 diameters.

(2) **Applied jointly to traction and reticulation systems.**

Drainage bonds.

(a) Direct to the negative return of the traction system through suitable fuse, resistances and copper oxide rectifiers or relay switches.

(b) Boosted by means of D.C. obtained from the Supply Mains, associated transformer and copper oxide rectifiers.

(3) **Applied to the telephone cable.**

Zinc plates.

Insulating joints.

Both the track feeding and track leakage resistance conditions can materially influence the extent of the current leakage from the traction systems and increase the difficulties of dealing satisfactorily with the electrolysis damage. The installation and maintenance of the satisfactory

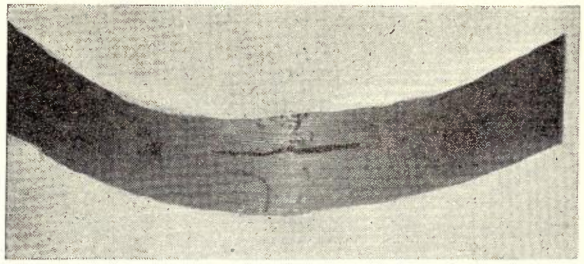


Fig. 3.—Manufacturing defect. Photomicrograph of section of sheathing × 8 diameters showing a void in the sheath due to gas inclusion.

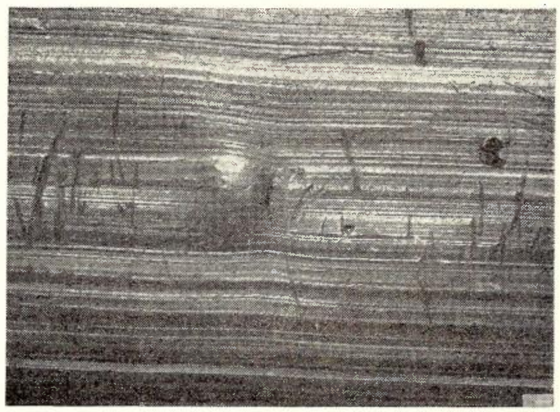


Fig. 3A.—Manufacturing defect. Photomicrograph × 8 diameters showing a transverse crack close to a "dross" protruberance on the sheath.

drainage bond system pre-supposes a well maintained traction system. The principal remedial measure is the drainage bond (approximately 340 are installed on Departmental cables throughout the Commonwealth) and its importance in reducing damage is shown by the graphs, Figs. 4 and 5 for Sydney and Melbourne conditions respectively.

Both the zinc plate and the insulating joints are used to a very small extent. Their application is primarily to small cables where the current discharge is low and other methods of treatment are not practicable.

A typical boosted drainage bond for electrolysis purposes is shown in Fig. 6.

For electrolysis arising from "non-traction" conditions, the first step is the investigation, and where practicable, the isolation of the source. In the case of fire alarms, D.C. supply systems, telegraph, dialling and similar exchange currents and connections to copper earthing or reticulation systems, the isolation of the source is preferable and is generally practicable.

In the case of "galvanic" or "long line" currents, cathodic protection either by zinc plates or boosted drainage bonds and insulating coverings are the principal protective measures. In determining the extent and location of these measures considerable assistance is provided by soil restivity survey along the cable route and current measurements at selected points.

Two particular applications of boosted drainage bonds for cathodic protection against "galvanic" currents are the Sydney-Newcastle-Maitland (124 miles) and Melbourne-Seymour (60 miles) trunk cable systems. For example,

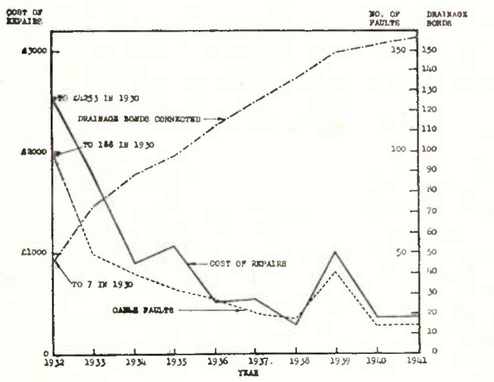


Fig. 4.—Influence of drainage bonds on anodic electrolysis failures due to stray traction current in the Melbourne network.

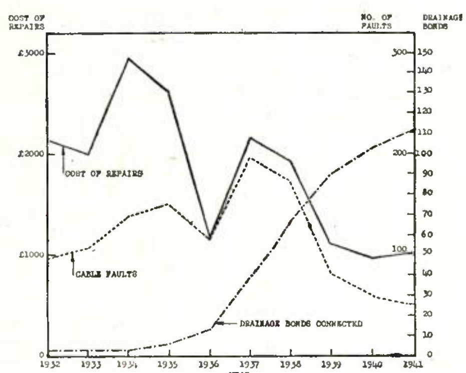


Fig. 5.—Influence of drainage bonds on anodic electrolysis due to stray traction current in the Sydney network.

on the route of the former, the following drainage bond installations have been made or are approaching completion:—

No.	Section of Route	Direct Drainage to Traction System	Boosted Drainage to Traction System	Boosted Drainage beyond Traction Networks	Mileage of Route concerned
1	Sydney Network	13	2	—	21
2	Newcastle Network	4	1	—	6
3	Remainder of cable	—	—	12	97

For eleven of the twelve boosted drainage bonds for cathodic protection purposes commercial power supply was available, but for one at Wallarah Creek it was necessary to use a windmill generator for the power supply. The maximum output is 12 v. 20 amp. and the unit is mounted on a 60 ft. steel tower to provide adequate clearance from the surrounding bush. Although a common method of supplying power for cathodic protection on oil and water pipe lines in U.S.A., the Wallarah Creek installation represents the first of its type in Australia specifically for cathodic protection.

Fig. 6.—Boosted type drainage bond for electrolysis protection.

The principal remedial measures adopted for "cathodic" or "alkaline" corrosion on small cables in iron pipe are the extensive use of petroleum jelly in drawing the cable into the pipe and a change in the type of construction to bitumen and jute protected and armoured cable.

Chemical Corrosion.—The treatment of chemical corrosion is largely associated with either the removal of the source of contamination, the re-routing of the cable or the provision of an insulating covering.

Intercrystalline Fracture.—Prevention follows three main directions:—

Provision of an alloy sheath—where a particular cable is likely to be subject to vibration, and in the case of subscribers' cables up to 54 pairs in size, a sheath with 0.8-0.9% of antimony is provided. Statistics show that subscribers' cables up to 54 pair are the most liable to vibration due to the location of these cable sizes in the distribution system (on walls, cable terminal poles, etc.).

The design of the distribution system to obviate locations subject to vibration (bridges) or high temperature (walls). In the case of river bridges the use of a submarine cable is often a preferable arrangement.

Where locations such as bridges or walls cannot be avoided the adoption of construction practices to limit the influence of vibration and temperature (jute wrappings and steel tape or wire armouring protection, and the provision of adequate supports).

Apart from the precautions adopted in installation of cables it is important to ensure that the conditions of transport of the cable to the site does not set up incipient intercrystalline fracture. The use of an alloy sheath, and subsequent care in installation, will not compensate for severe transport conditions, particularly over long railway journeys. Under some conditions it may be necessary to specify armoured cable to reduce the possibility of vibration damage during transport.

Miscellaneous.—As will be seen from Table No. 4, the causes of failures under this heading are widely distributed and a large proportion is beyond the direct control of the Department. They are, consequently, the most difficult to design remedial measures for. The following outlines the more important of the methods adopted to reduce this form of damage:—

For cables laid directly in the ground, the choice of a suitable location for the cable in the first instance, the provision of iron pipe or concrete cover boards at the more hazardous points, adequate marking and recording of the cable location (including advices to authorities likely to operate in the vicinity of the cable), and ensuring that the cable is at an adequate depth below the surface, form the best safeguards.

In the case of city and town cables in iron pipes and conduits, disturbance of the cables by outside sources is relatively infrequent and can best be guarded against by active co-operation between the various reticulation and similar authorities concerned.

Damage by Departmental workmen is largely a question of close supervision of construction and operational practices. The type of faults which occur at manholes, pits, terminal poles, etc., in many cases indicates the necessity for improvements either in the design of the equipment or the method of arranging the cable. In addition, the adequacy of linemen — training methods will be largely reflected in this fault subdivision.

In the case of lightning and power contacts, and where the desirable aim of complete separation cannot be obtained, the provision of suitable fuses and lightning arresters on Departmental plant, the provision of special earthing systems, and attention to the mutual arrangement of the power and communication systems, including possible alteration to open-wire crossing methods. increasing factors of safety, rearrangement of joint construction, etc.

Prevention of damage due to termites consists mainly of treatment of the cable system in areas affected with a repellant material such as Seekay wax (chlorinated napthalene and petroleum jelly). The efficacy of this method has not yet been proved and further investigation is required on this type of damage including entymological examination of the reasons why the termite attacks a metal such as lead.

Damage by rodents and borers is not extensive and can generally be eliminated by enclosing the cable in a pipe or treatment of the cable with a repellant material.

Faults arising from the manufacturing process involve close attention to the check testing of the cable at the factory, and to pressure tests in the field, in some cases both before and after installation.

Gas Pressure Alarm System.—Apart from the remedial measures outlined in the foregoing, and working on the principle that "prevention is better than cure," the gas pressure alarm system has been applied as a first step to the Sydney-Newcastle-Maitland trunk cable, and to the Melbourne-Seymour cable at present nearing completion. The general principles and method of operation are similar to the system used extensively by the A.T. & T. Company, of U.S.A.

With this arrangement, a continuous pressure of dry air at 15 lb./s.in. is maintained within the cable and Bourdon Gauge types of alarm connected to a pilot pair in the cable are distributed at regular intervals along the cable route. When a fault occurs the gas pressure falls and at a pre-determined pressure (10 lb./s.in.) the Gauge contacts short-circuit the alarm pair and provide a suitable audible or visible indication at the nearest exchange. Measurement of the loop resistance to the closed contact point, together with the measurements of the pressure gradient along the cable enable the fault to be located. The internal gas pressure prevents the ingress of moisture and due to the close packing of the conductors and paper insulation, an appreciable period elapses between the hole occurring in the sheath and the pressure approaching zero, thus permitting the trouble to be located, the sheath repaired, and continuity of service maintained.

Conclusion.—In a paper of this nature only general aspects of cable damage and corrosion can be dealt with. Many special and interesting problems arise in the course of the Department's investigation of cable damage throughout the Commonwealth, and these in many cases entail considerable field and laboratory testing. In this connection the work of the Research Laboratory, and in particular Mr. D. O'Donnell, has played an important part and forms a valuable contribution not only to the study of telephone cable damage, but to the corrosion problem generally.

AERIAL LINE CONSTRUCTION

A. S. Bundle

PART IV.—SETTING OUT POLE ROUTES (Continued)

This section deals with:

Layout of Transposition Sections.
Grading.

LAYOUT OF TRANSPOSITION SECTIONS

The planning of modern open-wire trunk routes requires special attention to crosstalk under the following headings:—

(a) Selection of transmission systems.
(b) Separation of conductors—pole plan, disposition of circuits.
(c) Transposition arrangements.

These have been dealt with by Mr. W. H. Walker, B.E.—Vol. 3, page 90—and the main object of the following is to illustrate the requirements of (c) in relation to the layout of transposition sections.

Before proceeding with the layout of sections some of the more important factors concerned are summarized.

Discontinuities.—It seldom occurs in practice that the electric conditions on a trunk route remain constant between main exchanges or repeater stations, variations being due to all or some of the following:—

(i) Increase or decrease in the number of telephone circuits.
(ii) A change in the "paralleling" of the telephone route by a power transmission line.
(iii) Intermediate offices.

Every point where the electrical conditions change is called a "discontinuity."

Use of Sections.—Because of discontinuities, it is necessary, when dealing with the transposition design of a route, to divide the route into a number of "sections" of several standard lengths, and to provide standard transposition designs for such sections. There are four standard transposition sections designated by the letters E, L, R and X, and having nominal lengths of 8, 4, 2 and ½ miles respectively. Table 7 shows details of these sections, including permissible variations. The section lengths are such, that any length of route may be divided into one or more complete transposition sections so arranged that each discontinuity occurs at a junction of two sections.

Basis of Transposition Section.—Primarily, a transposition section consists of a length of route divided into a number of (transposition) "intervals" of equal length. The lengths of the sections are based upon a uniform number of spans of uniform length, being 256, 128, 64 and 16 for E, L, R and X sections respectively, each span length being of the order of 55 yards. The permissible uniform increase or decrease in span length is shown in Table 7.

Transposition Designs.—For each route a transposition design is prepared for each type of transposition section required. This design is intended to provide satisfactory balance against crosstalk for the number and frequency ranges of carrier systems which will be required to operate over the route.

TABLE 7.—TRANSPOSITION SECTIONS

Designation	Nominal length	Nominal number of spans	Nominal average span-length	Maximum length	Minimum length	Normal Transposition Intervals: 10 K.C. (Usually fundamental transposition types)	30 K.C. (Usually single-extra transposition types)	150 K.C. (Involving double and triple-extra transposition types)
E	8 m.	256	165 ft.	8½ m.	7 m.	32	64	128
L	4 m.	128	165 ft.	4¼ m.	3½ m.	16	32	64
R (long)	2 m.	64	165 ft.	2⅛ m.	1¾ m.	8	16	32
R (short)	1 m.	32	165 ft.	1¼ m.	⅞ m.	8	16	32
X	½ m.	16	165 ft.	⅝ m.	7/16 m.	4	8	16

Note: The R section involves a maximum of 32 transposition intervals which would normally be 2 spans long, but a "short" R section is sometimes used in which the transposition intervals may, with 12-channel working, be single spans.

Fig. 24 shows a typical design for an R transposition section. The poles at the beginning and end of each section are called "section" or "S" poles. The intermediate poles which occur at the junctions of the various transposition intervals and which carry the transpositions are termed "transposition poles." They are referred to by the transposition letter, followed by a number indicating the position of the transposition pole in the section, e.g., R.1. is the first transposition pole in an "R" section. The "R" section transposition design in Fig. 24 is for 30 kc./sec. working and has 16 transposition intervals, each of which will be 2 spans long for the short "R" section, or 4 spans long for the long "R" section. It will be seen from Table 7 that, for 12-channel (150 kc./sec.) working, twice as many intervals each half as long would be used.

Pole Spacing Irregularities.—While the crosstalk calculations on which a transposition design is based assume that the transposition intervals will be exactly equal in length, in practice this is not always possible, because of obstructions such as rivers, roads, buildings, etc.

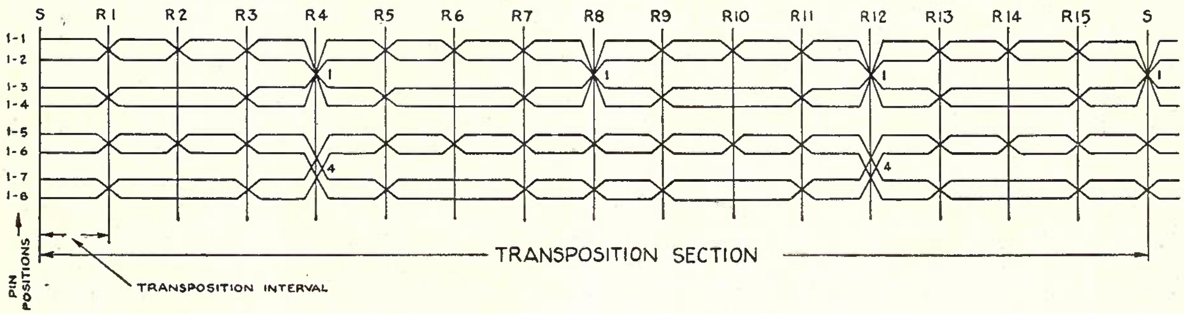


Fig. 24.—Typical Transposition Design (R section for Carrier Systems using Frequencies up to 30 kc./sec.).

This is provided for by an arbitrarily chosen "Irregularity Factor," which is the sum of the squares of the irregularities within a section (in feet) divided by the total length of the section (in feet). The irregularities are the variations of the lengths of the individual transposition intervals from the average transposition interval length. Thus, if a transposition pole is 10 ft. beyond the theoretical position one interval will be 10 ft. longer (i.e., a "plus" irregularity of 10 ft.), and the next one 10 ft. shorter (i.e., a "minus" irregularity of 10 ft.). If these be the only irregularities in a section of 2 miles, then the irregularity factor k will be:—

$$\frac{10^2 + 10^2}{2 \times 5280} = \frac{200}{10560} = 0.019$$

The maximum irregularity factors aimed at are 3 and 1 for frequency ranges up to 30 kc./sec. and 150 kc./sec., respectively, provided that the plus and minus irregularities are reasonably well distributed and not, for example, a series of small "minus" irregularities, combined with one "plus" irregularity. It is desirable to avoid large isolated irregularities exceeding 100 feet. On new routes it should be possible to layout the route with poling irregularities considerably less than the figures quoted, and normally the value of k should not be greater than 0.1.

When setting out a transposition section, the object should be to have the transposition poles as evenly spaced as possible. A basis for setting out the transposition poles when retransposing an existing route is to ensure that they are not more than 45 ft., for frequencies up to 30 kc./sec., or 18 ft. for frequencies up to 150 kc./sec., from the correct position. Having set the positions for the transposition poles, it is necessary then to review the whole of the irregularities and check that the irregularity factor is not exceeded. The actual irregularities permitted in any particular case will be influenced by local factors such as, whether a new or existing route is concerned, the extent of carrier system development, etc. This work would be done in the office from the information contained in the field book.

If a large obstruction such as a river crossing were found to limit the location of a transposition pole so that an irregularity exceeding 100 ft. would occur, then some other arrangement must be made, such as:—

(a) A revision of the pole locations, including the "S" poles.
(b) The provision of a special structure to provide for transpositions in the span.
(c) Insertion of a length of cable.
(d) Deviation of the route from the obstacle, or, in the case of a river-crossing, to a point where the river is narrower.

Power Parallels.—The commonest sources of electrical interference external to telephone routes are, power transmission lines running parallel and within fairly close proximity, normally within 150 ft.

It is usual for wires on 3-phase power lines to be transposed so that each in turn occupies for an equal distance each of the pin positions. The term "barrel" is used to describe a complete change in the wire positions of a transmission line, e.g., in a 6-mile barrel on a 3-phase line each wire will occupy one position for 2 miles and then be rotated to occupy another pin position for the next 2 miles and then rotated to occupy the remaining pin position for the balance of the distance. The points where the wire positions change have been referred to here as "barrel points" and it is important to arrange for this barrelling scheme to be co-ordinated with the transposition scheme on telephone circuits by having each barrel point opposite the section, $\frac{1}{4}$-section, $\frac{1}{2}$-section, or $\frac{3}{4}$-section points, of an E section, or the section and $\frac{1}{2}$-section points of an L section.

Layout of Transposition Sections.—Having accurately measured the route and noted discontinuities, as discussed in the previous issue of this Journal, the next stage is to divide the route into transposition sections in the light of the foregoing. Although the same general principles apply in each case, the problem will be different for new and existing routes.

Discontinuities in the telephone route must be made section boundaries, while discontinuities external to the route must be located opposite either the section, $\frac{1}{4}$-section or $\frac{1}{2}$-section, etc., points as described.

It is desirable to keep to the longer types of sections where practicable as the transposition design is simplified thereby.

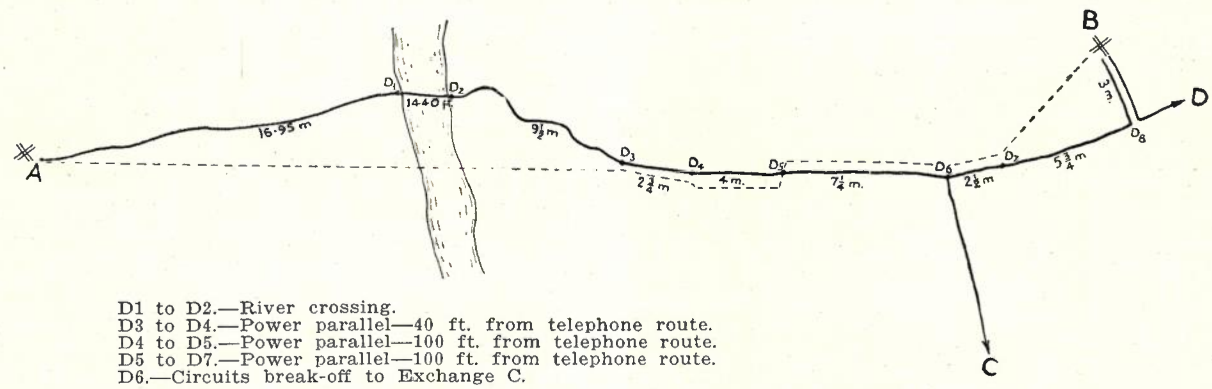
Example of Layout.—The division of a route into transposition sections is illustrated here by an example. Fig. 25 is a diagram of a route which includes most of the problems met with in practice. It is assumed that the route will be required to carry circuits using frequencies up to 30 kc./sec.

Fig. 26 shows the straight line diagram of the route illustrated in Fig. 25, with the proposed layout of transposition sections. The following paragraphs form explanatory notes showing how the layout was arrived at.

Starting from town A, the first problem is that of the river crossing and the method of dealing with it is to arrange for the "S" pole to be located theoretically at or near the centre of the river and with an "E" section on either side so as to spread the irregularities due to the long span lengths at the river, over long sections. Assuming the "S" pole is theoretically located in the centre of the river, the span lengths on either side of the imaginary "S" pole will be 720 ft. long. The average span length of the section towards A is 165 ft., and if the transposition scheme calls for 64 transposition intervals then the distance between the transposition would be 660 ft. The transposition at E63 would be put on the pole on the river bank and would leave two irregular transposition intervals with "minus" and "plus" irregularities respectively of 720-660 ft., i.e., 60 ft. The effect of this irregularity will be to give an irregularity factor, $k = (60^2 + 60^2)/8 \times 5280 = 0.17$, which is within the required limit and therefore satisfactory.

The above solution to the river crossing has been practicable in view of the comparatively short crossing, but if it had been longer, or for some other reason it was not practicable to keep the irregularity factors for the two adjacent "E" sections below the required limit, then consideration would have to be given to one of the alternatives mentioned previously.

It will be noted that some transposition patterns provide for transpositions at the "S" poles. These transpositions are provided to bring the wires back to the same positions as those they occupied at the beginning of the transposition section and thereby control the crosstalk summation of consecutive transposition sections. In the isolated cases of obstructions such as the river crossing referred to in the above example, they may be omitted.



D1 to D2.—River crossing.
D3 to D4.—Power parallel—40 ft. from telephone route.
D4 to D5.—Power parallel—100 ft. from telephone route.
D5 to D7.—Power parallel—100 ft. from telephone route.
D6.—Circuits break-off to Exchange C.

NOTES.—1. The route is expected to carry at least two 3-channel carrier system.
2. For mechanical strength a minimum of 32 poles per mile are required.
3. A 3-phase 66 kv. transmission line is indicated by the dotted line and crosses over the telephone line at D5.

Fig. 25.—Example of Pole Route.

The balance of the distance from "A" would be divided into an 8-mile "E" section and a short "R" section 1.08 miles long.

Beyond the river, thought must be given to the 40 ft. power parallel. It will be necessary for the transmission line to be "barrelled" over the distance of the close parallel, and for the barrel points to be co-ordinated with the transpositions on the telephone route.

This will mean barrel points 11/12 mile apart. The telephone transpositions must be co-ordinated with the barrel by arranging the section, $\frac{1}{4}$-section, $\frac{1}{2}$-section, or $\frac{3}{4}$-section points to be opposite the barrel points.

The distance from the "S" pole in the river to the "S" pole before D3 will, therefore, be 450 + ($9\frac{1}{2} - {}^{11}/_{12}$) 5280 feet = $8^2/_3$ miles. This is too long for an "E" section so that the distance is divided into an "E" section $7^2/_3$ miles long and a short "R" section one mile long.

The power crossing over the telephone route at D5 can be met simply by inserting a transposition in the power wires and the $11\frac{1}{4}$ mile section between D4 and D6 is thus treated as a whole with two barrels of equal length in the power line. The barrel points will thus occur at the $\frac{1}{4}$-section, $\frac{1}{2}$-section and $\frac{3}{4}$-section and section points of the "E" section and at the $\frac{1}{2}$-section point of the "L" section.

The section D6 to D7 will require a barrel in the power circuit with barrel points 5/6 of a mile apart and will thus result in an "L" section 3-1/3 miles long (i.e., 4 x 5/6 miles) with the barrel points opposite the $\frac{1}{4}$-section, $\frac{1}{2}$-section and $\frac{3}{4}$-section points.

The remaining 4-11/12 miles to D8 will be divided into an "L" section 3-11/12 miles long and a short "R" section 1 mile long.

The 3-mile loop could either be made an "L" section or be divided into a 2-mile "R" section and a 1-mile "R" section. Either method would be satisfactory electrically as the circuits to "A" can be kept on separate arms to those going to "D." The same number of transpositions would be required but an "L" section would need 128 spans each 123 ft. 9 in. long while the short and long "R" sections would altogether use 96 spans of 165 ft. each.

The example taken contains more discontinuities, and consequently more short transposition sections, than the average route, these being provided merely to illustrate the various methods of dealing with discontinuities.

Laying Out Existing Routes.—The layout of an existing route is usually more difficult than is the case of a new one because, for economy, it is necessary to fit the positions of existing poles into the scheme in the most advantageous manner. Normally, there are two methods of dealing with this problem:—

(a) By adopting a fixed distance for each transposition section and dividing this distance into the requisite number of intervals. The nearest pole to each transposition point would be used as the transposition pole or, if the pole is too far away, an additional pole would be erected at the correct position. The route would be planned so that as pole renewals take place the new poles would be erected in the correct positions.

(b) By counting off 1, 2, 3, or 4 spans per interval for the total number of intervals required in the transposition section.

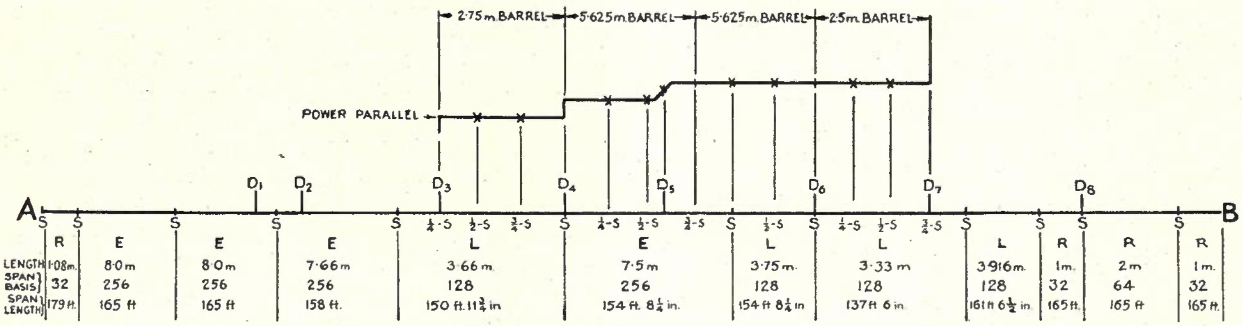


Fig. 26.—Layout of Transposition Sections of Route shown in Fig. 25.

Whether (a) or (b) is adopted will depend primarily upon the following factors:—

(1) The importance of the route.

(2) The maximum length of section permitted.

(3) The necessity for having "S" poles at certain points.

(4) The mechanical requirements of the route especially as related to the desirable length of span.

(5) The regularity of the spans.

(6) Whether the pole route has wood or iron poles. With a wood pole route, pole replacements will be involved year by year, and there is an opportunity to continuously reduce the irregularities. The route is thus continually improving as the demands for high-frequency circuits are increasing.

(7) The extent of the poles requiring replacement immediately, or within the next few years.

(8) How long the route has to cater for.

(9) Transposition types involved, i.e., some types will be more affected by irregularities than others.

(10) The extent of the transpositions in existing circuits which may have to be altered by the adoption of method (b), and the consequent alteration in length of the existing transposition section. A comparison of these transposition costs against the poling costs involved in method (a) is necessary.

(11) The proportion of sections in the route which have special irregularity conditions. Thus, if only one or two sections are involved, on a long route, and the costs are consequently small in proportion to the total cost of the route, there is less justification for permitting conditions on these sections to control the whole route.

Span Length.—The length of span between telephone poles is governed primarily by the strength of the poles used in relation to the loads they are to carry and the possibility of the wires contacting (which is much more likely in the case of long spans). Thus, it is necessary to consider the type of material used in telephone poles and their shape, and the wire tension and spacing and the importance of the route when determining what are the lengths of spans to be adopted.

The general practice is to work as closely as possible to an average span length of 55 yards (32 poles per mile) as this not only fits in reasonably well with the transposition design requirements and with the mechanical strength of average routes using wood poles of standard sizes, but also with the contact-liability of wires at standard spacing and tensioned to allow factors of safety of 2.5 to 3. With standard wires and 9 in. spacing no span should exceed 66 yards, and it is preferable to keep below 60 yards where possible.

Determination of Pole Positions on New Routes.—On new routes the length of the section is divided equally by the number of spans (see table 7) to find the average span length. Each pole location is checked against the presence of obstructions shown in the field book. If this check shows that the irregularities will be well within the permissible limit then the positions of the poles are entered in the field book.

Should the check prove that the irregularities would be excessive, the layout of the poles must be reviewed and if possible re-arranged, or some alternative method adopted to avoid or overcome the more serious obstructions as indicated in the foregoing notes.

On existing routes where the nearest pole to the ideal transposition point is used as the transposition pole, plans should be made at the time of the layout, for rearrangement of pole positions as pole renewals take place. This information is recorded on printed forms of semi-transparent paper, called "Pole Respacing Sheets." Blue-print copies of these sheets are then distributed to the Line Foreman and other officers concerned so that as each new pole is erected it will be positioned in accordance with the plan. (The location of the peg should be clearly marked on the existing pole by an arrow indicating the direction, and figures indicating the distance in feet.)

Pegging Out.—On new routes and preferably on existing routes, too, every pole position should be pegged out, special care being taken with the pegging of positions for transposition poles. As well as pegging new pole positions on existing routes the pole positions in relation to existing poles should be checked from the pole respacing sheets. This forms a reliable (and necessary) check upon the first measurement.

For setting out the positions of the pegs two methods are available:—

(a) To make a running chainage with the tape used in the previous measurement and marking off the peg positions at measurements previously set down in the field book; or

(b) To make a special tape from 150 or 200 lb. G.I. wire in 2, 3 or 4 sections, each the exact length of a span. Such a tape if properly labelled and stored is available for future measurements and checks over the transposition section or sections having the particular span length. It is advisable to check the length of the tape every 2 or 3 miles to ensure that it does not stretch.

Pegs.—The pegs used should be of good quality hardwood 2 in. x 2 in. and pointed for about 7 in., with the top edge chamfered. They should be driven into the ground until only 1 in. to 1½ in. is projecting. The upper end should be painted a prominent colour such as red, white or yellow, different colours being used to distinguish angle poles, transposition poles and regular poles.

Care should be taken when driving the peg, to avoid excessive damage to the top. A 7 lb. hammer is preferable to an axe; if necessary place a piece of wood on top of the peg to take the direct blow. In hard or stony soil use a gad to make a good-sized starting hole for the peg. For solid rock make a good daub of paint with a chisel mark in the centre.

Angle and transposition pegs should be located with tie-measurements as described previously. To assist in the location of the peg later, a paint mark should be made on a nearby fence, wall or tree. Grass or scrub within a foot or so of the peg should be well beaten down to provide a cleared area which will last for several weeks.

Checking.—The same accuracy of measurement should be adopted as in the first measurement. The tape should follow as near as possible the anticipated grade of the line wires as in the case of the first measurement.

At each of the "reference points" (see Vol. 3, No. 5, p. 298) the chainage should be checked. If the measurements differ by not more than 5 ft. the "reference" mark should be taken as correct. If there is a greater variation the half-mile should be re-measured several times to determine which measurement is correct. If there is a serious error in the first measurement it will be necessary to review the layout of the poles over the whole transposition section. This will depend upon the extent of other irregularities within the section.

GRADING OF POLE ROUTES

Definition: The term "grading" is used here to describe the determination of pole heights so that the vertical angles in the line wires will be controlled and the wires not follow haphazardly the contour of the ground. This is illustrated in Fig. 27.

Purposes: The purposes of grading are as follow:—

(a) **Appearance.**—A well-graded route has a very pleasing appearance in contrast to an ungraded route.

(b) **Reduction of stresses on pole.**—Sharp vertical angles in line wires impose heavy stresses on crossarms and frequently necessitate the use of steel spindles instead of wood, thereby increasing construction costs appreciably.

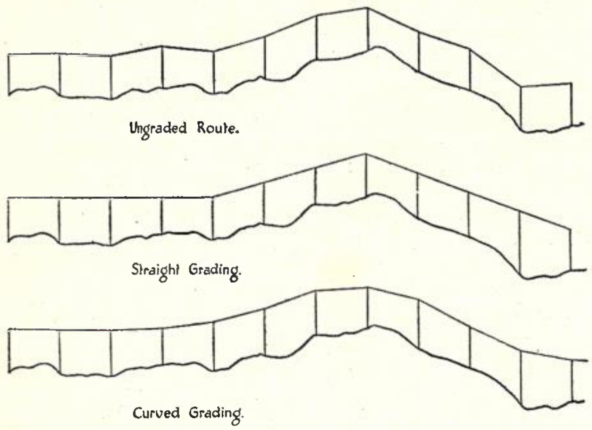


Fig. 27.

(c) **Better wire conditions.**—It is extremely difficult to regulate wires satisfactorily where there are sharp and frequent vertical angles. The attachment of line wires to insulators at vertical angles is not entirely satisfactory as greater stresses are imposed on line wire and ties and there is consequently a greater tendency to broken wires or ties.

Change of Grade.—It is convenient to measure the vertical angle in line wires at any pole, in terms of the difference in height on an adjacent pole, of the line wires as they are and as they would be if there were no vertical angle. Thus at poles 1 and 3 in Fig. 28A the distance *ab* is the change in grade and would be referred to as a change of grade of *y* ft. in an *x* ft. span. In the case of a span of normal length, viz., 165 ft., it is only necessary to refer to a change of grade of *y* ft.

The reference is the same in the case of a downward pull but, except with small changes of grade, there are obvious difficulties in the measurement of the height of the point (*b*) that the wires would reach if there were no angle. There are two methods available for determining the change of grade in such a case. The first method, illustrated in Fig. 28B, is to climb an adjacent pole (1 or 3) and sight on pole 2, the point (*c*) where the wires would be attached if there were no vertical angle in the line wire. Provided the spans are equal, the change of grade will be twice the distance *ac* on pole 2.

The second method (Fig. 28C) is to mark off points (*b*) on each pole, which are an equal distance below the point of attachment of the line wires. By producing the line joining two of

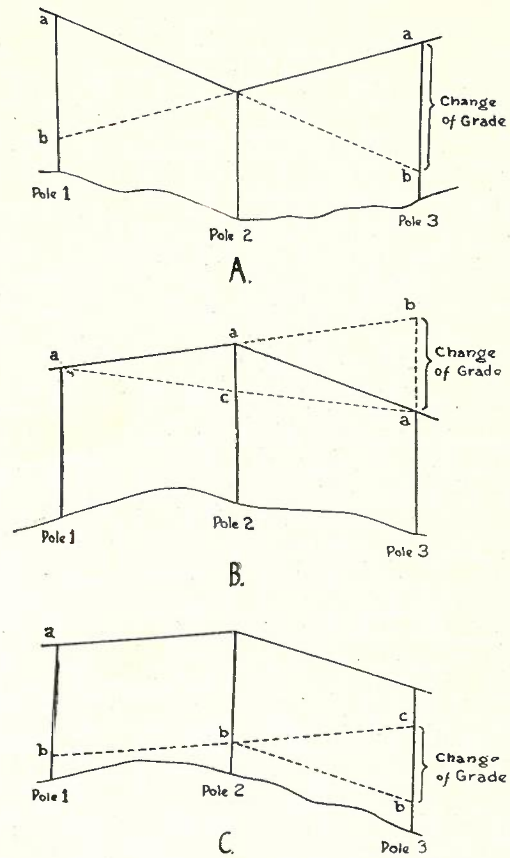


Fig. 28.

these points on adjacent poles to the point *c* at the third pole, the change of grade is obtained by the distance *bc*. In extreme cases the angles may be so sharp as to make it impossible to measure on the poles as described above. In such cases rods should be used as shown in Fig. 28D, and the actual change of grade to that measured at the rods will be proportional to the ratio between the full span length and the distance from the rods to pole 2.

Thus in Fig. 28D

$$\frac{\text{change of grade in ft.}}{a'b \text{ (in ft.)}} = \frac{\text{span length in feet}}{10}$$

$$\text{or change of grade} = \frac{a'b \times \text{span length}}{10}$$

Permissible Change of Grade.—The maximum permissible change of grade is the angle at which the technical difficulties become greater than the cost of higher or more frequent poles. This point is not sharply defined and up to the present has not been laid down by the Australian Post Office. It is interesting to note the standards of one or two other countries. In U.S.A. maximum limits set down by the Bell System are as follow:—

Normal Construction (i.e., using regular arms, insulators, spindles, etc): 16.5 ft. for 165 ft. span.

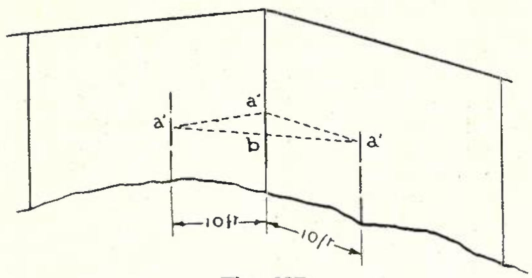


Fig. 28D.

Heavy Construction (i.e., using double cross-arms and special tying): 33 ft. for 165 ft. span.

Extra Heavy Construction: Using double cross-arms, and special graded fittings designed to support insulators in the most favourable position in relation to the wires: 50 ft. for 165 ft. span.

The South African Post Office sets an angle of 5 deg. (equivalent to a change of grade of 14.35 ft. in 165 ft.) as the desirable maximum. However, in difficult circumstances where specially long poles or short spans would be necessary to obtain this angle, a change of grade equivalent to 23 ft. (8 deg.) is permitted. In the case of any greater angles the wires are terminated and the pole stayed.

The above values refer to maximum limits and it is desirable to work well within these. It is suggested that normally a maximum change of grade of 10 ft. in 165 ft. would be preferable provided that cost is not unduly increased.

Types of Grading.—There are two types of grading as illustrated in Fig. 27. Straight grading consists of having the points of attachment of wires on intermediate poles in one straight line between two selected vertical angle poles at which the wires make a comparatively sharp change. If the change of grade at these poles exceeds the acceptable maximum the wires would be terminated and the pole anchored. By this method intermediate poles need only have wood spindles (unless there are horizontal angles) while the steel spindles and terminations of wires at the special vertical-angle poles provide a satisfactory means of anchoring the route. In hilly country this form of anchorage is more efficient and effective than the provision of longitudinal stays at regular intervals.

Curved grading consists of following the general contour of the country and having the changes of grade fairly evenly distributed over all of the poles. This is often used in extremely rough country and may also be essential to avoid the use of extremely long poles as might be required for straight grading. A good form of curved grading in valleys is to follow the general catenary of the line wires, although this would only be practical in special circumstances.

So far as appearance is concerned, curved grading is not always apparent, especially if there are many horizontal angles. A horizontal angle breaks the appearance of the grading. The route with the best appearance is one with straight grading between each horizontal-angle pole, or, in other words, with the angle poles taking both the vertical and horizontal angles. Where this is impracticable, additional vertical-angle poles may be inserted in a straight section between horizontal-angle poles. Except in the one case of a light horizontal angle permitting use of wooden spindles, there is no point in attempting to maintain a straight grade past a horizontal-angle pole as this must in any case be fitted with steel spindles.

The actual choice of the type of grading will depend almost entirely on the conditions applying to each individual pole route, and frequently, it will be found convenient to use a combination of both types. The principal considerations are the cost of providing higher poles (on the average) for straight grading against the cost of additional steel spindles for curved grading.

Measuring up for Grading.—The field work for grading is done after the precise position for each pole has been determined and pegged. This field work consists primarily of ascertaining the level of the ground at each pole peg. This information is then plotted on paper and the grading set out, after which action is taken to record in suitable form the desired pole lengths and depths of setting for the guidance of the construction party, etc. It is convenient to have the pole pegs numbered for this work, although it will suffice if only the transposition pole pegs are numbered.

There are two methods available for making the height measurement:—

(a) **Rise and Fall Method.**—This is the usual surveyors' method and requires a dumpy or engineers' level and surveyors' measuring staff.

(b) **Angle Plane.** — This is an alternative method which appeals to some operators, and requires a theodolite and surveyors' measuring staff.

Equipment.—The "level" is a telescope which is designed to provide a horizontal line of sight. The telescope is provided with cross-wires to indicate the precise centre of the telescope and is mounted on a levelling base which, in turn, is mounted on a tripod. The levelling base is provided with adjusting screws and spirit levels so that it can be set approximately horizontal each time that the level is set up. The telescope can then be rotated in any direction in the approximate horizontal plane, and a spirit level associated with the telescope, provides for exact adjustment for each reading. A clamping screw is provided to hold the telescope in the required direction. (An additional facility provided on some levels to increase the range of usefulness, is a calibrated vertical adjustment to enable the telescope to move slightly off the horizontal for setting out the small gradients used in drainage work.)

The theodolite is a more elaborate instrument in which a telescope can be set at a wide range of angles in the vertical plane as well as the horizontal plane. Consequently, it is more expensive and heavier than the level.

The measuring staff is used to measure vertical heights above ground and is usually of telescopic construction, being in three sections. Common types are made of light-weight wood in box form, the lower section being about 3 in. x 2 in. and some 6 ft. long. The total height, with three sections in use, is 14 to 16 ft. Figures and divisions are usually red and black respectively on a white background.

Rise and Fall Method.—The principle of this method is to find the difference in height between two or more points by sighting through a telescope adjusted to give a horizontal line of sight, to a measuring staff held on each of the points in turn. The difference in the measurements read at any two points will, of course, be the difference in their height. If the second point is higher than the first the difference in height is called a "rise" while if it is lower the difference is called a "fall." Knowing the "rises" or "falls" between each of a series of points, and the height of one of the points above some datum (such as sea level or the first pole on a section of the route, etc.) it is then possible to determine the height of each of the other points in relation to it. There are, therefore, two methods of expressing the heights of a number of points:—

(a) By a series of individual "rises" and "falls" between consecutive points; and

(b) By the rise or fall of each point in relation to a single point (or datum). These are referred to as "reduced" levels.

The level is set up at any convenient point where the maximum series of sights can be taken, thus reducing as much as possible the number of set-ups of this instrument. The point need not be on the line of the route but, if practicable, should be selected so that when the telescope is set to move horizontally, measurements on the measuring staff can be read on at least two (and preferably more) pole positions. The method is illustrated in Fig. 29. The staff is held on the starting point (peg A in Fig.

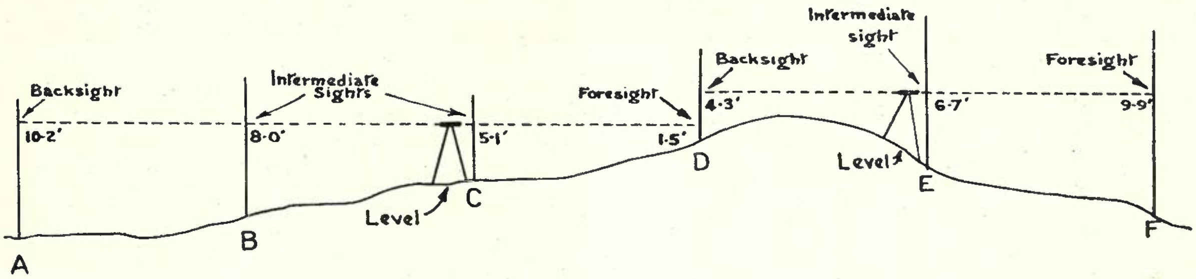


Fig. 29A.

29A), the levelled telescope is sighted to it and the measurement on the staff opposite the centre hair of the telescope is recorded. The staff is then moved to the next peg (B), the telescope sighted on it and a measurement taken. This procedure is continued until a series of measurements has been taken with the staff held on as many consecutive pegs (C and D) as can conveniently be seen through the telescope. The first reading is termed a "backsight" and the last reading in the run is termed the "foresight." The other readings are "intermediate" sights. If, for example, the recorded sights or measurements are as indicated in the diagram, it will be seen that:—

from A to B there is a rise of 2.2 feet;
from B to C there is a rise of 2.9 feet;
from C to D there is a rise of 3.6 feet.

When this series of measurements has been taken with the first set-up of the dumpy level, it is next necessary to shift the level and set it up

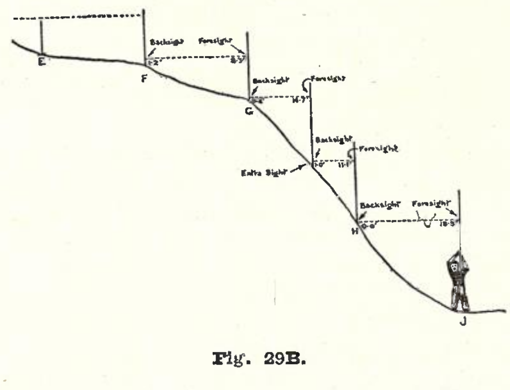


Fig. 29B.

some distance ahead but so that a "backsight" can be taken to the staff held at peg (D) where the previous foresight was taken. A new series of sights (D, E and F) can then be taken and the "rises" or "falls" ascertained. In the example they are shown as "falls" and peg F is selected as the point for the next foresight and backsight.

On steep slopes or other awkward situations where there are obstructions, it may not be possible to take sights to two peg positions. It is then necessary to take one or more extra sights to convenient points. Foresight and then backsight readings are taken to these extra sights and the rise or fall between the two pegs is the summation of the rises or falls including those to the extra points. Fig. 29B illustrates a case where an extra sight is necessary because the length of the staff is less than the amount of fall between the two pegs. A useful method of increasing the effective height of a staff and avoiding some of these extra sights is to have the operator hold the staff on his shoulder or head. The heights of shoulder or head of the individual operator once known can be added to the measurement read on the staff. This method is sufficiently accurate for practical purposes but needs a fairly strong operator. It saves time by obviating a second set up of the level and recording of additional readings.

Special surveyor's level books are printed for recording contours measured by the rise and fall method and can readily be converted to serve the requirements of a grading field book, by the insertion of extra columns. The recordings for the rises and falls in the cases of pegs A to H in Fig. 29 are shown in Fig. 30. The complete use of the field book is shown in Fig. 32, which illustrates a later example.

Levels taken for................ going from............to............
Datum................ ....day of................19

Peg	Back Sight	Intermediate Sight	Fore Sight	Rise	Fall
A	10.2				
B		8.0		2.2	
C		5.1		2.9	
D	4.3		1.5	3.6	
E		6.7			2.4
F	1.2		9.9		3.2
G	0.4		8.3		7.1
	1.0		14.7		
H	0.0		11.1		24.4
J			18.5		18.5

Fig. 30.

Angle Plane.—This method consists of sighting with the telescope in the line of the route and set at the general vertical angle of the pegs in the series to be sighted, see Fig. 31. The measurements on the staff held over each peg in the series are recorded, together with the vertical angle (angle of sight) of the telescope and its height above ground. The theodolite is then moved forward and set up over the point to which the last measurement was sighted.

In hilly country this method enables more sights to be taken with each set-up of the telescope but requires a theodolite and is also rather more difficult in the translation of the measurements on paper.

Determination of Pole Sizes

By Scale Plan.—The general method for determination of pole sizes is to set out the recorded information as a scale diagram and then to draw in the desired grading line, after which the heights of poles above ground are measured from the diagram and from this information the pole

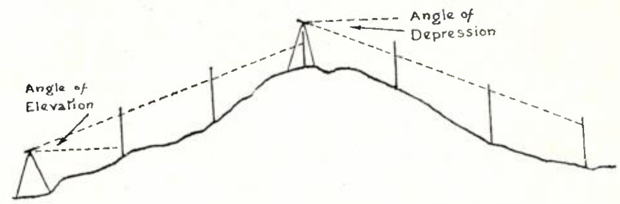


Fig. 31.

lengths are found. Blue print copies of these diagrams can be made out and utilized to furnish the construction staff with the information necessary for the placing and erection of the poles.

The length of a span in relation to the height of a pole is of the order of 7 to 1 so that if a true-to-scale plan were drawn, the scale being chosen to make the pole appear 2 to 3 inches high, each span would be about 14 in. long. It is necessary to have accuracy in drawing and measuring the pole heights so that it would be inadvisable to reduce the scale to make the pole appear shorter than 2 in. It is convenient to use different horizontal and vertical scales, so that the height of a pole will be exaggerated in relation to the span length. Proportions between 5 and 10 to 1 are satisfactory, and a typical example would be scales of 100 ft. per inch (i.e., 1/1200) for the horizontal plane and 10 ft. per inch (i.e., 1/120) for the vertical plane. Graph paper divided into inch and 1/10 in. squares is very useful for this work, particularly if the scales mentioned above are used.

If the measurements have been recorded by the rise and fall method then the height of each peg may be plotted from its height in relation to the previous peg. If the "angle plane" method of measuring up is used two methods are available: (a) to calculate the height of each peg from the peg where the sight was taken; or (b) to draw a line representing the line of sight and to project down from it the measurement read on the measuring staff, thus fixing the height of the peg. It should be noted that as the vertical scale is different to the horizontal scale the angle of depression or elevation of the line as drawn θ_r will not be the same as that of the actual angle of vision θ but will be $\tan^{-1} r \tan \theta$ where r is the ratio between the vertical and the horizontal scales.

The plotting of the span lengths requires consideration irrespective of which method of measuring was used. The easiest method is to work out beforehand a table of the horizontal scale distances for an average span for every foot of rise (or fall). To do this it will be necessary to assume that the wires will follow the general contour of the ground, i.e., the wires will be on poles of equal height. This approximation will be sufficiently accurate except in extreme cases in which it is best to take a special horizontal measurement between pegs. The horizontal distance between any two pegs is $\sqrt{S^2 - h^2}$ where S is the span length in feet and h is the rise (or fall) between the two pegs in feet. On the scale diagram the horizontal distance in inches will be $12/n \times \sqrt{S^2 - (rh)^2}$ where $1/n$ is the horizontal scale and r is the ratio between the vertical and horizontal scales. Thus with a span length of 165 ft. and the scales 1/120 (vertical) and 1/1200 (horizontal) the horizontal scale distance for the span with 1 ft. rise (or fall) will be $12/1200 \times \sqrt{165^2 - 10^2} =$ 1.629 in., which for plotting purposes is not appreciably different from the horizontal span length of 1.65 in. and for rises up to and including 5 ft. the difference from the direct horizontal measurement is negligible.

The location of each peg is plotted, together with any hillocks or roads the heights of which have been recorded. These points are joined together with straight lines to give a general outline of the contour of the ground. All gateways, horizontal angles and electric-power line crossings are then marked on the diagram.

It is then necessary to determine the minimum heights above ground for poles on the route having regard for:—

(a) The number of wires and crossarms which will be carried ultimately;

(b) The sag of the wires;

(c) The statutory wire clearances above ground, viz.,

(i) near fences: 8 ft. above ground;
(ii) in open country: 12 ft. above ground;
(iii) over roads (and gateways): 18 ft. above surface;
(iv) over railways: 22 ft. above rails.

Marks showing minimum pole heights should be made at poles adjacent to road or rail crossings, start of section of fence or open country, etc. The minimum suitable pole height at each horizontal-angle pole should similarly be marked. With this information plotted, it is necessary to set out a graded line for the wires, working in sections between horizontal angle poles. In plotting the grade line the object should be to arrive at the most favourable condition between the minimum height of poles and the minimum number and extent of vertical angles.

With the grade line drawn in to represent the tops of the poles, the heights of the poles can be measured and the figures marked on the diagram against each pole. The depths of setting should then be determined (see Fig. 17) and set out on the plan, together with the total lengths of each pole.

Method of Calculation.—With straight grading it is possible to determine the pole heights by calculation and thus obviate the scale plan. The method is:—

(a) To select two angle poles between which it is proposed to work a straight grade, and decide the heights of these poles.

(b) To determine the average gradient between these two points by finding the algebraic total of the rises and falls over this section and dividing by the number of spans.

(c) To determine how much each peg is above or below the average gradient.

(d) To determine the height of each pole to conform to the grade.

This method is illustrated in the example in Fig. 29. Poles A to D represent a simple case, but poles E to J present a problem which, until experience is gained with the method, might best be treated by plotting the small section on a scale plan. Assume that poles A, D, E and J are either horizontal-angle poles or must necessarily have vertical angles because of the contour of the ground. Then it is necessary to determine the height of intermediate poles between A and D and E and J so that the line of the wires over these sections will be straight.

The total rise from A to D (3 spans) is 8.7 ft., averaging 2.9 ft. per span and, therefore, if pegs B and C were to be in a straight line between A and D, Pegs B, C and D would have to rise 2.9 ft. each, i.e., peg

B must be 2.9 ft. higher than A;
C must be 2.9 + 2.9 ft. (= 5.8 ft.) higher than A;
D must be 2.9 + 2.9 + 2.9 ft. (= 8.7 ft.) higher than A.

As this is not actually the case, B being 2.2 ft. above A, and C 5.1 ft. above A. To compensate for this B must be raised 2.9 ft. — 2.2 ft. (= 0.7 ft.) and C must be raised 5.8 ft. — 5.1 ft. = 0.7 ft. In other words, poles B and C. must be 0.7 ft. longer than poles A and D if the arms are to be in a straight line. From E to J the total fall is 53.2 ft., averaging 13.3 ft. per span, so that to be in a straight line:

Peg F must be 13.3 ft. lower than peg E;
Peg G must be 13.3 + 13.3 = 26.6 ft. lower than peg E;
Peg H must be 26.6 + 13.3 = 39.9 ft. lower than peg E;
Peg J is 39.9 + 13.3 = 53.2 ft. lower than peg E.

Peg F is 3.2 ft. lower than peg E and should be 13.3 — 3.2 = 10.1 ft. lower to fall in the direct line between E and J.

Peg G is 10.3 ft. lower than peg E and should be 26.6 — 10.3 = 16.3 ft. lower to fall in the direct line between E and J.

Peg H is 34.7 ft. lower than peg E and should be 39.9 — 34.7 = 5.2 ft. lower to fall in the direct line between E and J.

Pole G is 16.3 ft. lower than poles E and J and as it must be at the minimum height the others must be longer, that is to say, long poles are called for. Obviously some alternative which would permit of shorter poles being used is desirable, and the simplest arrangement in this case would be to make G an additional vertical angle pole. Then, in the straight E-G, there is a total fall of 10.3 ft. or 5.15 ft. per span and peg F will be only 1.95 ft. (say, 2 ft.) lower than pegs E and G. Similarly between poles G and J we have total fall of 42.9 ft. or an average of 21.45 ft. per span, and pole H will require to be only 3 ft. higher than G and J. Other alternatives are possible by varying the angle of the grade line, but these are best done by plotting on paper as indicated previously.

When experience has been gained with this method, it will be possible by glancing over the field book to select most of the points where vertical angles are called for. These are indicated by appreciable changes in the rate of rise or fall, e.g., poles F and G falling 3.2 ft. and 7.1 ft., but poles H and J fall 24.4 ft. and 18.5 ft. respectively.

Practical Aspects.—In practice consideration has to be given to other aspects such as:—

(a) Road and rail crossings, which require special clearances. It is usually best to grade to the poles on either side of such a crossing.

(b) Rises in the ground between pegs (as between pegs D and E in Fig. 29A) will affect the minimum clearance and during the field work it is necessary to take an intermediate sight to any such point.

(c) Electric supply wires crossing the telephone route call for special clearances and their exact position should be recorded by taking an intermediate sight to the ground immediately below them and measuring their height above this point.

(d) The height of poles to which overhead stays are attached. These stays are usually fitted when the stay wires have to pass over roads or tracks and the pole must be of sufficient

Levels taken for.. going from.............................to.............................

Datum.. ....day of.............................19

1	2	3	4	5	6	7	8	9	10	11	12	
Peg	Back Sight	Inter-mediate Sight	Fore Sight	Rise	Fall	Reduced Levels	Wire Levels	Correc-tion	Height	Depth	Length	Remarks
1	13.8								20.00	4.00	24.0	
2		7.2		6.6		R. 6.6	6.08	—0.52	19.48	4.02	24.0	
3		10.4			3.2	R. 3.4	12.16	+8.76	28.76	6.24	37.0	Dry creek bed, + 1 ft.
4	19.8		1.8	8.6		R.12.0	18.24	+6.24	26.24	5.26	31.5	
5		16.5		3.3		R.15.3	24.32	+9.02	29.02	4.98	34.0	
6	9.6		1.6	14.9		R.30.2	30.40	+0.20	20.20	4.30	24.5	
7		3.3		6.3	Total 36.5 Av. 6.08	R.36.5	36.48	—	20.00	4.00	24.0	
8		1.6		1.7		R. 1.7	1.15	—0.55	19.45	4.05	23.5	
9		2.2		Total 2.3 Av. 1.15	0.6	R. 1.1	2.30	—	20.00	4.00	24.0	
10	2.6		12.5		10.3	F.10.3	10.1	+0.2	20.2	4.3	24.5	Allow extra rise for wires from 20 ft. to 28 ft. pole = 8 ft. Hence total wire fall = 46.4 ft. — 6 ft. = 40.4 ft. = 10.1 ft. per span.
11	1.2		15.4		12.8	F.23.1	20.2	+2.9	22.9	4.6	27.5	
12	2.4		14.3		13.1	F.36.2	30.3	+5.9	25.9	5.1	31.0	
13		12.6		Total 46.4 Av. 11.6	10.2	F.46.4	40.4	+6.0	26.0	5.0	31.0	
Rd.		12.0										Road Crossing requires poles 26 ft. high at 13, and 28 ft. high at 14.
14	0.7		16.8		4.2				28.0	5.0	33.0	
15		13.5			12.8	F.12.8	8.8	+4.0	32.0	5.5	36.5	Allow extra fall for wires from 28 ft. to 20 ft. pole. Hence total wire fall = 27.2 ft. + 8.0 ft. = 35.2 ft. = 8.8 ft. per span.
16	1.0		13.1	0.4		F.12.4	17.6	—5.2	22.8	4.7	27.5	
17		10.9			9.9	F.22.3	26.4	—4.1	23.9	4.6	28.5	
18			15.8	Total 27.2 Av. 6.8	4.9	F.27.2	35.2	—8.0	20.0	4.0	24.0	

Fig. 32.

height to provide at least the minimum statutory clearance between the stay wire and the crown of the road or of the track.

(e) False height. The point where a peg is driven into the ground may not represent the effective level of the ground. Take two examples:—

(i) The peg may be driven into a mound or the edge of an embankment or drain so that the pole would not be effectively supported if only installed at the standard depth below the ground where the peg is located. Such circumstances must be watched for and the additional depth of setting noted in the level-book by inserting " + 1 ft." (or whatever the additional depth should be) in the remarks column.

(ii) The peg may be driven into a drain or ditch or other channel which may be below the true level of the ground, and in the case of the lowest poles may not provide correct clearance between the line wires and the ground. Such instances must be watched for and noted in the remarks column.

to the general rise (or fall) between the two pegs.

Fig. 32 is a sample of a field book for the route shown in Fig. 33 and illustrates the steps taken to determine by the method of calculation, the heights of poles required. These are as follow:—

(i) The end of each straight section is marked by making a horizontal line across columns 5 to 10. This point will usually be a horizontal-angle pole or a special vertical-angle pole at a point where a distinct change of grade occurs such as at a change from a series of "rises" to a series of "falls" or where a general rise (or fall) of a foot or two per span changes to a general rise (or fall) of several feet per span.

(ii) The total rise or fall over this section is found and averaged and indicated under the dividing line as shown at 7, 9, 13 and 18 in the example.

(iii) The height of each peg (in the section) in relation to the first pole (in the section) is set out in column 7. Thus, e.g., peg 4 is 6.6 ft. — 3.2 ft. + 8.6 ft. (= 12.0 ft.) above peg 1.

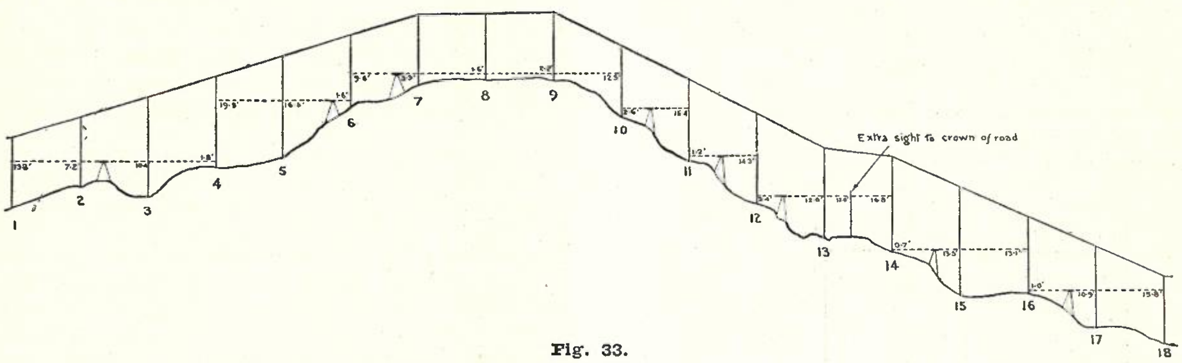


Fig. 33.

After a little practice it will be found possible to deal with many of these problems by the method of calculation just described, but to start with it will be better to graph any difficult sections. In very hilly or mountainous country, or where there are frequent complications, of the types referred to above, it will be found easier to graph the route and omit the method of calculation. On comparatively level or undulating stretches of country the latter method will generally prove the quicker. It tends to greater accuracy as it does not depend upon the accuracy of plotting.

In the planning of the grading it is desirable to adhere as much as possible to the minimum heights but it is also necessary to ensure that none of the poles planned will be less than minimum height.

It will often occur that a vertical angle pole at one end of a straight grade has to be higher than that at the other end, and consequently the grade of the wires is different to the general grade of the ground between these poles. In the method of calculation this is taken into account by making the difference in height between the two poles an addition or subtraction

(iv) The height of the wires in relation to their height at the first pole in each section is set out in column 8 by adding consecutively to each peg the average rise or fall determined for the particular section as described previously.

(v) The adjustment to bring the height of each pole to the same height as the wire grade is then found by addition and set out in column 9.

(vi) The height of each pole above ground level is then determined (and set out in column 10) by adding or subtracting the "adjustment" to the height of the first pole in the section.

(vii) A suitable depth of setting for each pole is then chosen so that:—

(a) The minimum depths (see Fig. 17) are observed.

(b) Provision is made for any additional depth noted in field book; and

(c) The total length of the pole is brought to a foot or 6 inch measurement as set down in columns 11 and 12.

If any pole in the section is below the minimum height necessary to provide regulation clearance between wires and ground, there are two alternatives:—

(a) To increase the average wire grade so that this pole is of minimum height and those following it in the section are correspondingly higher; or

(b) To make this pole an additional vertical angle pole and review the grades over each of the two sections thus formed.

The pegs will be driven so that about $1\frac{1}{2}$ in. will project above the ground and will not, therefore, represent ground level, so that the measuring staff will not be held on the top of the peg, but on the ground at the side of the peg. If the ground is sloping the staff should be held on the lowest point (which should also be flattened down slightly to form a small ledge of sufficient area to accommodate the base of the staff), adjacent to the peg. When the time comes for the pole to be erected a second peg should be driven in the ground about 1 ft. away (at the back of the pole-hole is a very convenient point), and at such depth that its top will be the same height as the ground where the staff was held. This peg will then form a datum from which the depth of the hole can be measured.

INFORMATION SECTION

Readers are invited to submit questions on either theoretical or practical aspects of Telecommunication Engineering. Answers will be published in this section.

THE ADAPTATION OF A TYPE 100A METER FOR USE AS A TIMING CLOCK

Timing clocks are essential for checking trunk line conversations, and owing to war conditions causing a shortage in supplies of B.P.O. Clock, Timing No. 44, the type 100A meter assembly has been adapted, by the addition of cams and springs, to perform similar functions. The recording mechanism and associated start key are mounted on a standard key plate for mounting on key shelves.

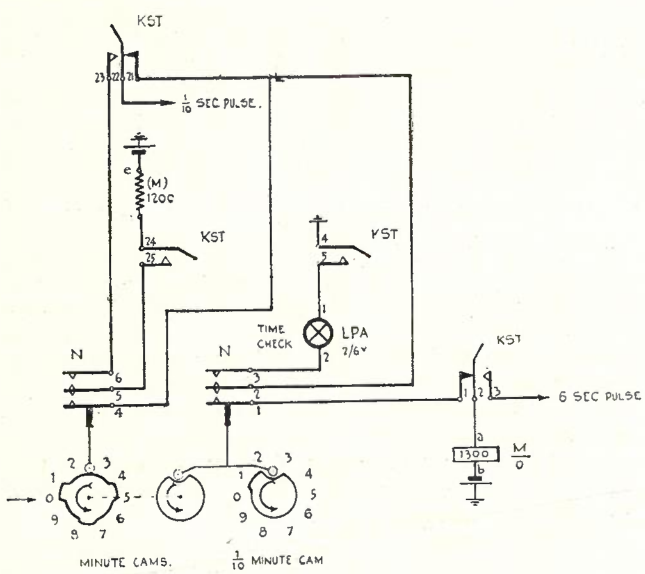


Fig. 1.

The circuit arrangements are shown in Fig. 1. Both indicating drums normally stand at OO. When conversation commences the start key KST is thrown, connecting the operating coil to the 6 second impulse. This impulse is repeated every 6 seconds and causes the 1/10th minute cam to take one step every 6 seconds. This sequence of events is continued until one minute has elapsed, and then the minute cam takes one step and steps every subsequent minute. At the first step of the 1/10th minute cam the "off normal" springs N1 and 2 close to prepare the homing circuit of the clock. At 48 seconds, springs N1, 2 and 3 close and prepare the lamp circuit. Springs 2 and 3 open again at one minute. After two minutes have elapsed, springs 4 and 5 close, followed by the closing of springs 2 and 3 when the 1/10th minute cam reaches 8. The lamp glows, therefore, at 2 minutes 48 seconds and remains alight until 3 minutes is indicated on the clock. The same sequence of events continues until 5 minutes 48 seconds is reached, when the lamp glows again, remaining alight until 6 minutes is indicated. This sequence is repeated again until 8 minutes is reached, when springs 5 and 6 close, followed by springs 2 and 3 at 8 minutes 48 seconds. The lamp will then flash intermittently at 10 impulses per second until 9 minutes is reached. The telephonist, on observing the lamp flashing, knows that the subscriber has had 9 minutes' conversation and can accordingly challenge the call. The clock can be reset by restoring the start key. The clock returns to normal at 10 impulses per second, the homing drive being interrupted when the normal springs 1 and 2 are opened by the roller dropping into notches on both cams when indicating OO.

—J.S.S.

THE CHARACTERISTICS AND APPLICATIONS OF PROTECTION EQUIPMENT FOR TELECOMMUNICATION SERVICES IN AUSTRALIA

It is regretted, that owing to pressure of other duties, Mr. J. H. T. Fisher has not been able to prepare the concluding article in this series. However, the articles published in Vol. 2, No. 5, and Vol. 3, Nos. 1 and 2, are in themselves complete in respect to current practice.

The earthing type heat coil, B Red, described in Vol. 3, page 77, is in general use, but since the preparation of the article, a new type which was developed by the British Post Office, has been introduced in Australia. This heat coil is designated "B B Black, Earthing type" and is depicted in Fig. 1. The characteristics are the same as for the "B Red," but the contact cap is of brass with a shoulder which fits into the clip on the protector strip. This shoulder prevents the heat coil turning in the clip and provides a more reliable electrical contact than the "B Red" type. Particulars in respect to the parts of the heat coil are:—

Cap, N.—Soft cartridge brass.

Cover, M.—Ebonite, grade 2 of B.S. Specification 234.

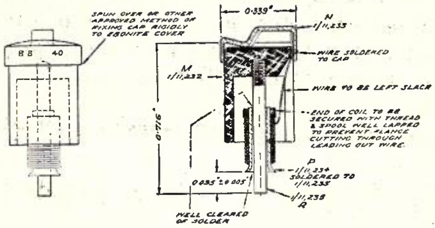


Fig. 1.

Bobbin, P.—Copper, electro-tinned. The bobbin is thoroughly soldered to pin R, in the position shown in Fig. 1. The connection edge of the bobbin is left clean and all superfluous solder is removed from both the bobbin and pin R within the bell mouth of the bobbin.

Pin, R.—Brass, electro-tinned. It is dipped in fusible alloy prior to assembly and soldering.

Resistance wire, is double silk covered with a conductor diameter of 0.007 in. It is evenly wound on the bobbin and the inner end is soldered to the bobbin at the V slot and the outer end to the contact cap N. The even layer winding is important, otherwise the operating characteristics will not be complied with.

The solder is fusible alloy of the following composition:—

Lead, 27.6%.
Cadmium, 34.5%.
Bismuth, 27.6%.
Tin, 10.3%.

Fuses.—In Table III., page 78, the approximate bore of porcelain fuses should read $1^1/_{16}$ in. not $1^1/_6$ in.

ENGINEERING DRAWING PRACTICE

The 1941 edition of "Engineering Drawing Practice," the Australian Standard Engineering Drawing Practice handbook, has been published and is recommended to all who are interested in drawing as an authoritative reference to Australian drawing practice. Compiled and issued by the committee of The Institution of Engineers, Australia, this handbook has been published with a view to assisting in the standardization of drawing practice, particularly with regard to the use of standard symbols. Consideration has been given to world standards, recent advances in Engineering, and suggestions submitted from a wide field of Engineering opinion.

The revised edition contains reference to many features not previously included. Special attention is directed to chapter 9, covering "Pencil drawings on tracing paper for reproduction." Adherence to the published information will save much time and allow of good print copies being produced from rough sketches or finished drawings. It is of interest to note that the British Standards Institution has accepted this work as a basis for discussion in the revision of the British Standards publication "Engineering Drawing Office Practice."

While the recommended standards, as published, do not fully cover the requirements of Australian Post Office Engineering, and in some cases are not in accordance with Departmental practice, the information included is an excellent reference, the tabulation of which has been handled with extreme care.

For those who are not familiar with this book, the contents in order of chapters are:—

Chapter.

1. Sizes of sheets.
2. Types of lines.
3. Title blocks and material lists.
4. Lettering.
5. Dimensioning.
6. Projection.
7. Sectioning and symbols for materials.
8. Scales.
9. Pencil drawings for reproduction.
10. Screw threads, bolts, nuts, etc.
11. Rivets.
12. Welds.
13. Structural steelwork.
14. Reinforced concrete.
15. Gauges—sheet, wire, etc.
16. Surface finish.
17. Gears.
18. Springs.
19. Pipe symbols.
20. Electrical symbols.
21. Survey plans.
22. Graphs.
23. Abbreviations.
24. Folding of prints.

The handbook is especially recommended for the guidance of students and juniors, but will also serve as an excellent reference for all those associated with the preparation and interpretation of all classes of engineering drawings.

It is available from all offices of The Institution of Engineers, Australia, or may be ordered through booksellers. The prices are 5/-, 5/6, or 6/-, depending upon the style of binding preferred.—R.D.F.

SOLDER

In view of the war situation and possible restrictions in respect to the use of tin, the following extract from an article "Restricting the Use of Tin" which appeared in the October, 1941, issue of "Tin and its Uses," a quarterly review issued by the Tin Research Institute, is of interest:—

Over a fifth of all tin used goes into solder. The most obvious expedient is to use alloys lower in tin and higher in lead; but this is seldom feasible, economic considerations having already led to the use of the lowest practical tin content. The thickness of the solder film required tends to increase with decrease in tin, and the use of a poorer solder may lead to an actual increase in the weight of tin consumed. Since the strength of a solder joint is greater when it is thin, the quality of the joint suffers by too low a tin content.

Nevertheless substitute solders are available—at a price. Part of the tin may be replaced by cadmium, and cadmium-zinc alloys are in use, but owing to the normal scarcity of cadmium, and the temporary scarcity of zinc, neither promises to meet the present emergency. The very large stocks of silver now in America give a special feasibility to solders containing from 6 per cent. to 2½ per cent. of silver and 94 per cent. to 97½ per cent. of lead. These solders are already employed for special purposes, and their use could be extended if allowance were made for their limitations. For instance, in radiator manufacture, dip-soldering with tin lead solders is done at 700 deg. F.; the silver-lead solder would require 850 deg. F. This would tend to soften the cold-worked copper at present in use and special alloys would have to be selected.

There are many alternative types of joint, such as lead burning, welding, hard soldering, etc., but the broad fact emerges that there are many jobs for which common solder is pre-eminently suitable and that at present there is no substitute solder available with the low melting point and good wetting qualities of the lead solders high in tin and that the next best alloys are much more costly.—O.C.R.

ANSWERS TO EXAMINATION PAPERS

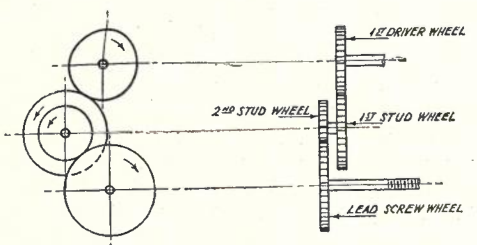
The answers to examination papers are not claimed to be thoroughly exhaustive and complete. They are, however, accurate so far as they go and as such might be given by any student capable of securing high marks.

EXAMINATION NO. 2326.—MECHANIC GRADE 2—ENGINEERING WORKSHOP

H. R. WADDELL

Q. 1.—In lathe work, what is meant by the term "compound gears"? How and when are they used?

A.—When a screw thread is being cut in a lathe, the main spindle, to which the work is attached, and the lead screw, which moves the carriage and tool along, are connected together through a train of gears. This train of gears may be arranged in either a simple train or a compound train. The compound arrangement is illustrated in Fig. 1.



Q. 1, Fig. 1.

In the sketch the first driver wheel is attached to the main spindle and meshes with the first stud wheel. The first and second stud wheels are both keyed to the same sleeve on the swing plate stud and therefore rotate together. The lead screw wheel is keyed to the lead screw and meshes with the second stud wheel.

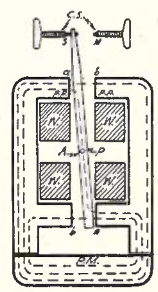
It is necessary to arrange a train of gears between the lead screw and main spindle so that the overall ratio of the train is suitable for the pitch of the lead screw thread and the pitch of the thread required on the work. An ordinary screw-cutting lathe is usually provided with a set of 22 gear wheels for this purpose; the smallest wheel having 20 teeth and the largest 120 teeth, with increments of five teeth up to 100 and ten teeth up to 120, and two wheels of 40, 60 or 80 teeth. It is sometimes not possible to obtain the ratio required by using a simple train of gears and a compound train must then be used. For example, if the lathe has a lead screw pitch of $\frac{1}{2}$ in. and it is required to cut a screw of 24 threads per inch, the gear ratio required is 1 to 12. It would not be possible to arrange this ratio with a simple train because, with the smallest wheel, 20 teeth, this would require a lead screw wheel with 240 teeth. A suitable compound train could be made up thus:—

$$\frac{1}{12} = \frac{(1 \times 30) \times (1 \times 20)}{(3 \times 30) \times (4 \times 20)} = \frac{30 \times 20}{90 \times 80}$$

First driver wheel—30 teeth.
First stud wheel —90 ,,
Second stud wheel —20 ,,
Lead screw wheel —80 ,,

Q. 2.—Describe the theory of operation of any type of polarized relay with which you are familiar.

A.—Fig. 1 shows the essential parts of the magnetic circuit of a Creed 27V. polarized relay. PM is a permanent magnet with pole pieces PP. A is the armature which is pivoted at P. and is connected to terminal T (not shown). Two sets of coils W encircle the armature and are terminated on terminals U and D and U circle, and D circle (not shown). With no current flowing in the coils, the armature may rest against, either the S or M contacts, and is held in either position by a small portion of the magnetic flux induced by the permanent magnet. In the sketch the armature is against contact S and the paths of the magnetic flux from the permanent magnet are shown; the path through the armature being between the parts of the pole pieces marked a. If the armature



Q. 2, Fig. 1.

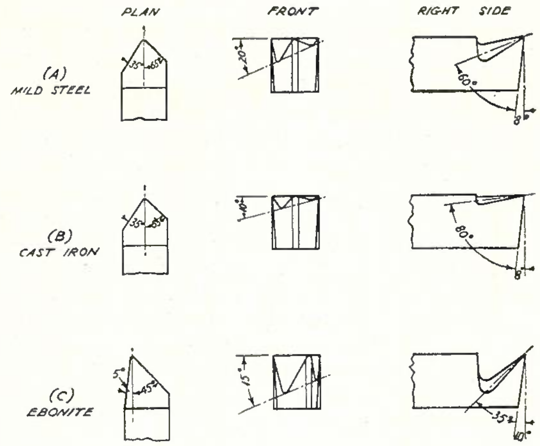
was against the contact M the flux path through the armature would be in the reverse direction and between the parts of the pole pieces marked b.

If a sufficiently strong current flows through the coils in the direction U to D or U circle to D circle, when the armature is in the position shown the direction of the flux through the armature is reversed so that the armature is repelled at points a and attracted at points b. This causes the armature to move rapidly over to the M contact. Similarly, when the current flows through the coils in the direction

D to U or D circle to U circle, the armature is moved from contact M to contact S.

Q. 3.—Show by means of sketches to what shapes you would grind lathe tools for the cylindrical turning of—(a) mild steel; (b) cast iron; and (c) ebonite.

A.—The shape viewed in plan of lathe tools required for cylindrical turning depends very largely on the



Q. 3, Fig. 1.

finish required on the work, the size of cut and the rate of feed. The sketches show shapes which would be suitable for general turning, using medium size cuts and feeds.

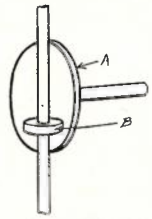
Q. 4.—Describe the different types of gearing with which you are familiar and indicate under what circumstances each would be used.

A.—Gearing is the means by which motion and power are transmitted from one rotating part to another by direct contact, although the term is sometimes extended to cover other means such as belt and chain drives. Some form of gearing must be used between the two rotating parts concerned, say one spindle driving another, if one or both of the following conditions apply:—

(a) They are required to rotate at different speeds. The ratio of the speeds of the two spindles is then referred to as the gear ratio.

(b) They are required to rotate about different axes, either parallel or intersecting.

Gearing may be effected by friction or by means of toothed gears. Friction gears are usually only employed where the power to be transmitted is small or the gear ratio is required to be continuously variable. Fig. 1 illustrates one form of friction gear which is sometimes used in small drilling machines and similar

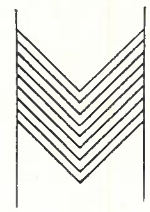


Q. 4, Fig. 1.

situations. The plate A is attached to the driving spindle while wheel B, which bears against A and which is faced with leather, is splined to the driven spindle. The position of B may be varied between the outer edge and centre of A, thus providing a variable gear ratio.

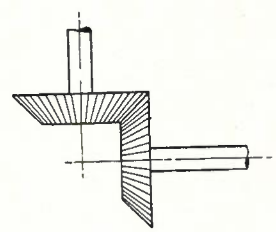
Toothed gears may be divided broadly into three classes, namely, spur gears, bevel gears and worm gears.

Spur gears are used when the driving and driven spindles are on parallel axes. The gearing consists of a toothed wheel keyed to each spindle arranged so that the teeth of the two gear wheels mesh together. The gear ratio of the pair is equal to the inverse ratio of the number of teeth on the wheels. Plain spur gears have teeth parallel to the axis of rotation and this type is very common in machine construction. An example is the change gears driving the lead screw on an ordinary screw cutting lathe. Plain spur gears must be used where it is required that they slide in and out of mesh, as in a variable speed gear box, but where gears are in constant mesh, a helical form of spur gear is often used. Helical gears are stronger than plain gears of the same size and are more silent in operation. The teeth of helical gears are at an angle to the axis of rotation and therefore impose an axial thrust on the spindle. For this reason double helical gears, with teeth sloping opposite ways as shown in Fig. 2 are often employed. Bevel gears are



Q. 4, Fig. 2.

used where the spindle axes intersect. Plain bevel gears are similar to plain spur gears except that the teeth are cut on a conical face. Fig. 3 shows a sectional view of plain bevel gears with the spindle axes at right angles. Another type of bevel gear is a spiral bevel gear. In this gear the teeth are cut in a slightly spiral direction on the conical face of the gear. A further type of bevel gear is known as a hypoid gear. In this gear the teeth are cut similarly to the spiral bevel gear, but the shape of the face of



Q. 4, Fig. 3.

the gear is based on a hyperboloid instead of a cone. Both of these types of bevel gear are more silent and stronger than a plain bevel gear of the same size.

Worm gears comprise a screw thread or worm meshing with a toothed gear wheel, the teeth on which are cut to fit the screw thread. This form of gear may be employed when spindles are at right angles and is very suitable where a large speed ratio is required between the spindles. In this case the pitch and lead angle of the worm thread are small compared with the number of teeth on the worm wheel—the worm being the driving member. In this case also the gear is self-locking in the reverse direction—that is, it is not possible to drive the worm by the worm wheel. This feature is very convenient for some purposes, such as driving the winding machines of lifts and hoists, etc., for which purposes worm gears are largely employed.

Q. 5.—Twenty dry cells each 1.5V. and one ohm internal resistance are connected in a series parallel arrangement consisting of an equal number in each of 4 rows of cells. What external resistance is necessary to enable 250 milliamperes to flow in the circuit?

A.—As there are 20 cells in 4 equal parallel rows, there are 5 cells in each row.

$\therefore$ Total EMF $= 5 \times 1.5$ volts
and Internal Resistance $= (5 \times 1)/4$
$= 1.25$ ohms.
The current is 250 mA. $= 0.25$ amps.
Total Resistance $= E/I$
$= (5 \times 1.5)/0.25$ ohms
$= 30$ ohms.
$\therefore$ External Resistance $= 30 - 1.25$
$= 28.75$ ohms.

Q. 6.—Name 5 insulating materials used in the Departmental Workshops and state the particular advantage of each material referred to.

A.—(a) **Mica**—Good quality mica has high insulation resistance, dielectric strength and resistance to change by high temperature and is mechanically rigid and tough. It can therefore be used where a thin barrier is required to sustain the highest electrical, mechanical, and thermal stresses.

(b) **Vulcanized Fibre**—Although a relatively poor insulating material this is cheap, mechanically strong and tough, does not soften with heat, can be machined to any desired shape and is available in a convenient range of sizes of sheets, rods and tubes.

(c) **Ebonite**—High grade ebonite has good insulating properties, is relatively cheap, mechanically strong and tough and can be machined to any desired shape. It also takes a high polished finish if required and is available in a convenient range of sizes of sheets, rods and tubes.

(d) **Bakelite—or Phenol Formaldehyde**—This material is available in several forms and is used in the workshops in the form of powder for moulding and in sheets with paper or fabric reinforcing. It is mechanically strong, can be machined, has good appearance, is moisture proof, has high grade insulating properties. With the moulding powder, an infinite variety of shapes can be produced quickly and cheaply. The mouldings so formed require no further machining as they are accurate in dimensions and have a finished surface. In sheet form it is largely replacing ebonite and vulcanized fibre. Various qualities are available but in the thinner sheets usually a punching quality is used so that various shaped pieces may be rapidly produced by punching.

(e) **Empire Cloth**—This material is a thin cotton fabric impregnated with a flexible baked oil varnish. It is an excellent insulator with high dielectric strength and is moisture proof. Due to its flexibility and small thickness and its good insulating properties it is largely used for such purposes as insulating relay cores from the windings and wrapping busbars and slot liners.

Q. 7.—What is meant by the following terms:—
(a) Residual magnetism;
(b) Tensile strength;
(c) Resistance (electrical)?

A.—(a) When a piece of iron or steel has been magnetized and the magnetizing force has been reduced to zero, it retains a certain amount of its magnetism. This remaining magnetism is called residual magnetism.

(b) Tensile strength is the term applied to indicate the strength of a material in tension, that is, the ability of the material in, say, a wire to withstand force pulling the two ends. Tensile strength varies with the nature and condition of the material and is usually expressed in tons or pounds per square inch of cross section. For example, mild steel may have a tensile strength of 30 tons per square inch, while in an alloy steel it may be 60 tons per square inch.

(c) Resistance is that property of an electric circuit which opposes the flow of current through it when a constant electromotive force is applied. Resistance may be likened to friction in mechanics in that it tends to reduce the current in the same way as friction tends to slow down motion. The practical unit of resistance is the Ohm which is the resistance offered by a column of mercury 106.3 cms. long, 1 square millimeter cross section, and at the temperature of melting ice.

Q. 8.—Give a description of a micrometer caliper and state what precautions you would take before and when using the instrument.

A.—A description of a micrometer caliper gauge is not given here but the reader is referred to the Telecommunication Journal of Australia, Vol. 3, page 181, for a detailed description given in connection with another Examination.

Precautions which should be observed before and when using a micrometer caliper are:—

Before using:—

(a) See that there is no grease or other matter likely to affect the accuracy of the reading, adhering to the face of the anvil, the end of the spindle, or the article to be measured.

(b) Using the ratchet stop, screw the caliper fully closed and check the zero reading so that any error may be corrected or allowances made when making measurements.

When using:—

(a) Hold the caliper lightly and square with the article being measured.

(b) Use the ratchet stop to screw the caliper closed so that the same pressure is applied when making the measurement as when checking the zero reading. This also guards against straining the caliper.

Q. 9.—Write what you know of the building up of worn parts of machinery such as cams and shafts and indicate instances where the methods referred to could be used.

A.—The principal methods of building up worn parts of machinery such as cams and shafts are:—

(a) Metal spraying.
(b) Welding.

In metal spraying, the metal being deposited is melted either by an electric arc or an oxy-acetylene flame and is atomized and sprayed against the work by a powerful jet of compressed air in much the same manner as paint from a spray gun. The sprayed metal is deposited in tiny particles which, striking the work in a plastic state, flatten out, interlock and key into the surface of the work. The deposited metal is not solidly fused to the work and for this reason will not stand heavy impact loads. It is also slightly porous and can be machined only by using light cuts or wet grinding.

The most suitable application of the process is in building up a worn spindle or cylindrical part. In this case, usually the worn part is roughly threaded with a fine V thread to an overall diameter about 40 mils less than the finished diameter required. The part is then revolved in a lathe with the metal spray gun mounted on the tool rest and built up to about 40 mils oversize before being finish machined or ground. No heat treatment is necessary to the repaired part because very little heat is applied to the work during the spraying process. If necessary, a harder metal than the original worn metal may be sprayed on.

Building up by welding may be done by either oxy-acetylene or electric arc methods. In both cases the normal welding processes are employed. The electric arc process permits of a greater speed in building up, but the oxy-acetylene process gives a closer control of temperature and allows a smoother deposit, thus saving in later machining to size. Small parts such as cams and small gears are frequently built up with manganese bronze by the oxy-acetylene process. As only low temperatures are attained with bronze, normalizing after welding is not necessary if the part being built up is of low carbon steel. Steel welding rods or electrodes of similar composition to the steel part being built up may also be used but the job should be heat treated after welding to relieve welding strains. It is generally unsatisfactory to weld on to steels in a hardened condition. Therefore, if the worn part is in a hardened state, it should be annealed before being built up by welding.

Building up by welding may be effected on practically any type of worn machine part such as spindles, studs, gears or cams where the built up surface can be again machined to size. Frequently in building up worn parts, wear resisting alloys such as "Stellite" are used.

Q. 10.—What is case hardening? How do the results compare with tempering of steel and under what circumstance would you use each process?

A.—Iron and low carbon or mild steel cannot be hardened and tempered in the ordinary way because of the small amount of carbon in the metal but it can be given a high degree of hardness on the surface by case hardening. Case hardening treatment essentially consists of heating the metal to a temperature of about 900 deg. C. in the presence of carbon containing material so that a skin or surface layer of high carbon steel is formed. Subsequent suitable heat treatment and quenching give this skin or surface layer a high degree of hardness while the core or main body of the metal remains in its original ductile condition. The depth of case hardening depends upon the length of time it is heated in the presence of the carburizing material, the temperature, and the nature of the carburizing material. Generally the depth is from 1/50 to 1/25 inch.

After the ordinary hardening and tempering as applied to high carbon or alloy steels, the material is practically of uniform hardness throughout.

Case hardening is used where a hard wearing surface is required but at the same time the part must stand shocks and repeated load applications,—for example, pivot pins, sliding members, races for ball bearings, etc. A major consideration in many cases is also the relatively low cost and easy machining qualities of low carbon steels compared with high carbon and alloy steels. Case hardening is unsuitable for such purposes as machine tools because of the small depth of the hard surface skin and the fact that tools must be ground from time to time. For such purposes high carbon or alloy steels are necessary.

EXAMINATION NO. 2295.—ENGINEER—LINE CONSTRUCTION (Continued).

W. H. WALKER, B.E., A.M.I.E.(Aust.)

Q. 5.—Discuss the need for the preservative treatment of wooden poles with particular reference to the two main hazards usually experienced. State what preservative is used by the Department and discuss briefly its merits. Describe the various method of applying treatment and indicate briefly their advantages and disadvantages.

A.—Wooden poles are subject to attack both by:—

(i) Decay which is due to fungi which grow in the wood and use the wood substance for food, breaking it down into simpler substances which are eventually lost as water or carbon dioxide and other gases. This greatly reduces the mechanical strength of the wood and renders it useless for structural purposes.

(ii) Termites or "white ants" which eat the timber.

The liability of attack is dependent principally upon:—

(a) The class of timber; and

(b) The locality in which the poles are erected.

Wooden poles erected in wet, humid areas are much more liable to attack by decay than those in drier localities, and consequently, such conditions call for more effective treatment to obtain the maximum life of the poles. The severity of termite attack varies considerably in different districts and is also dependent upon the class of termite indigenous to the particular locality. Thus, while considerable trouble may be experienced in localities where the small species of termite abound, in other areas such as in Northern Australia where the large species is found, they constitute a much more dangerous hazard and serious damage can only be prevented by constant inspections and treatment of the poles.

The preservative used by the Department is creosote which is cheap, readily obtainable, easy to handle and apply, and is effective in protecting poles from decay and, except in extreme cases, from termite attack.

The methods for treating poles with creosote may be divided into:—

(a) Those applied to the poles before and during erection.

(b) Those applied to standing poles which are included in pole maintenance.

Where poles can be treated in main depots or at other suitable points the most suitable method is the hot and cold tank process.

This method consists of immersing 6 ft. of the butts of the poles for about two to four hours in a tank containing creosote at 190 deg.-200 deg. F. At the end of this period, the creosote is allowed to cool and when a temperature of 90 deg. F. is reached the poles are removed. (Normally the penetration of creosote into the hardwood poles is confined to the sapwood, but the layer of treated sapwood serves to protect the pole from attack by termites or decay.)

While this method is mainly associated with main depots, portable tanks are used to treat poles on the job. In these cases, the poles are delivered at a selected site treated and then transported and laid out at the pegs. The hot and cold tank method ensures complete penetration of the sapwood, and, therefore, re-treatment will not be required for 10 years or more. This method requires considerable handling of poles, especially if proper facilities are not available.

Where this method cannot be applied, the butts of the poles should be placed over the hole and treated with creosote to a point 2 ft. above ground line by brushing or pouring. This is a cheap and easy method, but does not achieve any appreciable penetration of the sapwood. Hence retreatment at intervals of about two years is necessary.

In addition to the treatment of the butts, it is necessary before a pole is erected or fittings attached, to treat all cut faces, joggles, bolt holes, etc., with creosote with a brush or spray.

The portion of the crossarm which contacts the pole should also be well treated and in localities where timber is subject to severe attack the whole of the arm should be treated. Then before the pole is erected, half a gallon of creosote should be poured into the bottom of the hole to provide a preservative layer of soil. During the filling-in process, creosote should be puddled into the soil around the pole for its full depth.

The creosote treatment of standing poles should always be carried out in warm dry weather to ensure satisfactory absorption of the creosote. The ground around the pole should be opened up to a depth of 18 in. All decayed sapwood and wood should be removed from the pole by means of an axe, knife scraper, etc.

The pole is then treated with creosote by means of either—(i) the brushing method; or (ii) the spraying method. The brushing method consists of applying creosote to the pole by means of a long-handled brush. While sometimes useful for treatment of isolated poles, it is not possible to obtain good absorption of the creosote and it is difficult to ensure that the creosote goes well into cracks, etc.

Usually a number of poles will be treated at one time and the treatment is done by the spraying method. The most satisfactory equipment for this purpose consists of a semi-rotary pump mounted on a truck which carries a drum of creosote. A semi-circular spray is mounted at the end of a length of ½ in. iron pipe and the creosote is fed from the drum through a length of hose by means of the pump.

The spray is rested against the pole and is kept horizontal as it is moved downwards, spraying the creosote on to the pole. When one side of the pole is finished the spray is turned over and the other side treated in the same manner. By this method the whole of the pole can be treated, and any surplus creosote runs down the pole and collects at the bottom, where it forms portion of that required for puddling. When the spraying has been completed about half gallon of creosote should be puddled into the soil round the pole.

When using the spraying method, great care must be taken to prevent damage to trees, fences, etc. Where it is impossible to spray the poles without causing damage, the spray treatment should be restricted to those portions which can be treated without danger and the remainder treated with the brush method. In some cases the risk of damage to property may be greatly reduced by carrying out the work when the wind is blowing in the most favourable direction.

Q. 6.—It is found necessary to provide an 800 pair 10 lb. conductor star quad subscribers' cable between an exchange and a point 1 mile distant in order to relieve a congested area. Spare ducts are available with manholes at 110 yard intervals. No lateral cables are required to break off between the exchange and the end of this cable.

(1) List of items of material required to provide and connect up such a cable from the line fuse blocks on the main distributing frame to the last manhole on the conduit run.

(2) List the tools and equipment required.

(3) Describe in detail the laying, jointing and identifying operations involved in carrying out the work up to the point where everything is in readiness to connect to the existing cable which is to be relieved.

(4) Assuming you were the Engineer-in-charge of such a work what are the principal points in the carrying out of the work to which you would consider it necessary to direct the attention of the workmen to ensure a satisfactory job?

A.—(1) Material required for jointing 1760 yards of 800 pair cable in 110 yard lengths:—

Cable, 800 pair, 10 lb. conductor, P.I.Q.L., 1780 yards.
Lead sheet, 7 lb., 320 lb.
Lead sheet, 5 lb., 120 lb.
Solder wiping, 80 lb.
Solder, soft, 20 lb.
Solder, R.C., 4 lb.
Sleeves, paper, 10 lb., 32,000.
Paper, cable jointing, 4 in., 20 rolls.
Compound, cable pulling, 300 lb.
Tallow or stearine, 2 lb.
Tags, linen, identification, 4,800.
Linen tape, 16 yards.
Black, plumber's, 4.
Cable, 200 pair, 10 lb. conductor, E and C, 40 yards approx.

(2) The equipment and tools required for the pulling in operations would comprise:—

Motor truck, with trailer if available.
Rods, conduit.
Rope, flexible steel wire, and brush and rag mop.
Winch (power or hand operated).
Spindle, 3 in., for cable drum.
Lifting jacks (if cable drum not on cable trailer).
Swivels and split link.
Cable grips.
Flags, red.
Guards, manhole.
Guide sheaves and pulleys.
Hammers, engineer's, claw and sledge.
Keys, manhole.

CO_2 gas with fittings and gauges.
Knives, hack and pocket.
Lamps, blow and hurricane.
Picks.
Pliers, side-cutting.
Saw, hack.
Shovel.
Pump.

The tools and equipment required for the jointing of the cable would comprise:—

Flags, red.
Guards for manholes.
Keys, manhole.
Tents and frames.
Telephones, portable.
Air acetylene outfit or blow lamp and fuel.
Pliers, side-cutting.
Knife, hack and heavy pocket.
Cable identification sets.
Dressers, boxwood.
Files.
Rasps.
Saw, hack.
Snips, plumber's.
Hooks, shave.
Hammers, Engineer's and claw.
Moleskins.
Mirrors.
Mallets, plumber's.
Lamps, hurricane.
Rule, 2 ft.
Screwdriver.
Wiping cloths.
Wire cleaner.
CO_2 Gas, fittings and gauges.
Iron, soldering (electric).

(3) The drawing in and jointing of the cable would be carried out to the following procedure:—

(a) The duct is first rodded and then a wire to which a brush, a short length of 800 pair cable and a further draw wire are attached, is pulled through the duct. Any obstructions encountered are investigated and removed.

(b) Determine the direction of drawing in of the various cable lengths to ensure that all lengths are drawn into the duct in such a direction that the colours of the pilot pairs will correspond for jointing and the rotation of the cable corresponds with that of the other cables in the exchange area.

(c) Set up the first drum ready for drawing in and see that the cable will enter the duct without kinking. Set up the winch at the next manhole and pull the flexible steel rope through the duct with the draw wire previously inserted. Attach the steel rope to the cable by means of the cable grip, swivel and steel link.

(d) Completely covering the cable sheath with cable pulling compound, draw the cable carefully into the duct until sufficient cable has been drawn into the further manhole to allow for the setting up of the cable and jointing. Cut the cable in the first manhole and seal all ends. A party of seven men would normally be required for this operation, two men attending to the drum, one guiding the cable to avoid kinks, one applying the cable pulling compound, two on the winch and one supervising.

(e) Pressure test cable length drawn in with CO_2 gas.

(f) Repeat this procedure with each 110 yard length.

(g) In the meantime, the EC. cables at the exchange should be fanned out, then placed in position and connected to the M.D.F. terminals.

(h) The joint between the P.I.L.C. cable and the E and C cables will next be completed in accordance with the directions supplied to the jointer. The joints in the P.I.L.C. cable will then be made, working from the exchange.

(i) The general jointing procedure will be as follows:—

(i) Ensure that there is no likelihood of moisture coming in contact with any exposed conductors.
(ii) Set up the ends of the cable in manhole, placing each in its final position.
(iii) Cut off approx. 2 ft. of sheath from each cable end and prepare quads for jointing.
(iv) Joint pairs by rotation in each joint.
(v) Identify pairs with cable identification set at 1st, 4th, 8th, 12th and final joints from the exchange M.D.F., in conjunction with the jointing of the wires in these joints. All identified pairs will be tagged for future reference.
(vi) On completion of each joint, the conductors will be wrapped with brown paper and the lead sleeve will be fitted over the conductors and wiped to the cable sheath. As it would be impossible to complete one joint in a day, temporary sleeves of lead sheet or tacky rubber should be fitted to unfinished joints overnight.
(vii) As each lead sleeve is completed, it should be pressure tested with CO_2 gas and soap suds before being left.
(viii) On completion of the jointing of the P.I.L.C. cable, all pairs should be tested with a megger and identified, preparatory to connection to the existing cable.
(ix) A plan will be prepared showing actual cable lengths between manholes. Any abnormalities such as faulty pairs will be recorded and returned with the plan.

(4) The principal items to which the workmen's attention should be drawn include:—

(i) Position of duct into which cable is to be drawn.
(ii) Final position of cable in manholes and cable tunnel, and lengths to be left for jointing.
(iii) Necessity for fitting of temporary sleeves or taking of other precautions with joints which have to be left unfinished or untested for any period.
(iv) Locations of joints where pairs should be identified or tagged.
(v) Particulars of:—
  (a) Megger tests for I.R.
  (b) Pressure tests of individual joints.
(vi) Directions regarding the M.D.F. numbers to which individual pairs of 800 P.I.L.C. cable should be connected.
(vii) Details required on completed plan for record purposes.

EXAMINATION NO. 2295.—ENGINEER—TRANSMISSION

R. B. Dodds, B.E., A.M.I.E. (Aust.)

GENERAL THEORY AND MEASUREMENTS

Q. 1.—Determine the attenuation in db per mile and the primary constants of an unloaded underground cable circuit which, at 796 cycles per second, has the following characteristics:—

Z = Characteristic impedance
= 274 — j 243 ohms.
P = Propagation constant
= 0.12 $\angle 48° 10'$

A.—

Let a = attenuation constant
b = wave length constant

the Propagation constant

$$= PL\theta$$
$$= a + j\,b$$
$$= P(\cos\theta + j\sin\theta).$$
$$a = P\cos\theta$$
$$= 0.12 \cos 48° 10'$$
$$= 0.12 \times .667$$
$$= .08 \text{ nepers per mile.}$$
$$1 \text{ neper} = 8.686 \text{ db.}$$

∴ Attenuation per mile

$$= 0.695 \text{ db/mile.}$$

Let R = resistance per mile
L = inductance per mile
G = leakance per mile
C = capacitance per mile

$$\text{Then } P = \sqrt{(R + j\omega L)(G + j\omega C)}$$
$$Z = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$
$$Z = 274 - j\,243$$
$$= \sqrt{274^2 + 243^2}\ \angle \tan^{-1} 243/274$$
$$= \sqrt{134125}\ \angle \tan^{-1} 0.8868$$
$$= 366.2\ \angle 41°34'$$
$$PZ = \sqrt{(R + j\omega L)(G + j\omega C)}\ \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$
$$= R + j\omega L$$
$$= 0.12\ \angle 48° 10' \times 366.2\ \angle 41° 34'$$
$$= 0.12 \times 366.2\ \angle 48° 10' - 41° 34'$$
$$= 43.944\ \angle 6° 36'$$
$$= 43.944\,(\cos 6° 36' + j \sin 6° 36')$$
$$= 43.944\,(0.9934 + j\,0.1149)$$
$$= 43.65 + j\,5.05$$

Equating real and imaginary quantities—

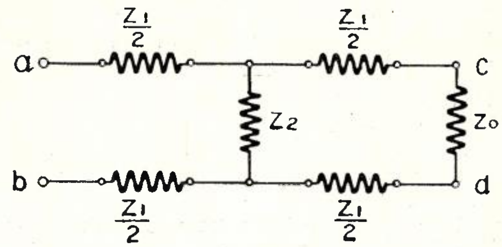
$$R = 43.65 \text{ ohms per mile.}$$
$$\omega L = 5.05 \text{ ohms per mile.}$$
$$L = \frac{5.05}{2\pi \times 796}$$
$$= 1.01 \text{ millihenries per mile.}$$
$$P/Z = \sqrt{(R + j\omega L)(G + j\omega C)} \div \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$
$$= G + j\omega C$$
$$= \frac{0.12\ \angle 48° 10'}{366.2\ \angle 41° 34'}$$
$$= .000327\ \angle 89° 44'$$
$$= .000327\,(\cos 89° 44' + j \sin 89° 44')$$
$$= .000327\,(.00465 + j\,0.9999)$$
$$= .0000015 + j\,.000327$$
$$G = .0000015$$
$$= 1.5 \times 10^{-6} \text{ mho.}$$
$$\omega C = .000327$$
$$C = 0.0000652 \text{ farads.}$$

Q. 2. (a) Develop the expression for the values of the series and shunt elements in a H type resistance network having a characteristic impedance Zo.

(b) If Zo = 600 ohms, calculate the resistance of the elements of a passive network having an attenuation of 40 db.

A.—

Let abcd, Fig. 1, represent the H network.



Q. 2, Fig. 1.

Suppose the terminals cd are terminated in an impedance Zo and an emf applied to the terminals ab.

Let I_1 be the current flowing into the network.

Let I_2 be the current flowing into the load Z_o.

Since the characteristic impedance of the network is Zo and cd is terminated in Zo, then the impedance looking into ab will be Zo.

∴ from series and parallel circuits—

$$Z_o = \frac{Z_1}{2} + \frac{Z_2(Z_1/2 + Z_o + Z_1/2)}{Z_1/2 + Z_o + Z_1/2 + Z_2} + \frac{Z_1}{2}$$
$$= Z_1 + \frac{Z_2\,(Z_1 + Z_o)}{Z_1 + Z_2 + Z_o} \quad \text{.... .... (1)}$$

Let θ = attenuation of network in nepers

$$\text{then } \frac{I_2}{I_1} = e^{-\theta}$$

But from parallel circuits—

$$\frac{I_2}{I_1} = \frac{Z_2}{Z_1 + Z_2 + Z_o}$$
$$\therefore e^{-\theta} = \frac{Z_2}{Z_1 + Z_2 + Z_o} \quad \text{.... .... (2)}$$
$$\therefore \text{From (1) } Z_o = Z_1 + e^{-\theta}\,(Z_1 + Z_o)$$
$$= Z_1 + Z_1 e^{-\theta} + Z_o\,e^{-\theta}$$
$$= Z_1\,(1 + e^{-\theta}) + Z_o e^{-\theta}$$
$$\therefore Z_o - Z_o\,e^{-\theta} = Z_1\,(1 + e^{-\theta})$$
$$Z_1 = \frac{Z_o\,(1 - e^{-\theta})}{(1 + e^{-\theta})} \quad \text{.... .... (3)}$$

Multiply 3 by $\frac{e^{\theta/2}}{e^{\theta/2}}$

$$Z_1 = \frac{Z_o\,(e^{\theta/2} - e^{-\theta/2})}{(e^{\theta/2} + e^{-\theta/2})}$$
$$= Z_o \tanh \theta/2 \quad \text{.... .... (4)}$$
$$\text{From (2) } Z_2 = (Z_1 + Z_2 + Z_o)\,e^{-\theta}$$
$$Z_2(1 - e^{-\theta}) = (Z_1 + Z_o)\,e^{-\theta}$$
$$= \left(Z_o\frac{(1 - e^{-\theta})}{(1 + e^{-\theta})} + Z_o\right) e^{-\theta}$$
$$= \left(\frac{Z_o - Z_o\,e^{-\theta} + Z_o + Z_o\,e^{-\theta}}{1 + e^{-\theta}}\right) e^{-\theta}$$

$$= \frac{2 Z_o e^{-\theta}}{1 + e^{-\theta}}$$

$$Z_2 = \frac{2 Z_o e^{-\theta}}{(1 - e^{-\theta})(1 + e^{-\theta})}$$

$$= \frac{2 Z_o e^{-\theta}}{(1 - e^{-2\theta})}$$

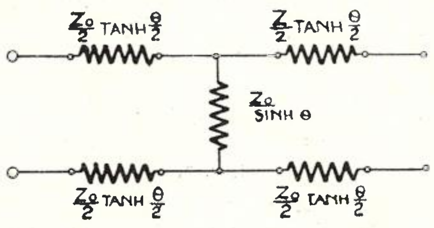
$$= \frac{2 Z_o}{e^{\theta} - e^{-\theta}}$$

$$= \frac{Z_o}{\sinh \theta} \quad \text{.... ....} \quad (5)$$

$$\therefore Z_1 = Z_o \tanh \theta/2$$

$$\text{and } Z_2 = \frac{Z_o}{\sinh \theta}$$

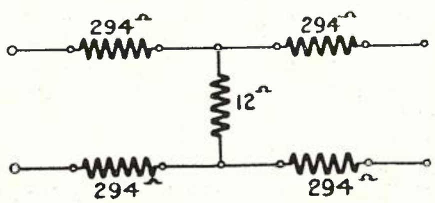
The network will therefore be as in Fig. 2.



Q. 2, Fig. 2.

$$Z_o = 600 \text{ ohms}$$
$$\text{Attenuation} = 40 \text{ db}$$
$$= 40/8.686$$
$$= 4.6 \text{ nepers.}$$
$$Z_1 = Z_o \tanh 2.3$$
$$= 600 \times 0.9801$$
$$= 588.1$$
$$Z_2 = \frac{Z_o}{\sinh 4.6}$$
$$= \frac{600}{49.737}$$
$$= 12.$$

The required network will therefore be as shown in Fig. 3.



Q. 2, Fig. 3.

EXAMINATION NO. 2295.—ENGINEER—TELEPHONE EQUIPMENT

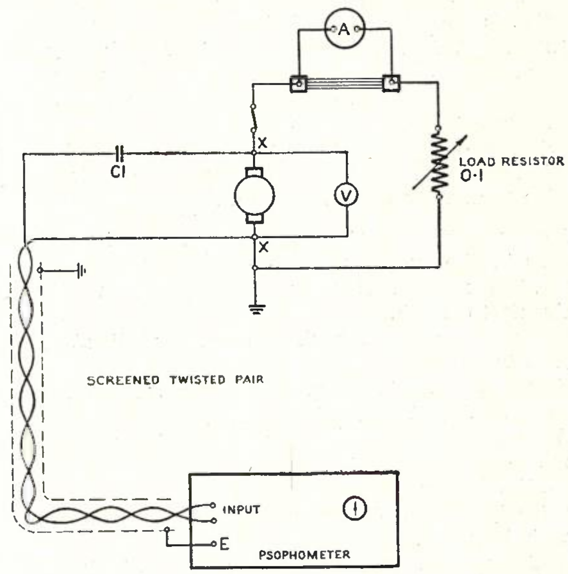
J. A. Kline, B.Sc.

Q. 4.—(a) What methods would you adopt in order to carry out a quantitative measurement of noise at a manufacturer's works, on a rectifier or motor generator, which is intended for charging or floating the batteries of a telephone exchange? Illustate your answer with suitable sketches. What precautions would you take when carrying out the tests?

(b) What is the maximum noise level which can be tolerated at the bus bars of a telephone exchange and what is the optimum frequency for the measurement of the noise?

(c) Is a 50-volt exchange battery installation inductive when measured at 1000 P.P.S.? In a case where the installation is inductive how would you reduce the inductance to the lowest possible value? Would any advantage be gained by such action? Give your reasons in full.

A.—(a) Quantitative measurement would be made with a noise measuring set or psophometer. The connections are shown in Fig. 1. If a motor generator is being tested it is important that the brushes should be in the non-sparking position and final adjustments should be made to the position where the minimum noise output is indicated on the psophometer.



Q. 4, Fig. 1.

The load resistor used to take the place of the battery should be non-reactive. Water resistors are suitable but the connecting leads should be placed close together and should not exceed 12 feet in length. The complete load circuit external to the unit being tested should not contain any inductive equipment. The screened twisted pair test lead must be as short as possible. The psophometer must be located where it will not be affected by stray magnetic fields.

(b) The maximum noise p.d. measured with a psophometer connected as shown in Fig. 1 must not exceed 2 millivolts r.m.s. with a load resistor of 0.1 ohm when the output varies from ¼ to full load. If other values of load resistor are used, the permissible voltage should give a potential difference which will make the conditions equivalent to those set out above. The optimum frequency for this measurement is about 1000 p.p.s.

(c) A 50 voltage exchange battery is inductive when measured at 1000 p.p.s. the inductance being of the order of 10 to 20 microhenries. The inductance is kept to a minimum if the common charge and discharge circuits form a loop in which both leads of the loop including the battery are of equal length and as close together as possible. The leads should be as short as practicable.

The noise is a minimum when the impedance of the battery circuit is a minimum. There is usually mutual inductance between the first and second battery circuits, therefore, when one battery is charging the other will have noise induced in its circuit, the value depending on the impedance of the circuit including the battery. The cross-talk between circuits connected to this common battery is proportional to the impedance of the battery circuit. It is, therefore, most important to keep the impedance of the circuit as low as possible.

Q. 5.—(a) In a telephone exchange what would be the ideal requirements for the lightning arresters?

(b) Do the standard arresters used on the M.D.F. in automatic telephone exchanges fulfil all these requirements and if not in what directions do they fail?

(c) Trace by means of suitable sketches the development of the carbon arrester so far as departmental practice is concerned and briefly describe each type.

(d) What is a gas-filled arrester? What gases do these arresters normally contain? What general limitations are required to be placed on the gases used in these arresters?

(e) Discuss briefly the theory of a gas-filled arrester.

(f) Is the gas-filled arrester any more satisfactory in service than the vacuum arrester?

A.—(a) The ideal requirements for lightning arresters in the exchange are:—

(i) With normal line voltages they must be open circuit to earth.

(ii) High insulation resistance under all atmospheric conditions.

(iii) Must breakdown at a definite voltage above the normal circuit operating voltage.

(iv) Breakdown delay must be small to ensure that the arrester operates before the dangerous voltage on the line can cause damage.

(v) On breakdown they must provide a low impedance path to earth.

(vi) They must operate to cause as little interruption and disturbance to the circuit as possible and to restore to normal immediately the voltages are normal. The arrester should not become damaged as a result of the breakdown.

(vii) The breakdown voltage must remain reasonably constant throughout the life of the arrester.

(viii) They should be compact in size.

(ix) They must be reasonably inexpensive.

(b) The standard carbon arresters do not fulfil all these requirements. They do not restore to normal after breakdown. They vary in the voltage of breakdown and since they do not restore to normal the breakdown causes an interruption to the circuit.

(c) The development of the carbon arrester is shown in Fig. 1.

(a) shows the 2 carbon blocks separated by a U-shaped mica approximately 4 mils thick. In the centre of the operating face is embedded a spot of alloy with low melting point. When the arrester operates this alloy plug melts and connects the line to earth, through the second carbon.

In (b) the longitudinal edges are chamfered, but fundamentally the arrester is the same as in (a).

In (c) there is a transverse recess 2 or 3 mils deep ground across the centre of the operating face leaving steps $^{3}/_{16}$ in. wide at either end. The mica had 3 holes to allow the passage of sparks as well as the fusing alloy. The faces of both carbons were treated with an anti-dust varnish.

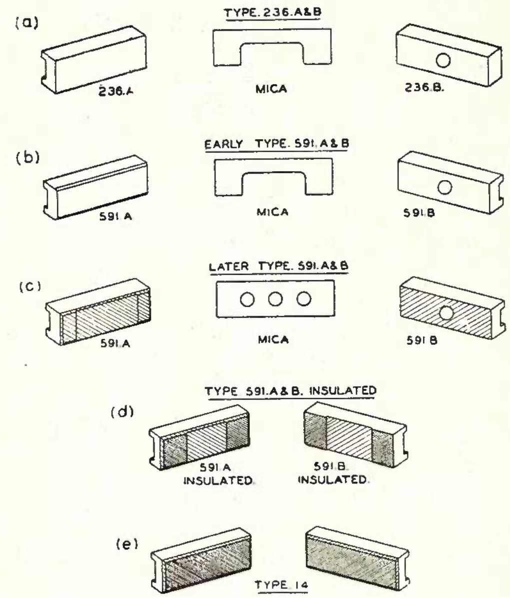


Fig. 1.

(d) The steps were made of an insulating varnish 2 mils thick and there is no alloy plug. Mica separators were not used.

(e) The latest type has two identical carbons chamfered all round their operating faces which are perfectly flat and treated with anti-dust varnish then coated uniformly with an insulating varnish $1\frac{1}{2}$ mils thick. Mica separators are not used.

(d) The gas filled arrester consists of 2 or 3 metallic electrodes enclosed in a glass tube containing an inert gas or mixture of gases at reduced pressure. The gases may be Neon, Argon or Helium.

The gases used must be chemically inactive and must not form compounds with, or become absorbed by, the metals used in the electrodes or other parts of the arrester with which it may come in contact.

(e) When a D.C. potential difference is applied between 2 electrodes in the arrester the electrostatic field set up between them causes stray electrons and negative ions in the gas to move towards the anode and causes positive ions to move towards the cathode. The electric current so constituted is minute when the p.d. is small. As the p.d. increases the velocity of these electrons increases until a critical velocity is reached at which electrons and ions collide with neutral molecules causing these to be split up into pairs of positive or negative ions which in turn collide with other neutral molecules producing more ions so that a sudden very large increase of current is produced and the gas is said to "breakdown."

(f) The vacuum arrester with carbon electrodes was not so satisfactory in service as the gas filled arrester because the carbon absorbed some of the rarefied air at certain discharge temperatures causing the gas pressure to fall and the breakdown voltage to rise dangerously.

The current carrying capacity of the vacuum arrester was not as high as the modern gas filled arrester.

(Index to Volume 3, continued from Cover ii.)

8. TELEPHONE TRANSMISSION.

9. MISCELLANEOUS.

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