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## CONTENTS

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# TRANSMISSION IMPROVEMENTS IN EXCHANGE AND SUBSCRIBERS' EQUIPMENT

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This article treats in some detail the transmission improvements which have been made in recent years in exchange and subscribers' equipment. The subject will be introduced by a brief discussion of the transmission plan of the Commonwealth, and later some details will be given of the International Master Telephone Transmission Reference System (S.F.E.R.T.) as maintained at Paris by the International Telephone Consultative Committee (C.C.I.F.). The remainder of the paper will consider the following aspects:—

(1) The Local Line connection as a unit,
(2) The influence of outside plant,
(3) Public Exchange Equipment,
(4) Subscribers' Instruments,
(5) P.B.X. Equipment.

### Commonwealth Transmission Plan.

The realisation of this plan will mean that any subscriber in any part of the country will be able to converse with reasonable ease with any other such subscriber. Bearing in mind that this may mean in certain cases a route distance of the order of 6000 miles, it will be seen that the task is not a simple one. The first major attempt to plan the Australian telephone network as a whole was made in 1923. Since that date there have been numerous improvements in the transmission qualities of both lines and equipment with the result that a new standard has been set to which all connections in the Commonwealth will ultimately conform. The "Standard Grade of Overall Transmission" is the name given to this telephone objective and it is illustrated in skeleton form in Fig. 1.

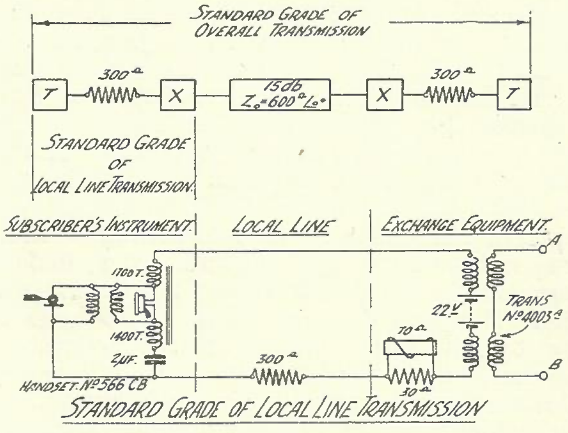


Fig. 1.—Standard Grade of Overall Transmission.

This diagram shows that each connection may be considered as made up of three units, two of them being the separate local lines and instruments at the ends of the connection, whilst the third is the transmission line joining the local line units and consisting of junction circuits, switching exchanges, trunk lines, transmission aids, e.g. repeaters, as may be required. It will be noted that this transmission line is to be equivalent to a 15 db. attenuator of 600 ohms $\underline{/0^{\circ}}$ impedance. Figure 2 gives three instances of typical connections conforming to this standard of overall transmission.

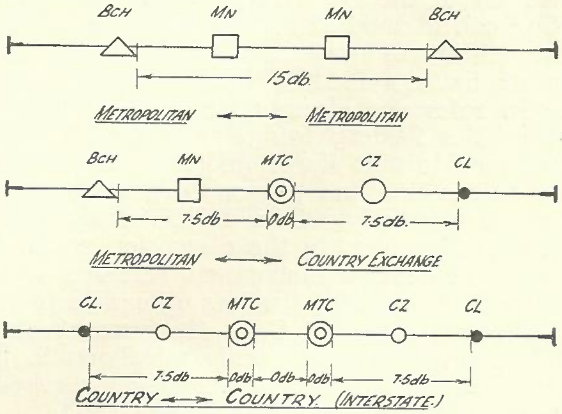


Fig. 2.—Typical connections of Standard Overall Grade.

BCH = Branch Exchange.
MN = Main Exchange.
MTC = Main Trunk Centre.
CZ = Country Zone Centre.
CL = Country Local Exchange.

An interesting point is the requirement of zero loss for connecting cord circuits as well as for trunk lines between main trunk centres.

In the newer trunk switchboards zero loss cord circuits are obtained by using "sleeve control" and by associating any essential line bridging apparatus with the line itself. The cord circuit virtually becomes a straight-through pair of wires. Monitoring by telephonists is effected with quite negligible loss by means of amplifiers, the input circuits of which are of very high impedance. The use of four-wire circuits with both carrier and v.f. repeater systems has done much to enable low-loss trunk lines to be operated. Echo suppressors and provision for maintaining a termination of 600 ohm continuously at the ends of trunk lines are essential for zero-loss trunks. As far back as 1921 trunk junctions of zero-loss or better were being operated in New York. Great Britain has a number of fairly long trunks of zero loss in use at present. In Australia few of the longest circuits are operated below 6 db.

### The Local Line Connection.

The main aim of this article is to consider the local line portion of the connection consisting of the telephone instrument, the physical line and the local public exchange equipment. The lower half of Fig. 1 is a diagram of connections, and it is so planned that ultimately no local connection will be inferior to this in performance. The quality of service by the connection illustrated or its equivalent is known as the "Standard Grade of Local Line Transmission." For common battery working, the local exchange as well as acting as a switching point supplies current for talking purposes through a transmission or battery feeding bridge. The "reference" connection, as that shown in Fig. 1 may be called, makes use of the low voltage transformer or repeating coil method of current supply sometimes called the Hayes system. This is a very early type of battery feeding bridge and has been used in reference circuits for many years. In practice the feeding bridge will almost always be different to that shown and the same remarks apply to the line and to some degree to the instrument especially where P.B.X. equipment is involved. However, in the discussion which follows the substation instrument referred to will be that shown in Fig. 1 unless otherwise indicated, i.e., Telephone 566 C.B.—the present standard handset telephone. This telephone is precisely equivalent from a transmission view point to the automatic model—Telephone 566A.

In considering the transmission effects in this local line connection, there will be the purely A.C. or voice-frequency loss from the telephone to the junction terminals A.B. and an exactly similar loss in the opposite direction from these same terminals to the telephone. This is usually known as the Receiving loss although it also occurs in the sending condition. In sending, however, there is an additional factor influencing the V.F. energy sent to line, namely, that due to the change of current fed to the telephone transmitter proportionally to the change in the D.C. resistance of the circuit between the battery and the transmitter. The change of efficiency due to change in transmitter current supply is usually termed "Feeding Current Loss." These three "losses" may only be considered relative to the "Standard Grade of Local Line Transmission" (Fig. 1) and in what follows relative loss is understood in all cases. In certain instances due to the use of higher battery voltages, lower resistance battery feeding elements, and shorter lines, more current than "standard" will be fed to the transmitter in which case a feeding current gain will be experienced. For somewhat similar reasons it is quite practicable to obtain a receiving gain. It is the gains obtained from the use of more efficient apparatus and from improved battery feeding conditions which have enabled the "Standard Grade of Local Line Transmission" to be given on lines in excess of 300 ohms.

Figure 3 illustrates the relation of the various losses just described to the "Standard Grade."

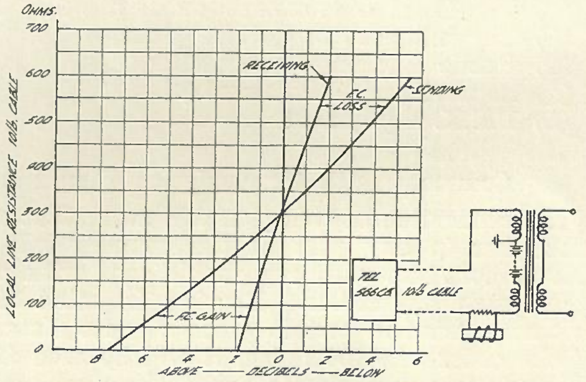


Fig. 3.—Local line sending and receiving losses (common battery).

It will be noted that the feeding-current loss or gain is equal to the difference between the curves. Below 300 ohms it is a gain, above 300 ohms it is a loss. The curves shown are for a local line of 10 lb. cable construction and it will be noted that both sending and receiving curves are very slightly better than the "Standard Grade" at the 300 ohm point. This is due to the fact that the "Standard Grade" assumes a non-reactive resistance for the local line whilst the practical case always consists of a line with reactance. The effect of the reactance is two-fold. The pure V.F. loss of the 10 lb. line assuming it to be terminated in its characteristic impedance, is greater than the 300 ohm resistance shown. However, the phase difference between the cable line and the terminating instruments is such as to give a transmission gain which more than offsets the increase of V.F. loss due to the "attenuation" loss of the 10 lb. line. It will be noted that the feeding current loss at the 300 ohm point is zero, because it is only effected by the D.C. resistance of the circuit which is still identical with the "Standard Grade."

Figure 4 shows the sending and receiving loss curves for a telephone for long C.B. lines using local battery transmission and illustrates the difference between the feeding current losses with common battery (C.B.) and the local battery (L.B.) transmission. It will be noted that unlike the curves shown in Fig. 3 the difference between them, i.e., the feeding current factor is constant and in this case is a loss.

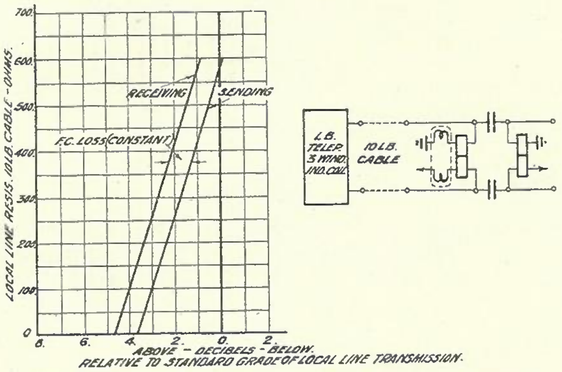


Fig. 4.—Local Line sending and receiving losses (L.B. transmission).

This follows immediately from the fact that the current through the transmitter is independent of the length of the line and is determined by the voltage and internal resistance of the local battery, the resistance of the transmitter and of the associated induction coil winding. The type of the transmitter and the efficiency of the internal telephone circuit (when this differs from "standard") are also very important factors. The feeding current loss of a telephone on a particular connection may therefore be defined as a measurement compared with some standard condition of the open circuit A.C. voltage of the telephone, the transmitter being fed with the particular value of current which the connection permits.

## The Influence of Outside Plant.

In all the curves in this paper illustrating, amongst other things, the effect of changes in the length of subscribers' lines, the vertical axis will be expressed in units of 10 lb. cable. For the lengths of lines normally met with in subscribers' services, the error introduced in regarding them all as 10 lb. cable lines in lieu of 6½ lb., 12½ lb., 20 lb., or a mixture of such gauges, is quite small provided the line is measured on a resistance basis. The differences between what are really the receiving losses for the same resistance of various types of line is due to the variations in capacitance. These variations effect the impedance conditions of the connection, the capacitance reacting with the inductance or positive reactance component of the impedance of the telephone to give transition gains or losses which together with the other A.C. losses cause small changes in receiving loss for the different types of line. Rigorously the loss caused by any transmission line inserted between any two impedances such as the instrument and the exchange equipment with its termination consists of three factors:—

(1) The Attenuation loss.
(2) Reflection factors.
(3) Interaction factors.

The first is that mentioned previously and is the loss of that length of line terminated in its characteristic impedances. The second is due to the mismatch between the line and its terminations and takes into account phase as well as modulus differences. The third is due to the fact that the line may be electrically short enough to enable the terminations to "interact" on one another.

One method of improving transmission on the longer lines is to resort to the bunching of cable pairs whereby the D.C. resistance of the connection is considerably reduced; thus for the same length of line a higher D.C. current flows through the transmitter. For a line of 600 ohms connected to a 48 volt exchange using 200/200 ohm battery feed coils an improvement of 2 db in feeding current loss is obtained for 2 pairs bunched. As might be expected voice-ear tests under precise conditions indicate that there is practically no measurable change in receiving loss. In using cable pairs in parallel, care must be taken to see that one wire of each pair is taken to form one side of the new line and not one pair as a side, otherwise bad crosstalk will be experienced. Put briefly, common tip to tip and ring to ring to form the new circuit.

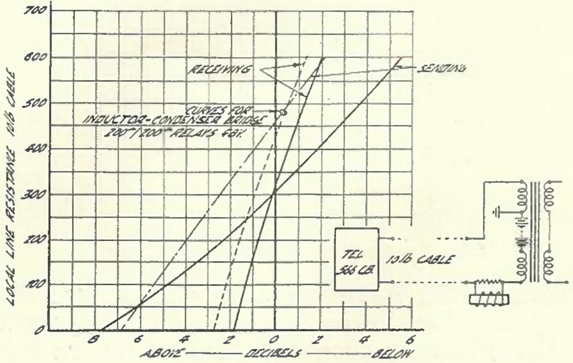


Fig. 5.—Effect of 48-volt battery on local line losses.

### Public Exchange Equipment.

It has already been mentioned that the battery feeding bridge for "Standard Grade" (Fig. 1) is one of the earliest forms. Most bridges are now those usually referred to as the "Stone" or Inductor-Condenser type.

With the higher voltages required in automatic exchanges for switch operation, better current supply conditions are obtained with inductor-condenser feed. This effect is shown in Fig. 5 where a comparison is made between 48 volts 200/200 I.C. feed and the transformer feed. For small line resistances much higher current values are obtained with transformer feed. The maximum line current with 48 volt I.C., i.e. zero line, is 100 mA. With 22 volt transformer feed it is 176 mA. The C.B. handset transmitter is capable of carrying 200 mA without noticeable deterioration, but the optimum efficiency is obtained with approximately 100 mA and higher current values are therefore uneconomical and of no advantage. Values of 100 mA and upwards with solid back transmitters have been the cause of much maintenance difficulty.

In some of the earlier Strowger automatic exchanges the battery feed relays were of 250/250 ohm resistance. Later exchanges used 200/200 ohm relays. The latest development in battery feeding bridges is in the provision of relays of quite low resistance 50/50 ohms—together with ballast resistors or barretters which limit the current under any line condition to a predetermined value—usually 100 mA. These barretters, which consist of two filaments, one for each side of the line, are tungsten wires in an atmosphere of hydrogen, and have been described more fully in Telecommunication Journal No. 2. The gauge of the wires is such that any tendency to increase the current above 100 mA causes a large increase in resistance, the hydrogen acting as a good thermal conductor to transfer the heat generated to the glass envelope whence it is radiated. Small changes in current can thus cause large changes in temperature and consequently of resistance, without the burning out of the filament. Hence the limiting effect. On account of this latter feature the feeding current loss curves compared with other types of battery feeding bridge are quite different as shown by Figure 6.

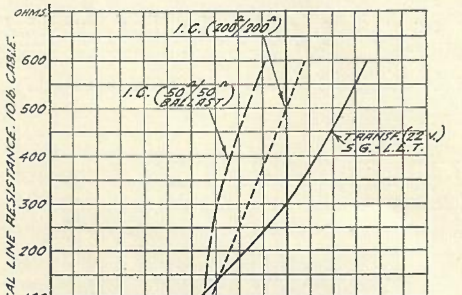


Fig. 6.—Feeding current loss curves.

Figure 7 has been included to give a comparison between the 200/200 ohm bridge and that using 50/50 ohm relays. A slight improvement is shown in the receiving loss due to the use of Nickel-Iron sleeves on the relays. Owing to the lower number of turns on these relays some action has to be taken to maintain the impedance at voice-frequency. The main soft iron core of the relay takes the D.C. flux whereas the nickel-iron sleeve takes the A.C. flux which does not penetrate the main core to any extent. The use of these sleeves more than offsets the effect due to the smaller number of turns on the relay.

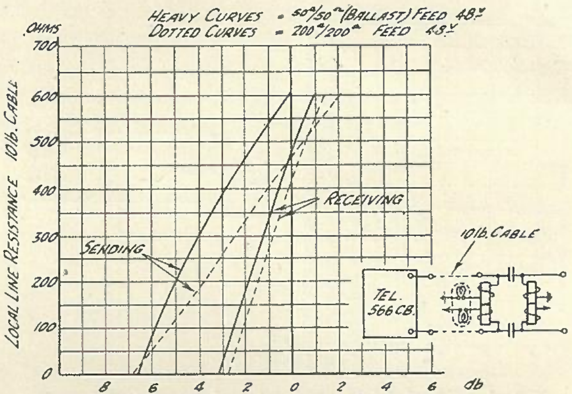


Fig. 7.—Local line losses with 50/50 and 200/200 feeding bridges.

### Subscribers' Instruments.

The most important of recent developments under this heading has been the production of a handset telephone suitable for C.B. working. The main feature of this development is the design of a new type of transmitter usually known as the immersed electrode inset. As the name implies, the electrodes remain immersed in the carbon granules in whatever position the handset may be placed, thus preventing large changes in the resistance of the transmitter and the sending efficiency, so detrimental respectively to the supervisory and transmission qualities of the circuit. Such difficulties were being continuously experienced on P.B.X.'s equipped with the star-wheel pattern of transmitter which was particularly susceptible to frying and burning troubles. In America, England, and the continent of Europe, much work has been done on new types of insets to overcome these disadvantages. The inset adopted up to the present by this Department is the British Post Office standard and is known as the No. 10. A cross section of this familiar inset is shown in Figure 8.

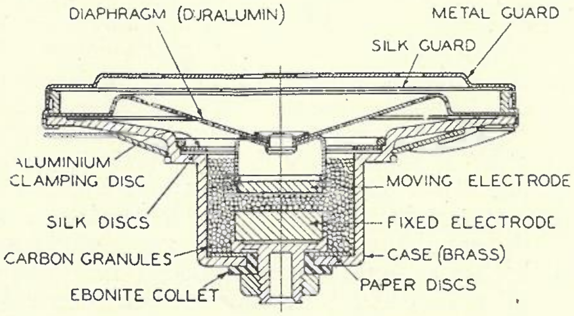


Fig. 8.—Transmitter Inset No. 10.

In this inset the diaphragm, whilst not forming one of the electrodes as is the case with the Starwheel type, carries the current from the moving electrode. This electrode moves in and out of a series of silk washers which are accurately fitted. One of the disadvantages from which some samples of this inset have suffered is the loss of carbon from the carbon chamber. This has been due to badly fitting silk washers allowing the carbon to escape granule by granule. This difficulty is not experienced with the inset transmitter developed by the International Standard Electric Corporation and marketed by Standard Telephones and Cables. This is known as their type 4005A and is illustrated in Fig. 9.

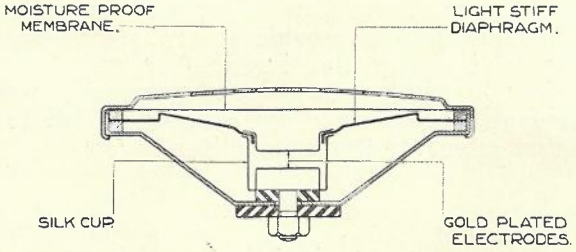


Fig. 9.—I.S.E.C. Inset No. 4005A.

It will be seen from this diagram that the carbon is held in a silk cup the chamber being hermetically sealed. Another interesting feature is the fact that the electrodes are gold plated whereas in the No. 10 inset they are of the usual polished carbon.

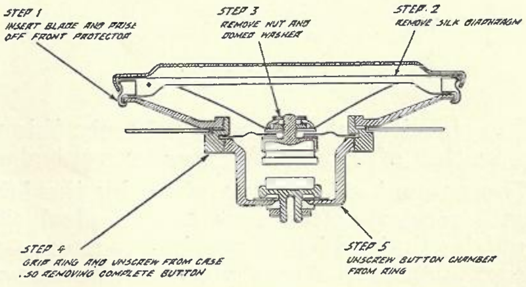


Fig. 10.—Transmitter Inset Type F2.

Figure 10 illustrates an inset developed by the British General Electric Company and known as their F.2 type. It differs from both Inset No. 10 and the 4005A type in that it may be dismantled and recarboned.

As was mentioned previously, one of the disadvantages of the former transmitters used as handsets, was the relatively large changes of efficiency with change of position.

Fig. 11 gives two curves, one of efficiency and one of resistance for change of position of a No. 10 transmitter through an angle of 90 degrees. Precise figures are not available for the older type transmitters. However, using the present local battery Star Wheel Inset in a handset, it is possible for the transmitter to go entirely open circuit in certain positions.

Not only is the immersed electrode inset more uniform in service as indicated, but it is, of course, considerably more efficient.

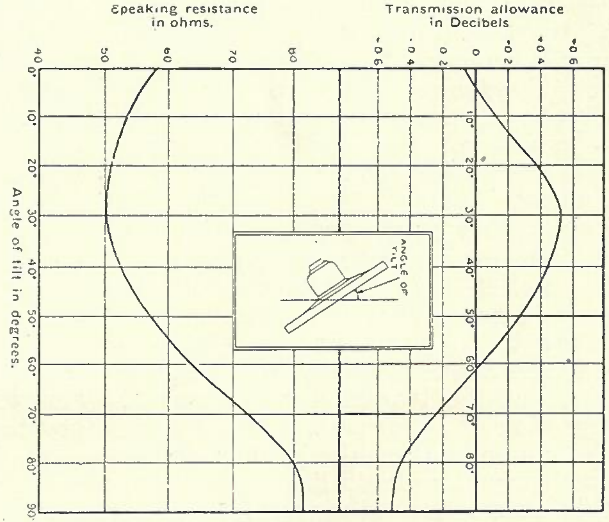


Fig. 11.—Effect of angle of tilt on transmission efficiency and speaking resistance.

Experience of the No. 10 inset in service both in England and Australia has shown that certain changes in its design are desirable. The defects discovered have been mainly as follow:—

Reduction of sending efficiency due to silk membrane adhering to the front guard.

Corrosion of diaphragm by moisture.

Carbon leakage due to imperfect fit of silk washers.

Breakage of ebonite collet which insulates back electrode.

The B.P.O., in association with Siemens Bros., have developed a new inset—No. 13 (Siemens 18A)—which is designed to overcome these faults, and trials in public telephones are being carried out in England. A small quantity are also under test in pay stations in Australia. The new inset is illustrated in Figure 12.

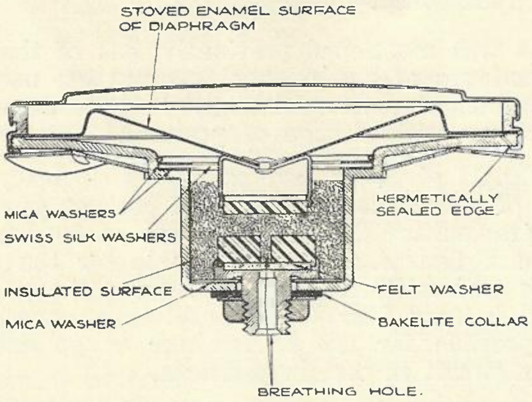


**Fig. 12.—Sectional view of B.P.O. Inset No. 13.**

The main changes in the new inset are the coating of the diaphragm with a corrosion-resisting enamel and the sealing of the junction of the diaphragm and the clamping ring by a special cement. The sealing prevents electrolytic action between the two dissimilar metals—nickelled brass and duralumin—in the presence of moisture. For further information on this new inset the reader is referred to P.O.E.E. Journal, January 1937, p. 335, and Siemens' Engineering Supplement, January 1937, p. 11.

Tests of a number of No. 13 insets against the No. 10 type indicate that the volume efficiency of the new type is slightly less. This was found to be due mainly to the absence of the silk membrane whereby the frequency response curve of the transmitter is changed. This disadvantage is, however, offset by the fact that the elimination of the membrane in the No. 13 overcomes the fault liability in the No. 10, of this membrane adhering to the front guard. This condition, which is frequently encountered, may cause a reduction in sending efficiency sometimes as high as 10 db.

| Test (in Reference Circuit). | Reference Equivalents (Sfert.). | | |
|---|---|---|---|
| | Base Line | Average Supplies | Worst Individual Supplies |
| | db. | db. | db. |
| Sending for Trans. C.B.1 (¼" from Mouthpiece) .... | 8.0— | 11.2— | 12.5— |
| Sending for Telephone, 566.C.B. (At Modal Distance) .... | 7.9— | 7.9— | 8.9— |
| Receiving for Bell Rec., 1A .. | 4.8— | 6.3— | 7.3— |
| Receiving for Telephone, 566.C.B. .... .... .... .... .... | 5.9— | 5.9— | 7.9— |

— Indicates below the level of the corresponding section of Sfert.

This table gives information of the relative efficiency of the solid back transmitter (Trans. C.B. 1) compared with the new inset as well as certain information on reception. It will be noted that the figures are given as reference equivalents compared with S.F.E.R.T.—further information about which is given later. The "modal distance" referred to under Telephone 566 C.B. is the standard test distance of the lips from the mouthpiece with handsets, and the results given may be compared with the results with Telephone C.B.1 when the lips are ¼ inch from the mouthpiece. With these comparable conditions there is a gain of approximately 3 db. for average supplies in favour of the Telephone 566 C.B. (handset with inset No. 10). There is also a small improvement of 0.4 db. for the receiver. The receiver has a cobalt steel magnet giving a much higher impedance (1000 cycles) than the old type Bell receiver, the figures being of the order of 500 ohms and 200 ohms respectively. One very important feature of the new instruments is their greater uniformity of efficiency compared with the former type.

An improvement which has been effected with the new handset telephones is the reduction of sidetone. This was bad enough on short lines with the older type telephones but with the increased efficiency and with the speaker's lips being brought close to the transmitter because of the handset, some action to bring about a reduction in the sidetone was necessary. As is well known, the action taken with the 566 C.B. telephone, was to provide an anti-sidetone transformer coupling the transmitter with the receiver in such a way as to provide a current through the receiver opposing that due to the direct effect of the transmitter.

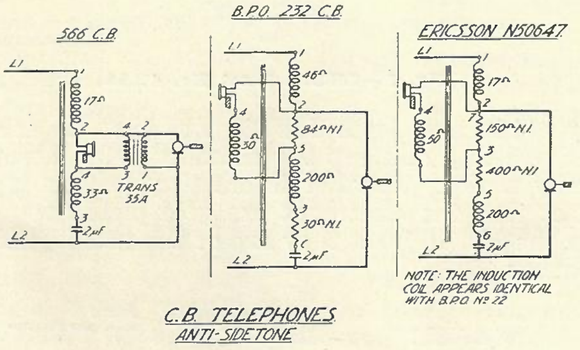


**Fig. 13.**

The circuit is shown in Fig. 13. By this means a reduction of 7 to 10 db. was brought about.

The amount of sidetone given by the 566 C.B. is still somewhat too great. The ideal sidetone would be that which a speaker receives—unconsciously—from his own voice in the absence of the telephone. The British Post Office have developed their Coil No. 20 to meet this sidetone difficulty in noisy situations, and this provides a further reduction of the order of 8 db. to that of Telephone 566 C.B. The amount is variable, depending on the impedance of the lines connected to the telephone but the value quoted may be taken as that which would be experienced in the majority of cases.

The middle circuit in Fig. 13 gives Telephone 232 C.B. which includes Coil No. 20, whilst on the right hand is an Ericsson telephone circuit incorporating a similar type of induction coil. These circuits show the differential method of obtaining reduced sidetone as well as the auto-transformer effect for the matching of the transmitter to the line.

In all modern handset telephones special consideration has been given to the relative position of the receiver earpiece and the transmitter mouthpiece to ensure that the speaker's mouth comes as near as is practicable to the transmitter. Thousands of measurements have been made on the heads of telephone users to determine the optimum dimensions and shape of the handset. The importance of the distance of the speaker's mouth from the transmitter can be gauged by the fact that a movement of 1 inch from the transmitter will cause a reduction of 9 db. in the output volume.

### Long C.B. Lines.

It will have been noticed from the various diagrams shown that there is a limit between 500 and 600 ohms beyond which the "Standard Grade" is exceeded for the most favourable transmission bridge. Beyond the point at which the grade of transmission given by any particular set of conditions exceeds the "Standard Grade," some improvement can be given by the use of local battery transmission. With this method, the feeding current loss remains constant irrespective of the length of the line, and is usually quite low compared with the corresponding feeding current loss for C.B. conditions.

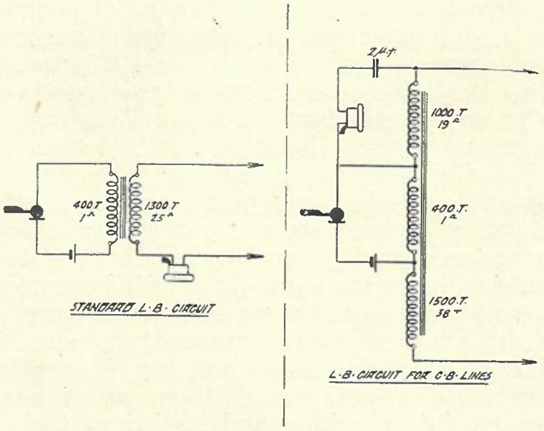


Fig. 14.—Local battery telephone circuits.

Figure 14 shows the standard circuit for local battery exchanges as well as the circuit adopted up to the present for long C.B. lines. The second circuit gives a considerable improvement from the point of view of sidetone, the original circuit giving no reduction whatever, as the whole of the v.f. line current passes through the receiver. The local battery telephones used for C.B. working have up till recently used the star-wheel inset as a transmitter.

These, as will be referred to in the next paragraph, have a very much higher efficiency than the immersed electrode transmitters; in fact they can give standard grade of transmission in the sending condition for lines as high in resistance as 1000 ohms or more whereas the handset of Telephone 566 C.B. reaches its limit between 700 and 800 ohms. The explanation lies in two directions: firstly the type of transmitter and secondly its resistance. The average resistance of star-wheel insets is from 30-40 ohms, giving quite a high current in the transmitter. The average resistance of immersed electrode insets on the other hand is nearer 70 ohms so that 50 per cent. reduction in feeding current can be expected.

Experiments are now being conducted on a C.B. telephone for long lines which promises to give a gain of the order of 3 db. in the sending direction and 2 db. in the receiving direction. This is illustrated in Figure 15.

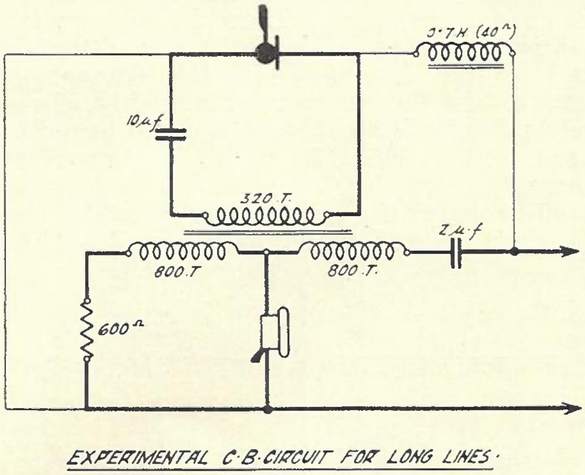


Fig. 15.—Experimental long-distance C.B. Telephone Circuit.

It will be seen that the transmitter, whilst being fed from the exchange battery over the normal line circuit, is actually in a local circuit from an A.C. point of view. The transformer shown is the normal closed core type and its differential action gives effective control of the sidetone. The adaptation of this circuit to automatic working has still to be considered.

### Local Battery Telephones.

Some reference has just been made to the effect on the sending efficiency of a telephone if the star-wheel inset is replaced by a handset transmitter. Quite a number of these changes are now being made and complaints are not infrequent about the poorer quality of transmission from the handset telephone. The change in sending efficiency may be as much as 10 db.

The difficulty can be overcome by increasing the local battery at the subscriber's station. This, however, means at least doubling the number of cells and whilst the immersed electrode inset will not be injuriously affected by the higher current value, the economics are, however, bad.

Reference has already been made to the B.G.E. F2 type of inset in which the carbon chamber can be dismantled. Tests were made using the coarser grain of carbon as is found in the star-wheel insets, in one of these F2 insets, and a resistance of the order of 30 ohms was obtained. On account, however, of the different physical shape and dimensions of the immersed electrode type compared with the star-wheel, this did not result in any appreciable change in efficiency. It is understood that at least one English firm is working on a new immersed electrode transmitter for local battery working, the further details of which are being awaited with interest. Before completing the section on subscribers' instruments, it is desired to refer to a new development of an old idea—the use of a receiver unit as a transmitter. There is now available what is known as a Magnetic Monophone produced by the Automatic Electric Company of America. In this instrument a highly efficient receiver unit is also used as a transmitter. Placed in the 566 C.B. circuit in lieu of the standard receiver inset it gives a gain in receiving efficiency of the order of 10 db. The same unit that is used with the transmitter is of course still relatively inefficient as it has to be borne in mind that the carbon transmitter is really an amplifier giving a power gain of the order of 1000, whereas there is no such effect present in an acousto-magneto-electric device which the receiver unit becomes when it is used in the sending condition. The magnets are of the Cobalt-steel type and the armature is a balanced movement connected to a diaphragm which plays no part in the magnetic circuit. The movement is very much like some of the magnetic speakers of the cone type which were in considerable use for radio purposes some years ago.

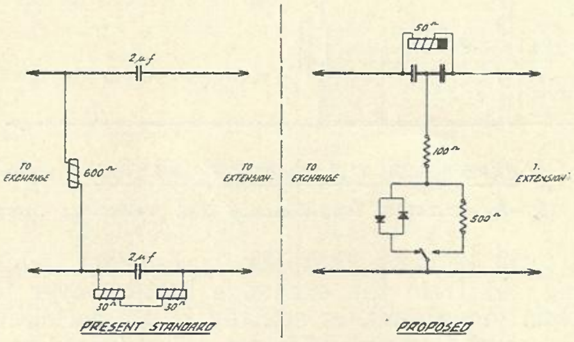


Fig. 16.—Proposed P.B.X. modification.

### P.B.X. Equipment.

Alterations to the standard C.B. P.B.X. circuit are now being considered whereby considerable improvement in transmission efficiency will be brought about. The old and the new circuits are shown in Fig. 16 in the exchange—extension condition.

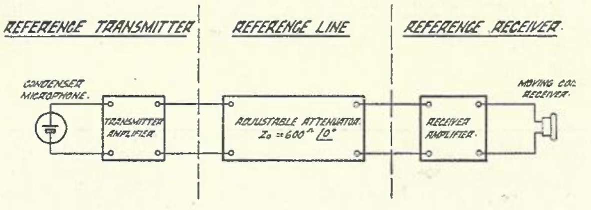
The main alteration has been the removal of the holding coil when the extension telephone answers. This has had the effect of decreasing the insertion loss from 0.6 to 0.3 db., and at the same time increasing the current supplied to the extension instrument by removing the D.C. shunt across the line. This latter improvement is of the order of 1-2 db. depending on the relative lengths of the exchange and extension lines.

The new circuit in addition to giving improved transmission provides a suitable V.F. loop at the P.B.X. until the extension answers, direct dialling from the extension telephone, simple night switching without special keys or cords and several other very desirable operating features.

### Master Telephone Transmission Reference System.

In order to compare the performance of complete telephone systems as well as of telephone instruments some basis of reference is necessary. The system in general use until 1925 consisted of two local line connections joined together by 24 "miles of standard cable." The local line connections were identical with "Standard Grade" (fig. 1) excepting that the 300 ohm non-reactive resistances were omitted. Such reference systems were not entirely satisfactory as standards mainly on account of the transmitters which were specially selected samples of the solid-back type for general subscribers' use. The difficulty of these transmitters was their variation of performance making it necessary to maintain a number of them as standards. Extensive interchecking and testing of the standards by voice-ear methods was required. Receivers, whilst being considerably more stable than transmitters, nevertheless also required the maintenance of a group in order to be reasonably safe in rating their average performance.

To overcome these disabilities, in 1924 the Bell System of America developed a new reference system, the performance of which could be accurately specified and reproduced by a series of purely physical measurements. This system is shown in block schematic form in Fig. 17.



MASTER TELEPHONE TRANSMISSION REFERENCE SYSTEM (SFERT.)

Fig. 17.

It will be seen to consist of three parts:—

1. The Reference Transmitter.
2. The Reference Line.
3. The Reference Receiver.

The microphone is of the condenser type as used until recently in broadcasting work. To offset its low efficiency, an amplifier is associated with the condenser microphone. The reference line consists of an adjustable attenuator of impedance 600 ohms $\underline{/0^{\circ}}$. The reference receiver is a highly damped moving coil receiver of quite uniform frequency response. An amplifier is associated with the receiver on account of its low efficiency.

The calibration of the transmitter is effected by means of a thermophone—a sound generator depending on the heating effect produced by a known current passing through a pair of gold leaf strips. The performance of such an instrument when operating in an atmosphere of hydrogen and properly coupled to the condenser microphone can be accurately and completely specified by a series of physical measurements without recourse to subjective voice-ear methods of test. The receiver is subsequently calibrated in terms of the condenser microphone by coupling it to the latter and again taking only physical measurements. The development of this new standard has thus provided a basis of reference which is capable of accurate calibration and therefore reproducible. The efficiencies of the reference transmitter and of the reference receiver were made to approximate those of the corresponding portions of the original reference system. The precise value of the reference line depends on the connection under discussion, e.g., the "Standard Grade of Overall Transmission" believed to be the standard in the Bell System, is equal to a reference equivalent of 31 db., i.e., this grade of transmission would be equal in loudness to that given by the system illustrated in Fig. 17 but with a "Reference Line" of 31 db. Where only transmitters or receivers and their associated lines and equipment are being considered, the "Reference Equivalent" represents the comparison with the corresponding portion of the "Reference System." Owing to the basis of adjustment of this system all figures are usually "below" or negative with respect to the sending or receiving sections of the system, hence the negative signs in the table on page 186.

In 1927 a second model of this reference system was manufactured by the Bell System and presented to the C.C.I.F. to become the European Telephone Transmission Reference Standard, generally called S.F.E.R.T. This unusual name is derived from the initial letters of the French rendering of the title just given—Système Fondamentale Européen Référence Transmission. The American and European systems are identical and together they represent the basis of transmission reference for perhaps 90 per cent of the world's telephones.

For further information on Transmission Reference systems the following articles will be found helpful:—

1. Bell System Technical Journal, 1924, p. 400.
2. Electrical Communication, 1924, p. 114.
3. Bell System Technical Journal, 1929, p. 536.
4. Publications of the C.C.I.F.—particularly the unofficial translations made by International Standard Electric Corporation.

# POST OFFICE PUBLICITY

*E. M. Dowse*

During recent years the Post Office has undertaken considerable publicity work in an endeavour to advertise its numerous services and to improve its relationship with the general public. Various forms of excellent publicity have been exploited but the type which makes the greatest call on the ingenuity of the technical staff is the staging of post office displays at agricultural and industrial shows and radio exhibitions. This class of work is very exacting and contains all the problems of original design, construction, management and showmanship. To add to its difficulties, something different is required each year, and, as the period of showing is usually short, the question of costs is important. Every effort must be made, therefore, to keep costs at a minimum and at the same time provide a worth while exhibit with a wide advertising appeal. These apparently irreconcilable factors make heavy demands on the ingenuity of the designer, who, in his endeavours to produce a striking display at minimum cost, is obliged to make use of any available scrap material and to adapt standard items of communication equipment for uses quite foreign to the intentions of the original constructor.

How such adaptation of material and apparatus made possible the production of an effective post office display at the Royal National Show, Brisbane, is briefly described in this article.

Fig. 1.—Central section of exhibit depicting "World-wide Communications."

### Purpose of Display.

In the various forms of advertising, ideas are conveyed to the public by an appeal to the senses, either orally, as in broadcasting, or visually, as in poster and newspaper advertising. In the type of display under review it was possible to exploit both means simultaneously, the underlying idea being to provide an exhibit which would attract and hold the interest of the public for sufficient time to enable effective spoken and visual propaganda to be introduced and assimilated. Big crowds were attracted by the display, giving an indication of how successfully this objective was achieved.

### General Description.

The main section of the exhibit was a composite outdoor scene introducing, in model form, representations depicting the development of signalling, the possibilities of world-wide communications and the evolution of mail transport. Other sections consisted of a court of public opinion and working units of telephone, telegraph and mail handling equipment.

The three features of the main exhibit were grouped together to form a spectacular colour picture, full of life and action, compelling attention and forcing home, in a subtle manner, the wide and varied ramifications of the post office organisation. Figure 1 gives a view of the central section, depicting world-wide communications.

The general effects were very pleasing and attractive and the intention to show how the post office organisation covers the world and serves by land, sea and air and by day and night was well displayed. Every four minutes the scene changed through all the various stages of day and night: the night session was represented by deep blue illumination and formed quite an enchanting scene, enhanced by the head lights of motor cars and the interior lighting of buildings, shops, railway trains, etc. Overhead the moon shone and hundreds of stars twinkled. Then came the dawn, with the red reflection in the sky of the rising sun, followed by changes of light through red, pink and amber to the brilliant white of day, then back again in reverse order to depict the fading light of afternoon and the red glow of sunset. And the most subtle point about the arrangements was that all the time the onlookers were standing there trying to absorb the optical display, a voice from a loud speaker gently, but very effectively, poured into their ears excellent P.M.G. propaganda.

### Calvalcade of Signalling.

This section, as its name implies, illustrated the progress made in the art of signalling. Working models demonstrated a wide variety of systems, including the smoke signals of the Australian aboriginals, and beating of drums by New Guinea natives, beacon fires, semaphore towers, naval flag signals, military heliographs, the telephone, the telegraph, radio telegraph, beam wireless and broadcasting.

Smoke signals were reproduced by jets of steam intermittently cut off to correspond with the rise and fall of a tree branch manipulated by an aboriginal. Semaphore towers, flag signalling and heliographs were arranged to signal continuously the letters "P.M.G."

All sections were grouped together in an attractive scenic setting, including a complete aboriginal camp, waterfalls and creeks with actual running water, a seaside resort, a country township complete with post office, telephone lines, etc., an old English fir forest and feudal castle, a city scene including 4QG building and Central Automatic Exchange complete with air-conditioning plant, cable tunnel, etc. Each individual unit was designated by an illuminated sign.

### World Wide Communications.

This was represented by a large contour map of Australia with the rest of the world shown in perspective at the rear. This map showed by miniature pole lines all the main telegraph and telephone routes of Australia. Towns were indicated by small red pillar boxes and national broadcasting stations by flashing "Neon" signs mounted between miniature steel towers. The locations of commercial radiogram stations were shown by tall masts carrying flashing lamps.

The air mail routes of Australia were outlined by red ribbons linking together model aeroplanes and miniature aerodromes. This ribbon extended across the Timor Sea to the map of the world at the rear and outlined the whole of the air mail route to England. Postal services were represented by model mail trains, camel teams, ocean liners, etc., the steamers and sailing ships at the rear being fitted to belt conveyors and moved across the sea.

### Evolution of Mail Transport.

In this section an effort was made to illustrate the evolution of mail transport. The various stages of development were represented by aboriginal runners, horsemen, camels, mules, carrier pigeons, bullock teams, coaches, sailing ships, motor buggies, mail trains, ocean liners, motor cars and aeroplanes. All were set in suitable scenery and each item was indicated by an illuminated sign.

The front section was arranged in the form of model streets along which P.M.G. cars travelled with their loads of mails to and from the post office, wharf, railway station and aerodrome, stopping at pillar boxes to collect letters. Model electric railway trains ran to and from the railway station and at regular intervals a blue painted air mail vehicle left the post office and travelled to a waiting aeroplane, which then flew across the world to England. The plane was carried on fine wires and returned underneath the exhibit to the aerodrome. Its propellers were turned by three miniature electric motors.

An item of particular interest was the lighting of the head and tail lights of moving motor cars. The manner in which these cars were propelled and lit proved very mystifying to the general public and it was extremely amusing to listen to the many and varied theories offered by the onlookers. Fig. 2 shows a section of the model roadway with a portion of the front cut away to reveal the system of control. It will be seen that a miniature electric railway track was built immediately underneath the streets and each moving motor car was associated with a train consisting of three units—an engine, an electro-magnet truck and an oscillator truck. Five such trains were provided. The front wheels of each motor car were mounted on a "U" shaped soft iron armature and followed the track travelled by the electro-magnet immediately underneath the phenol-fibre street surface. The two head lamps and tail light were connected in series with a coil tuned in resonance with an oscillating coil carried on the oscillator truck. The engine motor was driven by 220 volts D.C. picked up by brushes on its own truck from the centre rail. The pulling magnets and oscillator were fed from 220 volts D.C. picked up by brushes on the rear truck. It was thus possible, by having intermittently dead sections on the centre rail, to stop the cars at pillar boxes, railway stations, etc., without losing the magnetic grip or extinguishing the head lights. The switching off of the head lights during the periods representing day was effected by reversing the direction of the D.C. current, thus stopping the valve from oscillating.

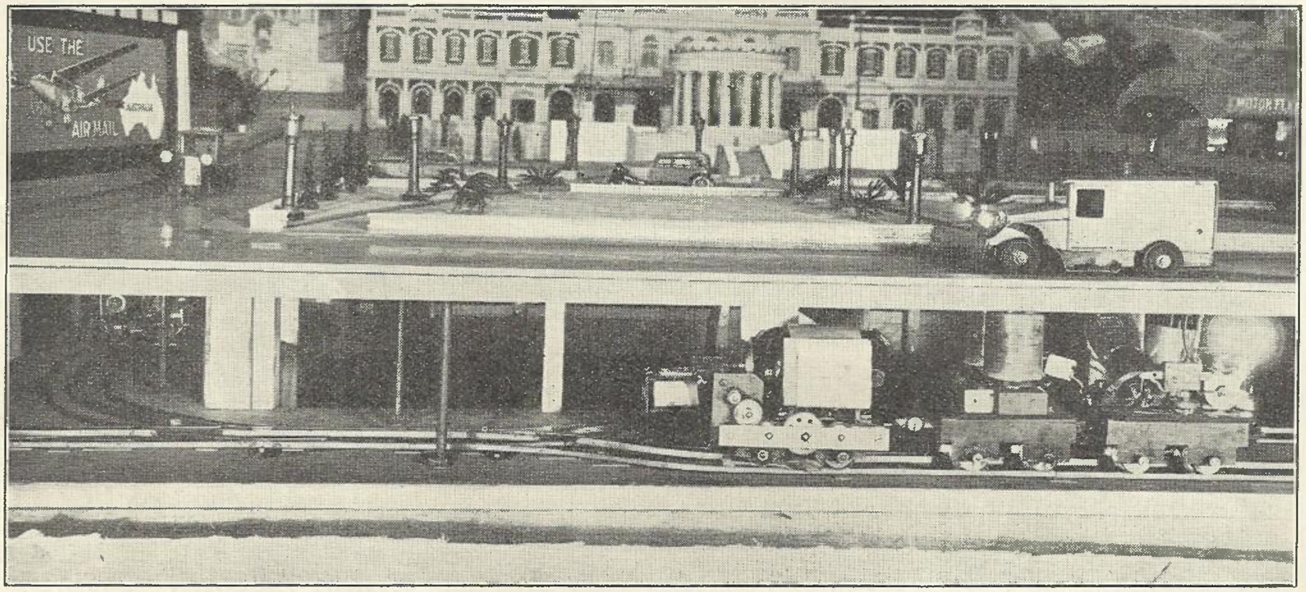


Fig. 2.—Section of model roadway showing system of control.

The intermittent open circuiting of the centre rail at stopping places and the electrical operation of the control points of the track were effected automatically by a number of cam-operated spring sets associated with a master control machine. This machine provided the following features:—

(a) Dimmer controls for day and night effects in main lighting, fading in and out in sequence 28-1000 watt lights.

(b) Control of track points and dead sections of centre rails for trains associated with moving motor cars.

(c) Starting and stopping of model electric trains and aeroplane.

(d) Control of "Phrase by Phrase" electric signs which periodically shone through the map of the world at the rear of the exhibit.

(e) Switching on and off of moon, stars, street lights and interior lighting of buildings, ships and other models.

(f) Flashing or morse signals for radiogram stations and heliographs and the twinkling of stars.

(g) Miscellaneous synchronised movements, such as arrow indicating time of day, operation of clocks on model buildings, etc.

### Court of Public Opinion.

This was an original feature which enabled unique and very valuable advertising matter to be presented to the public. Although purely telephone propaganda, the subject was presented in such a manner that it captured public imagination and was the main topic of conversation among show visitors. It was considered of such public interest that a Newsreel Organisation requested permission to make a talking picture of portion of it for inclusion in their Australian Gazette. By this means further valuable publicity was obtained, as the picture has been shown throughout Australia. Fig. 3 shows a section of the court setting. The ends of the public galleries can be seen but the jury and press boxes, which were situated on the left and right sides respectively, are omitted from the picture.

The defendant was charged before the honourable Court of Public Opinion that he, being the head of his family, criminally neglected his social responsibilities in that he failed to have a telephone service provided in his home for the protection and comfort of his wife, his children and himself. The story told at the trial introduced in a subtle manner the advantages of a telephone in the home and the surprisingly low cost involved.

It will be seen that all the figures, with the exception of the defendant, were enlarged models of pedestal telephones decorated to represent the characters of a criminal court. These characters were arranged with mechanical movements providing the following effects:—

Judge: Enter and retire, stand and sit, turn right or left and rap on desk with mallet carried in hand.

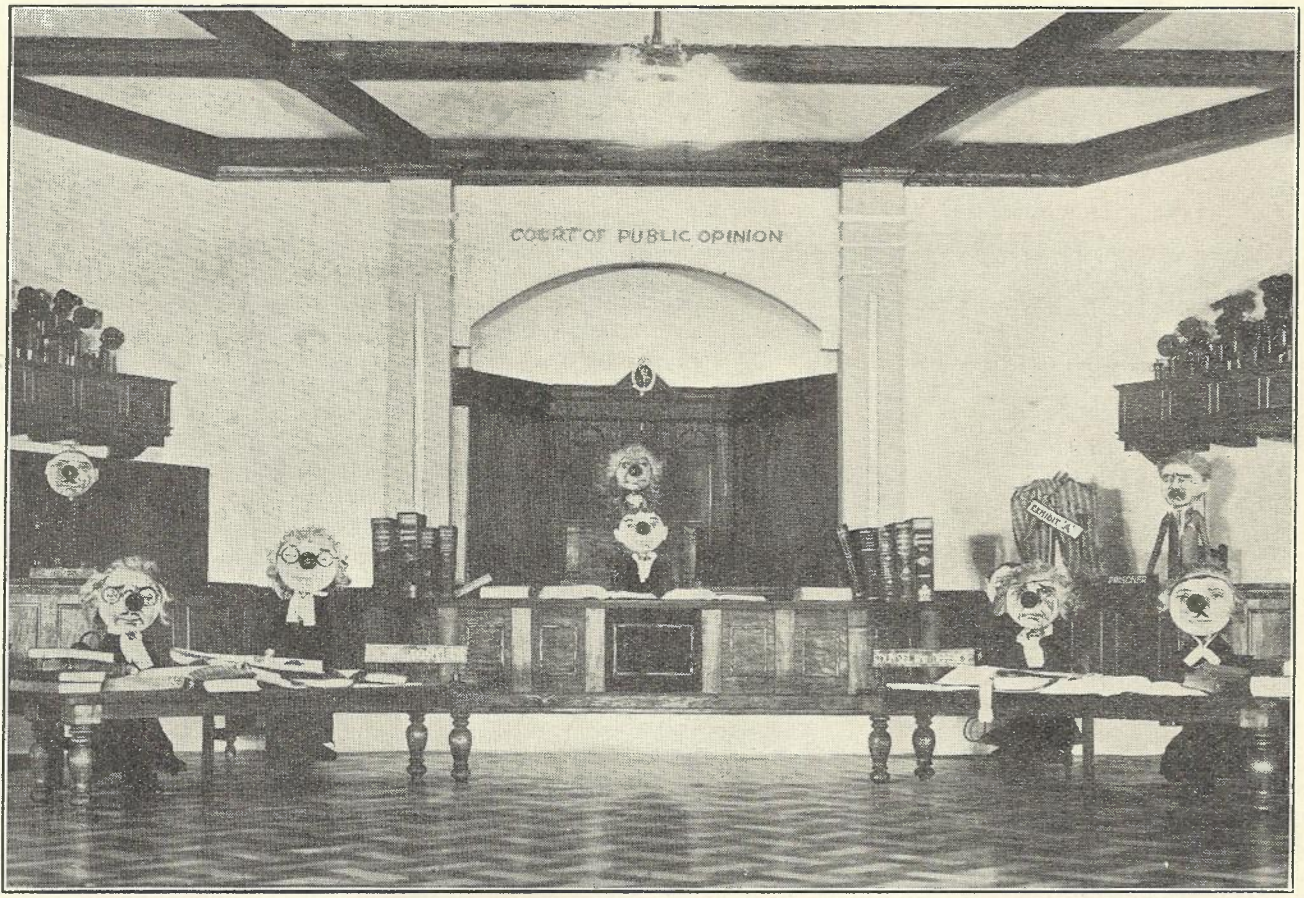


Fig. 3.—Court scene, "Court of Public Opinion."

Witnesses: Enter and retire, turning as necessary and raising right hand during swearing in process.

Judge's Associate, Crown Prosecutor and Counsel for Defence: Stand, sit and turn as required.

Jury and Foreman: Stand, sit and confer with each other in medley movement and turn as required towards the various characters as they speak.

Press: Stand, sit, write, and sit at leisure.

Prisoner: Stand, sit and raise right arm.

Other characters on floor of court: Stand, sit, and turn as required.

Telephones in public galleries: To simulate hand-clapping by jiggling hook-switches and receivers at appropriate times.

Each speaking character was equipped with a solenoid operated mouth movement. Three loud speakers—right, centre and left—were provided and automatically switched into use according to the location of the character talking.

The play was recorded on gramophone records and the whole scheme was designed so that these records would provide not only voice reproduction, but control the whole of the synchronised mechanical movements. To enable this to be done, the records had recorded thereon normal voice and special signals of 4 k.c. frequency. In the process of reproduction the voice and the special 4 k.c. signals were separated by filters, the voice currents passing through the low-pass side being used to operate the various loud speakers and also a voice frequency relay controlling the mouth solenoids. The 4 k.c. signals, which appeared as a spurt whenever a change of mechanical movement was required, passed through the high-pass side and were utilised to step on rotary preselectors which in turn switched the voice currents to the various loud speakers, connected the correct mouth solenoid to the voice frequency relay, and started and stopped the motors and solenoids controlling the various mechanical movements. It will thus be understood that the operation of the court scene was completely effected by a system of remote control, all mechanical movements being automatically started and stopped, even including the opening and closing of the proscenium curtains. During each performance, which occupied 25 minutes, the preselectors made 150 steps, thus bringing about over six hundred changes of mechanical movement.

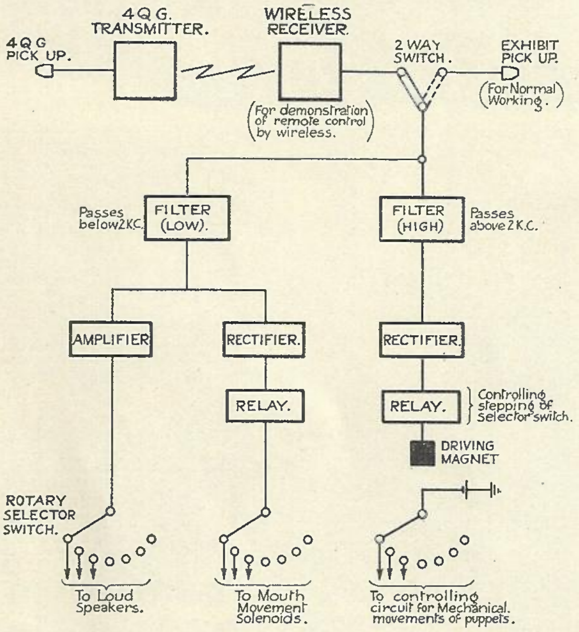


Fig. 4.

In order to stimulate public interest, it was arranged during the official opening of the display, for the idea to be further extended by having the records broadcast by National Station 4QG. The broadcast speech and signals were then picked up at the exhibit and utilised for the purpose of presenting a complete performance without the assistance of any of the exhibit attendants. Listeners to the broadcast from Station 4QG heard the speeches associated with the court scene as well as the 4 k.c. spurts, which sounded something like time signals. Onlookers at the exhibit could hear only the voices passing through the low-pass filter but saw the actual movements of the various figures resulting from the receipt of the 4 k.c. signals. A schematic diagram of the remote control arrangements is reproduced in Fig. 4.

Unfortunately, complete automatic operation could not be maintained throughout the period of the display, as the records, which were, necessarily, of a comparatively cheap type, did not maintain sufficient level on the 4 k.c. notes to permit reliable operation of the high-pass relay controlling the stepping preselector. It became necessary, therefore, to monitor the records and correct, by means of a key, any omitted signal. Longer life records or recordings on sound film would overcome this minor difficulty, which, however, in no way affected the efficiency of the performance. The control room was situated behind the court scene and housed the gramophone turn-tables, filter and amplifier equipment, and rack accommodating stepping preselectors and motor control relays.

To enable advertising slides to be shown immediately before and after each performance, the stage was equipped with a ground glass screen which was lowered from the ceiling.

### Working Units.

These were accommodated on an island section in front of the main exhibit and included a teleprinter, model automatic exchange and stamp-cancelling machine. Each item was arranged in an appropriate setting carried out in modern style in a colour scheme of black and white. The teleprinter was worked continuously from the G.P.O. and the "received" slogans distributed amongst the crowd. The model automatic exchange unit was arranged to work continuously without any demonstrator. Model figures carried out automatically all the operations of lifting the receiver, dialling, answering and restoring the receiver. The progress of each call was indicated by illuminated lamps on an explanatory chart.

### Behind The Scenes.

The foregoing is mainly a front stage description of the effects as seen by the general public. An inquisitive engineer, probing behind the scenes, would make many interesting discoveries. He would find, for instance, that the beautiful twinkling stars and the ornamental model lights were ordinary switchboard lamps in new settings; the magnificent waterfall was nothing more or less than a standard manhole pump circulating water from an old creosote drum; the electric trains drawing the model vans along the model streets were combinations of gell perforator coils, Baudot motors and preselector magnets; and so on, right throughout the exhibit, he would find similar adaptations of telephone and telegraph apparatus. Discarded gears from busy-tone attachments of old ringers were utilised to provide a 10,000 to 1 reduction gear for the master controller, whilst old bicycle sprocket wheels and chains gave variations of speed to the different countershafts. The control of the court scene was effected by an adaptation of circuits for automatic exchange switch routiners, all the equipment used being standard telephone switches and relays, carrier filters and amplifiers. The motors used to produce the mechanical movements in the court scene were "borrowed" from fans temporarily out of use for the winter months, whilst reduction gears for these movements were obtained by purchasing, for a few shillings, cream separator parts salvaged from a fire.

Fig. 5.—General view of exhibit.

Although the outward appearance of the exhibit was bright and attractive, many of the items used for its construction were obtained from packing materials—3-ply, cardboard, brown paper, case linings. Model buildings were constructed from scraps from the carpenter's shop, and so on, an ever-watchful eye being kept for suitable scrap material and discarded apparatus. Other economies were effected by obtaining on loan excellent models of aeroplanes, railway trains, etc., whilst the drawing power of the exhibit was so great that the Show authorities not only made available without charge the valuable space occupied, but supplied, free of cost, all necessary electrical energy.

### The Value of The Exhibit.

The Post Office needs the good will of all the people, but a very large majority are uninformed and hold definite views in ignorance. Logic will not reach them; the appeal must be to the eye and ear rather than to the brain. And so the bright lights, the moving models, the vast expanse of showmanship, the staring crowds, the colours and grouping of familiar objects in new settings, attract and hold them. Then they hear the story of the service they own, and, being impressed, they may become advocates and defenders of what they previously held in disrespect. There are, too, those with inquiring minds who find in the display information which gives rise to thought and there is an appeal to join in and help a great national undertaking to do its job still better. In these cases the appeal is to the brain rather than to the senses. But, however it is assimilated, the appeal of the post office exhibit to many different types is, undoubtedly, favourable to the objective of gaining and maintaining good will. And that is its real value.

# SUPERVISORY ALARM SYSTEM FOR AUTOMATIC EXCHANGES

*B. Draper, A.M.I.E.E. (General Electric Co. Ltd., Coventry)*

The following article, though intended primarily as a description of the alarm system used in 2000 type exchanges, will also apply in many respects to existing systems in step by step automatic exchanges.

## 1. Requirements of an Alarm System.

Faulty conditions may arise in an automatic exchange from two causes; they are:—

1. Failure of the switching plant.
2. Incorrect operation by the subscriber.

The alarm system must be designed to give a clear indication to the maintenance officer when either of these conditions arise and in such a manner that he may proceed directly to the faulty portion of the equipment. The method of alarm indication to be used in the City West Exchange, Melbourne, is similar to that now employed by the British Post Office, and consists of bells and lamps associated with sections of the equipment.

When the alarm is operated, it can only be restored to its normal condition by actually clearing the fault, excepting in certain non-urgent cases where the service is not dependent on prompt clearance.

## 2. Alarm Indication.

Each floor of the Exchange is divided up into areas called sections, and each section is further divided into sub-sections. The actual area of each section or sub-section depends on the equipment which it serves, and the following details of the 1st Floor at the City West Exchange may be taken as a typical example.

The floor is divided into 2 sections, which are referred to as Section 11 and Section 12. Section 11 is divided into 5 sub-sections, which are numbered S.S. 111 to S.S. 115. Section 12 is divided into 2 sub-sections, which are numbered S.S. 121 and S.S. 122.

Some sub-sections carry a larger load than others, due to the fact that the Exchange is only partly equipped at present, and the arrangement of the sub-sections is planned for the ultimate capacity.

Each sub-section is equipped with a terminal block fitted in a convenient position, to which all the alarm leads in that sub-section are taken. Associated with this terminal block, which is usually referred to as a classification block, are 2 tubular lamps, one indicating prompt alarms (red) and the other deferred alarms (white) within that particular sub-section.

In some cases an alarm cut-off key is located adjacent to the classification block in order to disconnect a deferred alarm from the main exchange alarm. This key is connected so that it will only control those alarms which may be temporarily neglected without appreciably affecting the service.

Cables are taken from each sub-section classification block to the Alarm Equipment Rack (A.E.R.), where they are grouped and connected to the operating coils of the Section Relays. Each section is provided with a Prompt and a Deferred relay, the contacts of which are commoned and control the floor lamps and bells.

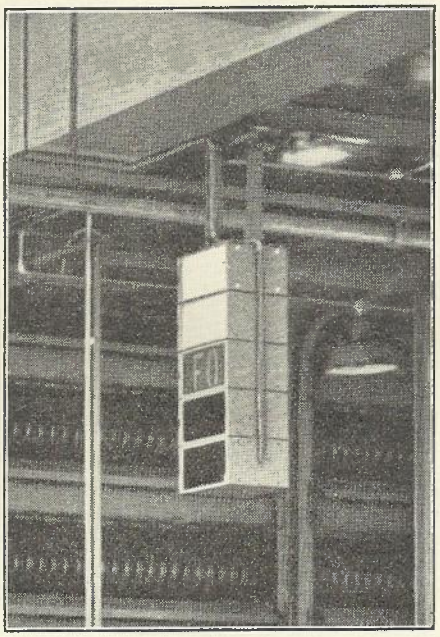


Fig. 1.—Floor Lantern.

Groups of floor and section lamps are provided on each floor in as many positions as may be necessary to allow easy observation. The lanterns are built up in a vertical column from individual box-shaped units, three sides of which are visible from the Exchange floor. Each unit has a coloured glass screen with a stencil carrying the number of the floor or section with which it is associated. The number of units in each lantern is controlled by the number of floors and sections. A floor lamp is provided for each of the other floors and a section lamp for each section on the floor concerned.

Section lamps are only equipped on their own floor with the exception of the lamp for the power section which appears on every floor.

Fig. 1 shows a typical lantern assembly with the FO unit illuminated. The standard colours for the glass screens are white for floor lamps, red for section lamps and blue for the power section.

In order to call attention to a lamp indication, floor and section bells are provided. A fault in a particular section will operate the section bell and the floor bells on all floors. At City West Exchange, section bells will not be used at present as they are only considered necessary when there are three or more sections on one floor.

During hours of continuous attendance on each floor, the floor bells may be isolated so that they will only operate when an alarm occurs on their own floor. This is effected by the operation of the floor bell cut-off key fitted on the Test Desk.

With this system of alarms, the Maintenance Officer will make the following movements in order to trace a fault:

1. Observe the floor or section indicated on the nearest group of floor lamps, and proceed to the floor concerned.

2. On arriving at the particular floor, observe the section lamps.

3. Observation of the sub-section lamps within the faulty section will indicate whether the fault is prompt or deferred.

4. Localisation within the sub-section is easily obtained by observing the rack lamps, which are usually provided for each type of fault. In some cases shelf lamps are equipped on the racks in order to facilitate the detection of the faulty circuit.

In a small exchange not continuously attended, the alarm indications may be transmitted to the nearest main exchange and arranged to operate a lamp and bell signal usually provided on the Test Desk.

### 3. Alarm Delay Circuit.

During the normal operation of the automatic equipment, a condition may be set up which would constitute a fault if it persisted for a certain period of time. The object of the alarm delay circuit is to ensure that a certain minimum time elapses between the commencement of an alarm signal and the operation of the exchange alarm system.

The apparatus consists of a combination of relays and a uniselector under the control of electrical pulses occurring at regular intervals.

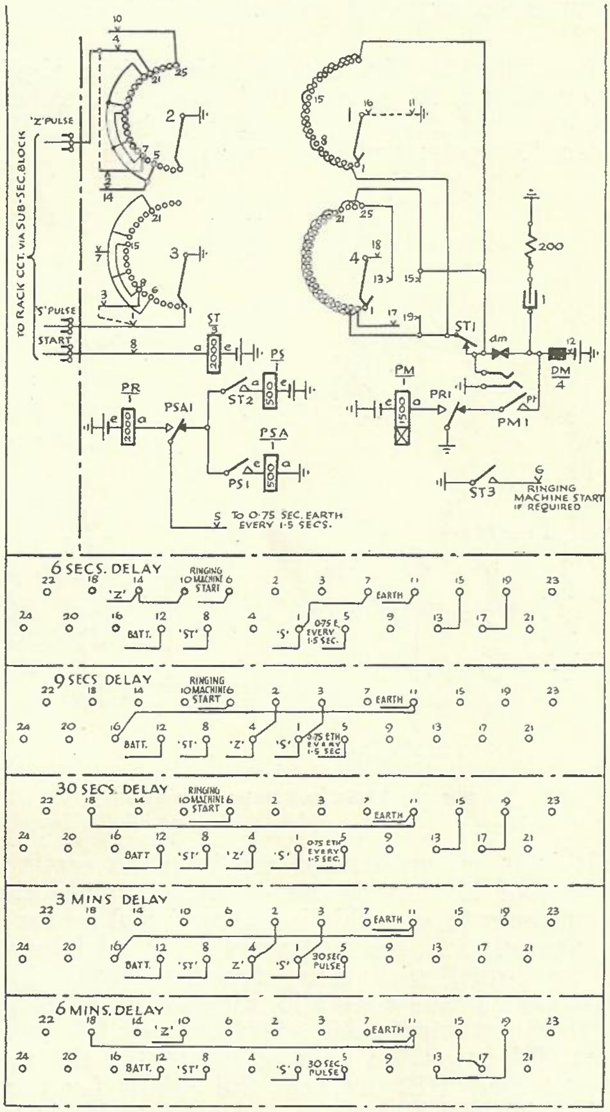


**Fig. 2.—Alarm Delay Circuit. U-Jack Connections shown for nine seconds delay.**

For short delay periods such as 6 seconds, 9 seconds and 30 seconds, the interrupted earth pulse (0.75 second earth every 1.5 seconds) from the ringing machine is used, and longer periods up to 6 minutes are controlled by a 30 second pulse derived either from the exchange clock or from an auxiliary equipment operating from the interrupted earth pulse.

Five delay periods are usually necessary, i.e., 6 seconds, 9 seconds, 30 seconds, 3 minutes and 6 minutes, and one delay equipment mounted on a jacked-in relay plate is provided for each. The internal wiring of each set is precisely the same so that they may be interchanged or replaced by a spare set without making any wiring alterations. The period of time delay is controlled by varying the strapping on the shelf U-jack strip.

Referring to Fig. 2 which shows the alarm delay circuit, it is seen that three connections are required from the selector racks, i.e., "S" pulse, "Z" pulse and Start wire. When the circuit is in an unoperated condition, an earth is connected to the "S" pulse; as the uniselector commences to step this is removed and an earth is connected to the "Z" pulse after an interval of time equal to the delay period required. The operation of the circuit is initiated by an earth on the Start wire which operates relay ST. Contact ST1 opens the homing circuit for the uniselector and ST2 prepares the circuit for relay PS which operates when the earth pulse is received from the ringing machine. Contact PS1 prepares a circuit for relay PSA which operates in series with relay PS during the next "off" period of the interrupted earth. The next earth pulse will operate relay PR via PSA1, and PR1 closes a circuit for relay PM at PR1. Relays PR and PM will now respond to each earth pulse and the uniselector driving magnet will be energised during the releasing time of relay PM. At the completion of a certain number of steps (6 in the case of a 9 seconds delay) an earth will be transmitted from wiper 2 over the "Z" pulse to the selector rack, causing the rack relays to operate and give the desired alarm. The earth condition on the Start wire is also removed and the uniselector returns to a normal position by self-interruption via contact ST1. Since the delay period is dependent on the relative position of the "S" and "Z" pulse leads on the uniselector bank the variation in time can be accomplished by external connections on the shelf U-jack to which the uniselector banks have been connected internally. Fig 2 also shows the various U-jack connections required in order to produce each delay period.

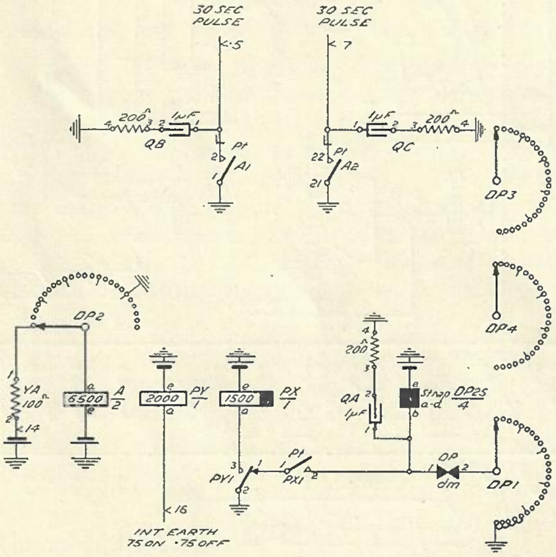


Fig. 3.—30-Second Pulse Circuit.

If a 30 second clock pulse is not available, an equipment utilising the interrupted earth is provided to give this facility. As the circuit, shown in Fig. 3, is very similar in principle and operation to the alarm delay arrangement, a detailed description is not necessary. It should be noted, however, that as the 30 second pulse is required for several purposes other than alarms, a start lead is not provided, and the circuit operates continuously.

The delay equipments are mounted on the alarm equipment rack which is situated in a convenient central position, the Start, S and Z leads being fed to the selector racks via a distribution tag block on the A.E.R. and the sub-section classification blocks.

### 4. Classification of Alarms.

Alarm signals are classified into two groups, prompt and deferred. The former indicates that a failure of an urgent nature has occurred and requires immediate attention, whilst the latter is used for faults which may be temporarily neglected without affecting the service. The classification into prompt or deferred is carried out by making suitable connections on the subsection classification block.

Either of the above may be required to operate via an alarm delay circuit, the period of delay depending on the nature of the fault.

In the following table each kind of fault is described, and details of its classification into prompt or deferred and its delay period is given:

| Alarm | Cause of Alarm | Prompt or Deferred | Delay Period |
|---|---|---|---|
| 1. Fuse Alarm | Operation of a fuse on the power distribution or ringing and tone circuits | Prompt | No delay. |
| 2. Release Alarm | Switch failing to restore to a normal position when its release circuit is energised | Prompt | 9 seconds. |
| 3. Ring Fail Alarm | Failure of ringing current not due to the operation of a fuse | Prompt | No delay. |
| 4. Voltage Alarm | Voltage on the distribution bus bars below 46.5 volts or above 52.5 volts | Prompt | No delay. |
| 5. Charge Fail Alarm | Operation of the Charge circuit breaker through overload or reverse current | Prompt | No delay. |
| 6. Line Finder Supervisory Alarm | Line Finder fails to find a calling subscriber | Prompt | 6 seconds. |
| 7. P.G. Alarm (permanent glow) | First Selector held for an excessive period before receiving impulses | Deferred | 6 minutes. |
| 8. C.S.H. Alarm (Called Subscriber held) | Calling or called subscriber holding the connection for an excessive period after the other party has cleared | Deferred | 3 minutes. |
| 9. N.U. Tone Supervisory Alarm | Subscriber maintaining a connection to an unallotted or ceased line for an excessive period | Deferred | 9 seconds. |
| 10. N.U. Tone Overload Alarm | A low resistance earth fault on a line temporarily connected to N.U. tone | Deferred | No delay. |
| 11. Failure of ringing machine No. 1 | Failure of power supply. (This does not necessarily indicate a failure of ringing current since machine No. 2 will start up and take the exchange load automatically.) | Deferred | No delay. |

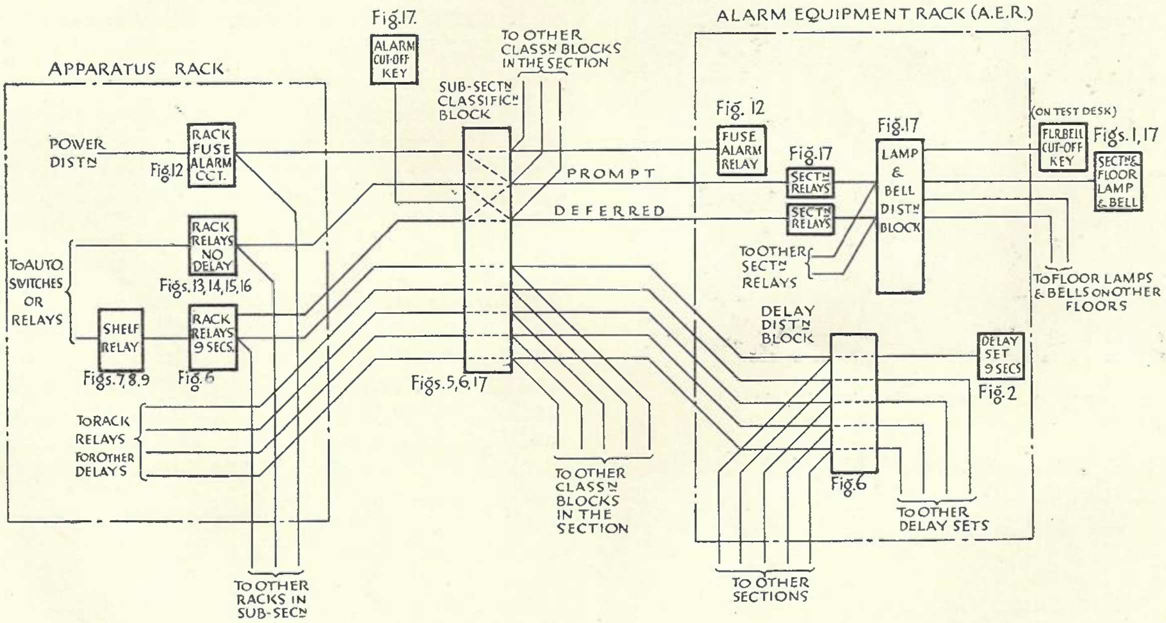


Fig. 4.—General Lay-out of Alarm Equipment.

### 5. General Lay-out of Alarm Equipment.

Fig. 4 is a key diagram to the exchange alarm system and shows a typical automatic rack connected via the sub-section classification block to the alarm equipment rack. The figure numbers against each item refer to diagrams contained in this article, thus allowing the relation of each circuit element to the whole to be readily seen. Commencing at the right hand side, the various delay sets are shown connected to a distribution block on the A.E.R., from whence suitable leads convey the pulses to the classification blocks. Here they are further distributed to other classification blocks in the section, and to the automatic racks where they are commoned to other racks within the sub-section. Rack relays are provided for as many delay periods as may be required, and these in turn are under the control of the shelf relays which are directly connected to the switching equipment. If required, further rack relays are provided for alarms without delay and for fuse alarms. The alarm operating lead from each of these rack circuits is taken back to the sub-section classification block where, by suitable connections, it is caused to operate the prompt or deferred section relay on the A.E.R.

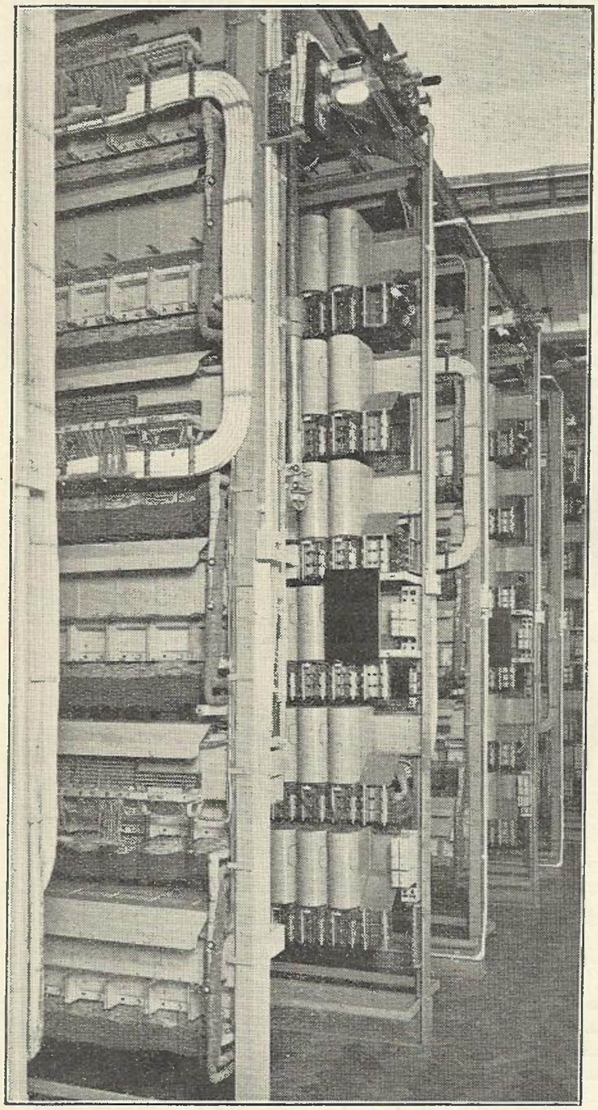


Fig. 5.—Classification Block, etc.

The contact springs of the section relays are wired out to the lamp and bell distribution block, where by suitable strapping the appropriate floor and section lamps and bells may be operated.

A typical sub-section classification block with the deferred lamp in operation is shown in Fig. 5. The shelf and rack relays, which are mounted on removable plates, can be seen on the right hand side of the group selector rack just below a small panel carrying the shelf alarm lamps. The tubular rack alarm lamps are fitted near the top and project beyond the level of the switches so that they may be easily observed from the end of the suite. Above the top of the rack and fitted to the overhead ironwork is the group fuse panel, which distributes the power supply through suitable fuses to one or two suites of racks; the fuse alarm lamp mounted on this panel is operated by an alarm type fuse connected in parallel with the main fuse.

### 6. DESCRIPTION OF RACK CIRCUITS.

#### (a) DELAYED ALARMS.

In order to illustrate the method of connecting the alarm delay circuit with the rack and shelf circuits, the 9 seconds delay has been taken as a typical example and is shown, in Fig. 6, associated with a rack release alarm.

The relay RA and shelf alarm lamp are usually provided for each 2 shelves of switches and the AR and BR relays and rack lamp for each rack. Relay RA will be energised during the releasing time of the switch, thus closing a circuit for relay AR at Contact RA2. Relay AR operates and locks at contacts AR1 and RA1. Relays RA and AR remain operated if the switch fails to restore to a normal position and earth is applied to the start wire at AR2 to operate relay ST in the alarm delay circuit. The uniselector now steps under the control of the interrupted earth pulses until it has completed 6 steps, representing a period of 9 seconds, when wiper 2 connects an earth to the "Z" lead to operate relay BR in the rack alarm circuit. Contact BR1 provides a locking circuit for relay BR and at the same time illuminates the shelf lamp and releases relay AR by short circuiting one of its windings. Contact BR2 disconnects relay AR from the "S" pulse and BR3 forwards an earth to the sub-section classification block to operate the floor and section alarms. Contact BR4 completes the circuit for the rack lamp. The release of relay AR removes earth from the start wire, relay ST restores and the uniselector returns to its normal position.

A similar rack alarm circuit, i.e., relays AR and BR and a rack lamp is provided for each delayed alarm, the only variation on that described being the period of delay, which is as stated in section 4 of this article.

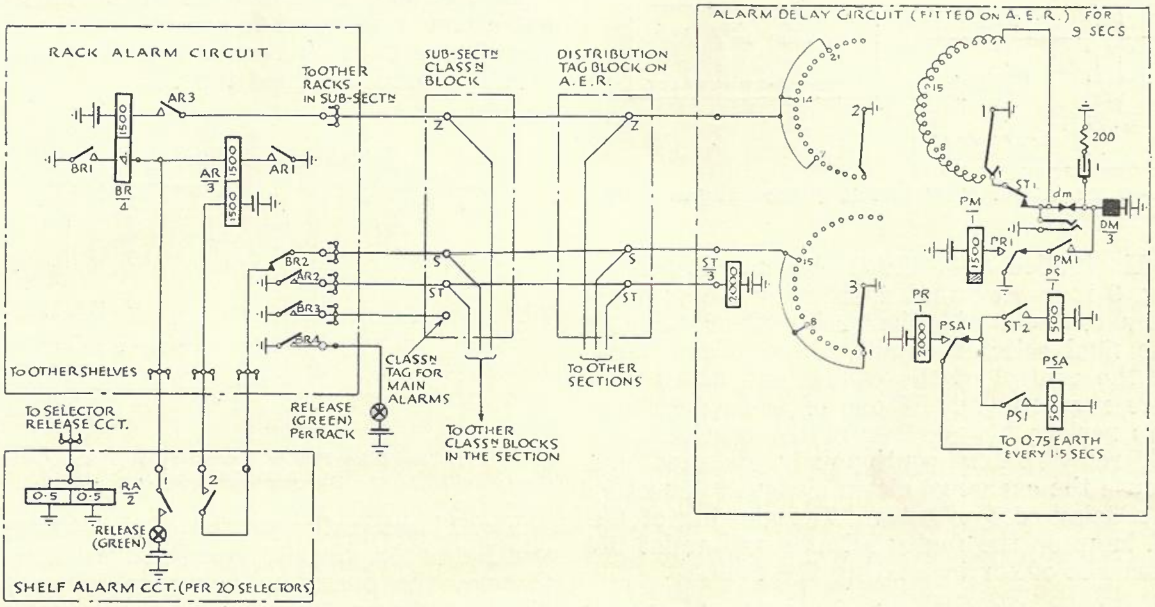


Fig. 6.—Typical Delay and Rack Circuit.

From the foregoing description it is seen that the operation of the rack relays and the alarm delay circuit is initiated by the operation of the shelf relay which is common to one or more shelves of equipment. The method of operating the shelf relays for each type of alarm is now dealt with.

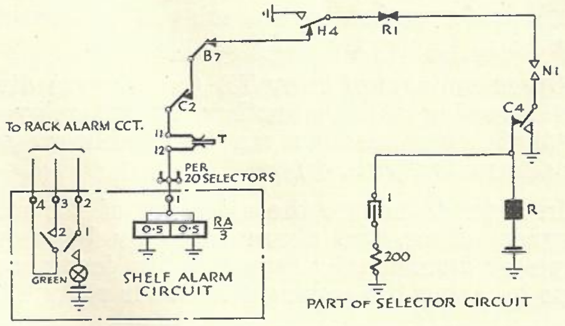


Fig. 7.—Release Alarm Shelf Circuit (nine seconds delay).

**Release Alarm.**—The release alarm shelf relay RA, which is provided for each two shelves of switches, is shown in Fig. 7, associated with the selector releasing circuit. During the restoring period of the selector the rotary magnet draws its earth supply via relay RA which operates and remains operated until the off normal contact N1 is broken, indicating that the selector has fully restored. Should the wiper carriage fail to return to its normal position within 9 seconds, the alarm delay circuit completes its operation and an alarm is given. This feature is provided on every rack carrying selector mechanisms.

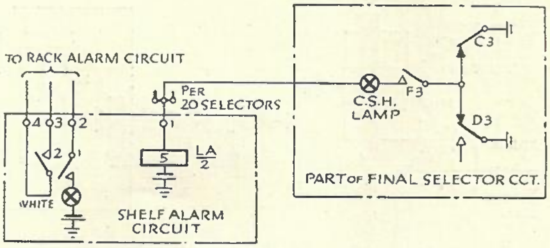


Fig. 8.—P.G. Alarm Shelf Circuit (six minutes delay).

**P.G. (Permanent Glow) Alarm.** Fig. 8 shows how the shelf relay LA is associated with the selector supervisory circuit. When the selector is seized, relay B in the selector circuit operates and contact B4 provides a circuit for shelf relay LA and the selector P.G. lamp until the selector moves from the normal position. If relay LA remains operated continuously for a period of at least 6 minutes, a fault will be indicated on the alarm system and may be quickly located by the glowing of the P.G. lamp on the selector concerned.

This alarm is only provided, as a rule, on 1st selectors and incoming 2nd selectors.

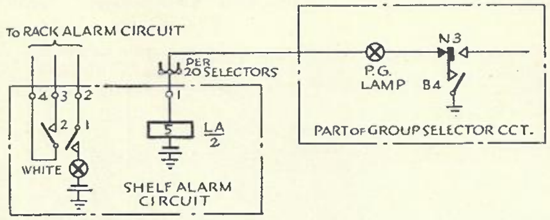


Fig. 9.—**C.S.H. Alarm Shelf Circuit (three minutes delay).**

**C.S.H. (Called Sub. Held) Alarm.** Referring to Fig. 9 it is seen that shelf relay LA is operated by contacts of either relay C or relay D on the final selector circuit, these relays being under the control of the calling and called subscribers respectively. If one of the subscribers fails to replace his receiver at the conclusion of a call, relay LA is continuously operated and will cause the exchange alarm system to function after a delay of 3 minutes. The glowing of the C.S.H. lamp on the faulty selector will assist the maintenance officer in locating the fault.

This alarm is equipped on all final selector racks.

**N.U. Tone Supervisory Alarm.** The method of supplying N.U. tone to unallotted and ceased lines is on the balanced tone principle, relay NU (Fig. 10) fulfilling the functions of transformer and control relay.

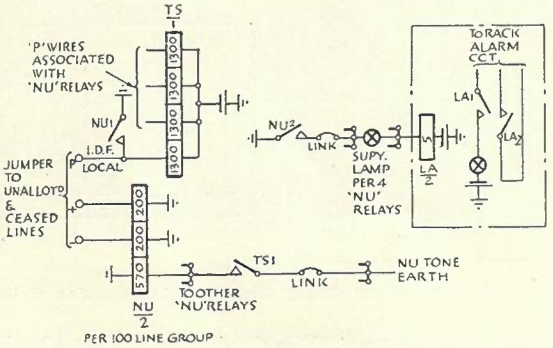


Fig. 10.—**N.U Tone Supervisory Alarm Circuit (9 secs. delay).**

When a subscriber dials a line connected by means of an I.D.F. jumper to the N.U. tone circuit, relay NU operates and supplies N.U. tone to the calling subscriber. Contact NU2 completes a circuit for the supervisory lamp in series with relay LA which operates and causes the rack alarm circuit to function.

If the circuit is held for a minimum period of 9 seconds, the exchange alarm system will be brought into operation, the location of the line concerned being facilitated by the provision of one supervisory lamp per 400 lines and a localising link per 100 lines.

**Line Finder Supervisory Alarm.** This important alarm is designed to operate when a Primary line finder fails to locate a calling subscriber within a predetermined time.

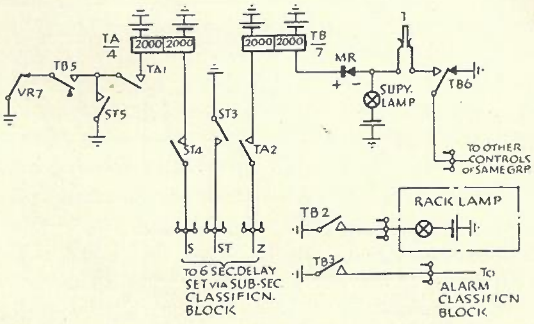


Fig. 11.—**Line Finder Supervisory Alarm Circuit (6 seconds delay).**

Fig. 11 shows the portion of the Primary Control Relay Set circuit, associated with the alarm feature, the operation being as follows:—relay ST (not shown) operates at the initiation of a call and remains operated until the calling line is switched through to a 1st selector. Contact ST3 forwards an earth on the ST lead to the 6 seconds delay set which commences to step. Relay TA operates via ST4 to earth on the S pulse lead, locking up to its own contact TA1 and ST5.

If relay ST remains operated for 6 seconds an earth will be received from the delay set over the Z pulse lead to operate relay TB via contact TA2; relay TB locks through contact TB6.

The supervisory lamp on the control set and alarm lamp on the rack are illuminated and an earth is forwarded to the sub-section classification block to operate the prompt alarm.

Other contacts of relay TB (not shown) divert the incoming call to another control relay set so that the connection can be established over an alternative path. (¹)

In order to ensure the attention of the maintenance officer, the alarm can only be cleared down by momentarily removing the test plug T, thus breaking the locking circuit for relay TB.

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(¹) For further information, see The Telecommunication Journal of Australia, No. 4, page 131.

### (b) ALARMS WITHOUT DELAY.

**Fuse Alarm.** Fig. 12 which shows the fuse alarm arrangement for selector racks may be taken as typical for all automatic racks.

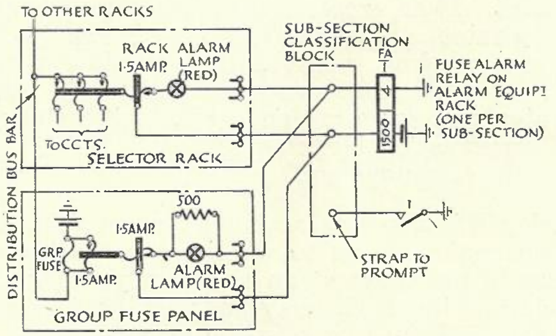


Fig. 12.—Fuse Alarm Circuit.

The operation of a fuse serving the selector circuits allows a connection to be made between the main battery bus bar and the alarm bar, battery is thus extended via the fuse alarm fuse, rack alarm lamp and 4 ohm coil of the FA relay to earth. Relay FA operates and contact FA1 puts an earth forward to the sub-section classification block to bring in the exchange alarm system. The faulty rack is readily seen by the glowing of the rack alarm lamp.

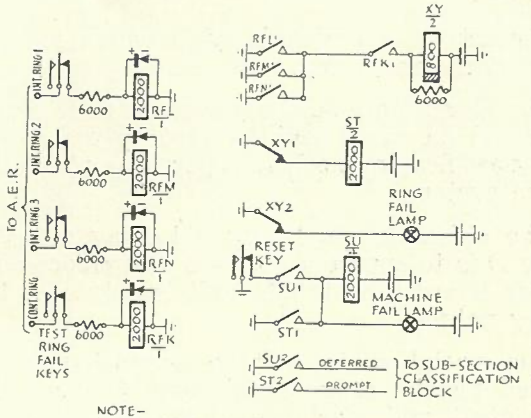
In the event of the fuse alarm fuse operating, the two coils of relay FA are connected in series, the alarm is brought in as before, but in this case only the sub-section alarm lamp is illuminated.

Fig. 12 also shows the provision for fuse alarm on the Group Fuse Panel which is the distribution point for one or two suites of racks. The group fuse is usually of the cartridge type and in order to provide supervision, a 1.5 amp alarm fuse is connected in parallel so that in the case of a fault both fuses will operate almost simultaneously.

A 500 ohm resistance in parallel with the alarm lamp ensures that the circuit will still function if the alarm lamp becomes disconnected.

**Ring Fail and Machine Fail Alarms.** Two machines for supplying ringing current are usually installed, one, referred to as Ringer No. 1, is driven from the supply mains, the other, designated Ringer No. 2, operates from the 50v battery.

Normally Ringer No. 1 carries the exchange load, but in case of failure, an automatic change-over arrangement comes into operation starting up Ringer No. 2 and transferring the load thereto. In order to continuously test the supply of ringing current a tapping is taken from each ringing bus bar on the alarm equipment rack to testing relays designated RFK, RFL, RFM and RFN as shown in Fig. 13.

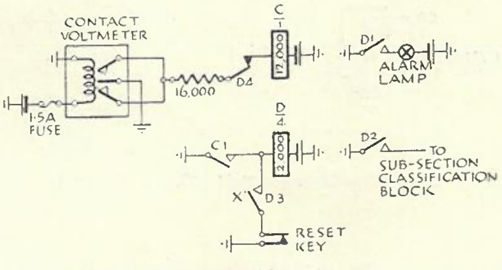


NOTE—
CONTACTS SU3 & SU4
CONTROL THE MACHINE
CHANGE-OVER CIRCUIT

Fig. 13.—Ring Fail and Machine Fail Alarm Circuit.

If a failure occurs, the appropriate testing relay releases, thus allowing relay XY to restore and operate relay ST at contact XY1. Contact ST1 illuminates the machine fail lamp and operates relay SU which locks via the Reset Key. Contact ST2 forwards an earth to the sub-section classification block to give a prompt alarm.

Contacts SU3 and SU4 (not shown in diagram) operate the machine change-over circuit which starts up Ringer No. 2 and connects it to the load. If ringing current is now restored on all bus-bars relay XY re-operates and releases relay ST at contact XY1. The prompt alarm is cleared but a deferred alarm is maintained by contact SU2 until the reset key is depressed, thus ensuring a personal attendance at the control panel.



'X' CONTACTS OPERATE FIRST

Fig. 14.—Voltage Alarm Circuit.

Test keys are provided for disconnecting each testing relay so that the operation of these important alarms can be verified by the maintenance officer.

**Voltage Alarm.** In order to supervise the voltage on the discharge leads, a contact voltmeter is permanently connected across them, and set so that any fall or rise of voltage beyond allowed limits closes a contact to operate relay C (see Fig. 14).

Contact C1 operates relay D which locks via D3 and the reset key.

The alarm lamp on the power board is illuminated and an earth sent forward to the sub-section classification block for operation of the main alarm system.

The object in employing a locking circuit on relay D is to ensure a personal attendance at the Power Board even if the fault is only of a transitory nature.

The variation in voltage permitted is controlled by the range over which the switching equipment will work satisfactorily. For a 50 volt system this is usually 46 volts to 52 volts at the rack bus-bar.

**Charge Fail Alarm.** When the Power Room is remote from the automatic apparatus and is not permanently under supervision, it is desirable that premature tripping of the charge circuit breaker should operate the exchange alarm system. This is achieved by having supervisory contacts fitted on the circuit breaker bridged by a relay CB (see Fig. 15).

When the circuit breaker is closed the relay is short circuited and remains unoperated. If, however, the circuit breaker trips the short circuit is removed and the relay operates in series with the voltage coil. Contact CB1 illuminates the alarm lamp on the Power Board and contact CB2 extends an earth to the sub-section classification block to operate the main alarms.

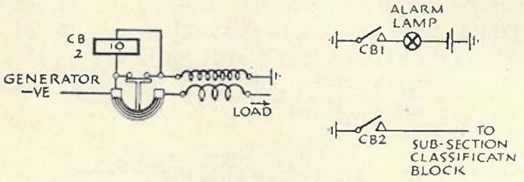


Fig. 15.—Charge Fail Alarm Circuit.

**N.U. Tone Overload Alarm.** When a subscriber's line becomes faulty or is required to be temporarily out of service (T.O.S.), N.U. tone is connected to the internal negative line on the M.D.F. protector by means of a flexible lead from the N.U. tone bar. In order that the ringing trip relays in the final selectors may be operated when a faulty line is dialled, the N.U. tone must be connected to battery and consequently distribution fuses and relays have to be provided to guard against overload.

Referring to Fig. 16 it is seen that the N.U. tone is fed through the 2 ohm winding of relay TB which under normal conditions remains unoperated. If an excessive load is connected relay TB operates and contact TB1 switches in the 400 ohm winding thus reducing the flow of current. Contact TB2 energises relay EA which operates and forwards an earth to the sub-section classification block at EA2 for operation of the main alarm system.

Relay EA also acts as a fuse alarm relay but a clear indication as to whether an overload or a fuse is the cause of an alarm is given by the glowing of the N.U. relay lamp in the first case and the N.U. fuse lamp in the second.

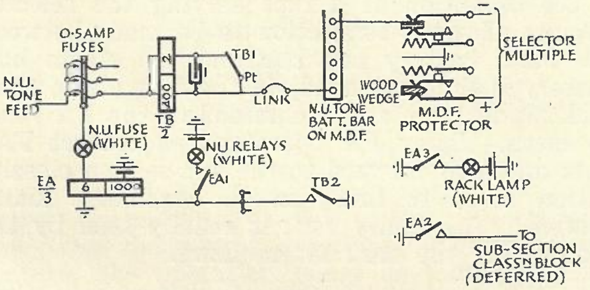


Fig. 16.—N.U. Tone Overload Alarm Circuit.

## 7. DESCRIPTION OF SECTION AND FLOOR LAMP CIRCUITS.

In each of the rack circuits already described, an earth is put forward to the sub-section classification block for operation of the exchange alarms, i.e., illumination of the appropriate section and floor lamps and control of bell signals. Discrimination can be made on the classification block as to whether an alarm shall illuminate the prompt or deferred sub-section lamp, also, in the case of the latter, whether it shall be connected via the alarm cut-off key. The relays associated with this equipment are mounted on the Alarm Equipment Rack together with the necessary terminal blocks for cross connections.

Fig. 17 shows the circuit arrangements for an alarm scheme serving 2 floors and having 2 sections on each floor. Details of the classification block are shown for sub-section 211 and the alternative strapping for prompt, deferred and deferred via cut-off key is indicated. Alarms are only connected via the cut-off key when they are of such a nature that they can be temporarily ignored, e.g., P.G. Alarms on 1st selectors;

and as a reminder to the maintenance officer, a warning light glows when the key is thrown.

The earth from the rack alarm relay passes via the sub-section lamp to either the P or D relay which is of a very low resistance to permit the lamp to be fully illuminated. These relays have a single make contact to operate the slave relays AP or AD, which can carry sufficient spring sets to control the floor lamps, section lamps, and bells.

The terminal blocks on the A.E.R. provide a convenient point for cross connecting from the section relays to the lamps and bells and also allow extensions to be made without causing any interference to the working equipment.

The floor bell cut-off key is situated on the Test Desk and its function is to isolate the floor bells during hours of continuous attendance on each floor. In cases where the floor contains less than 3 sections, the section bell is not provided and the particular FB terminal for this floor is commoned to other floors via contacts on the floor bell cut-off key. The floor bell will thus serve as a section bell when the cut-off key is thrown. In Fig. 17 this arrangement is shown in dotted connections for Floor 1.

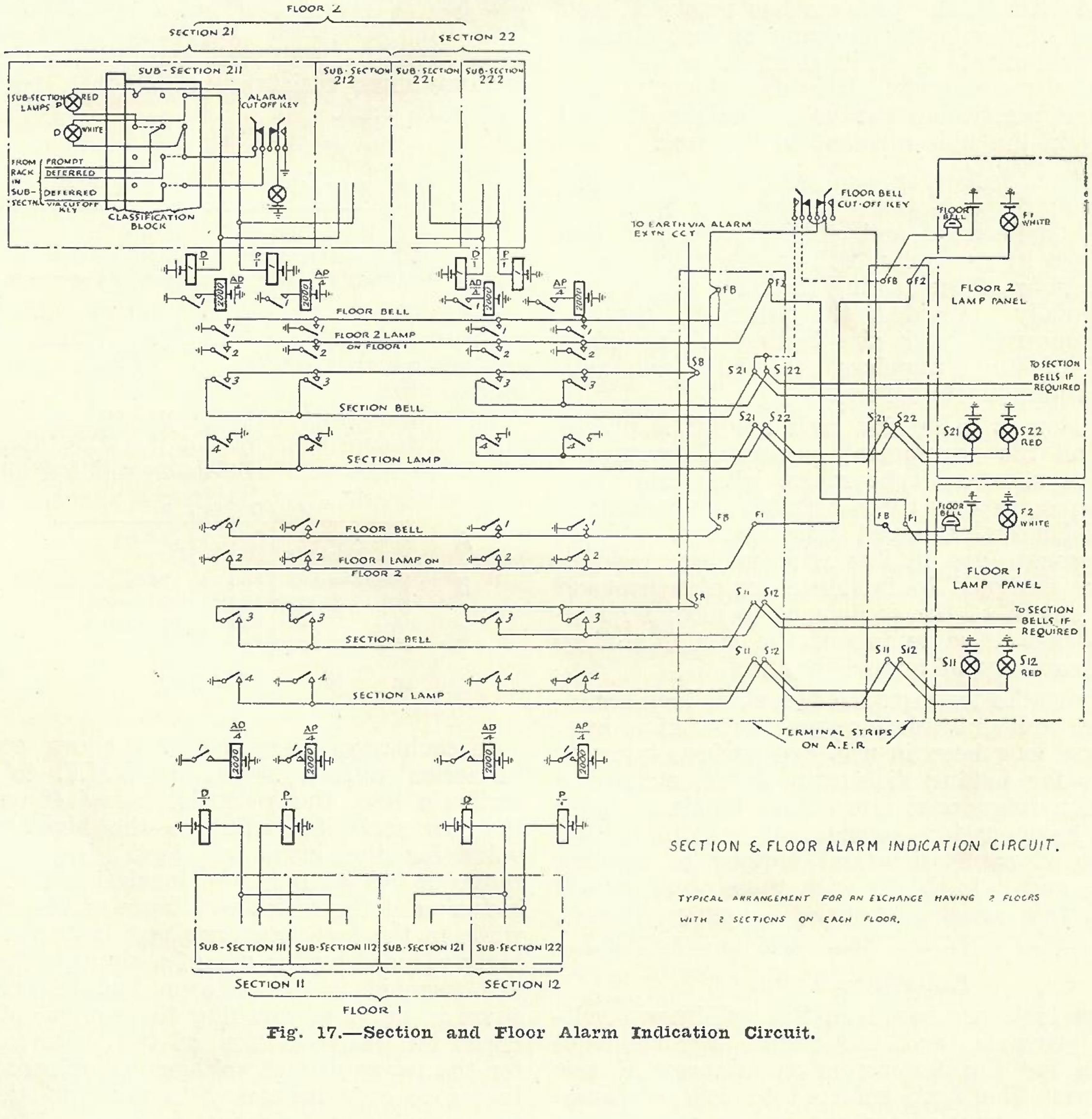


Fig. 17.—Section and Floor Alarm Indication Circuit.

# AUTOMATIC EXCHANGE TEST DESK CIRCUITS

W. B. Wicking

Considerable effort has been expended in recent years in developing a group of test circuits which will satisfactorily meet the requirements of a modern automatic exchange while keeping at a minimum the amount of equipment to be provided for testing, and, at the same time, avoiding undue complexity, both in the arrangement of circuits and in the manipulative processes necessary to apply any of the tests required.

The desirability of using one testing instrument has always been recognised, and since the use of the voltmeter for testing has become so well established, the problem has resolved itself into one of developing a group of test circuits, the measurements of all of them being indicated on the voltmeter scale. It is desirable also that wherever practicable the voltmeter should read directly in the unit relevant to the test.

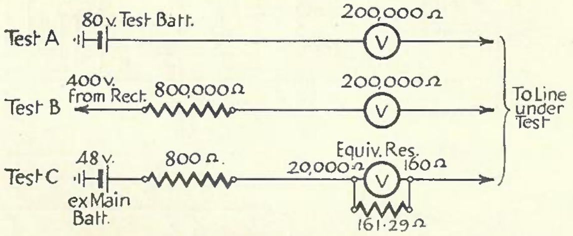
The test desks for use with the 2000 type equipment to be installed in the City West Exchange, Melbourne, and with subsequent new exchanges in Australia, will incorporate several modifications of the testing facilities which have been usually provided, the principal changes being concerned with the testing of insulation and of dialling impulses received from subscribers and junction lines.

Provision is made for rack mounting practically all the equipment associated with the desks on standard type racks, while relay sets will be mounted on bases suitable for jacking in to position on Channel type shelves. These arrangements are in line with modern practice and are designed to facilitate maintenance and the extension of the equipment to meet requirements, as well as to permit the use of a more convenient type of manual position.

Many of the tests required, such as loop resistance, capacity, insulation resistance, etc., have of course long been in use, and various types of circuits for testing dial ratio, speed, etc., have also been introduced from time to time; these latter have varied considerably, both in the manner of application and method of reading results, and it is chiefly with these that we will deal in this article. A brief account, however, of the first mentioned tests may be desirable.

### Resistance Tests.

These tests are based on the well-known voltmeter principle, and the circuit arrangements provide for the testing of resistances in two divisions. The first, referred to as "resistance test", is for general testing, and is suitable for resistances exceeding approximately 3,000 ohms. See Test "A," Figure 1. The second, referred to as "low scale," uses a low voltage and a shunted voltmeter and is for testing resistances not exceeding, say, 10,000 ohms. See Test "C," Figure 1. The use of this test is, therefore, to give greater accuracy at the low resistance end of the scale. In addition, the "Insulation test" is provided and is for testing insulation resistances under more severe conditions than those applied during "resistance tests." See Test "B," Figure 1. The use of either the high or low scale is not, of course, confined to the resistance ranges quoted, but taken together they give sufficiently accurate readings over the whole range of resistances met with in telephone practice and furnish a reasonably searching test for insulation weakness. Figure 1 shows simplified connections for each scale and also the maximum and minimum resistance which it is possible to test with each.



$R = V\left(\frac{D}{D_1} - 1\right)$ where R = Res. under Test
V = Res. of Voltmeter System
D = Deflection with no Res. in Test Line
$D_1$ = Deflection with R Res. in Test Line

| | V | D | $D_1$ | R |
|---|---|---|---|---|
| A | Max. 200,000 Ω | 80 | 1 | 15·8 mΩ |
| | Min. 200,000 Ω | 80 | 79 | 2531 Ω |
| B | Max. 1,000,000 Ω | 80 | 1 | 79 mΩ. |
| | Min 1,000,000 Ω | 80 | 79 | 12,658 Ω |
| C | Max. 960 Ω | 80 | 1 | 75,840 Ω |
| | Min. 960 Ω | 80 | 79 | 12·151 Ω |

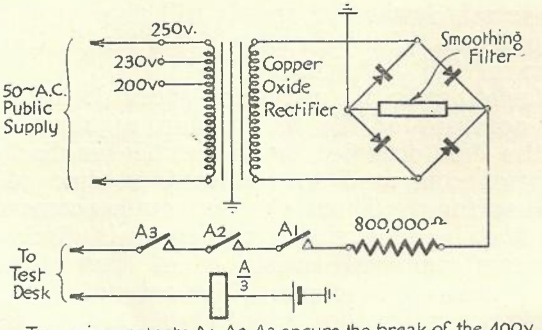
Fig. 1.

In each case the voltmeter is shown connected in series with a source of E.M.F. to a subscriber's line, the potential being 48 volts for the low scale, 80 volts for the high, and 400 volts for the insulation test. The voltmeter range is increased in the insulation test by the inclusion of the series resistance of 800,000 ohms while in the low resistance test it is correspondingly reduced by the use of a shunt. The standard formula is also shown, but in practice a chart is provided showing the equivalent resistances for each division of the voltmeter scale for the range of test voltages experienced. It is therefore only necessary to refer to the chart to convert any deflection to ohms. The necessity for providing for two voltmeter ranges will be appreciated if we consider the congestion on the high scale, the range of which represents a resistance spread of 16 million ohms. Obviously an attempt to determine accurately the value of any reading, say one of approximately 75 scale divisions, would be futile. The overlapping of the ranges is not a disadvantage, but the range selected for use in any instance will depend on the order of the resistance to be measured. As a general guide the scales used should be:—

Resistances up to 5000 ohms: Low Scale.
Resistances from 5000 ohms to 16 megohms: High Scale.
Resistances Insulation: Insulation Test.

The provision of a higher test voltage for insulation testing has been included to meet modern requirements. At present the testing of insulation resistance is confined to the use of voltages varying from approximately 40 to 75, depending on the type of test desk. While reasonably satisfactory in other regards, these pressures have little value in detecting break down or flash over troubles which with the high voltage peaks frequently developed in dialling and ringing are a considerable source of trouble. On all new test desks the potential will be 400 volts. This potential is specified for the break down test on condensers, the presence of which in the subscriber's loop renders it necessary to limit the test voltage to this figure.

The potential for the insulation test is derived from the 50 cycle A.C. supply, a transformer, rectifier and smoothing network incorporated in a separate unit suitable for wall mounting being provided for this purpose. The schematic connections of the rectifier unit are shown in Fig. 2.



The series contacts A1, A2, A3 ensure the break of the 400v supply.

Fig. 2.

### Capacity Test.

The condenser "kick" test for determining whether or not a subscriber's line is disconnected has not been varied. This test relies on the charging and discharging via the voltmeter of the condenser in the subscriber's telephone. The voltmeter acting as a ballistic galvanometer indicates the discharge by the swing of the pointer, the deflection being proportional to the capacity under test. By operating the line reverse key the test may be repeated at will.

### Howler.

The Howler circuit has been modified by the introduction of a rotary preselector arranged to remove a short circuit from the howler circuit by the progressive insertion of resistance via its bank contacts. This gives a graduated howl, soft when first applied but swelling rapidly to its full intensity. The object of this alteration is to avoid causing acoustical shock to anyone who may be listening on the line when the howler is connected by giving time for the removal of the receiver from the ear before the howl reaches its maximum amplitude. A homing type preselector is employed, the switch stepping to its home position immediately the circuit is released, or when a further circuit connects to the howler. Under the latter conditions the preselector then commences to restep.

### Dialling Impulses.

The existing arrangements for the testing of dial impulses differ greatly as between exchanges. In some instances desks are equipped with circuits for testing ratio, speed, and counting, while in others speed tests only are provided for. The type of equipment also varies, circuits employing indicating lamps being commonly used for counting, whilst circuits employing part of the voltmeter scale are frequently used for ratio and speed tests. On many desks the mechanical dial speed indicator originally supplied by the manufacturers is still in use. In cases where the voltmeter is used the normal zero of the voltmeter is made to represent the normal or O.K. condition, the pointer moving off normal only to indicate the departure from the O.K. condition. This arrangement is essential with the type of voltmeter at present in use to ensure that the amount of pointer swing and oscillation is reduced to a minimum. The impulse testing circuits designed for use with new exchanges all utilise part of the voltmeter scale, the readings being given directly in percentage make, pulses per second and number of pulses for ratio, speed and counting respectively.

The voltmeter is similar to those now in use but is wound to 200,000 and 20,000 ohms for the high and low scale respectively, and is more heavily damped to reduce pointer swing and oscillation. Both the ratio and speed test circuits employ a pre-setting device by which means the pointer is set at the point on the scale corresponding to an O.K. test. The test potential employed is 46 volts and is drawn from the exchange main battery. The low scale of the voltmeter suitably shunted is used in the tests, and a series resistance R of 12,000 ohms plus a further resistance X (200 ohms in the form of a rotary variable rheostat of the radio type) is employed to compensate for variations in the voltage of the exchange battery, resistance of lines, etc. The 200 ohm rotary portion of the rheostat is mounted on the face of the test panel for convenience in making adjustments.

### Impulse Ratio Test.

For this test a full scale deflection represents 100 per cent. make, i.e., continuous make, while a zero deflection represents 0 per cent. make, i.e. continuous break. Any intermediate scale reading therefore represents a corresponding percentage between 0 and 100, i.e., half a full scale deflection would represent 50 per cent. make, etc. 75 scale divisions have been selected as a full scale deflection equal to 100 per cent. make. The make ratio of 33 1-3rd per cent., which is the normal dial ratio, will therefore be represented by a reading of 25 scale divisions.

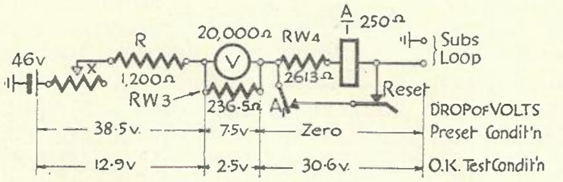


Fig. 3.

The circuit arrangements for this test are shown in Figure 3, which represents the connections when the ratio test key is thrown connecting a subscriber's loop to the test circuit. The resistance R + X is such that a full scale reading of 75 scale divisions is registered on the voltmeter; actually 7.5 volts on the low scale. The variable resistance X facilitates adjustments to compensate for any variation in subscribers' loop resistance or battery voltage. In the figure the subscriber's loop is shown as of zero resistance. In testing a loop of 100 ohm resistance X would be adjusted accordingly. The operation of the reset key at this stage by removing the short circuit on RW 4 and A inserts a resistance (2863 ohms) such that the voltmeter deflection is reduced to 25 scale divisions, which represents a 33 1-3rd per cent. make ratio. The series relay A forms part of this additional resistance and now operates, its No. 1 contact maintaining the reset condition after the release of the reset key. Upon the receipt of a train of impulses the first break releases A, which has been held over the subscriber's loop, A1 restoring the short circuit to A and RW 4. The voltmeter pointer thereupon tends to take up a position showing 75 scale divisions during make periods and zero during break periods, the resultant scale reading representing the percentage of the total dialling time for which the impulse springs are closed, i.e., the make ratio.

It will be readily appreciated that the voltmeter movement requires to be more heavily damped than is the case with test voltmeters of the existing type, otherwise oscillation of the pointer greatly increases the difficulty of obtaining accurate readings.

### Impulse Speed.

This test depends on the average value of the current flowing in the voltmeter circuit during the impulsing period. Two similar and equal capacities, in this instance 2 m.f. condensers, are alternately charged from a common source of potential, 46 volts, and then discharged through the voltmeter and its shunt, via contacts AS1 and AS2, Figure 4. Both capacities are discharged every impulse, one during the make and one during the break portion of the impulse, the voltmeter receiving two discharges for every impulse dialled. The capacity of each condenser and the charging voltage is constant at 2 m.f. and 46 volts respectively. Each condenser charge will therefore contain a quantity of electricity

$Q = KV = 2 \times 10^{-6} \times 46$ coulombs where $K$ = capacity of each condenser in farads and $V$ = voltage of the charging source. Assuming standard dial speed of 10 I.P.S. the total quantity of electricity to be discharged through the voltmeter in one second is 20 times Q—the quantity shown above—since there are 10 impulses and 2 discharges per impulse.

$$Q_{20} = 2 \times 10^{-6} \times 46 \times 20 \text{ coulombs}$$
$$= 0.00184 \text{ amp. seconds.}$$

As the time of discharge is 1 second, the rate of flow will equal 0.00184 amp. or 1.84 m.a. Higher dial speeds will cause the twenty condenser discharges to occur in a shorter period of time than one second, and as the total quantity remains the same the rate of flow will be increased giving a higher scale deflection. Conversely lower dial speeds will give lower scale deflections. The voltmeter deflection is thus an index of the dial speed.

Variations in the ratio and speed do not affect the accuracy of the test within required limits as the time occupied by the condenser discharge is brief compared to the contact time of the dial springs. Thus at the commencement of the first break period a condenser is discharged via the combined resistance of the voltmeter and shunt—2174 ohms. The rate of discharge will vary with the potential of the condenser from a maximum of 46 volts at the beginning to a minimum of 0 volts at the end of the discharge. The average potential is therefore 46/2 = 23 volts. The average rate of discharge I is, therefore,

$$I = 23/2174 \text{ amps.}$$

The time required to complete the discharge of the condenser is obtained by dividing the rate of discharge into the quantity to be discharged, thus:—

$$T = \frac{Q}{I} = \frac{2 \times 10^{-6} \times 46}{\frac{23}{2174}} = 8.696 \text{ milliseconds.}$$

At normal speed each complete impulse occupies 100 m.s. of which 33.3 m.s. is make and 66.6 m.s. is break. A condenser discharge occurs at the beginning of each period so that the deflection is not normally affected by rate or speed. In order to affect the accuracy of the test the make period would need to be less than 8.7 ms. equal to a time for one complete impulse of 8.7 + 17.4 = 26.1 m.s. and a dial speed of 1000/26.1 = 38 i.p.s., while at normal speed the break ratio must increase from 66.6 per cent. to 91.4 per cent. to cause inaccuracy.

The normal speed of a dial, 10 i.p.s., gives a deflection of 40 scale divisions, equal to 4 volts on the voltmeter. The voltmeter is pre-set by means of a key to show a normal reading, 46 volts from the test supply via the high scale of the voltmeter in series with a suitable resistance being used for this purpose. The pre-set condition is maintained until the receipt of the first break of the impulse train which removes the condition allowing the voltmeter to be influenced by the condenser discharge only.

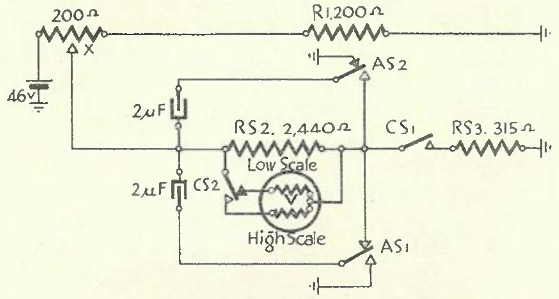


Fig. 4.

The test connections of the circuit are shown in Figure 4, the potentiometer providing a ready means of adjustment to compensate for variation in battery voltage. The average current in the voltmeter system for a speed of 1 impulse per second is: $4 \text{ x } 10^{-6}$ farads x 46 volts x 1 pulse per second, i.e., .000184 amps. The combined resistance of the voltmeter low scale and shunt is 2174 ohms. The deflection D corresponding to 1 impulse per second is equal to the voltage drop in the voltmeter shunt produced by the average value of the current due to the condenser discharge, i.e., D equals .000184 times 2174 equals 0.4 volt. The deflections, in scale divisions, for impulse speeds of 2, 5, 10 and 15 pulses per second are therefore:—

| | | | | |
|---|---|---|---|---|
| 2 | 5 | 10 | 15 | pulses per second. |
| 8 | 20 | 40 | 60 | scale divisions. |

Any variation in the capacity of the condensers or the test voltage would introduce corresponding variation in the respective readings. The condensers are therefore carefully selected and matched.

**Impulse Counting.**

This test employs a 25-point rotary uniselector and a series resistance in conjunction with the test voltmeter. The series resistance comprises the 1200 ohm + 200 ohm (R + X) resistance previously referred to with the addition of two 220 ohm resistances R.C.2 and R.C.3. The latter is tapped every 20 ohms and the tappings connected to consecutive bank contacts of the 25 point switch. The total series resistance is 1840 ohms. 46 v. is connected via the series resistance to ground. The drop of volts in each 20 ohms section will, therefore, be:—

$$46 \times 20/1840 = 0.5 \text{ volts.}$$

The positive terminal of the voltmeter is connected to one terminal of the tapped resistance, and the negative to the switch wipers. The impulse train steps the preselector to a position corresponding to the number of impulses dialled, thereby connecting the voltmeter across 1, 2, 3 etc. of the 20 ohms resistances. The voltmeter deflection, therefore, increases with each step by an amount equal to the voltage drop in one 20 ohm resistance, i.e., by 0.5 volts for each step, the final deflection being 0.5 times the number of steps, i.e., for 10 steps, 5 volts, etc. The switch pauses after the final impulse for a period equal to the release of two slow relays, facilitating the reading of the final deflection. On the release of the two relays the switch returns to the home position ready for the next impulse train. Test connections are shown schematically in Figure 5.

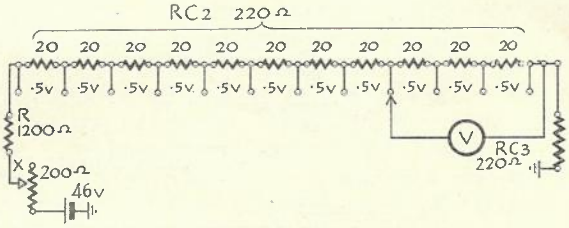


Fig. 5.

The results of the above tests may, of course, be read from the ordinary voltmeter scale, but to facilitate reading, the scale is separately calibrated for each test in addition to the ordinary calibration. Figure 6 shows the scale markings of that part of the voltmeter scale which is used for the impulse tests.

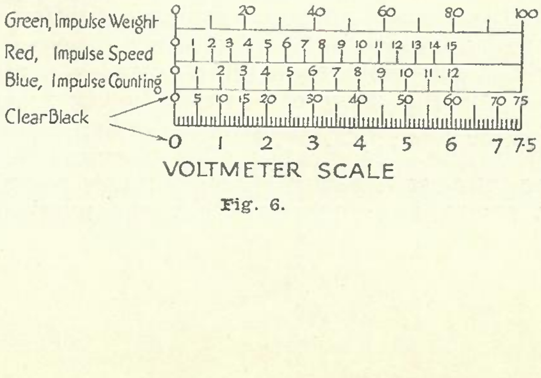
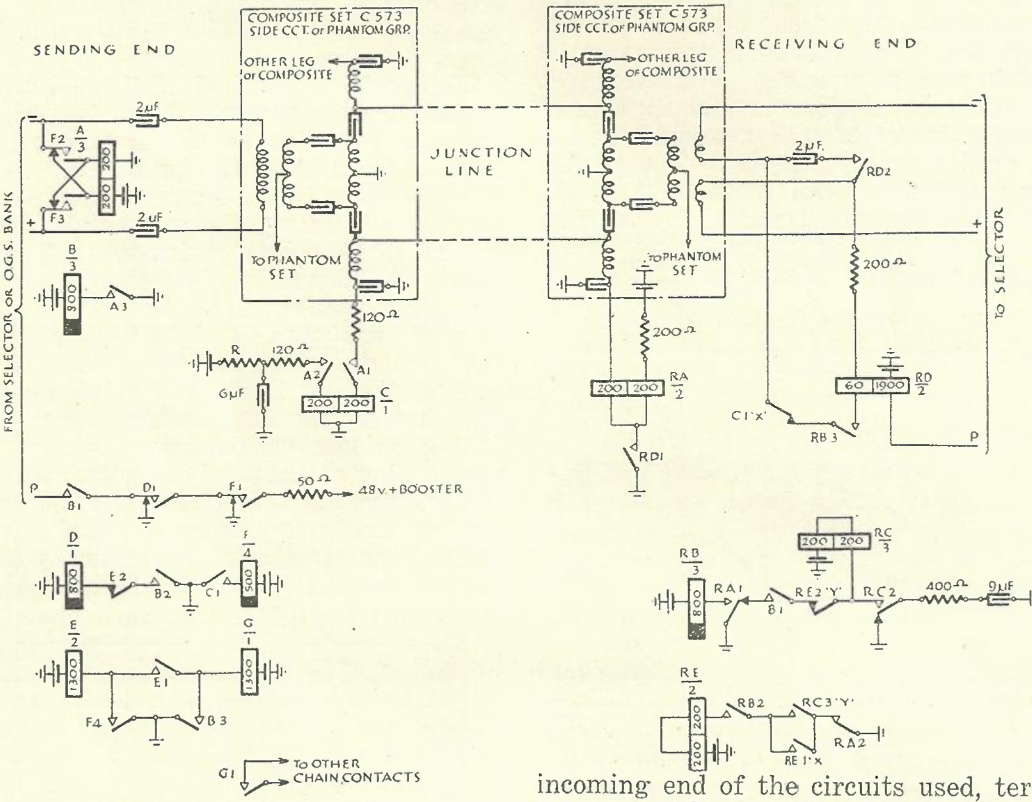


Fig. 6.

# AN IMPROVED METHOD OF DIALLING ON COMPOSITED LINES

*D. D. Knuckey*

The economic provision of trunk and junction telephone plant frequently necessitates the use of the well-known "Phantom" circuit whereby three audio frequency channels are obtained from two pairs of wires.



NOTES
1. VALUE OF R IS DEPENDENT ON RESISTANCE OF LINE
2. 'X' CONTACTS TO OPERATE BEFORE 'Y' CONTACTS

For magneto services the ringing frequency signalling is readily passed over the transformers and as the use of the phantom in such circumstances is well established, it is unnecessary to deal further with its characteristics here. However, where DC signalling is required for more than one channel, some modification of the simple phantom is necessary. For instance if the telephone channels are to be associated with auto switching, loop dialling on each channel is obviously impossible. Telegraphy and dialling use signals of the order of 10 impulses per second, so that somewhat similar conditions apply to the transmission of either of these. The familiar composite type filter provides a means for separating these comparatively low frequencies from the audio channels and when incorporated in the side circuits of a phantom set up gives four earth return signal channels per phantom group, i.e., one more than the number required for dialling control of each audio channel.

Such facilities have been in use for many years, giving four telegraph circuits with the three telephone channels, the latter using 135 cycle ringers for signalling over the audio circuits. Similar conditions have also been applied to automatic circuits, but have been confined to manual to auto channels. The incoming end of the circuits used, terminates on a repeater that provides the three wire-two wire conversion required, i.e., it re-associates the signalling and speaking circuits to give the normal conditions for incoming loop circuits in an auto exchange.

The conditions met in dialling over composited lines are much more exacting than those met in ordinary loop dialling circuits owing to the high capacity to earth (6 m.f.) at each end of the line. This restricts the range over which the impulses can be received within the limits of distortion necessary to obtain reliable operation of the automatic switches. A further difficulty is that such circuits are usually associated with long open wire lines, whose electrical characteristics are subject to considerable change due to varying weather conditions.

Under favourable conditions the usual type of terminating repeater has given reasonably satisfactory service on manual to auto services, although it makes no correction to the characteristics of the dialling impulses received. The reasons for the success obtained are:—

(a) Few dials (one per operator's position) have access to the dial line, and these being under constant supervision can be kept rigorously within standard adjustment.

(b) The dials are connected to the dialling line over connections of similar and constant electrical characteristics, consisting merely of a few feet of internal wire.

Considering now the auto to auto service, entirely different conditions have to be met, for the reason that the dialling line is accessible to every dial in the exchange area served, these being connected via lines having a wide range of electrical characteristics.

In these circumstances there is a very serious limit to the type and length of line over which the impulses can be transmitted and still give reliable dialling from the repeater.

In fact, a practical solution is possible only by regeneration of the dialling impulses to overcome distortion introduced by the factors mentioned or other normal causes. Simultaneous bothway signalling is required to provide for holding at the same time as metering and supervision. As only one wire is available the usual reversal cannot be employed.

A circuit to give the full requirements was developed by the writer and is illustrated in the accompanying diagram. In developing the impulse correction circuit, two methods were available, these being to provide for:—

(a) a constant impulse ratio, or

(b) a constant magnet operating period.

The latter was chosen as it is the simpler.

The period used is 45 milliseconds, this figure being selected as follows:—A selector of the type in general use in the Commonwealth will, if in correct adjustment, operate reliably with a vertical magnet operating period of 30 milliseconds. To provide for adjustment irregularities met in practice, a 50 per cent. margin was arbitrarily selected, thereby increasing the figure to 45 milliseconds. This has proved satisfactory in practice. Since the circuit of the vertical magnet is closed during the released time of the impulse relay, the open circuit time of the loop is to be measured as a 45 milli-second period. This has been done in timing, by capacity and resistance, the operated time of a relay (CR in the diagram), the commencement of the period only, being controlled by the incoming impulse. The simultaneous two way signalling is based on the well-known duplex telegraph connections. The operation will be clear from the following circuit notes and reference to the circuit diagram.

At the sending end relays A B and G perform normal functions. When registration signal is received, C operates and by medium of relays F then E and D the booster pulse is applied to the P wire in the normal manner. Relay F is slugged at the armature end to guard against false operation due to any "flutter" on relay C that may occur during dialling.

When relay A is operated an earth is applied over a winding of relay C to the line and also to a balancing resistance R. Relay C does not operate but at the receiving end the circuit is completed to battery over both windings of relay RA, which therefore operates and operates RB. The impulses received on relay RA operate the connecting circuit at the back of contact RA1. This closes the circuit of relay RC which first opens the dialling loop and closes the timing circuit at RC2, then closes the circuit of relay RE. RE locks at RE1 and then breaks the operating circuit of RC so that RC is dependent on the timing circuit only, and this is designed to give a total holding time of 45 miliseconds. Relay RE is held till RA re-operates, and the operating circuit of RC is restored only after it has been opened at the back of RA so that the length of time RA is energised or released has no effect on the transmitted loop impulses from RC1. Each release is the only part of the incoming impulse which is effective. When the reversal on the receiving end loop operates relay RD, the closing of contact RD1 so increases the line current that relay C at the sending end operates due to the unbalancing of the differential connection.

Battery is connected to relay RA to guard against false registration due to an earthed junction line. If the registration facility is not required, battery is connected to relay C (sending end) and earth to relay RA (receiving end).

Circuits of this type are in operation on two auto to auto junction routes in the Sydney network. In both cases portion of the route consists of aerial construction, and the use of this circuit, by enabling the provision of "phantom" junctions, has deferred for a number of years heavy expenditure on cable plant.

It was stated above that for manual to auto service "the old type terminating repeater has given reasonably satisfactory service under favourable conditions." Under unfavourable conditions the service has not been satisfactory, but dialling difficulties have been overcome by the use of the later type circuit and a large proportion of the dialling trunks in New South Wales is now so equipped.

For manual to auto service without supervisory facilities, the sending repeater is not required, and the RD relay in the receiving repeater may be eliminated. If supervisory facilities are required the RD relay is retained and at the sending end the C relay and associated circuit is required, the C1 contact controlling a supervisory lamp circuit.

# TRANSMISSION PRACTICE

## PART 2 THE LOADING OF TELEPHONE CABLES

*S. O. Jones*

It is well known that, due to the electrical characteristics of telephone cables, the attenuation per mile of such circuits is considerably greater than that of open-wire lines. Quite early in telephone history it was realised that considerable economy could be effected by placing subscribers' lines underground, and this practice was extended later to inter-exchange junctions and more recently still, in many cases, to country trunk routes. One of the greatest difficulties which were met in undergrounding these lines, particularly the long junctions and trunk lines, was the large attenuation constant of the cable circuits, and recourse was made by the telephone engineers to the work which had been done previously by Heaviside and Pupin in connection with the development and application of the distortionless line theory.

### Distortionless Line:

The propagation constant of any line is given by the expression $P = \sqrt{(R + jwL)\ (G + jwC)}$ where

$R$ = resistance per mile in ohms.
$L$ = inductance per mile in Henries,
$G$ = leakance per mile in Mhos,
$C$ = capacitance per mile in Farads.
$w$ = frequency in radians per sec.

From this expression we derive the equations for the attenuation constant, "a," and the wavelength constant, "b."

$$a = \sqrt{\tfrac{1}{2}\left\{\sqrt{(R^2 + w^2L^2)\ (G^2 + w^2C^2)} + (GR - w^2LC)\right\}} \text{ Nepers per Mile.}$$

$$b = \sqrt{\tfrac{1}{2}\left\{\sqrt{(R^2 + w^2L^2)\ (G^2 + w^2C^2)} - (GR - w^2LC)\right\}} \text{ Radians per Mile.}$$

By adding and subtracting $2\ w^2RCLG$ to and from the quantity under the square-root sign Heaviside re-wrote these expressions as:—

$$2a^2 = \sqrt{(RG + w^2LC)^2 + w^2\ (CR - LG)^2} + (GR - w^2LC)$$

$$2b^2 = \sqrt{(RG + w^2LC)^2 + w^2\ (CR - LG)^2} - (GR - w^2LC)$$

From these expressions it can be deduced that if RC be made to equal LG—

$$\text{then } 2a^2 = 2RG$$
$$\therefore\ a = \sqrt{RG}$$
$$\text{and } 2b^2 = 2w^2LC$$
$$\therefore\ b = w\sqrt{LC}$$

Heaviside proved theoretically, therefore, that when $RC = LG$ the attenuation "a" is equal to $\sqrt{RG}$. w is not contained in this expression—therefore, "a" is independent of frequency, i.e. all frequencies are attenuated to the same extent. He proved also that the wave-length constant "b" is equal to $w\sqrt{LC}$ and, because the velocity of propagation "V" = w/b then $V = w/w\sqrt{LC} = 1/\sqrt{LC}$ and it also is independent of frequency, i.e. all frequencies are propagated at the same velocity and, therefore, no distortion occurs when a complex wave is being transmitted.

The expression for Characteristic Impedance of any line is $Z_0$ (ohms) $= \sqrt{\dfrac{R + jwL}{G + jwC}}$ and if $RC = LG$ it can be deduced that $Z_0 = \sqrt{\dfrac{L}{C}} = \sqrt{\dfrac{R}{G}}$ and the Characteristic Impedance is, therefore, also independent of frequency.

When this condition obtains in a line, i.e. when $RC = LG$, all components of a complex wave, which is a wave made up of a fundamental frequency plus a number of harmonics such as a voice-frequency signal, are transmitted with the same velocity, all suffer the same amount of attenuation and all meet the same impedance. Therefore, the relative amplitude of the components and the initial phase relationship between them are maintained throughout, and the line is said to be "distortionless."

### The Theory of Loading.

It is possible to construct a distortionless line by merely selecting or manufacturing conductors such that the product of L and G equals the product of R and C, but in practice certain limitations are imposed.

There are three possible methods of achieving the distortionless condition, e.g.:

1. By continuous inductive loading introduced by the Danish Engineer, Krarup. This method consists of winding around the conductors continuously an iron or iron alloy wire and so increasing the inductance to a point at which $LG = RC$. As G, the leakance, is always a very low value, however, in an underground or submarine cable, the added inductance necessary for the distortionless condition would normally be a very large value and the cost would be considerable.

2. By introducing high resistance leakage paths to earth at regular intervals. This method is called leak loading. Its disadvantage lies in the fact that, although the distortionless condition can be attained, the increase in G increases the attenuation because in the distortionless condition $a = \sqrt{RG}$, therefore "a" increases as the square root of G.

3. By the insertion of inductance coils in series with the conductors at regular intervals. This method is known as "lumped" loading, and was introduced by the late Prof. Pupin. For underground cables this method of loading has been proved to be the most satisfactory and economical for reasons which are set out later.

The limitations found in practice are:—

(1) Because the Velocity of Propagation, V, is equal to $1/\sqrt{LC}$ it is clear that the high value of L which is necessary for distortionless transmission will cause a very low value of V, and this introduces difficulties in the operation of telephone circuits which render the distortionless condition undesirable.

(2) The application of the "lumped loading" system to an extent which would provide the distortionless condition introduces a limit due to the creation by the spaced inductance coils of sections of cable which are, in fact low-pass filters. For instance, a length of cable which has been lumped loaded can be represented by the network shown in Figure 1. It will be seen from the figure that the loading coils and mutual capacity of the conductors are so arranged that a low-pass filter section is created, one which has an appreciable amount of resistance in its elements. The circuit will pass, therefore, frequencies only below a certain value depending upon the relation between $L_1$ and $C_1$, where $L_1$ is the inductance of each loading coil and $C_1$ is the cable-pair capacity between adjacent coils. The highest frequency which would be transmitted is given theoretically by the expression $f_c$ (cut-off frequency) $= \dfrac{1}{\pi\sqrt{L_1C_1}}$ and in order that this be high enough to permit the satisfactory transmission of the voice-frequency range—i.e. 200-2600 cycles per second—$C_1$ would need to be very small when L (per mile) was large enough to provide distortionless transmission. This means that a large number of coils per mile would be necessary for the distortionless condition, and the cost is not considered to be justified. Again, of course, in the lumped loaded case also the low Velocity of Propagation prohibits the use of the distortionless condition.

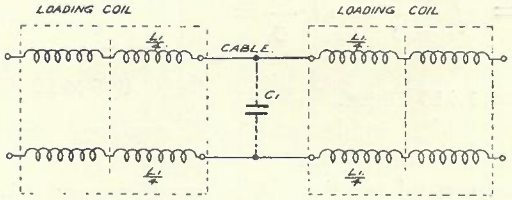


Fig. 1.—Equivalent circuit of one loading section.

### Practical Application of Loading.

The practical application of the principles brought out in the distortionless line considerations lie, not in the attainment of the completely distortionless condition, but in a compromise which consists of adding inductance sufficient to bring either the attenuation or Characteristic Impedance to a value which will permit the satisfactory use of cable circuits in lieu of aerial lines.

By an examination of the expressions set out earlier and by working out some examples it will be seen that inductive loading does three important things, e.g.:—

(1) It reduces the attenuation per mile.
(2) It reduces the Velocity of Propagation.
(3) It increases $Z_0$ and makes it fairly constant at all frequencies.

For voice-frequency telephone circuits the practical application of loading is almost exclusively for the first purpose; while for carrier frequency circuits the third is more generally the aim, excepting in the cases of long underground trunk routes and submarine cables.

Then the two different methods of inductive loading present themselves for consideration, i.e. "Krarup" or continuous loading and "lumped" loading.

### Continuous Loading.

The advantages are:—

(i) Does not increase the difficulty in handling submarine cable.
(ii) It gives a smooth Impedance v. Frequency characteristic.

The disadvantages are:—

(i) More expensive than "lumped" loading.
(ii) Cannot be applied to existing unloaded circuits.
(iii) Liability to inductance unbalance due to ageing of the inductive material wound around the conductors.

### Lumped Loading.

The advantages are:—

(i) Cheaper than continuous loading.
(ii) Can be applied to existing unloaded cables to any extent required.

The disadvantages are:—

(i) Increases enormously the difficulty in handling submarine cable. For instance, the bulge in the cable armouring caused by the existence of the loading coils causes trouble in manufacture and when passed over the sheaves of the cable ship.
(ii) Tendency to an uneven Impedance v. Frequency characteristic under certain conditions.

For the reasons set out above the usual practice is to adopt the continuous loading method for submarine cables and the lumped loading method for underground cables, although there are some departures from this practice.

All calculations connected with the determination of Attenuation Constant and Characteristic Impedance of lumped loaded cables are based upon the assumption that the circuit constants, including the added inductance, are distributed uniformly throughout the length of the conductor. At first it was thought that this assumption was not justified and that the existence of "lumps" of inductance at intervals would introduce reflection effects. Pupin deduced, however, that so long as there were not less than $\pi$ loads per wave-length the loaded line would behave as a uniform line, and the characteristics (excepting cut-off frequency) could be calculated as though the primary constants, including added inductance, were uniformly distributed throughout the length of it.

The practical problem, therefore, is to find a system of loading and a spacing between coils that will give transmission improvement as well as a satisfactory cut-off frequency. Velocity of Propagation is, as stated earlier, also an important consideration, while the Characteristic Impedance must be kept down to a value such that direct connection to an open wire line or to a terminal equipment of 600 ohms impedance does not cause excessive reflection.

## VOICE FREQUENCY LOADING.

### Australian Practice.

The object of loading cables for voice frequencies is almost solely for the purpose of reducing the attenuation constant per mile. For long junction cables and for trunk cables 88 mH coils are used and spaced at 6,000 feet. Each 6,000 feet of such a cable then appears as 1 section of a L.P. Filter in which $L_I = 88$ mH and the shunt arm = C x S (C = capacity per mile, and S = spacing in miles, i.e., 6000/5280.

$L_I$ therefore $= L_a S$ if $L_a =$ added inductance **per mile.** The cut-off frequency of such a section is $f_c = \dfrac{1}{\pi\sqrt{L_I CS}} = \dfrac{1}{\pi\sqrt{L_a CS^2}}$ and this is an important formula to remember.

In this case—

$$f_c = \frac{1}{\pi\sqrt{88 \times 10^{-3} \times .065 \times 10^{-6} \times \frac{6000}{5280}}} = 4000 \text{ cycles per sec.}$$

Now, a cable has an appreciable amount of resistance so that the attenuation characteristic

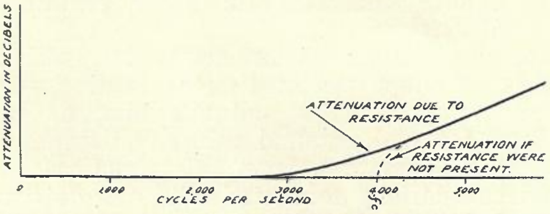


Fig. 2.—Attenuation vs. frequency of one loading section.

of any one section loaded as above would be as shown in Figure 2, so that, although $f_c$ theoretically occurs at 4000 cycles, actually, due to resistance, the cut-off occurs at about 3000 cycles. It is standard practice in calculating cable cut-off frequencies to allow not more than 75 per cent. of the calculated $f_c$ as the actual cut-off.

The actual cut-off of the above cable is, therefore, 3000 cycles approximately, so that the band of 0-3000 cycles is transmitted, and this more than covers the voice-frequency telephone range which is normally 200-2600 cycles or even 200-2400 cycles.

The characteristic impedance $Z_0$ is $\sqrt{\dfrac{R + jwL}{G + jwC}}$

Now the value of R is relatively small compared with wL, so that it is normal practice to drop R out as well as G and say that—

$$Z_o = \sqrt{\frac{jwL}{jwC}} = \sqrt{\frac{L}{C}} = \sqrt{\frac{88 \times \frac{5280}{6000} \times 10^{-3}}{.065 \times 10^{-6}}}$$

= 1,090 Ohms.

for a 20-lb. cable at 5,000 radians per sec. (neglecting the natural inductance of the cable).

For normal loading R is small compared with wL $\therefore$ R + jwL is a vector having an angle substantially equal to 90 degrees, also G is small compared with wC $\therefore$ G + jwC is a vector having an angle substantially equal to 90 degrees also, and from these facts it can be shown that

$$\text{"a"} = \frac{R}{2}\sqrt{\frac{C}{L}} \quad (1)$$

This formula applies only to a cable which is loaded and is approximate only, but it is standard practice to use it in calculations.

For the above cable, therefore,

$$a = \frac{R}{2}\sqrt{\frac{C}{L}} = \frac{88}{2} \times \sqrt{\frac{.065 \times 10^{-6}}{88 \times 10^{-3} \times \frac{5280}{6000}}}$$

= .0403 Nepers = .0403 × 8.7 = .35 db. per Mile.

(Unloaded this cable has an attenuation of approx. 1.04 db. per mile).

This system of loading, therefore, applied to a 20 lb. u.g. cable increases the $Z_0$ from 520 ohms to approximately 1,100 ohms and reduces attenuation to 1/3 of its unloaded value (at 5000 radians).

For ordinary junction cables the Australian practice is to load with 88 mH. coils at 9000 ft. spacing.

For 20 lb. cable loaded at 9000 ft. with 88 mH coils:—

$Z_0$ = 890 ohms.
a = .43 db per mile.
Cut-off = 2,400 cycles,

which are quite suitable characteristics for a

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(1) "Communication Engineering"—Everett. Page 96.

telephone circuit, the reduction in attenuation being more than 50 per cent. at 5000 radians.

As an indication of the effect of loading on certain cable circuits the following table sets out the results obtained by loading with 88 mH coils spaced at 6,000 ft.

| Gauge | Unloaded | | Loaded with 88 mH coils at 6000 ft. | | |
|---|---|---|---|---|---|
| | $Z_0$ ohms | Atten. at 5000 rad/sec. (796 c.p.s.) | $Z_0$ ohms | Attenuation | Actual Cut-off Frequency |
| 10 lb. | 736 | 1.46 db/Ml | 1,100 | 0.73 db/Mile | 3000 c.p.s. |
| 20 lb. | 520 | 1.0 ,, | 1,100 | 0.365 ,, | 3000 c.p.s. |
| 40 lb. | 369 | 0.7 ,, | 1,100 | 0.194 ,, | 3000 c.p.s. |

## CARRIER FREQUENCY LOADING.

### General Case.

The factors upon which the system of loading is to be based are:—

(a) Band of frequencies to be effectively transmitted.

(b) Value of Characteristic Impedance ($Z_0$) which the loaded cable is to have.

In preparing a loading scheme for a trunk entrance cable, or for a relatively short cable intermediate in a trunk route, for instance, attenuation is a factor which is normally neglected, the object of loading such cables at carrier frequencies being to make the characteristic impedance equal to that of the aerial lines to which they are directly connected, e.g., approximately 630 ohms.

If the characteristic impedance $Z_0$ is to be 630 ohms then it is necessary to calculate the value of "L" per mile which will give it.

$$Z_0 = \sqrt{\frac{L}{C}} \quad \therefore Z_0^2 = \frac{L}{C} \quad \therefore L = Z_0^2 C$$

The usual value of C for a trunk cable is .065 mF.

$$\text{Then } L = (630)^2 \times .065 \times 10^{-6}$$
$$= .0257 \text{ Henries per mile.}$$

The inductance per mile of an unloaded cable is usually of the order of 1 mH so the **added** inductance in this case would be 24.7 mH.

If 50,000 cycles is to be effectively transmitted then the calculated value of $f_c$ should be at least 50,000 x 1/.75 = 67,000 cycles.

$$f_c = \frac{1}{\pi \sqrt{L_a C S^2}} \quad \therefore S = \frac{1}{\pi f_c \sqrt{L_a C}}$$

$$\therefore S = .119 \text{ miles} = 630 \text{ feet.}$$

so that in this case the loading would be 24.7 millihenries per mile made up of coils spaced at .119 miles or 630 feet.

Inductance per coil = 24.7 x .119 = 2.94 mH.

### Carrier Loading—Australian Practice.

For carrier loading the coil that has found the most general use in Australia is 3.5 millihenries.

Lead-in cables and intermediate cables are, as a standard practice, loaded to a characteristic impedance of 630 ohms.

For this impedance the spacing is obtained as follows for a cable whose C = .065 mF per mile.

$$Z_o = \sqrt{\frac{L}{C}} \quad \therefore L = Z_0^2 C = (630)^2 \times .065 \times 10^{-6}$$
$$= 25.7 \text{ millihenries.}$$

Allowing 1 millihenry per mile as the natural inductance of the cable the added inductance will be 25.7 — 1 = 24.7 mH per mile.

The highest carrier-frequency at present in use in Australia is 42,500 cycles, i.e., the carrier frequency of the carrier programme systems.

$$f_c \therefore = 42{,}500 \times 1/.75 = 56{,}500 \text{ cycles per sec.}$$

$$S = \frac{1}{\pi f_c \sqrt{L_a C}} = .14 \text{ miles} = 740 \text{ feet.}$$

In practice the coils are placed at intervals of 730 ft. for a cable of .065 mF capacity per mile.

### General Requirements To Be Met In Selection of Loading Coils.

High insulation resistance—of order of 1000 megohms between windings.

Low capacity between windings—of order of .003 mF.

Magnetic stability with time and current, i.e., the value of L should not change with age or with varying current values. (High values of D.C. should never be passed through loading coil).

Non-interference between coils of neighbouring circuits.

Accurate inductive and resistance balance between windings.

Economy of space.

Reasonable cost.

### Phantom Loading.

Phantom circuits on cable pairs can be loaded and the same theory applies exactly, the only difference being that the primary constants of a phantom may be different from those of its side circuits, therefore resulting in somewhat different cut-offs being encountered, and the coils are wound differently from those inserted

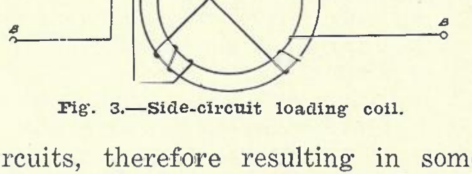


Fig. 3.—Side-circuit loading coil.

in the side circuits. A diagram of a side circuit loading coil is shown in Figure 3.

Phantom loading coils are wound in the same way except that each winding consists of a pair of wires, i.e., the side circuit pair takes the place of the single A or B wire in the side circuit coil.

### Half-Coil Terminations and Half-Section Terminations.

Where loading is introduced into a network, such as a metropolitan junction network, attention has to be paid to the conditions possible when two loaded junctions are connected together.

If it be decided to load a junction network with 88 mH. coils at 6000 ft., it is necessary at any central point in the network, such as the Central Exchange, to space the coils so that, when two junctions are connected at Central, the correct spacing is maintained. This can be done in two ways: at Central a ½-coil (44 mH) can be used to terminate each junction while at 6000 ft. a full 88 mH. coil is inserted. The condition in this case when two junctions are joined together will be that the whole circuit will actually be loaded with 88 mH at 6000 ft. The method necessitates the purchase, however, of 44 mH coils.

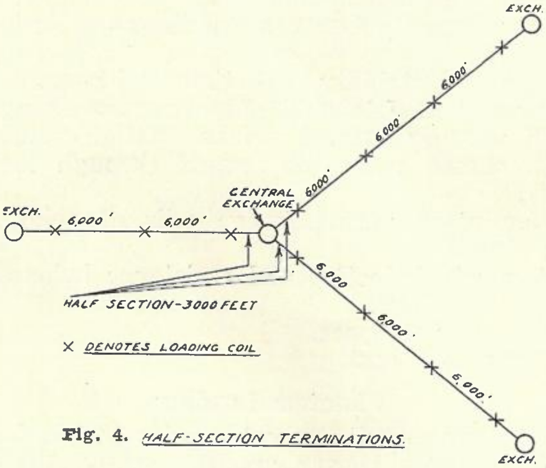


**Fig. 4.** HALF-SECTION TERMINATIONS.

The second method, shown in Figure 4, which admits of the use of standard 88 mH coils throughout, is to place the first coil from central in each junction only 3000 ft. from the central point. On connection of two junctions S = 6000 ft. is therefore maintained.

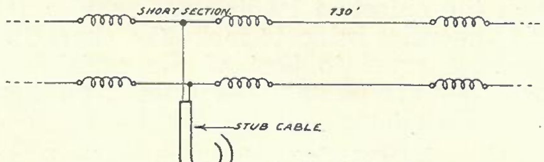
If these precautions were not taken it would mean that on each occasion that two junctions were joined S would become 12,000 ft. and from the expression—

$$f_c = \frac{1}{\pi\sqrt{L_a C S^2}}$$

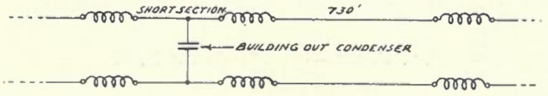
it can be seen that an unduly low cut-off would result. Such a condition, of course, must be avoided.

### Building Out.

For loaded trunk cables particularly, and especially carrier loaded cables, it is necessary, in order to avoid impedance irregularities between loading sections, to keep the value of CS (capacity per section) constant. By placing the coils in a carrier loaded cable 730 ft. apart, a reasonable constancy is maintained, but due to practical difficulties in locating manholes in the exactly ideal position, and also due to slight irregularities in the cable itself it often occurs that CS will vary from one section to another. The practice, therefore, in any case where CS cannot be made the right value by spacing, is to reduce S below 730 ft. and build out the cable by paralleling a piece of stub cable on to it. This stub cable is merely wiped on to the U.G. cable and the length required to bring CS up to the right value is rolled up in the manhole, the open end of the stub cable being properly insulated. (Refer to Fig. 5). Building-out condensers are an alternative, but it is frequently difficult to house these conveniently in a manhole.



A. USE OF STUB CABLE.



B. USE OF CONDENSER.

**Fig. 5.—Building out.**

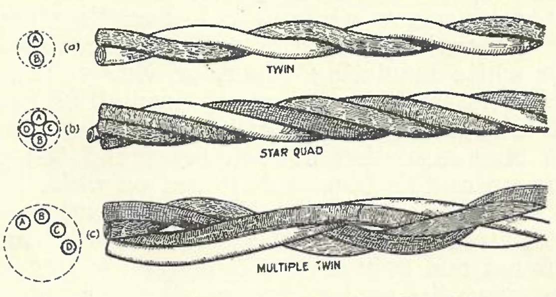
If this building out were not done it will be seen from the expression $Z_0 = \sqrt{\frac{L}{C}}$ that $Z_0$ would vary between sections if the ratio $\frac{L}{C}$ were not the same for all sections.

# CABLE JOINTING. PART 1

## CODE INDENTIFICATION AND NUMBERING. PREPARATION FOR JOINTING

*G. O. Newton*

The first requirement of a modern telephone line is a high grade of service, i.e., the received speech must be clear and distinct and of good volume, and the service must be as free as possible from interruption and extraneous noises (commonly referred to as inductive troubles—crosstalk being one form of these), and since the question of finance always enters into these things, this must be associated with reasonably low installation and maintenance costs. It is also necessary that the supervisory and signalling arrangements in each circuit function correctly and without interruption. The tendency towards a continuously improving grade of service and the developments over recent years in exchange equipment are both increasingly exacting on the standards of the line plant, and when applied to cable jointing demand accuracy and care in all operations and improved methods and practices. The need for accuracy and care on the part of cable jointers cannot be too highly stressed since errors and bad workmanship in cable jointing result in considerable loss of revenue and annoyance to subscribers apart from the fact that the faulty work is usually difficult to locate and expensive to rectify. Too frequently these instances of errors and bad workmanship occur during the performance of the simpler operations such as jointing, testing and numbering of conductors on new non-working cable, and unfortunately are due in many instances to the sacrifice of accuracy for speed or laxity during what may have been a monotonous operation rather than to inexperience and lack of knowledge. The correct and careful performance of these simple operations when installing a cable not only has considerable effect on the grade of sèrvice and future working expenditure costs, but also facilitates future operations on the cable, especially where identification is involved. Before dealing with them, however, it will be advisable to examine the design of the different types of cable in common use and to discuss their various features. For the present the discussion will be confined to the two types of paper insulated lead covered cable in general use for subscribers' services, viz., twin and star quad cable.



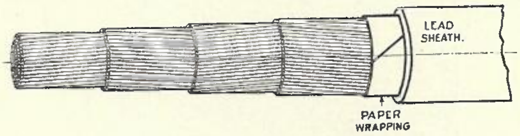
SHOWING MAKE UP OF CONDUCTORS IN (a) TWIN (b) STAR QUAD (c) MULTIPLE TWIN CABLE

**Fig. 1.**

### TWIN CABLE.

**Construction:** Until recent years this type of cable was the only one used for subscribers' services, but it has now been superseded by the star quad, local type, except for small sizes of 10 lb. cable up to 15 pairs. In twin cable, pairs of wires are insulated with paper and uniformly twisted together, referred to as twinning (See Fig. 1 (a)), and the pairs are formed spirally in layers around a centre core consisting of from one to five pairs, to form the complete cable. This process is generally referred to as stranding. Fig. 2 shows the spiral formation of the layers and Fig. 3 (a) a cross section of a 75 pair twin cable.

An examination of a sample of twin cable will show that the length of a complete twist (referred to as the length of lay of the conductors) in a pair of wires is either 4, 5, 6 or 7 inches in the case of cable having 6½ lb. or 10 lb. conductors, and 5, 6, 7 or 8 inches in the case of cable with heavier conductors, and that no two adjoining pairs in the centre core or in a layer have the same length of lay. The stranding is also carried out in such a way that the direction of the spiral formation in the layers is alternately right and left-handed as shown in Fig. 2.

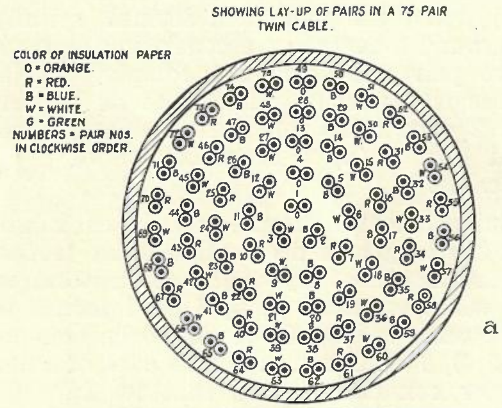


SHOWING SPIRAL FORMATION OF LAYERS OF CONDUCTORS WITH ALTERNATE DIRECTIONS IN SUCCESSIVE LAYERS

**Fig. 2.**

This formation of the cable by first taking the wires in pairs, twisting the pairs with different lengths of lay and stranding the pairs, with the direction of stranding changing in successive layers, is for the purpose of keeping the interference to the telephone service, due to induced noises, e.g., crosstalk, ringing induction, etc., as low as possible. For a good standard of transmission it is essential that this formation be retained to the greatest possible extent, that the electrical characteristics of the conductors be kept balanced and that the highest possible insulation resistance and lowest possible conducting resistance be retained.

**Identification:** The code arrangements for identifying conductors in twin cable have varied considerably in the past, but in the latest type of twin cable five different coloured papers (orange, red, blue, white and green) are used for insulating the conductors, and while both wires of a pair have the same coloured insulating paper, except as discussed later, no two adjoining pairs have the same coloured insulating paper, the majority of the pairs having red, blue and white insulation in rotation. The orange coloured paper is mostly confined to one pair in each layer called "the marker" (sometimes it is called "the pilot" or "the king pair"), whilst the green, if used at all, is confined to one or two pairs on one side or other of the orange coloured pair, according to which end of the cable is exposed. Fig. 3 (a) shows the arrangement of colours used for the insulating paper on the various conductors in a 75 pair twin cable. Reference to this diagram (3 (a)) will also show that if the orange coloured pair in the centre core is taken as the first pair in the cable, and the pairs counted around the core in either a clockwise or anti-clockwise direction, and thence in the same direction around each layer in turn, commencing with the orange coloured pair, it will provide a standard method of numbering the pairs of a cable and form a ready reference in identification work. It is essential that this scheme of numbering be made uniform throughout an area by laying down a rule as "count clockwise when facing the exchange and anti-clockwise when facing away from the exchange," as indicated by Fig. 4. In the case of junction cables, the larger exchange can be taken for this reference. Throughout the remainder of these articles, the rule used will be that given by Fig. 4. Fig. 3 (a) shows how a 75 pair twin cable is numbered in a clockwise direction according to this rule. Table 1 shows the numbers of the pairs usually found in the core, and in each layer of each size of twin cable which conforms to the latest Departmental Specification (No. 548C) for Twin P.I.L.C. cable, and will provide a ready reference when it is desired to know in what part of a cable a particular pair or group of pairs is likely to be found.


SHOWING LAY-UP OF PAIRS IN A 75 PAIR TWIN CABLE.

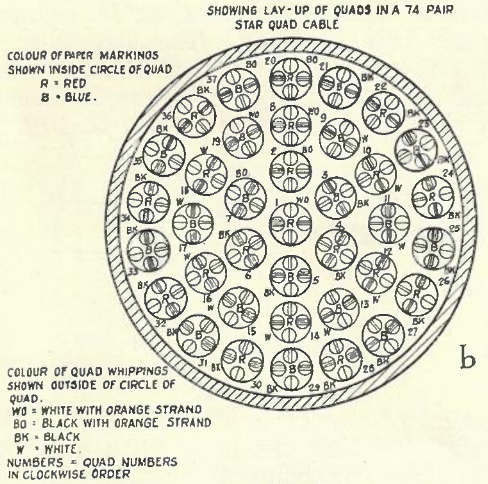
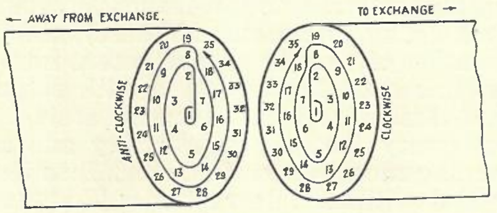

SHOWING LAY-UP OF QUADS IN A 74 PAIR STAR QUAD CABLE

Fig. 3.



SHOWING RULE FOR NUMBERING P.I.L.C. CABLE PAIRS

NOTE: PAIRS 2, 8, & 19 ARE MARKER PAIRS FOR 1ST, 2ND & OUTER LAYERS. IN THIS CASE THERE IS ONLY ONE PAIR IN CENTRE CORE. FOR QUAD CABLE SUBSTITUTE QUADS FOR PAIRS.

Fig. 4.

In previous types of twin cable the two wires of a pair were insulated with different coloured papers or the same coloured paper with different coloured threads wound spirally around it, the most common type being one where one conductor of every pair has red insulating paper, and the majority of the remaining conductors have white insulating paper, or vice versa, the residue having blue or green insulating paper. In this type there is normally only one conductor with blue insulation in each layer and the pair made up of this blue and its red or white mate can be taken as the "marker" for counting purposes. In other makes of cable there will usually be found one pair or one conductor which is in some way distinguished from all other pairs or conductors in the layer; this pair or the pair containing this conductor can be taken as the marker, and the cable pairs numbered according to the rule already suggested.

## STAR QUAD CABLE.

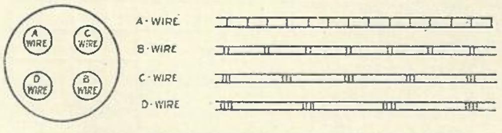
**Construction:** In this type of cable the paper insulated conductors are taken in groups of four and uniformly twisted to form a quad as shown in Fig. 1 (b), the diagonally opposite wires of the quad forming the pairs. These quads are then built up or stranded into the complete cable in a similar manner to the pairs of a twin cable. Fig. 3 (b) shows a cross section of a 74 pair star quad cable. Here again the lay or length of a complete twist in the conductors forming a quad varies for adjacent quads, and the direction of stranding alternates in successive layers, the purpose being the same as stated in the case of twin cable.

**TABLE No. 1.**

Showing the numbers of the pairs which will usually be found in each layer of twin cable of the latest type. In cables containing 75 pairs or more of 6½-lb. or 10-lb. conductors there is usually one extra pair per 100 pairs or portion of 100 pairs. These extra pairs are usually to be found in the outer layers alongside the marker pairs with not more than one in any one layer. The numbering shown in the table does not include these, but when they are present in a cable they should be counted in the layers in which they appear and the numbers in the table below will be varied accordingly. Apart from this, minor variations may be encountered due to different manufacturers adopting slightly varying arrangements of pairs, but usually the table will be found to be sufficiently close for all practical purposes.

| NOMINAL TOTAL No OF PAIRS OF CONDUCTORS IN CABLE | CENTRE. | NUMBERS OF THE PAIRS TO BE FOUND IN LAYER. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1ST. | 2ND. | 3RD. | 4TH. | 5TH. | 6TH | 7TH. | 8TH. | 9TH. | 10TH. | 11TH. | 12TH. | 13TH. | 14TH | 15TH. | 16TH. | 17TH. |
| 1 | 1 | | | | | | | | | | | | | | | | | |
| 2 | 1-2 | | | | | | | | | | | | | | | | | |
| 5 | 1-5 | | | | | | | | | | | | | | | | | |
| 7 | 1 | 2-7 | | | | | | | | | | | | | | | | |
| 10 | 1-2. | 3-10. | | | | | | | | | | | | | | | | |
| 15 | 1-4 | 5-15 | | | | | | | | | | | | | | | | |
| 25 | 1-2 | 3-10 | 11-25. | | | | | | | | | | | | | | | |
| 35 | 1 | 2-7 | 8-18 | 19-35 | | | | | | | | | | | | | | |
| 50 | 1-3 | 4-12 | 13-28 | 29-50 | | | | | | | | | | | | | | |
| 75 | 1-3 | 4-12 | 13-27 | 28-48 | 49-75. | | | | | | | | | | | | | |
| 100 | 1-2 | 3-10 | 11-24 | 25-44 | 45-69 | 70-100. | | | | | | | | | | | | |
| 150 | 1-3 | 4-12 | 13-27 | 28-48 | 49-75 | 76-109 | 110-150 | | | | | | | | | | | |
| 200 | 1-4 | 5-14. | 15-30 | 31-52 | 53-80 | 81-114 | 115-154 | 155-200 | | | | | | | | | | |
| 250. | 1-3 | 4-12 | 13-27 | 28-48 | 49-75 | 76-109 | 110-149 | 150-196 | 197-250 | | | | | | | | | |
| 300. | 1-3 | 4-12 | 13-27 | 28-48 | 49-75 | 76-108 | 109-147 | 148-192 | 193-243 | 244-300 | | | | | | | | |
| 400. | 1 | 2-7 | 8-19 | 20-37 | 38-61 | 62-91 | 92-127 | 128-169 | 170-217 | 218-271 | 272-332 | 333-400 | | | | | | |
| 500 | 1-2 | 3-10 | 11-24 | 25-44 | 45-70 | 71-102 | 103-140 | 141-184 | 185-234 | 235-290 | 291-353 | 354-423 | 424-500 | | | | | |
| 600. | 1-3 | 4-12 | 13-28 | 29-50 | 51-78. | 79-112 | 113-152 | 153-198 | 199-250 | 251-308 | 309-372 | 373-442 | 443-518 | 519-600 | | | | |
| 800 | 1-4 | 5-14 | 15-30 | 31-52 | 53-80 | 81-114 | 115-154 | 155-200 | 201-252 | 253-310 | 311-374 | 375-445 | 446-523 | 524-608 | 609-700 | 701-800 | | |
| 1000. | 1-4 | 5-14 | 15-30 | 31-52 | 53-80. | 81-114 | 115-154 | 155-200 | 201-252 | 253-310 | 311-374 | 375-444 | 445-520 | 521-602 | 603-691. | 692-787. | 788-890 | 891-1000 |

**Identification:** Unlike the standard twin cable all conductors in star quad are insulated with the same non-coloured paper, the reason being that the different colouring materials were found to effect in varying degrees the electrical characteristics of the cable, and therefore to obtain uniform properties of a high grade it is necessary that only one type and colour of paper be used. To obtain identification of the wires of the quad, use is made of markings on the paper insulation, as shown in Fig. 5. The spacing of these markings is so arranged that on each conductor there are the same number of identification marks per unit of length, this refinement being also adopted to assist in obtaining uniform electrical properties. For the purpose of identifying quads use is made of the colour of these paper markings and of coloured threads (referred to as quad whippings) as set out in Table 2 which shows that there are two distinguishing quads in each layer, but for the numbering scheme the marker only (as indicated by the table) will be taken as a guide. The other distinguishing quad referred to as the "reference" is used to identify the ends of the cable where it is desirable or essential that the cable be drawn in a particular direction and in such cases is normally the last quad in the layer.



SHOWING MARKINGS FOR CONDUCTOR IDENTIFICATION IN EACH QUAD OF STAR QUAD CABLE.

Fig. 5.

It is usual to count star quad cable by the quads, and this is done by commencing with the marker (i.e. the one with red paper markings and quad whippings of white with orange) of the centre core, and following the rule of Fig. 4 around the core (if more than one quad), thence to the marker of the first layer and around it, thence to the marker of the next layer and so on. The numbering of 74 pair star quad cable is shown in Fig. 3 (b). The identification of the wires of the quad is generally by the letters A-B, C-D as shown in Figs. 1 (b) and 5, A and B being one pair and C and D being the other. To obtain the pair numbers as in twin cable, the A and B wires form the odd pairs and the C

**Table 2.**

| Position of quad in layer | Colour of wire paper markings | Colour of quad whippings | |
|---|---|---|---|
| | | Centre and even layers | Odd layers |
| First (Marker) | Red | White with orange strands | Black with orange strands |
| Intermediate | | | |
| 2nd, 4th, etc. | Blue | White | Black |
| 3rd, 5th, etc. | Red | White | Black |
| Last (Reference) | Blue | White with orange strands | Black with orange strands |

and D wires the even pairs, quad 1 containing pairs 1 and 2, quad 2 pairs 3 and 4 and so on.

Table 3 shows the numbers of the quads and pairs to be found in the core and in each layer of each size of star quad cable which conforms to the latest specification for Local Type Star Quad cable (B.P.O. No. 569D), and will provide a ready reference when it is desired to know in what part of a cable a particular pair or quad or group of pairs or quads is likely to be found when working on this class of cable.

**Further considerations regarding Numbering of Cable Pairs:** It is important to remember that the pairs or quads in the cable on each side of a joint should be numbered in accordance with the rule adopted, vide Fig. 4, **and the pairs or quads recognised by these numbers and not by the colour of the insulating paper, markings or threads.** The pair numbers and the colours will only correspond on each side of a joint when each section of cable is of the same size and type with the same number of pairs in each layer and has been drawn into the ducts in a uniform direction. Wherever circumstances permit, it should be the aim of the installing officer to obtain these ideal arrangements, but unfortunately local considerations, convenience and expense often render it necessary to depart from the ideal, and the numbering rules must be formulated to meet these conditions. If cable of the same size and type is drawn in opposite directions on consecutive sections it is possible that the only instances where pairs will correspond on each side, both for numbers and colours, will be the marker pairs, and where the number of pairs in corresponding layers differ, then probably only the first pairs or markers in the centres will correspond. As an example of what may happen take the case of a 75 pair twin cable of the lay-up shown in Fig. 3 (a) which has been drawn in opposite directions on consecutive sections. If on the exchange side the order of the colours in a clockwise direction is as shown in the figure, they will also be in the same order in a clockwise direction on the side away from the exchange, but as the rule for this side is to count in an anti-clockwise direction, the order of the colours of pairs with the same number will be opposite to that for the exchange side, as shown in Table 4.

TABLE 3.

| TOTAL No. OF PAIRS IN CABLE | | | NUMBERS OF THE QUADS AND PAIRS IN EACH LAYER | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NOMINAL | ACTUAL | | CENTRE | | 1ST. | | 2ND. | | 3RD. | | 4TH. | | 5TH. | | 6TH. | | 7TH. | | 8TH. | | 9TH. | | 10TH. | | 11TH. | | 12TH. | | 13TH. | | 14TH. | |
| | 6½ & 10 LB. CONDUCTORS | 20 LB & 40 LB CONDUCTORS | QUADS | PAIRS | QUADS | PAIRS | QUADS | PAIRS | QUADS | PAIRS | QUADS | PAIRS | QUADS | PAIRS | QUADS | PAIRS | QUADS | PAIRS | QUADS | PAIRS | QUADS | PAIRS | QUADS | PAIRS | QUADS | PAIRS | QUADS | PAIRS | QUADS | PAIRS | QUADS | PAIRS |
| 2 | | 2 | 1 | 1-2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | | 6 | 1-3 | 1-6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | | 8 | 1-4 | 1-8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | 14 | 14 | 1 | 1-2 | 2-7 | 3-14 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | 20 | 20 | 1-2 | 1-4 | 3-10 | 5-20 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | 28 | 28 | 1-4 | 1-8 | 5-14 | 9-28 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 38 | 38 | 38 | 1 | 1-2 | 2-7 | 3-14 | 8-19 | 15-38 | | | | | | | | | | | | | | | | | | | | | | | | |
| 54 | 54 | 54 | 1-3 | 1-6 | 4-12 | 7-24 | 13-27 | 25-54 | | | | | | | | | | | | | | | | | | | | | | | | |
| 74 | 74 | 74 | 1 | 1-2 | 2-7 | 3-14 | 8-19 | 15-38 | 20-37 | 39-74 | | | | | | | | | | | | | | | | | | | | | | |
| 100 | | 100 | 1-4 | 1-8 | 5-14 | 9-28 | 15-29 | 29-58 | 30-50 | 59-100 | | | | | | | | | | | | | | | | | | | | | | |
| 100. | 102 | | 1-4 | 1-8. | 5-14 | 9-28 | 15-30 | 29-60 | 31-51 | 61-102 | | | | | | | | | | | | | | | | | | | | | | |
| 150 | | 150 | 1-3 | 1-6 | 4-12 | 7-24 | 13-27 | 25-54 | 28-48 | 55-96 | 49-75 | 97-150 | | | | | | | | | | | | | | | | | | | | |
| 150 | 152 | | 1-3 | 1-6 | 4-12 | 7-24 | 13-27 | 25-54 | 28-48 | 55-96 | 49-76 | 97-152 | | | | | | | | | | | | | | | | | | | | |
| 200 | | 200 | 1-3 | 1-6 | 4-11 | 7-22 | 12-25 | 23-50 | 26-44 | 51-88 | 45-69 | 89-138 | 70-100 | 139-200 | | | | | | | | | | | | | | | | | | |
| 200 | 202 | | 1-3 | 1-6 | 4-11 | 7-22 | 12-25 | 23-50 | 26-45 | 51-90 | 46-70 | 91-140 | 71-101 | 141-202 | | | | | | | | | | | | | | | | | | |
| 250 | | 250 | 1 | 1-2 | 2-7 | 3-14 | 8-19 | 15-38 | 20-37 | 39-74 | 38-61 | 75-122 | 62-90 | 123-180 | 91-125 | 181-250 | | | | | | | | | | | | | | | | |
| 250 | 252 | | 1 | 1-2 | 2-7 | 3-14 | 8-19 | 15-38 | 20-37 | 39-74 | 38-61 | 75-122 | 62-91 | 123-182 | 92-126 | 183-252 | | | | | | | | | | | | | | | | |
| 300 | | 300 | 1-4 | 1-8 | 5-14 | 9-28 | 15-30 | 29-60 | 31-51 | 61-102 | 52-78 | 103-156 | 79-111 | 157-222 | 112-150 | 223-300 | | | | | | | | | | | | | | | | |
| 300 | 302 | | 1-4 | 1-8 | 5-14 | 9-28 | 15-30 | 29-60 | 31-52 | 61-104 | 53-79 | 105-158 | 80-112 | 159-224 | 113-151 | 225-302 | | | | | | | | | | | | | | | | |
| 400 | | 400 | 1-4 | 1-8 | 5-14 | 9-28 | 15-30 | 29-60 | 31-52 | 61-104 | 53-80 | 105-160 | 81-114 | 161-228 | 115-154 | 229-308 | 155-200 | 309-400 | | | | | | | | | | | | | | |
| 400 | 404 | | 1-4 | 1-8 | 5-14 | 9-28 | 15-30 | 29-60 | 31-52 | 61-104 | 53-80 | 105-160 | 81-114 | 161-228 | 115-155 | 229-310 | 156-202 | 311-404 | | | | | | | | | | | | | | |
| 500 | | 500 | 1-4 | 1-8 | 5-14 | 9-28 | 15-30 | 29-60 | 31-52 | 61-104 | 53-80 | 105-160 | 81-114 | 161-228 | 115-154 | 229-308 | 155-199 | 309-398 | 200-250 | 399-500 | | | | | | | | | | | | |
| 500 | 504 | | 1-4 | 1-8 | 5-14 | 9-28 | 15-30 | 29-60 | 31-52 | 61-104 | 53-80 | 105-160 | 81-114 | 161-228 | 115-154 | 229-308 | 155-200 | 309-400 | 201-252 | 401-504 | | | | | | | | | | | | |
| 540 | | 540 | 1 | 1-2 | 2-7 | 3-14 | 8-19 | 15-38 | 20-37 | 39-74 | 38-61 | 75-122 | 62-91 | 123-182 | 92-127 | 183-254 | 128-169 | 255-338 | 170-217 | 339-434 | 218-270 | 435-540 | | | | | | | | | | |
| 600 | 606 | | 1-3 | 1-6 | 4-12 | 7-24 | 13-27 | 25-54 | 28-48 | 55-96 | 49-75 | 97-150 | 76-108 | 151-216 | 109-147 | 217-294 | 148-193 | 295-386 | 194-245 | 387-490 | 246-303 | 491-606 | | | | | | | | | | |
| 800 | 808 | | 1 | 1-2 | 2-7 | 3-14 | 8-19 | 15-38 | 20-37 | 39-74 | 38-61 | 75-122 | 62-92 | 123-184 | 93-129 | 185-258 | 130-172 | 259-344 | 173-221 | 345-442 | 222-276 | 443-552 | 277-337 | 553-674 | 338-404 | 675-808 | | | | | | |
| 1000 | 1010 | | 1-3 | 1-6 | 4-12 | 7-24 | 13-27 | 25-54 | 28-48 | 55-96 | 49-75 | 97-150 | 76-108 | 151-216 | 109-147 | 217-294 | 148-192 | 295-384 | 193-243 | 385-486 | 244-300 | 487-600 | 301-363 | 601-726 | 364-431 | 727-862 | 432-505 | 863-1010 | | | | |
| 1100 | 1110 | | 1 | 1-2 | 2-7 | 3-14 | 8-19 | 15-38 | 20-37 | 39-74 | 38-61 | 75-122 | 62-91 | 123-182 | 92-128 | 183-256 | 129-171 | 257-342 | 172-220 | 343-440 | 221-275 | 441-550 | 276-336 | 551-672 | 337-403 | 673-806 | 404-476 | 807-952 | 477-555 | 953-1110 | | |
| 1200 | 1210 | | 1-4 | 1-8 | 5-14 | 9-28 | 15-30 | 29-60 | 31-52 | 61-104 | 53-80 | 105-160 | 81-114 | 161-228 | 115-154 | 229-308 | 155-200 | 309-400 | 201-252 | 401-504 | 253-310 | 505-620 | 311-374 | 621-745 | 375-445 | 749-890 | 446-522 | 891-1044 | 523-605 | 1045-1210 | | |
| 1400. | 1410 | | 1-4 | 1-8 | 5-14 | 9-28 | 15-30 | 29-60 | 31-52 | 61-104 | 53-80 | 105-160 | 81-115 | 161-230 | 116-156 | 231-312 | 157-203 | 313-406 | 204-256 | 407-512 | 257-315 | 513-630 | 316-381 | 631-762 | 382-453 | 763-906 | 454-531 | 907-1062 | 532-615 | 1063-1230 | 616-705 | 1231-1410 |

If the cable on the side away from the exchange happens to have four pairs in the centre, the order of the colours according to pair numbers will be orange, green, white, blue, and these will correspond in order on the exchange side to the orange, blue and white of the centre and the orange of the first layer.

Star quad cable would be dealt with in a similar manner except that in this case quads would be involved instead of pairs. If star quad cable of the same size and lay-up is drawn in the same direction on consecutive sections and if quads with corresponding numbers are jointed together, it will be found that they also correspond according to colours of identification markings and whippings vide Table 2. If the same cable were drawn in opposite directions on two consecutive sections, only the marker quads of each layer at the joint between the two sections would correspond on each side according to identification marks, and the reference quad on one side would correspond to a quad with blue markings and plain coloured whippings on the other, or, in other words, each reference quad on one side would be the second quad of its layer and on the other side it would be the last quad. Where mixtures of star quad and twin cable or different sizes of cable, or cables of the same type and size but different lay-up are to be jointed together no difficulty should be experienced if the pairs or quads on each side are selected for jointing strictly in rotation of numbers according to the rule of Fig. 4. Where star quad cable is to be jointed to twin cable, Pair 1 of the twin cable will correspond to the A and B wires of quad 1 of the star quad cable, Pair 2 to the C and D wires of quad 1, Pair 3 to the A and B wires of quad 2 and so on.

In the case of 6½ lb. and 10 lb. twin cable containing 75 or more pairs, the specifications provide for an extra pair per 100 pairs or portion thereof, i.e., that a nominal 75 pair cable should actually contain 76 pairs, a nominal 100 pair cable 101 pairs, a nominal 200 pair cable 202 pairs and so on. A similar provision on a slightly different basis is also made in 6½ lb. and 10 lb. star quad cable 100 pairs and over in size. (See Table 3.) These extra pairs or quads are normally provided in the outer layers, not more than one per layer, and unfortunately are often identical with and alongside the marker pair or quad. For example, in 6½ lb. and 10 lb. twin cable of the latest type there are two adjacent orange pairs in some of the outer layers in all the larger sizes of cable. In such cases the best rule seems to be to treat one as the first or marker pair and the other as the last pair in the layer according to the direction in which the counting is done. Under this arrangement, the extra pairs according to the numbers will then be the last pairs in the outer layer.

Table 4.

| Pair Number | Colour of Insulation of pair on Exchange side of joint, counting clockwise | Colour of Insulation of pair on side away from exchange, counting anti-clockwise |
|---|---|---|
| 1 | Orange (centre) | Orange (centre) |
| 2 | blue (centre) | white (centre) |
| 3 | white (centre) | blue (centre) |
| 4 | orange (1st layer) | orange (1st layer) |
| 5 | blue (1st layer) | white (1st layer |
| 6 | white (1st layer | blue (1st layer) |
| 7 | red (1st layer) | red (1st layer) |
| 8 | blue (1st layer) | white (1st layer) |
| 9 | white (1st layer) | blue (1st layer) |
| etc. | | |

The numbering of cable pairs has been dealt with at some length because its value, when properly and uniformly applied, is very considerable. This will become more apparent as these articles proceed. It is therefore most important that a cable jointer should become thoroughly familiar with the methods of numbering pairs or quads in the various types of cable, and apply them wherever possible throughout all phases of cable jointing work.

It is neither necessary nor advisable that the existing rules in use in any area be altered to comply with those described herein so long as they satisfactorily fulfil the purpose, and are strictly and uniformly applied. Any material departure from long standing practice in such cases is likely to lead to considerable confusion in the future without any compensating benefit.

### JOINTING OF CABLE.

Throughout all jointing operations it is essential that—

(i) A high and uniform standard of insulation be retained, i.e., that the paper covering of the conductors remain undamaged and without a trace of moisture, or that the conductors do not become exposed at any point, or contact with one another or with the sheathing.

(ii) The resistance of the conductors be kept low and uniform. This requires well made joints giving a firm clean contact between the wires and the avoidance of nicked and broken wires.

(iii) The lay-up formation of the cable be retained, i.e., that pairs be jointed to pairs, and each wire of a quad to its relative wire in the opposite quad—A to A, B to B, C to C and D to D, or in other words, that the cable pairs and quads are not split.

It must be remembered that the average town cable has from 20 to 30 joints per mile, and the cumulative effect of minor defects in the joints is likely to be serious, even on comparatively short cables, although individually these defects may not give rise to any noticeable trouble. When cognisance is taken of the fact that conversations in the larger capitals over distances of 20 or more miles of subscribers' and junction cables (i.e., through 400 or more joints) are common, the probable effects of slovenly and imperfect work should be apparent. These points should therefore always be kept in mind, and every effort made to ensure that the final condition of each joint is as good as possible.

**Preliminary Precautions:** Before opening the sheathing of any cable, steps should be taken to guard against the possibility of danger to the cable due to the entrance of water into the manhole, either from along the ducts, through the lid opening or through cracks in the wall or roof. If the manhole is drained, it is advisable to make sure that the drain is functioning. In abnormal circumstances the presence of a power-driven pump may be necessary. Where manholes "sweat", carefully wipe all moisture away from and dry the roof and surrounding walls. Failure to take such precautions at the least will reduce the quality of the insulation on the cable so that needless expenditure will be incurred in bringing it back to normal, and the submerging of an open cable due to sudden flooding of a manhole will probably result in the destruction of cable worth many pounds. Any danger from surface water can be removed either by cutting a drain or, where the surrounding surface is paved, by building a clay bank around the manhole.

Since the paper insulation readily absorbs any traces of moisture, every possible precaution should be taken to minimise the effects of moist conditions. The burning of hurricane lamps under the joint whilst jointing is in progress assists this object very materially, but may have the objection, especially in hot weather, that the consequential perspiring on the part of the jointer may do still greater harm. When the weather can be relied upon, and circumstances permit it, exposure of the joint to a warm sun is the best way of retaining a high degree of insulation during the jointing operation. Whatever method is adopted, it is most desirable to divert away from the joint any moisture which may evaporate from the ground or floor of the manhole beneath the joint by placing waterproof sheeting or sheet iron around and beneath it. When the weather is damp, misty or unreliable, or at night when dew is falling, use should always be made of a tent or tarpaulin to guard against moisture condensing or falling on the joint. If it becomes necessary to leave the manhole for a period during the progress of the work, the joint should always be completely wrapped with waterproof sheeting or bound with rubber strip. Needless to say, any heat for drying a joint or keeping it dry must be applied with care to ensure that the paper insulation will not be charred or damaged in any way. The precautions to be taken with the cable also apply to the materials to be used. If such items as paper sleeves and wrapping, tape and thread are kept stored in canisters, and when required for use are first placed in a tray in a warm sun, or over a lamp to dry them out thoroughly, it will ensure that they are in a properly dry condition for use.

**Setting up Cable ready for Jointing:** Before a cable is set up for jointing it is essential that future operations and the ultimate layout of cables in the manhole be given consideration, and the work so arranged that it will meet these future requirements in addition to the convenience of the operation in hand. Care should be taken to avoid any arrangement that is likely to affect the accessibility of existing and future cables or expose any cable to the risk of failure or cause any other difficulties or unnecessary expense. Except where conditions are simple and straightforward, it is considered very advisable that Engineers and Supervisory Officers should direct cable jointers in such matters as much as possible. If there is any danger of flooding in the manhole at any time, the joint should always be set above the level of the ducts along which the water is likely to escape. This will especially apply to large joints which are likely to be control points during future rearrangements, and which are therefore likely to be open for considerable periods during such operations. The probable necessity of obtaining access to inner pairs of a cable in the future can be met by ensuring that it will be possible to slacken the conductors sufficiently for this purpose when the sleeve is taken off. If this cannot be done the outer pairs will have to be pieced out until access to the required pairs can be obtained—a most expensive and undesirable operation. Even where rearrangements are not likely as on long sections of one size of cable serving a distant area, there is always the possibility that a section of cable will become faulty and will require replacement. If the cable does not contain any slack it will be necessary to first cutover the outer pairs loosely and shorten them up to the correct tension after the cutover work is complete. This adds considerably to the expense and difficulty of the operation.

The provision of proper and sufficient arrangements for resting the cable is most important. Failure in this regard accounts for a considerable proportion of the maintenance troubles on cables. When leading cable from the ducts to rests or from one rest to another, always ensure that the cable is kept straight for at least a few inches after leaving the duct or rest, and before meeting the next rest, so that the sheathing will not be bearing on any corners. Any bends that are made should be as gentle as circumstances will permit. To ensure that a cable is properly set up in a manhole, it is better to use an extra yard or two of cable than incur future expenditure on attention to cable failures. This is a point worth noting by officers supervising cable-hauling operations.

**Opening Cable and Fanning out Conductors:** The operation of removing the sheathing after carefully setting up the cable and marking it to obtain the correct width of opening for the joint requires that care be taken not to cut the outside wires or damage the insulation. The circular cut made where the cable is marked should not completely penetrate the lead, and the final break should be made by gently bending the cable at the cut. On the other hand if the cut is made too shallow, it will result in a ragged break, the sharp points or edges of which may endanger the outer conductors. Where it is necessary to also cut the sheathing along the length of the cable, the cutting should be commenced at the end and should be done on a bevel so that when the knife penetrates the sheathing it will tend to pass between the outer paper wrapping and the inner surface of the sheathing rather than in amongst the conductors. Normally there should be no ragged edges or projections left on the end of the sheathing when breaking it, but if any have been left they should be carefully trimmed off with a shave hook. The outer conductors and their insulation are very prone to damage at this point, and to ensure their safety, the whole of the conductors, including the outer wrapping of insulating paper, should be bound with linen tape, taking care to work portion of the turns under the end of the sheathing.

The fanning out of conductors requires close attention to ensure that each layer is accurately separated out, after which it should be divided into groups of pairs which are then bent back along the sheathing out of the way, taking care not to bend them sharply so as to kink them or cause them to break through their insulation. It will be found convenient for subsequent jointing to divide each layer along the top and bottom so that these dividing points on all layers form a vertical line. Immediately a layer is separated and the pairs bent back a tie should be placed around the remaining layers close to sheathing, using, for preference, linen tape which has the advantage that it is less likely to cut the insulation of the conductors. It is considered preferable to leave these ties on the cable and not remove them as jointing proceeds, since their presence will allow of the layers being readily identified during future operations. The ends of each group which has been bent back should also be twisted or bound together, to prevent the conductors of different groups becoming mixed, and to prevent the twist of the pairs or quads becoming unravelled. The separation of the layers of star quad cable generally requires a little more care than for twin cable since, in most cases, there is no helical paper wrapping around each layer. The layers can, however, be readily identified by the spiral lay of the quads, vide Fig. 2, and the alternate black and white quad whippings, vide Table 2.

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**Editor's Note.—This article is the first of a series dealing with the various operations performed by a Cable Jointer. The next article will deal with some phases of conductor jointing and with testing out and identification of cable pairs, with particular attention to the use of cable pair numbering on such work.**

# SIGNAL DISTORTION ON TELEPRINTER CIRCUITS

*B. Edwards and S. T. Webster*

To permit the handling of a maximum number of words per minute while still complying with the C.C.I.T. stipulation that the transmission speed on the line shall be 50 bauds for teleprinter working, the Creed teleprinter 7c as used by the Department has been arranged to make use of a code comprised of 7 equal elements for each symbol.

The first and last of these 7 elements are invariably a spacing and a marking signal respectively, and are included to control the starting and stopping of the receiver at the beginning and ending of every letter code. The other 5 elements, any one of which may be a spacing or marking signal, are permutated in accordance with the requirements of the 5 unit code. These latter elements convey the intelligence which it is desired to transfer from the sender to the receiver. The operation of the teleprinter sending and receiving units has been described in papers previously read before the Postal Electrical Society of Victoria.

Figure 1 shows the 7 equal elements transmitted during every revolution of the transmitter cam-drum. One revolution corresponds to the sending of one character. In the rest position of the transmitter the stop (marking) signal is applied to the line and holds the receiver in the stop position until the next character is transmitted.

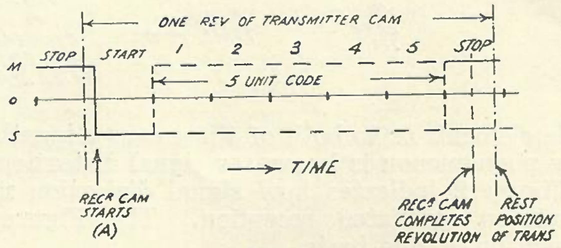

Fig. 1.

Change from marking to spacing at the commencement of the start signal releases the receiver cam-drum which is cut to effect setting up of mechanical conditions in the receiver in synchronism with the arrival of signal elements perfectly spaced in time from the moment of release.

Although the design of the machine allows some latitude in respect of this ideal spacing, the beginning of the start signal (A, in Figure 1) with respect to the time of the currents of any of the other elements of the train is of extreme importance. Any divergence from the conditions of Figure 1 will reduce the working margin of the system, and ultimately will result in faulty reception. Defective spacing may be entirely due to the early or late arrival of the start signal, to the incorrect occurrence of any code element, or to both of these causes together. The phenomenon is known as signal distortion.

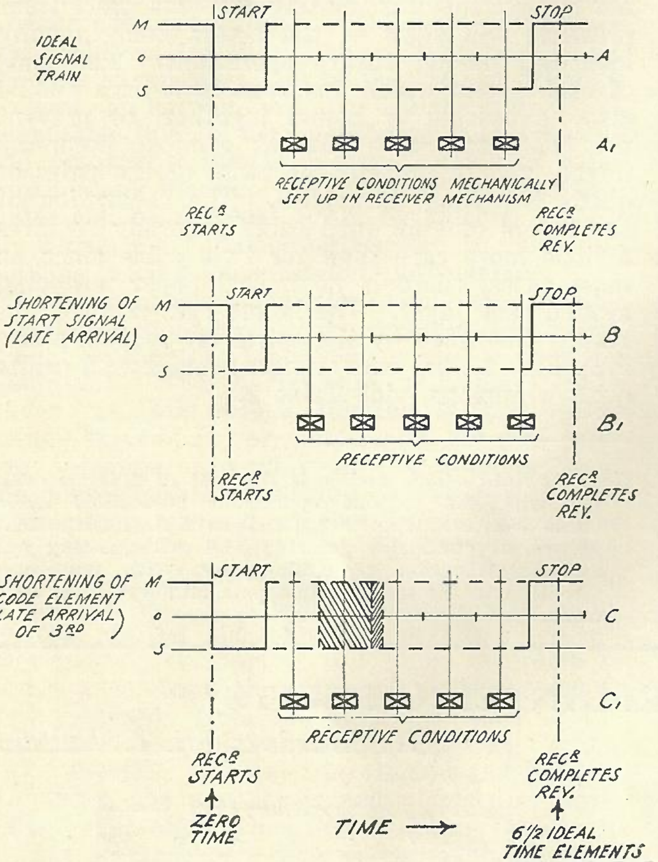

Fig. 2.

Figure 2 indicates how signal distortion may result in mutilated reception. The Figure is drawn on a time basis.

A represents the arrival in the receiver electromagnet of an ideal signal train for one character. It will be seen that acceptance occurs in the middle of each code element. $A_1$ shows the time intervals, after the arrival of the start signal, during which the receptive mechanism of the receiver is in a condition to accept and store marking or spacing code elements occurring at those times. These time intervals are mechanically fixed and may be regarded as invariable. $A_1$ also indicates that the receiving cam completes its revolution in 6½ time elements from the start, although the transmitting cam does not complete its revolution until 7 elements from the start. This feature of the start-stop system is necessary to ensure stoppage of the receiver cam after every revolution, so as to nullify the otherwise cumulative effect of speed difference between the sender and receiver.

In B, signal distortion has resulted in the cutting off of some of the front part of the start signal. Because the receiver cannot anticipate the arrival of a signal, the receiver cam does not commence rotation until the change from marking to spacing actually occurs. The result, as shown in $B_1$ is a displacement of the acceptance periods towards the latter ends of the code elements. It may be seen how an acceptance period may overlap the occurrence of 2 code elements and so, in responding, say, to the marking signal carried by the second element, cause mutilation in the reception. From conditions at the end of the train, also, it is evident that the cessation of the receiver cam movement may not have occurred before the arrival of the next start signal. From this cause cumulative speed discrepancy may cause mutilation in the reception of the following character.

At C, the second code element is shown as being prolonged. Consequent overlapping of the second element into the acceptance period for the third as shown in $C_1$ illustrates the possible effects of distortion when applied to elements of the train other than the start signal.

In the remainder of these notes only a particular case of signal distortion, as experienced on some teleprinter services, will be described. Before relating the distortion to the characteristics of the teleprinter circuit, however, some general remarks on the effects of this type of signal distortion on reception will be given.

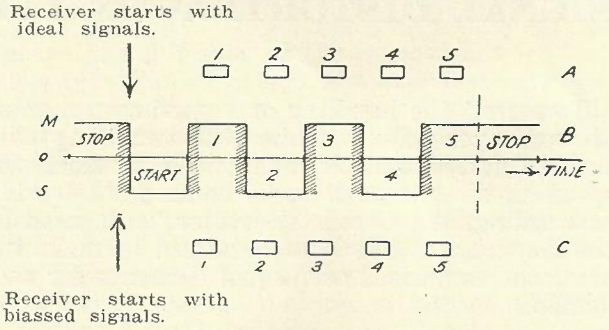

Fig. 3.

Bias, whether inherent in the signals being passed into an ideal relay, or present in the operating characteristics of the relay receiving perfect signals, has always the same effect so far as the signals passed on from the relay tongue are concerned. It causes a lengthening of the unit signal of one sign, and a corresponding shortening in the unit signals of the opposite sign. The operating margins of a teleprinter receiver are therefore reduced.

Figure 3 has been drawn to show the effects of spacing bias on the receiver operating margins. At B, the full line represents a perfect train of signals for the letter "Y" passed from the relay tongue into the teleprinter receiver. For this case A represents the acceptance periods. The receiver having started as indicated by the arrow at the left of A, the acceptance period for any signal is equally spaced about the centre of that signal. Maximum margin exists in the receiver so far as the spacing of the signals is concerned. The hatched additions to the start signal and to elements 2 and 4 in B show the lengthening of these signals due to an assumed spacing bias in the receiving relay.

It will be noted that the spacing signals are lengthened from both ends and that the marking signals are correspondingly shortened. Element 1, for example, is shortened both by the prolongation of the start signal, and by the early arrival of element 2.

C shows the occurrence of the acceptance periods, with relation to these bias signals, which results from early starting of the receiver as indicated by the arrow on the left of C.

By referring to the acceptance periods 1, 3 and 5 in C, and comparing them with the same periods in A, it will be seen to what extent the operating margin of the receiver has been reduced by the signal distortion depicted. Obviously, marking elements might be missed in the reception.

The standard local point-to-point teleprinter circuit may be divided into 2 main parts: (a) transmitting loops over which the relay is controlled from the contacts of either teleprinter transmitter, and (b) the receiving loops over which the relay tongue directly controls both the teleprinter receivers. Signal distortion generated in either of these parts will be passed on to the receivers, reducing their margins.

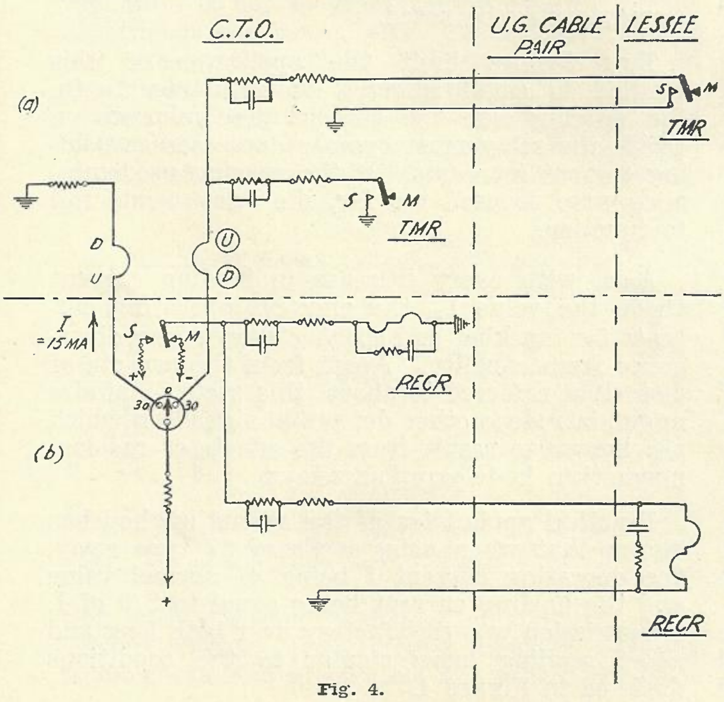

Fig. 4.

Figure 4 shows schematically a printer-gram installation which is one form of local point-to-point service. (a) is the transmitting section, including the loops and (b) is the receiving section including the loops. In the rest position, the relay tongue is held to marking by the holding current I of 15 mA continuously flowing in one coil of the relay. When transmission takes place from either teleprinter, the transmitting tongue of that teleprinter grounds the sending loop for the duration of the spacing signals, and causes a current of twice the value I to flow in the operating winding of the relay. Assuming ideal signals in the operating winding of the relay, the relay tongue would be constrained to pass on perfectly timed double-current signals into the receiving loops as indicated in Figure 5. It will be noted that transit time of the relay tongue has been neglected.

When the transmitting loop includes long sections of cable having appreciable capacity, the conditions of Figure 5 are considerably modified due to the effects of distributed capacity on the loop. On the closing of the transmitter contacts during the spacing signals, current in the operating winding of the relay rises almost immediately to the full value 2 I, and the conditions of Figure 5 are closely maintained at the front of the signal. When the steady state has been reached the potential difference at points along the sending loop taper from a maximum at the relay end to zero at the ground connection. The elements of distributed capacity are charged accordingly, and consequently those elements nearer the ground connection carry a lower charge than those nearer the relay or battery connection. When the transmitter contacts open for the duration of the marking signals a redistribution of potential charges must take place in the loop. This is shown diagrammatically in Figure 6.

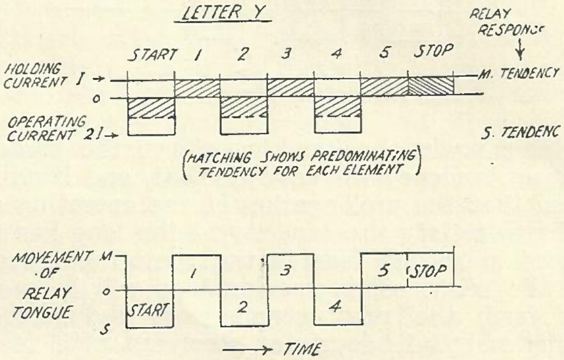

Fig. 5.

The dotted line (a) indicates graphically the distribution of potential (and charge) on the loop for the spacing signals; and the chain line (b) shows the distribution during the marking signals. To pass from the condition (a) to the condition (b) means that a transient current must flow in the line to raise the charge to the value indicated by (b). This transient current has a marked effect on signal shape as illustrated in Figure 7. Figure 7 should be compared with Figure 5.

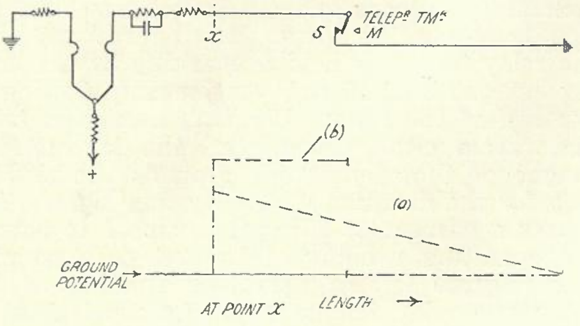

Fig. 6.

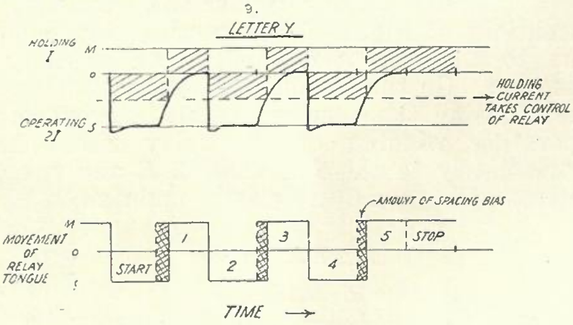

Fig. 7.

Here again the hatching shows the predominating tendency for each element, and it will be seen that the prolongation of the operating current to satisfy the capacity of the loop has produced a spacing bias in the operating response of the relay. This spacing bias will be passed on from the relay tongue into the receiving loops and the teleprinter receivers with results similar to those depicted in Figure 3.

Figures 6 and 7 suggest two means by which the distortion introduced by sending loop capacity might be minimized.

Firstly: most of the transient charging current could be supplied from the transmitting end without affecting the relay if a voltage of equal value and the same sign as the voltage supplied to the relay were connected to the marking transmitter contact as shown in Figure 8.

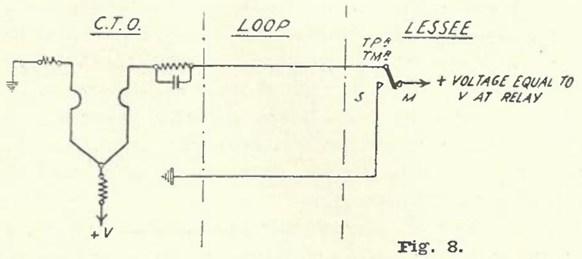

Fig. 8.

The use of this method would involve the provision of the appropriate potential at the lessee's premises. On services so far installed, provision of this kind has not been justified and would not be convenient.

Secondly: the holding current might be increased, within limits, so that the point of control on the spacing die-away curve might occur earlier. Figure 9 shows the effect of variation in the value of the holding current.

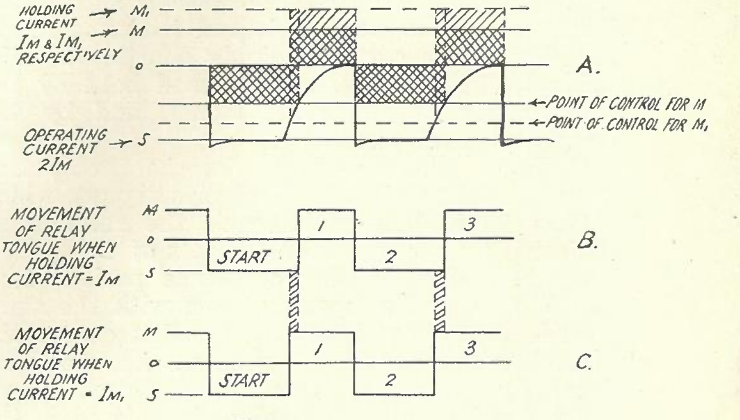

Fig. 9.

In A of the Figure, the spacing (operating) current is shown to remain at a steady state value 2 $I_m$ for both conditions of the hold current. The variation in the points of control for holding currents $I_m$ and $I_{m_1}$ is indicated.

By comparing B with C, the extent to which the shortened marking elements have been restored at the expense of the lengthened spacing elements may be noted.

Two factors limit the application of this method to small amounts of adjustment. On the spacing side the current predominance on which the relay must operate decreases as holding current increases. If the spacing predominance were reduced too far, the relay would fail to function.

Also, with every increase in holding current above the value $I_m$ the effective operating currents for marking and spacing show wider divergence from equality. Apart from the aspects of distortion referred to above, this state of affairs might introduce other defects in signalling which are known to result from the effects of residual magnetism in telegraphic relays.

Practical application of the second method has shown that when using a Creed 27 type relay, the operating current I being of normal value and the holding current being equal to 2/3 of I, transmission was satisfactory over both long and short sending loops similar to the conditions depicted in Figure 4.

# BROADCAST IN AUSTRALIA OF THE
## BRITISH BROADCASTING CORPORATION CORONATION PROGRAMME.

*A. H. Kaye*, B.Sc.

**Brief Description of Short Wave Propagation.**—It is generally well known that the reception of "short" radio waves over long distances depends on the presence about 150 miles above earth of a "layer" of ionized atmosphere. The frequencies in question cover the range approximately 6 to 20 megacycles per second or wave lengths 50 to 15 metres. This layer, is, in fact, much more complicated than a simple envelope around the earth, but this need not concern us here.

The rays transmitted straight along the ground are of little use for the purpose discussed, but a ray projected skywards is refracted or bent as it passes through the ionized layer, this bending in the useful cases continuing until the ray is re-directed towards the earth. Further "reflections" between earth and layer carry the signal around the globe. For any particular ionic density there is a maximum usable frequency, above which the bending is insufficient and all rays penetrate the layer and are lost; and in general the attenuation goes up with decreasing frequency. This ionic density increases with the intensity of sunlight and, as the great circle, i.e. the direct route, between two points a long way apart on the earth's surface, of necessity passes through varying intensities, the selection of usable frequencies must first ensure that we are below penetration frequency over the whole path and that the attenuation is not so great that the signal is lost in atmospheric noise, etc. These requirements are often incompatible, and communication on short waves is then impracticable.

Due largely to the work of Eckersley and Tremellin, data has been prepared from which it is possible, by consideration of the distribution over the earth's surface of sunlight in its various degrees from strong summer sunlight to darkness at a given time and season, to forecast the received signals and hence select the most suitable frequency; but of course extraneous effects such as local storms, sun spot disturbances, etc., may, even so, spoil transmission. Curves showing the signal strength to be expected in Melbourne of a London transmission, assuming a 10 kw. transmitter and a simple receiver, are shown in Figure 1. These curves are merely relative, but for average weather conditions are quite reliable.

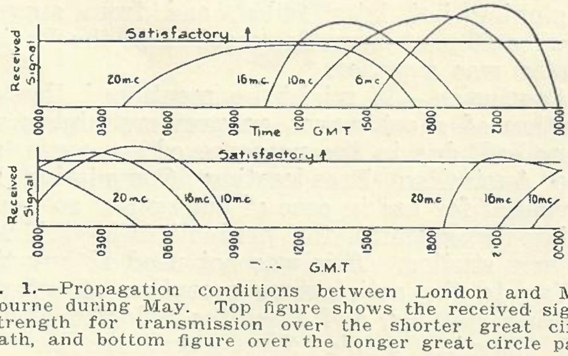

Fig. 1.—Propagation conditions between London and Melbourne during May. Top figure shows the received signal strength for transmission over the shorter great circle path, and bottom figure over the longer great circle path.

**The British Broadcasting Corporation Coronation Broadcasts.**—Proceeding to the subject proper of this article, namely, the arrangements made for receiving the broadcast descriptions of the Coronation of His Majesty King George VI, emanating from the B.B.C. transmitters at Daventry, the time of the ceremony, 7 p.m. to 12.30 a.m. E.S.T. (0900 to 1430 G.M.T.) covered a period, say up to 10 p.m., during which reception from England was practically impossible for the reasons discussed above—(See Figure 1). After the description of the Coronation proper, further items were required, but as these were either at a good time or were merely repetitions we need not consider them further.

Consideration was, therefore, given to receiving a relay via another country. Examination of sunlight conditions, supplemented by observations, showed that reception was most likely through Hong Kong, Northern America or the Dutch Indies, and enquiry revealed that each of these countries possessed high power transmitters rebroadcasting at least portions of the required programme. A good deal of hope was placed in Hong Kong, as calculations showed transmission from London to Hong Kong on about 16 megacycles to be excellent, whilst 10 megacycles was very good Hong Kong to Melbourne, although neither frequency was suitable London to Melbourne.

This arrangement proved most helpful, and for the actual programme 116 minutes' transmission was taken through Hong Kong, 74 minutes from Canada, 33 minutes from U.S.A. and 157 minutes direct from London.

**Receiving Arrangements.**—In order to have thorough search for the best programme, and to avoid trouble due to local static and interference, the resources of the Postmaster-General's Department and Amalgamated Wireless (A'sia) Ltd. were pooled. Eight receiving stations distributed over a wide area were brought into use, each station searching with a number of receivers and supplying the best programme found, whether direct from Daventry or from rebroadcasting stations, to a Special

Central Control Room set up in the City West Exchange Building, Melbourne, where representatives of the Post Office and the Australian Broadcasting Commission selected the best transmission for use over the National network. This arrangement is shown in Figure 2.

All the equipment in the Special Control Room, being the nerve centre of the organisation, was in duplicate, and order wires were held for speaking and for emergency use to each main point, as Melbourne Test Room, 3LO Control Room, Recorder Room, etc. The programme selected by each receiving station was monitored from time to time at this point, and the best available transmitted to 3LO for relay in the ordinary way.

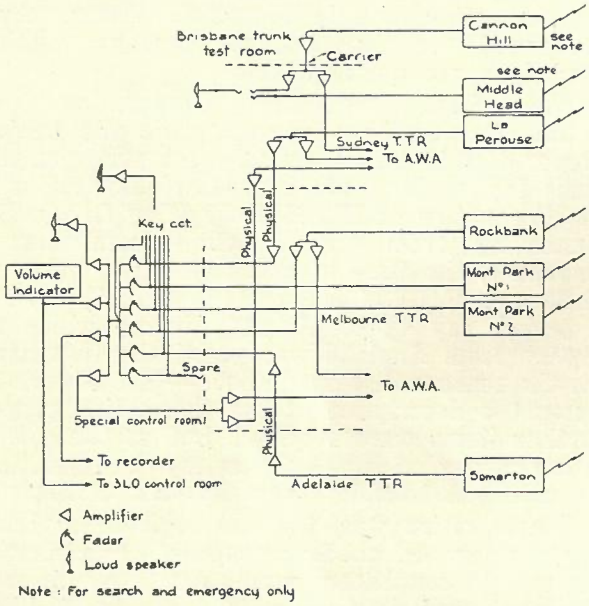

Fig. 2.—Arrangements made for selecting the best transmission from those provided by receiving stations.

This selection was also provided to the offices of A.W.A. for use if required by the Commercial station networks. It is interesting to note that at times it was found possible to reduce fading and improve quality by mixing the programme from Mont Park and La Perouse, these two receiving stations having selected the same transmitter. In all, 20 changes were made in the receiving station selected by the Special Control Room.

**The Relay Network.**—In order to provide for relaying the National programme from 3LO Melbourne to all National stations, from the Melbourne offices of A.W.A. to Victorian, South Australian and Tasmanian Commercial stations, and from the Sydney offices of A.W.A. to New South Wales and Queensland Commercial stations, approximately 16,000 miles of land line was required, apart from those circuits used by the Trunk Test Rooms Staffs for lining up. In nearly all cases carrier programme systems or physical lines were available, thus providing, after replacing the usual telephone repeaters, etc. by special programme amplifying equipment, "music" circuits transmitting an audio frequency band of approximately 50 to 5,000 cycles per second.

Figure 3 indicates the arrangement of the equipment required for this purpose as set up in the Melbourne Trunk Test Room.

**West Australian Arrangements.**—A difficulty was struck in connection with the provision of a programme for the Commercial stations in Western Australia as, to provide a line from Adelaide, would take the only telephone circuit available. For this reason a local receiving centre was set up using four short-wave receivers in and near Perth, from which centre programme was provided with satisfactory results. The change of receiving signal with location was clearly demonstrated here, for the locally received programme was considerably better than that received over the National programme line from the Eastern States at the beginning but later failed, and from approximately 10 p.m. onwards reception in the Eastern States was superior.

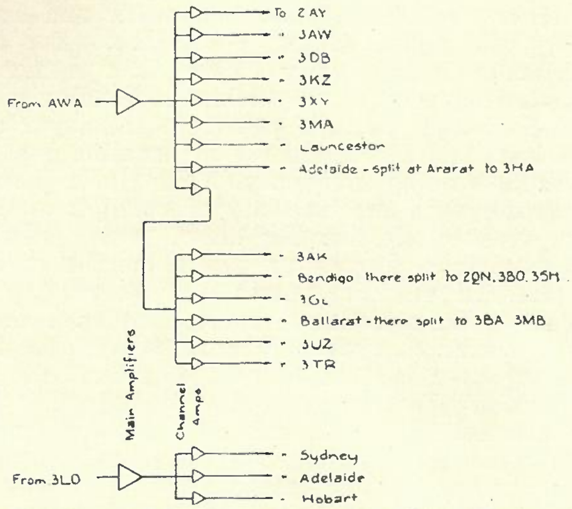

Fig. 3.—Set-up of amplifiers required in Trunk Test Room, Melbourne, for relay of programme to National and Commercial stations.

**Conclusion.**—It might be mentioned that reception of short waves on previous nights was very bad, due to the presence of sun-spots, and the Australian Broadcasting Commission had prepared for use in case of emergency an appropriate programme for production in the Melbourne studios. This was not used at any time owing to the satisfactory reception of rebroadcasting stations, and from the point of view of the listening public the programme was apparently satisfactory—adequate justification for the somewhat elaborate precautions. In all, a total of 96 National and Commercial stations participated in the programme.

# 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. 2043.—MECHANIC, GRADE 2.

*H. K. GREGG*

### SECTION A.

**Q. 1.—Name and define the practical units of measurement of the following:—**

**(a) Electromotive force.**
**(b) Resistance.**
**(c) Quantity of electricity.**
**(d) Electrical power.**

A.—(a) **Volt.** It is equal to 0.6974 of the electrical pressure between the poles of a voltaic cell known as the Clark's cell at a temperature of 15° Centigrade.

(b) **Ohm.** The electrical resistance offered to a non-varying current by a column of mercury 106.3 centimeters long, 14.4521 grams in mass, of a constant cross-sectional area, at 0° C.

(c) **Coulomb.** It is that quantity of electricity conveyed by a current of 1 ampere in 1 second.

(d) **Watt.** It is equal to 1 joule per second (the joule is the practical unit of work and is equal to $10^7$ ergs). It also equals the product of volts and amperes.

**Q. 2.—The resistance of the moving coil system of a combined ammeter and voltmeter is 10 ohms, and a full scale deflection is obtained when a current of 10 milliamperes flows through the coil. Calculate the value of the resistance which would be required to make the full scale readings represent:—**

**(a) 2.5 volts.**
**(b) 50 milliamperes.**

**Show how the resistance should be connected in each case.**

A.—To use the meter as a voltmeter, a series resistance $R_1$ must be used (sketch A). Thus to obtain full scale deflection with an impressed voltage of 2.5 volts, the series resistance must be of such value that, together with the 10 ohms resistance of the voltmeter, it will limit the current flowing through the circuit to 10 milliamps.

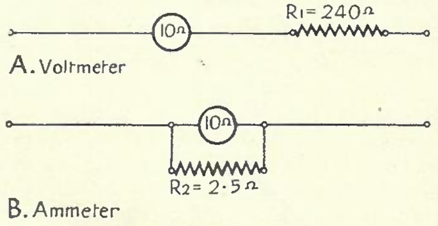

Fig. 1.

By Ohms Law $I = E/R$, i.e., $.01 = 2.5/(R1 + 10)$, from which $R1 = 240$ ohms.

If the meter is to be used as an ammeter with a full scale reading of 50 milliamps, it must be shunted by a resistance (sketch B) so that 40 milliamps will pass through the shunt and 10 milliamps only through the meter. Under these conditions the P.D. across the terminals of the shunt, and across the terminals of the meter will be the same.

$E = IR$; therefore the P.D. across the meter when 10 milliamps is flowing will be:

$$E = .01 \times 10 = .1 \text{ volts.}$$

This P.D. is also across the shunt when 40 milliamps is flowing through it:

i.e., $0.1 = .04 \times R2$ where $R2$ = resistance of shunt.

$\therefore R2 = 2.5$ ohms.

**Q. 3.—Two magneto telephones are connected together. Explain, with the aid of diagrams, how a simple sound wave reaching the transmitter of one telephone is reproduced in the receiver of the other.**

A.—

The diagram shows the fundamental circuit of two magneto telephones connected together before speech commences. A steady direct current from the local battery flows through the primary of the induction coil and the transmitter, and the magnetic field of this current in the induction coil is constant. No E.M.F. is, therefore, induced in the secondary winding. When speech waves strike the transmitter diaphragm it vibrates, causing the pressure on the carbon granules and therefore the resistance of the primary circuit to vary at the same frequency as that of the diaphragm, i.e., the frequency of the speech wave. The magnetic flux in the induction coil induces an E.M.F. in the secondary circuit, which is proportional to these fluctuations. This E.M.F. is an alternating one, and as a result an alternating current of the same frequency as that of the original sound flows around the loop via the two receivers. This alternating current varies the strength of the magnetic field of the receivers, and so there is varying tension on the diaphragm causing it to vibrate. Thus the speech currents from X cause a vibration of the diaphragm of the receiver at Y, and sound waves of the same frequency as were spoken at X are reproduced at Y.

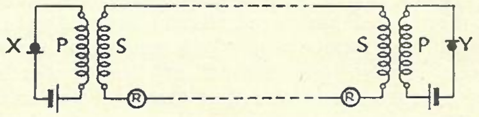

Fig. 2.

**Q. 4.—Explain why the Internal Resistance of a Leclanche cell increases when in continuous use. Twelve cells, each of 1.5 volts and 0.5 ohm internal resistance, are connected in series with each other, and an external resistance of 18 ohms. What is the current in the circuit? If four of the cells are connected in opposition to the others, what is the current in the circuit?**

A.—The four main reasons for the internal resistance increases are:—

(a) The gradual exhaustion of the depolarizing agent;
(b) The inability of the depolarizer to absorb the hydrogen liberated by the passage of an excessive current;
(c) The disintegration of the zinc;
(d) Gradual evaporation of the moisture in the exciting and depolarizing pastes.

$I = E/R = 12 \times 1.5/(6 + 18) = 18/24 = 0.75$ amps.

With four cells connected in opposition to the remaining eight,

$I = E/R = 6/(6 + 18) = 6/24 = 0.25$ amps.

**Q. 5.—Under what circumstances are coils said to possess mutual inductance? Two coils, A and B, have mutual inductance. Describe in detail the effect in coil A if—**

**(a) A steady direct current is flowing in coil B;**
**(b) A current flowing in coil B is interrupted suddenly;**
**(c) An alternating current is flowing in coil B.**

**A.**—Two coils are said to have mutual inductance if a change in the value of the current in one produces an induced E.M.F. in the other. Current passing through a coil sets up a magnetic field, the strength and distribution of which depends upon the value of the current and physical design of the coil. When a second coil is placed in the magnetic field of the first any variation of the current in the first coil causes magnetic lines of force to cut the turns of the second coil. In accordance with Faraday's Law, an E.M.F. is generated in any conductor when it is cut by lines of force. This E.M.F. lasts only while the change is taking place, and has a magnitude depending upon the change in the number of "linkages" per second, i.e., upon the change per second of the product of the number of turns, and the flux through the coil.

(a) When a steady direct current is flowing in coil B, there will be no inductive effect in coil A.

(b) When the direct current in coil B is suddenly interrupted, a momentary E.M.F. is produced in coil A due to the collapse of the magnetic field around coil B. The E.M.F. lasts only while the field is collapsing, and has a magnitude depending upon the original strength of B's field at A, and upon the speed with which this field diminishes.

(c) When an alternating current flows in B, the magnetic field associated with this coil is continually changing in magnitude and direction. An alternating E.M.F. of the same frequency and wave shape is, therefore, induced in A. The magnitude of this E.M.F. depends upon the number of turns in coil A, and on the strength of the field at A. The latter is governed by the proximity of the two coils, the current in B, and number of turns of B.

## SECTION B.

**Q. 1.—Draw a schematic diagram of the circuit conditions of an induction type automatic telephone when used under—**

**(a) Speaking conditions; and**
**(b) Dialling conditions.**

**Why is the different set of conditions necessary?**

**A.**—

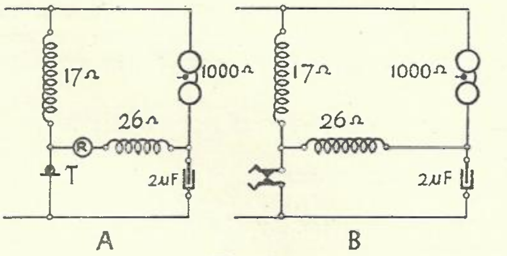

Fig. 3.

Sketch "A" shows the speaking conditions, but whilst dialling is in progress the circuit conditions are as shown in sketch "B." In this latter condition, off-normal springs associated with the dial operate when the dial is moved and short circuit the transmitter and receiver. Short circuiting the receiver results in an absence of clicks in the ear, while short circuiting the transmitter eliminates the impulse distortion which would occur were the transmitter in circuit. This distortion is due to the variation of the resistance of the carbon granules in the transmitter.

**Q. 2.—List and explain concisely the functions performed by a group selector in an automatic exchange.**

**A.**—

(1) Transmits dialling tone to the calling party, when used as a first selector.
(2) Returns guarding and holding earth on the private wire, to the preceding switch or selector.
(3) Steps vertically under the control of the calling party's dial.
(4) Steps automatically into the level dialled (cuts-in).
(5) If the No. 1 outlet is busy, searches for and seizes the first free outlet.
(6) Guards the outlet seized.
(7) Maintains the guarding earth on the private wire until a similar condition is returned from the selector seized. (Actually there is a guarding overlap.)
(8) Switches the calling party through for the next stage of operation, and disconnects the apparatus bridges.
(9) Steps to the 11th position in level if all outlets are engaged, and connects busy tone to the calling party.
(10) Releases when the earth connection is removed from the private wire by the final selector.

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Alternatively the question might be answered in reference to the Siemens No. 16 system.

**Q. 3.—Describe briefly and illustrate by diagrams the two common methods of supplying current to the subscribers' transmitters in C.B. manual and automatic exchanges. Explain how the components used in each method function.**

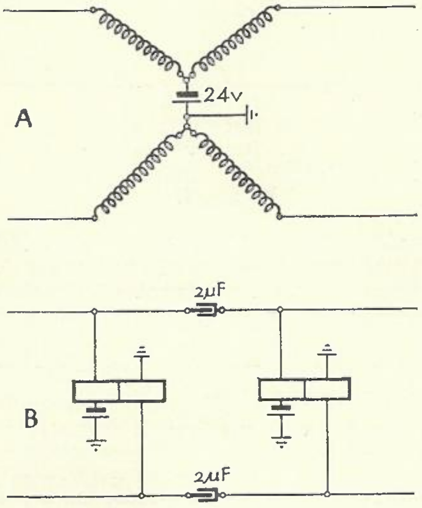


Fig. 4.

**A.**—Sketches A and B show two methods of supplying current to subscribers' transmitters, and are known as the repeating coil and condenser impedance methods respectively. Sketch A shows that the repeating coil has four equal windings, two of which are connected to one loop, and two to the other. A 24-volt battery is interpolated, as shown. A steady current flows from the battery around each circuit, and supplies the requisite voltage across each subscriber's transmitter. Speech transmission is the result of alternating speech current superimposed on this steady current by induction from one side of the repeating coil to the other.

Sketch B shows the condenser impedance method; 2 mF condensers are inserted in each leg of the connecting circuit, and the impedance coils are arranged as shown. The steady current supplied by the battery between the two windings provides current to the subscribers' transmitters. With this method of transmission speech is received by undulations of current from the condensers superimposed on the initial steady current. A decrease in resistance of one transmitter produces a potential difference between the ends of the windings of the impedance coil on the same side of the condensers, thus causing a variation in the charge of the condensers via the other sub-station instrument.

**Q. 4.—Draw a schematic diagram of a C.B. manual "A" position operator's telephone circuit and explain how—**

**(a) Sidetone in the receiver is reduced without reducing the efficiency of the receiver when voice frequency currents enter from the cord circuit;**

**(b) Voice frequency currents are prevented from entering the battery; and**

**(c) The two primary windings of the induction coil connected in parallel increase the efficiency of the circuit.**

**A.—**

(a) Sidetone is reduced by designing the circuit in the form of a wheatstone bridge with the 360 ohm resistance balancing the line circuit which is being spoken over, and with the receiver connected in place of the galvanometer. If the line circuit exactly balances the 360 ohm resistance, the receiver would be connected between points of zero potential in regard to induced currents from the primary winding, and there would be absolute immunity from sidetone. The varying resistances of subscribers' loops, however, prevent this absolute balance being obtained in practice, but the device secures very considerable reduction in sidetone. Received speech passes through one secondary winding and the receiver in series, the latter being shunted by the other winding and the 360 ohm non-inductive resistance in series. The major portion of the received speech current is, therefore, available to operate the receiver.

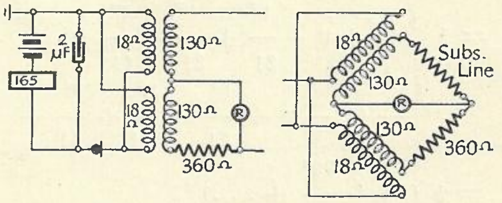


Fig. 5.

(b) The voice frequency currents are prevented from entering the battery by the 165 ohm inductive coil in series with the transmitter. This coil also serves to reduce the voltage applied to the transmitter to the requisite value. The condenser bridged across the primary of the induction coil and the transmitter provides a low impedance path for the speech current fluctuations in the primary circuit, and also assists the impedance coil to flatten out variations of battery potential.

(c) The reason the two primary windings of the induction coil are connected in parallel is to reduce the sidetone in the operator's receiver. It was explained in (a) above that the receiver circuit constituted a wheatstone bridge, and by arranging the primary windings in parallel, voice frequency currents are fed to the secondary circuit so that the receiver is in the "null" position. The advantage is that the operator is saved from fatigue due to hearing the full volume of her own voice, and similarly by the exclusion of room noises.

**Q. 5.—Draw a schematic diagram showing how a telegraph circuit may be superimposed on one pair of telephone wires. Explain**

**(a) Why telephone currents do not affect Morse signals, and**

**(b) Why the Morse signals are not heard in the telephone receivers.**

**A.—**

It is necessary for satisfactory work that the two lines of the loop exactly balance each other as regards

(1) Conductor resistance.
(2) Insulation resistance.
(3) Capacity.

The speech currents from station A in passing through the primary winding of the transformer produce induced currents in the secondary windings. These currents pass round the loop and in traversing the secondary windings of the transformer at station B result in induced currents in the primary winding which pass through the telephone at station B.

Provided that the line conditions set out above hold, and that the secondary windings of the transformer are electrically balanced, then points P and Q (the Morse tappings from the secondaries of the transformers) will be points of zero potential and the Morse sets will consequently be unaffected by the speech currents.

(b) The path of the current from the Morse set at station A is to the centre point of the secondary winding of the transformer over both legs of the line in parallel to the Morse set at station B. It will be seen that the secondary windings of both transformers are traversed by equal but oppositely directed currents; hence there will be no induced effect in the primary windings. As a result, the telephones at stations A and B will be unaffected.

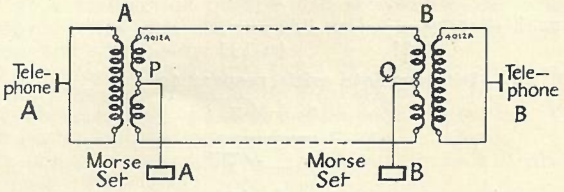


Fig. 6.

## EXAMINATION No. 2050.—FOR PROMOTION AS ENGINEER.—NATURAL SCIENCE.

*R. M. OSBORNE,* M.E.E., A.M.I.E.E.

**Q. 1.—Solve for x in**

$$\frac{a^2x^2}{k^2} - \frac{2ax}{m} + \frac{k^2}{m^2} = 0.$$

**A.**—Dividing by the coefficient of $x^2$ we get

$$x^2 - \frac{2k^2}{am}.\ x + \frac{k^4}{a^2m^2} = 0.$$

Factorizing the L.H.S. which is a perfect square

$$\left(x - \frac{k^2}{am}\right)\left(x - \frac{k^2}{am}\right) = 0.$$

Whence $x = \dfrac{k^2}{am.}$

**Alternatively** using the solution of

$$Ax^2 + Bx + C = 0.$$

$$\text{As } x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

And putting $A = \dfrac{a^2}{k^2}$ : $B = \dfrac{-2a}{m}$ and $C = \dfrac{k^2}{m^2}$

$$x = \frac{\dfrac{2a}{m} \pm \sqrt{\dfrac{4a^2}{m^2} - \dfrac{4a^2}{k^2}.\dfrac{k^2}{m^2}}}{\dfrac{2a^2}{k^2}} = \frac{k^2}{am}$$

**Q. 2a.—Differentiate with respect to x**

$$u = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots \frac{x^n}{n!}$$

**A.**—

$$\frac{du}{dx} = \frac{d}{dx}(1) + \frac{d}{dx}(x) + \frac{d}{dx}\frac{(x^2)}{(2!)} + \frac{d}{dx}\frac{(x^3)}{(3!)} + \ldots \frac{d}{dx}\frac{(x^n)}{(n!)}$$

$$= 0 + 1 + \frac{2x}{2!} + \frac{3x^2}{3!} + \ldots \frac{nx^{n-1}}{n!}$$

$$= 1 + x + \frac{x^2}{2!} + \ldots \frac{x^{n-1}}{(n-1)!}$$

**Q. 2b.—Differentiate with respect to x**

$$y = \frac{a + \sqrt{x}}{a - \sqrt{x}}$$

**A.**—This is of the form $\dfrac{d}{dx}\dfrac{(u)}{(v)}$

of which the solution is

$$\left(v\frac{du}{dx} - u\frac{dv}{dx}\right) \Big/ v^2$$

$$u = a + x^{\frac{1}{2}} \qquad \frac{du}{dx} = \tfrac{1}{2}x^{-\frac{1}{2}}$$

$$v = a - x^{\frac{1}{2}} \qquad \frac{dv}{dx} = -\tfrac{1}{2}\,x^{-\frac{1}{2}}$$

Therefore

$$\frac{dy}{dx} = \tfrac{1}{2}\,x^{\frac{1}{2}}\Big((a - x^{\frac{1}{2}}) + (a + x^{\frac{1}{2}})\Big) / (a - x^{\frac{1}{2}})^2$$

$$= ax^{\frac{1}{2}} / (a - x^{\frac{1}{2}})^2.$$

**Q. 3a.—Prove by trigonometrical transformation that**
**Arc Sin A = Arc Tan A / $\sqrt{1 - A^2}$**

**A.**—

Let Arc Sin A = X
Then Sin X = A (by definition)
and $\text{Sin}^2\ X = A^2$
and $\text{Cos}^2\ X = (1 - \text{Sin}^2\ X) = (1 - A^2)$
and $\text{Cos X} = \sqrt{1 - A^2}$

Therefore $\text{Tan X} = \dfrac{\text{Sin X}}{\text{Cos X}} = A/\sqrt{1 - A^2}$

So that X = Arc Tan A $/\sqrt{1 - A^2}$ Q.E.D.

**Q.—Prove by trigonometrical transformation that**

$$\textbf{Tan (u + a)} = \frac{\textbf{Tan u + Tan a}}{\textbf{1-Tan u Tan a}}$$

**A.**—

$$\text{L.H.S.} = \frac{\text{Sin (u + a)}}{\text{Cos (u + a)}}$$

$$= \frac{\text{Sin u Cos a} + \text{Cos u Sin a}}{\text{Cos u Cos a} - \text{Sin u Sin a}}$$

Dividing numerator and denominator by Cos u Cos a

$$= \frac{\dfrac{\text{Sin u Cos a}}{\text{Cos u Cos a}} + \dfrac{\text{Cos u Sin a}}{\text{Cos u Cos a}}}{\dfrac{\text{Cos u Cos a}}{\text{Cos u Cos a}} - \dfrac{\text{Sin u Sin a}}{\text{Cos u Cos a}}}$$

$$= \frac{\text{Tan u + Tan a}}{1 - \text{Tan u Tan a}} = \text{R.H.S.}$$

Q.E.D.

**Q. 4a.—Show that when u becomes exceedingly small**
**Sinh u $\doteqdot$ u.**

**A.**—

$$\text{Sinh u} = \frac{e^u - e^{-u}}{2} \quad \text{(where e is the base of naperian logs)}$$

$$= \tfrac{1}{2}\Big((1 + u + \frac{u^2}{2!} + \frac{u^3}{3!} + \frac{u^4}{4!} + \ldots)$$

$$- (1 - u + \frac{u^2}{2!} - \frac{u^3}{3!} + \frac{u^4}{4!} - \ldots)\Big)$$

$$= \tfrac{1}{2}\,(2u + \frac{2u^3}{3!} + \ldots)$$

$$= u\,(1 + \frac{u}{3!} + \ldots \text{ higher powers of u})$$

As u decreases indefinitely the factor in the bracket approaches unity.

Therefore the whole approaches (u × 1) = u. Q.E.D.

**Q. 4b.—Show that when u becomes exceedingly small $\cosh u \doteqdot 1$**

**A.—**

$$\cosh u = \frac{e^{u} + e^{-u}}{2.}$$

Using the same transformation as above

$$= \tfrac{1}{2}\left(2 + \frac{2u^2}{2!} + \frac{2u^4}{4!} + \ldots\right)$$

$$= \left(1 + \frac{u^2}{2!} + \frac{u^4}{4!} + \ldots\right)$$

As u decreases indefinitely, u and all higher powers of u approach zero and the whole term in the bracket approaches 1. Q.E.D.

**Q. 5.—Calculate the specific heat s of a body of mass M = 100 gm. given the following calorimetric observations: Mass of water W = 1000 gms.; initial temperature of the body t = 72°C.; initial temperature of the water t = 20°C.; final temperature of body and water t = 22°C. Assume that there are no heat losses and neglect the water equivalent of the calorimeter.**

**A.**—If we neglect heat losses and the water equivalent of the calorimeter the heat lost by the body equals the heat gained by the water.

The water rises 2°C. so that it gains

$2 \times 1000$ calories (since the s.h. of water = 1).

The body falls 50°C. so that it loses

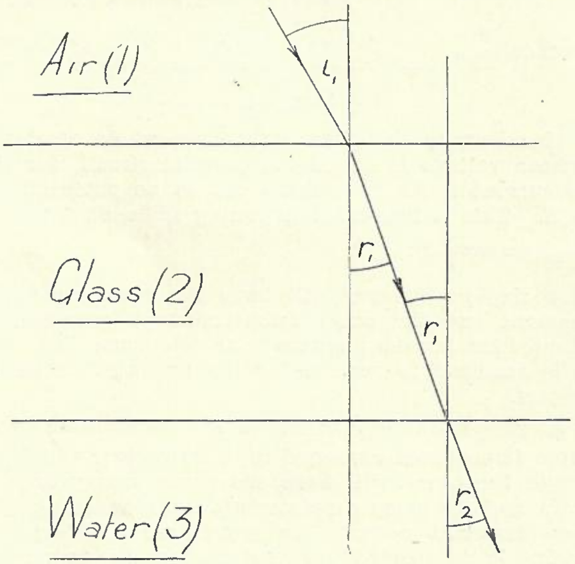
$(50 \times 100 \times s)$ calories.

Therefore $50 \times 100 \times s = 2 \times 1000$

and $s = 0.4$ calories per gram degree centigrade.

**Q. 6.—A ray of light passes through a sheet of glass into water. Given that the refractive index of glass to water $_2\mu_3 = 0.9$ and air to water $_1\mu_3 = 1.35$, calculate the refractive index of air to glass.**

**A.**—By definition the refractive index of medium A to medium B $(_A\mu_B)$ is the ratio of the sine of the angle of incidence to the sine of the angle of refraction when a ray of light passes from A to B.



From this and referring to Fig. 1 we see

$$_1\mu_2 = \sin I_1 / \sin r_1$$
$$_2\mu_3 = \sin r_1 / \sin r_2$$
$$_1\mu_3 = \sin I_1 / \sin r_2$$

Now $$_1\mu_2 = \sin I_1/\sin r_1 = \frac{\sin I_1}{\sin r_2} \div \frac{\sin r_1}{\sin r_2}$$
$$= {_1\mu_3} \div {_2\mu_3}$$
$$= 1.35 \div 0.9 = 1.5.$$

(**Briefly:** When a ray of light passes through several media a b c . . . . n.

$$_a\mu_n = {_a\mu_b} \times {_b\mu_c} \times {_c\mu_d} \times \ldots {_m\mu_n}.$$

In the particular case

$$_1\mu_3 = {_1\mu_2} \times {_2\mu_3},$$
or $1.35 = {_1\mu_2} \times 0.9$,
or $_1\mu_2 = 1.35/0.9 = 1.5$.)

**Q. 7.—A body of mass 50 gm. is allowed to fall freely from rest under the action of gravity. Calculate (a) the momentum it possesses after 5 secs.; (b) the force which causes it to move in this manner. ($g = 980$ cm sec$^{-2}$.)**

**A.**—The velocity of a body falling freely from rest after t secs. is gt (where g is the acceleration due to gravity).

Thus $V = 5 \times 980 = 4900$ cm/sec.

And the momentum $= 50\ V = 245{,}000$ gram.cm/sec.

The force = Mass × Acceleration
$= 50 \times 980 = 49{,}000$ dynes.
$= 50$ grams wt.

**Q. 8.—For an organ pipe of length L = 1.5 metres calculate the fundamental frequency when the end remote from the excitation is (a) Closed, (b) Open. (c) Under which conditions are only the odd harmonics produced and why? Assume velocity of sound in air is 330 metres/sec. and neglect for the end-effect of the pipes.**

**A.**—Consider a source of sound emitting a compression wave every P secs. (i.e., of period P secs. and frequency = 1/P) at the end of a tube L metres long with the end remote from the source closed.

A compression wave travelling towards the closed end at a velocity V metres/sec. is reflected as a compression when it reaches the end and will travel back towards the source end. When it reaches this end it will be reflected as a rarefaction since the end is open. The wave will take 2L/V secs. to perform this trip; and if either L or P are so chosen that the reflected rarefaction meets a rarefaction emitted from the source it will be reinforced and the tube will resonate.

But a rarefaction occurs P/2 secs. after the original compression which started the cycle, so if $P/2 = 2L/V$ resonance will occur.

Thus the natural period for the conditions specified is given by $P/2 = 2L/V$ or $P = 4L/V$.

Therefore the natural frequency $1/P = V/4L$ (55 cycles/sec. in this problem).

It must be remembered that rarefactions will also be emitted $(P + P/2)$ secs. $(2P + P/2)$; . . . . . . . . $(nP + P/2)$ secs. after the original compression, so that resonant conditions are given for any value of P which satisfy the equation.

$(nP + P/2) = 2L/V$ (where n = zero or any positive integer)

i.e., $P(2n + 1) = 4L/V = 1/f$;

where f is the natural (or fundamental) frequency of the tube calculated as above.

So that any period P which equals $1/(2n + 1)f$

is also resonant. But (2n + 1) is always an odd number, so that the above conditions mean that all the odd harmonics of f, but only these, are resonant.

With the tube open at both ends the original compression wave is reflected as a rarefaction from the far end of the tube and this rarefaction travelling back towards the source is reflected as a compression when it reaches the source end. Therefore under these conditions it must meet a compression being emitted from the source for resonance to occur. This happens P seconds after the first compression, so if $P = 2L/V$ the tube is resonant.

Therefore $f = 1/P = V/2L$ (110 cycles/sec. for this problem).

Similarly as for the case of the closed tube compressions also occur 2P 3P . . . nP seconds after the original compression, so any period P which satisfies the equation

$$nP = V/2L = 1/f \text{ is resonant.}$$

$$\text{i.e., } P = 1/nf.$$

But n may be any positive integer, odd or even, so this condition implies that all the harmonics of the fundamental frequency are resonant.

The answers to the problem are, therefore:

(a) 55 cycles/sec.

(b) 110 cycles/sec.

(c) Under the first condition for the reason given above.

**Q. 9.—A condenser of capacity C = 5mF is charged to a potential of v = 1000 volts; calculate (a) the energy stored in the condenser (b) the average power if the discharge is completed in 50 micro seconds.**

A.—The energy of a condenser = ½ Q V where V is the voltage between the plates and Q the charge in coulombs.

$Q = \text{Capacity} \times \text{Potential} = CV$.

Therefore Energy $= \frac{1}{2} CV^2$ (C = Capacity in farads)

$$= \tfrac{1}{2} \times 5 \times 1000^2 \times 10^{-6}$$

$$= 2.5 \text{ watt secs. or joules.}$$

The average power is the average rate of dissipation of energy, i.e., it equals the energy of the charge divided by the time of discharge.

$$= 2.5/50 \times 10^{-6} = 50{,}000 \text{ watts.}$$

**Q. 10.—A source of alternating e.m.f. E is connected to a network consisting of a resistance R in series with a parallel combination of a capacitance C and inductance L. The L and C elements are pure reactances. Show analytically that at the resonant frequency of L and C the current in R is zero.**

A.—The current in R equals the vector sum of the currents in L and C.

Assume the voltage across L and C equals e and the frequency of the supply is w radians per sec. Then the current in $L = e/wL$ and lags e by 90°, i.e., it equals $0 - j\, e/wL$ (see Fig. 2) (where L is the inductance in henries).

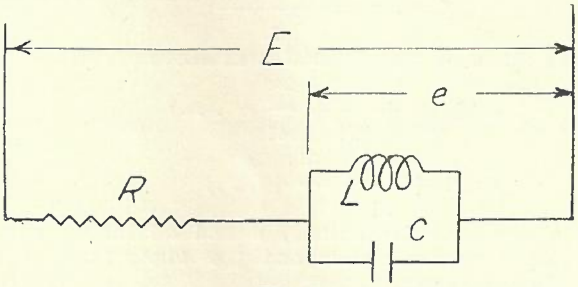


Fig. 1.

The current in C is $e \times wC$ and leads e by 90°, i.e., it equals $0 + jewC$ (where C is the capacitance in farads).

The vector sum is, therefore,

$$0 - j\, e/wL + 0 + jewC$$

$$= 0 + je\left(wC - \frac{1}{wL}\right).$$

But at the resonant frequency of C and L

$$wC = 1/wL$$

$$\text{so that } (wC - 1/wL) = 0.$$

And the vector sum is, therefore, $0 + j0 = 0$.

Q.E.D.

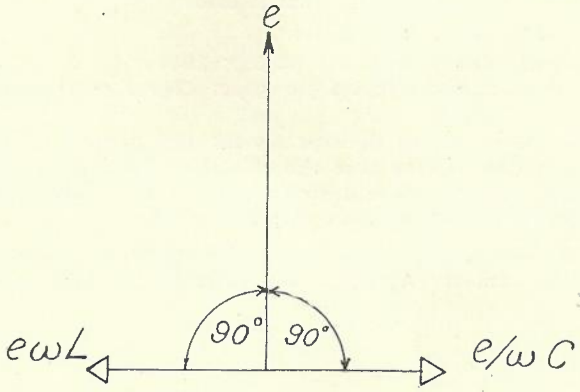


Fig. 2.

(**Incidentally** this means that the whole of the impressed voltage is across the parallel circuit, for since no current flows in R there can be no potential drop in it. This is important in tuning radio circuits.)

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## EXAMINATION No. 2050.

## TRANSMISSION TELEPHONE AND TELEGRAPH.

**Q. 1.—What do you understand by the terms—**

**(a) Equivalent T Network;**

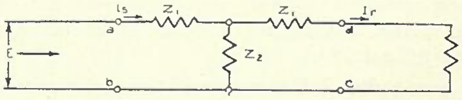
**(b) Equivalent $\pi$ Network?**

**Develop the equations for the series and shunt arms of a T network to represent a line having an attenuation at a given frequency of $e^{-P1}$ and characteristic impedance $Z_0$ where P represents the propagation constant and 1 the length of the line.**

A.—An equivalent T network is a network made up of three impedances arranged in T formation which at a single frequency will have the same propagation constant and the same characteristic impedance as a given four terminal network or telephone line which it is required to replace for the purposes of analysis or test.

An equivalent $\pi$ network is a network made up of three impedances arranged in $\pi$ formation, which at a single frequency will have the same propagation constant and the same characteristic impedance as a given four terminal network or section of telephone line, which it is required to replace for the purposes of analysis or test.

Let abcd represent a T network of three impedances which it is required shall be equivalent to a line of length 1 having a propagation constant P and characteristic impedance $Z_0$.



Let the terminals cd be terminated in an impedance $Z_0$ and let a source of emf. be applied to ab.

Then since the network is to be equivalent to a line having characteristic impedance $Z_0$ the impedance looking into ab, i.e., $Z_{ab} = Z_0$;

$\therefore$ from series and parallel circuits—

$$Z_0 = Z_1 + \frac{Z_2\,(Z_1 + Z_0)}{Z_1 + Z_2 + Z_0} \quad \ldots . \ (1)$$

Let Is be the current flowing into the network and Ir the current through $Z_0$.

Then $\dfrac{I_r}{I_s} = e^{-P1}$ but from parallel circuits

$$\frac{I_r}{I_s} = \frac{Z_2}{Z_1 + Z_2 + Z_0}$$

$$\therefore\ e^{-P1} = \frac{Z_2}{Z_1 + Z_2 + Z_0} \quad \ldots . \ (2).$$

$$\therefore \text{ from (1) } Z_0 = Z_1 + (Z_1 + Z_0)\,e^{-P1}$$

$$= Z_1\,(1 + e^{-P1}) + Z_0 e^{-P1}$$

$$Z_1 = \frac{Z_0\,(1 - e^{-P1})}{(1 + e^{-P1})} \quad \ldots . \ \text{Multiply by } \frac{e^{\frac{Pl}{2}}}{e^{\frac{Pl}{2}}}$$

$$= Z_0 \left\{ \frac{e^{\frac{Pl}{2}} - e^{\frac{-Pl}{2}}}{e^{\frac{Pl}{2}} + e^{\frac{-Pl}{2}}} \right\}$$

$$= Z_0 \tanh \frac{P1}{2}$$

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$$\text{From (2) } Z_2 = (Z_1 + Z_2 + Z_0)\,e^{-P1}$$

$$Z_2\,(1 - e^{-P1}) = (Z_1 + Z_0)\,e^{-P1}$$

$$= \left\{ Z_0\,\frac{1 - e^{-P1}}{1 + e^{-P1}} + Z_0 \right\} e^{-P1}$$

$$= \frac{Z_0 2\,e^{-P1}}{1 + e^{-P1}}$$

$$Z_2 = \frac{2\,Z_0\,e^{-P1}}{(1 - e^{-P1})\,(1 + e^{-P1})}$$

$$= \frac{2\,Z_0\,e^{-P1}}{1 - e^{-2P1}}$$

$$= \frac{2\,Z_0}{e^{P1} - e^{-P1}}$$

$$= \frac{Z_0}{\sinh P1}$$

$\therefore$ The equivalent T network will consist of two series arms each $Z_0 \tanh \dfrac{P1}{2}$ and a shunt arm $Z_0/\sinh P1$.

**Q. 2.—An entrance cable approximately six (6) miles long is installed between an open wire line and a terminal station and is to be loaded.**

**What loading would you provide for those pairs required to transmit—**

**(a) Frequencies up to 2,500 cycles p.s.;**

**(b) Frequencies up to 42,000 cycles p.s.?**

**Show what the attenuation, the cut-off frequency and the impedance would be in the case of (a).**

**The characteristics of the cable are—**

**Resistance—44 ohms p. loop mile.**
**Capacity—0.065 micro-farads p. mile.**
**Inductance—0.001 millihenries p. mile.**
**Leakance—5 × $10^{-6}$ mhos. p. mile.**

A.—The fundamental requirements to be met in this case are:—

(i) Sufficient coils per wave-length to ensure that the loaded cable will approach the condition of a continuously loaded cable, i.e., so that reflection will not occur at loading points.

(ii) Impedance of loaded cable to approximate that of the open-wire line to which it is connected—say, 650 ohms.

(iii) The theoretical cut-off frequency, $f_c$, to be approximately 40 per cent. higher than the highest frequency which it is required to transmit, owing to the rising attenuation near the theoretical cut-off.

(iv) The use of standard loading coils and a standard method of loading so as to avoid the purchase of special coils and also to fit in with the existing manholes which, in most cases, would be placed so as to permit some standard system of loading.

The standard loading systems which would meet these requirements are:—

For (a) 88 mH coils spaced at 6,000 feet.

For (b) 3.5 mH coils spaced at 715 feet (for a cable of .065 mF capacity per mile).

Attenuation of a loaded cable is closely equal to

$$A = \frac{R}{2}\sqrt{\frac{C}{L}} \text{ Nepers.}$$

where R = Resistance per mile in ohms,
C = Capacitance per mile in Farads.
L = Total inductance per mile in Henries.

$$\therefore \text{ in case (a) } A = \frac{44}{2}\sqrt{\frac{.065 \times 10^{-6}}{.001 + (.088 \times 5280/6000)}}$$

$$= .0201 \text{ Nepers;}$$

i.e., .0201 × 8.686 = 0.174 db per mile.

$$f_c = \frac{1}{\pi\sqrt{L'CS}}$$

where L' = added inductance per loading section.
S = length of loading section in miles.
C = capacitance per mile.
$\therefore$ SC = capacitance per loading section.

$$\therefore\ f_c = \frac{1}{\pi\sqrt{.088 \times .065 \times 10^{-6} \times \frac{6000}{5280}}}$$

$$= 3{,}950 \text{ cycles per second.}$$

This is the theoretical cut-off.

For practical purposes this should be regarded as approximately 40 per cent. higher than the highest frequency to be transmitted. In practice, the cut-off would be $\frac{100}{140} \times 3950 =$ **2,840 cycles per second.**

The characteristic impedance of a loaded cable is closely equal to

$$Z_0 = \sqrt{\frac{L}{C}} \text{ ohms}$$

$$= \sqrt{\frac{0.001 + (.088 \times 5280 / 6000)}{.065 \times 10^{-6}}}$$

$\therefore$ $Z_0 = 1095$ ohms.

**Q. 3.—In a circuit consisting of a section of open wire line and a section of underground cable connected together through an impedance matching transformer the sent current into the open wire line is 20 milliamps. while the received current at the further end is 1 milliamp. What is the attenuation? The impedance of the open wire line is 400 ohms and it is terminated in a resistance of that value. The impedance of the cable is 1600 ohms and it is terminated in a resistance of that value.**

**A.**—As the open-wire line is connected to the cable through a matching transformer, and each section of the circuit is terminated in its characteristic impedance there are no reflection losses at any point.

The attenuation in decibels is—

$$n \text{ (decibels)} = 10 \log_{10} \frac{Ps}{Pr}$$

where Ps = sent power,
Pr = received power.

$Ps = I^2Z_1 = .020^2 \times 400 = .16$ watts.
$Pr = I^2Z_2 = .001^2 \times 1600 = .0016$ watts.

$\therefore$ $n = 10 \log_{10} \frac{.16}{.0016} = 10 \log_{10} 100 =$ **20 db.**

**Q. 4.—Discuss the reasons justifying the use of the following types and combinations of tubes in the output stage of an audio amplifier operated directly from the mains:—**

**(i) Two triodes in parallel.**
**(ii) Two triodes in push-pull.**
**(iii) One pentode.**

**In your reply the following points should be covered:**

**(i) Sensitivity.**
**(ii) Distortion.**
**(iii) Power handling capacity.**

**A.**—This discussion of the characteristics of the various combinations of tubes as power amplifiers in the output stage of a mains-operated audio-frequency amplifier is confined to Class A operation.

**(i) Two Triodes in Parallel:**

(a) With this arrangement the power-handling capacity is doubled, which is equivalent to an increase of 3 db.

(b) This increase is obtained without increasing the oscillatory drive to the grids of the tubes, therefore an increase of 3 db. in the overall gain of the stage is obtained as against a single triode of the same type operating under similar conditions. It is, of course, essential to preserve the correct impedance relation between the tubes and the load, the impedance of two tubes in parallel being half that of a single tube.

(c) The distortion is not affected, and is typical of that of a single triode.

(d) The steady D.C. current through the output coupling device is doubled, which necessitates increasing the amount of iron to prevent saturation of the core, and increasing the gauge of the wire in this component. Furthermore, the greater the D.C. current, the more difficult it becomes to manufacture a transformer with a high-grade performance.

**(ii) Two Triodes in Push-Pull:**

(a) With this combination, as in the case of two triodes in parallel, the power-handling capacity is doubled, which is equivalent to an increase of 3 db.

(b) The increase in this instance, however, is obtained only by increasing the amplitude of the oscillatory drive to the grids of the tubes to a value twice that of a single tube. The overall gain of the stage is, therefore, 3 db. less than that of a single tube of the same type operating under similar conditions.

In this case the tubes are operating in series, therefore the output impedance is double that of a single tube.

(c) The distortion is considerably less than that of a single tube as the even harmonics cancel, provided the tubes are correctly matched. The odd harmonics are unaffected, provided the power output from each tube remains unaltered from that of a single tube.

Filament hum is also reduced as this component is applied to the two halves of the output transformer in opposite phase.

(d) Tubes arranged in this manner permit the use of an output transformer of efficient and economical design. The steady D.C. plate current of each tube flows in opposite directions in the two halves of the output transformer; thus, no magnetising flux is generated and the design of the transformer or choke, as the case may be, becomes purely an A.C. problem.

**(iii) One Pentode:**

(a) This type of tube has a comparatively large amplification factor, generally between 50 and 100, and in practice it is found that this value is not reduced to any appreciable extent when the tube is in operation. This also applies to the mutual conductance. The reason for this is that there is comparatively little change in the anode current for fairly large changes in the anode voltage resulting in a dynamic curve closely resembling the static curve.

(b) This feature permits a large power output being obtained from a comparatively small grid-swing which would give this type of tube a great advantage over a triode if other things were equal.

(c) The harmonic content generated in a tube of this type, however, is comparatively large. It is composed chiefly of third harmonic which increases rapidly in magnitude as the power output is increased.

(d) Owing to its constant current characteristic the best results are obtained if the tube operates into a non-inductive load. It is, therefore, never used as a power amplifier in high quality equipment, as its disadvantages more than outweigh its advantages.

(To be continued.)

## EXAMINATION 2050.—TELEGRAPH EQUIPMENT.

*B. EDWARDS*

**Q. 1.—Describe with the aid of sketches the purpose and functioning of the 3rd or local set of segments in a quadruple multiplex system. Give a sketch showing the layout of a quadruple plateau and allot all necessary segments for two channels, giving reasons for the allocations shown.**

**A.**—The purpose of the local set of segments is to arrange for the operation of the printer and transmitter cadence magnets at the correct times in each revolution of the distributor brushes.

The functioning of the segments in conjunction with the cadence set of brushes is shown in Fig. 1.

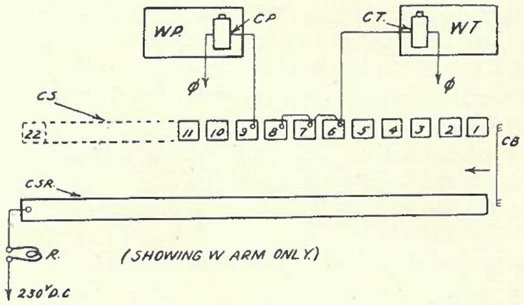


Fig. 1.

In the figure, CS is the cadence ring developed; segments 1-11 are shown, and 12-22 indicated. WT is the transmitter on W arm, and CT is its cadence magnet. WP is the printer on W arm, and CP is its cadence magnet. Ø is the neutral of the mains supply. CSR is the cadence solid ring (ring VI of the plateau) and is connected to the active side of the mains through a current limiting resistance. CB is the set of cadence brushes passing over the segments in the direction of the arrow, and connecting them consecutively to the main's potential through the solid ring. While CB is passing over 6-7 and 8, the transmitter cadence magnet is operated, and while CB is on 9 the printer cadence magnet is operated. The segments in each case are chosen with proper regard to the movement of the receiving and sending brushes over the relevant receiving and sending segments of the arm concerned, as shown in Figure 2.

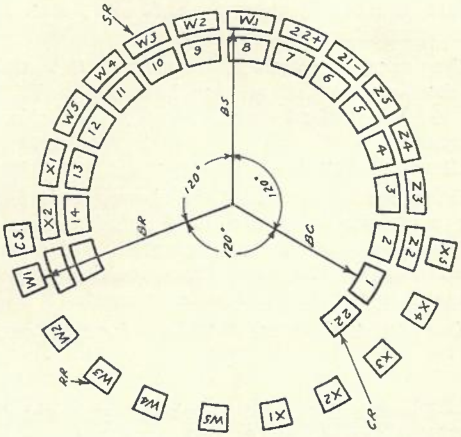
In Fig. 2:—

BR is the receiving brush set.
BS is the sending brush set.
BC is the cadence brush set.
RR is the receiving segmented ring.
SR is the sending segmented ring.
CR is the cadence segmented ring.
CS is the correction segment, if used.

21 and 22 are the correction cycle segments on SR.

The angular displacement of the No. 1, etc., segments on the three rings is due to the relative brush positions.

The transmitter cadence allocations shown ensure stepping on of the tape to the next letter perforations immediately the sending brushes have completed sending the code set up during their passage over the five segments of an arm. On a quadruple distributor running at 270 r.p.m. three segments are commoned, so that the time application of the cadence impulse will be sufficient for reliable action. The transmitter cadence magnet is heavily loaded.



**Solid ring connections.**
Receiving, Ring IV, to tongue of receiving relay.
Sending, Ring V, to send leg of line circuit.
Cadence, Ring VI, see Fig. 1.

**Cadence allocation.**
W trans. 6-7-8.
W printer 9.
X trans. 11-12-13.
X printer 14.

Fig. 2.

The printer cadence allocations shown ensure release of the translating mechanism of the printer almost immediately after the code corresponding to the letter received has been distributed to the printer selector magnets. The slight angular lag between, say, the disconnection of BR from W5 and the make of BC on 9, allows for the forward movement of RR during orientation. The printer cadence magnet is lightly loaded, so that only one segment is necessary to ensure reliable operation.

**Q. 2.—Answer briefly each of the following:—**

**(i) How frequently should the correction mechanism normally operate in a multiplex installation to maintain synchronism?**

**(ii) If 5ths are regularly missed on a multiplex channel and the trouble is not due to a fault in perforator, tape, transmitter, printer, plateau or associated wiring, where would you suspect the location of the trouble?**

**(iii) In a 7C Teleprinter how many units are transmitted for each letter and what are their respective lengths?**

**(iv) What is meant by "Distortion" in a Teleprinter installation?**

**(v) How many letters is it possible to receive in each direction on a duplex quadruple multiplex installation for each revolution of the brushes?**

**A.**—(i) An average of once every three revolutions. The average gain of the corrected station brushes over those at the correcting station would, therefore, be $\frac{1}{2}$° per revolution.

(ii) In the wrong allocation of the cadence segments at—

(a) the sending end; stepping the tape onwards before the sending brush had completed transmission from the 5th segment; or

(b) the receiving end; releasing the translating mechanism of the printer before the 5th impulse of the train had been received on the selector magnet.

(iii) Seven. Equal.

(iv) In accordance with (iii) above, each element of a letter code should occur at a definite time interval after the arrival of the start signal. If any element is displaced from its ideal time position with respect to the start signal, distortion is present.

(v) One on each arm, totalling four in each direction.

**Q. 3.—Discuss the relative advantages and disadvantages of the Creed, 215A and 209FA types of relays for use on a fast speed machine system. Describe any special features of each type of relay.**

**A.—Relay 215A.**

This relay is not fitted with vibrating circuit windings and, unless the operating current is relatively high, is subject to contact bounce. No adjustment is provided for varying the bias during operation.

It is, therefore, not suitable for use as a receiving line relay on a fast speed circuit, but will operate at fast speed in a circuit where the current value and signal shape are maintained.

**Relay 209FA.**

This relay is similar in mechanical design to the 215A. It is not fitted with a biassing adjustment, but is wound for gulstad operation. The operating current is much lower than the 215A, and the tendency to bounce is less, although still present.

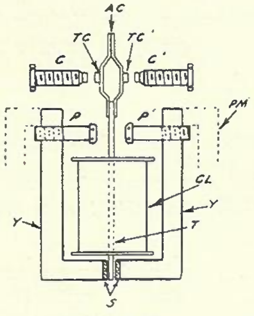


Fig. 1.

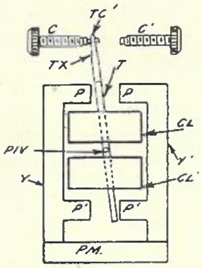


Fig. 2.

When used as a vibrating relay in the standard gulstad circuit arrangement, the speed of vibration has been found to wander in a manner suggesting frequency beating.

It may be said, therefore, that the 209FA relay is suitable for use as a fast speed receiving relay provided (a) the line conditions do not warrant the use of a gulstad relay, and (b) the usual practice of manually biassing the relay to preserve working under difficult conditions is not necessary.

**Features of 215A and 209FA Relays.**

The windings and contacts of these relays are terminated on contact pins arranged for jack mounting. The relays may, therefore, be readily removed from the circuit for adjustment.

Fig. 1 shows the general mechanical construction of both types.

Y,$Y^1$ are the permalloy yokes between which the permalloy tongue T is clamped at its lower extremity.

C,$C^1$ are the contacts between which T is free to oscillate. The "free" position of the tongue is central between the contacts as shown.

S are non-magnetic spacers providing a magnetic gap between Y,$Y^1$ and T.

TC, $TC^1$ are the tongue contacts mounted on the anti-chatter springs AC. These springs are rigidly fixed to T, but may slide upon one another. Their mutual friction tends to damp out chatter.

P,$P^1$ are adjustable pole pieces allowing variation in the gap between their faces and T.

PM indicates the permanent magnet. PM is actually horseshoe shaped and lies along Y,$Y^1$.

CL is the bobbin upon which the windings of the relay are wound.

CL encircles T, but does not move with T.

**Creed Relay.**

This relay is fitted with a bias adjusting screw, and may be arranged for gulstad operation. The operating current for practical purposes is substantially the same as the 209FA. As a vibrating relay connected in the standard circuit, its operation is reliable.

The relay contacts are particularly free from bounce at all current values. The sensitivity of the relay may be varied slightly by an adjustment which swings the permanent magnet through a small arc, its contact with the yokes being the pivot point.

The contact carrying screws are fitted with large graduated thumb-screws by means of which contact gap may be adjusted without special tools. Adjustments to meet particular circuit conditions may be carried out at the operating position. The relay is entirely suitable for use on the fast speed machine systems of the Department.

**Features of Creed Relay.**

Creed relays are jack mounted. The jack is circular and requires more space than the 215A and 209FA types.

Figure 2 shows the general mechanical construction of the relay.

Y,$Y^1$ are the laminated iron yokes between which the laminated iron tongue T is pivoted at PIV.

C,$C^1$ are the contacts between which T is free to oscillate. The "free" position of the tongue is at rest against one of the contacts.

TC, $TC^1$ are the tongue contacts mounted upon an extended lamination of the tongue TX.

P-P, $P^1$-$P^1$ are fixed pole-pieces, integral with the yokes. At any time, during operation of the relay, a pair of pole-pieces P,$P^1$ are attracting the tongue and the other pair are repelling it.

PM is the short horseshoe-shaped permanent magnet.

CL, $CL^1$ are bobbins upon which the windings of the relay are wound. They encircle T, but do not move with T. The differential windings are arranged so that one-half of each winding is on CL, and the other half of each is on CL$^1$.

**Q. 4.—Discuss the theory and electrical design of a telegraph artificial line for satisfactory Duplex operation over a physical channel. Explain the reason for the inclusion of the component parts in the artificial line. State approximate numerical values for the various component parts in the artificial line for satisfactory duplex working over a 200-lb. H.D.C. wire 300 miles long.**

**A.**—Duplex working necessitates some arrangement whereby the signals outgoing from either station will not affect the receiving relay at that station. One arrangement adopted uses the differential properties of a telegraph relay in conjunction with a compensation circuit (or artificial line).

In a circuit such as that shown in Fig. 1, a line having resistance only may be balanced so far as the receiving relay, RR, is concerned by a simple resistance R. If K is pressed, currents $I_s$ and $I_m$ arise simultaneously in the windings of RR, one tending to "space" the relay and the other tending to "mark." Since the two currents will be identical throughout their growth and at their steady state values, RR will be unaffected whatever movements take place at K.

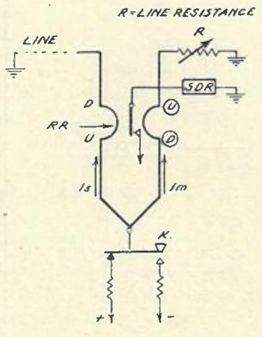


Fig. 1.

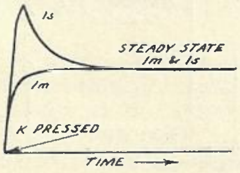


Fig. 2.

In actual lines, however, distributed capacity to ground exists in addition to resistance. The charging currents which flow into this capacity, whenever K changes the applied potential from one sign to the other, cause the transient period of the line current to assume a different shape from the simple one that would obtain under the conditions of Fig. 1.

Fig. 2 indicates the effect of attempting to balance a line having capacity, with a simple resistance as in Fig. 1.

It is seen that the charging current into the line momentarily predominates over the current in the compensation circuit. In this instance, therefore, the relay would be affected by the out-of-balance current, and, if a marking signal were being received from the distant end, that signal might be mutilated.

In order to compensate for this line condition, capacity must be introduced into the compensation circuit. But since the capacity existing on the line is distributed over its length, the "charging" of the line is progressively delayed as successive points outward from the sending end are considered.

Since the ideal balance condition would be one in which $I_m$ (in Fig. 2) coincided with $I_s$, it becomes necessary to introduce resistance into the compensating condenser circuit in order to simulate the retardation of the line resistance.

The network usually chosen for this purpose is shown in Fig. 3.

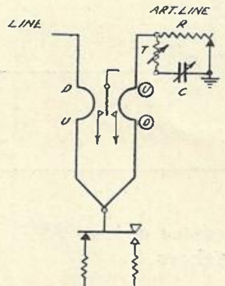
In the artificial line of Fig. 3 (a), R is the resistance which balances the resistance of the line and is responsible for the steady state balance. C is the capacity which balances the capacity of the line, and, in conjunction with the retardation coil (or timer) T, is responsible for the transient part of the line current being simulated in the compensating circuit.

Because of the distributed nature of the line capacity, a perfect balance could be obtained only with an infinite number of condensers and timing resistances in the artificial line. But since, with the type of relay generally in use, it is only necessary to reduce the out-of-balance potential between the ends of the two coils to about 0.02 volt, it is found in practice that two condensers and timers suffice for most aerial lines, while three condensers and timers balance long lines sufficiently well. [See Fig. 3 (b).]

Since, viewed from the sending end, the effect of line capacity decreases with distance, while the retardation increases with distance, the successive capacities of the artificial line are in decreasing order, and their timing resistances are in increasing order.

In the standard artificial line no component is included specifically for the simulation of line leakance. It is found in practice that leakage is sufficiently compensated for by a general reduction in the resistance components of the artificial line. Some reduction in capacity is also generally necessary.

In the manufacture of artificial lines for telegraph purposes, high insulation resistance is essential both between the different components and in the condensers. For the latter, a value of 1000 megohm-microfarads is specified. The resistance components are wound non-inductively on non-magnetic bobbins so as to eliminate the effects of transients due to inductance.



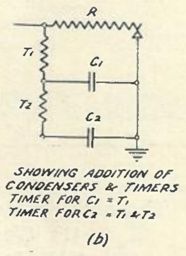


Fig. 3.

Approximate balance values for the line specified are:

$R = 1620$ ohms.

$C_1 = 1.25$ mF $T_1 = 200$ ohms.

$C_2 = 0.5$ mF $T_2 = 500$ ohms.

(To be continued.)

## EXAMINATION 2050.—TELEPHONE EQUIPMENT.

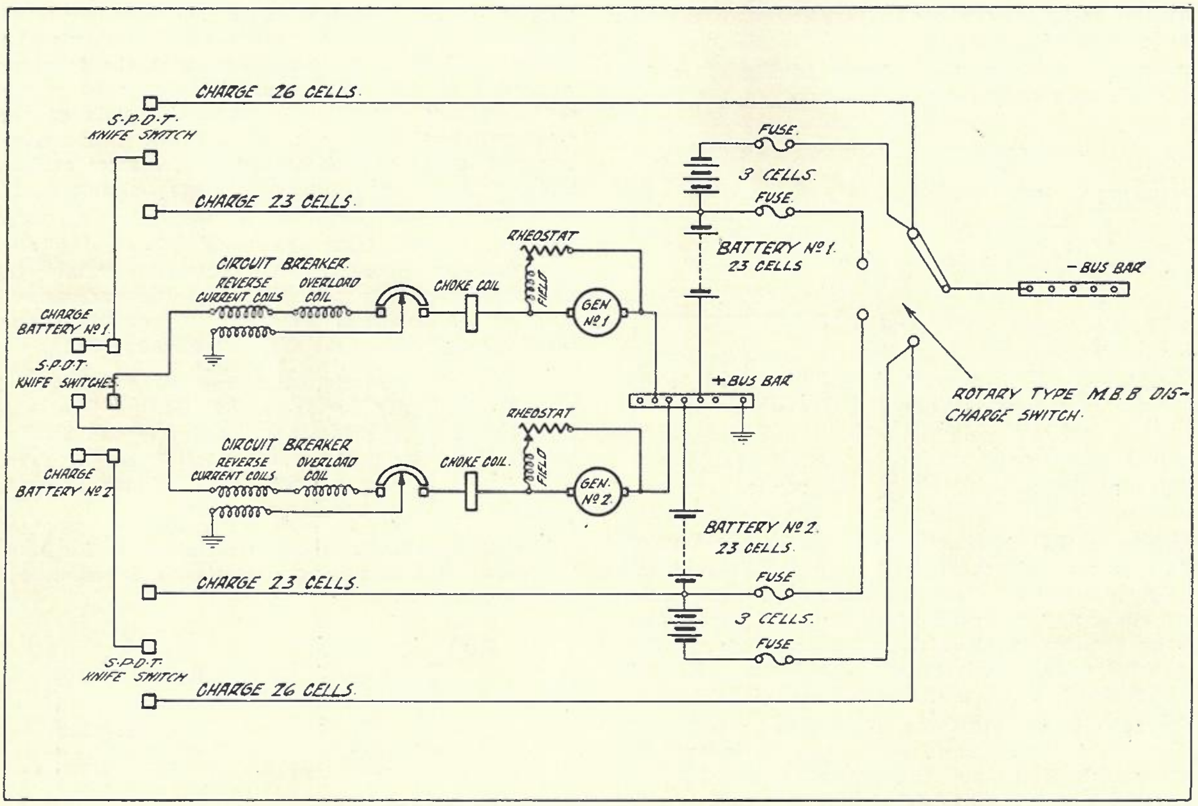
*J. A. KLINE, B.Sc., A.M.I.E.E.*

**Q. 1.—(a) Draw a schematic diagram showing the power circuit of a large automatic exchange, say, a main exchange of 8,000 lines. Show batteries in duplicate, end cells, discharge switch contacts, main discharge bus bar; also position in circuit of chokes, regulators, protective equipment and charge contacts.**

**(b) Describe the main protective devices and explain their operating principles.**

**(c) What type of discharge switch would you use and what are the important points in design of this switch?**

**A.—(a)—**



(b) The main protective devices are:—

(i) Circuit Breakers,

(ii) Fuses.

A circuit breaker consists essentially of a switch having a powerful spring and retained in the closed position by a catch which may be withdrawn by the operation of either the overload or reverse current coils. The overload coil is set to operate at a current value slightly in excess of the maximum charging rate for the battery, whilst the polarized reverse current coil operates with a current reversed such as would occur with the failure of the generator. The overload coil protects the battery from an excessive current and the reverse current coil prevents the battery from discharging through the generator. The current is carried by a heavy brush of laminated copper. Auxiliary contacts which make first and break last are provided to prevent sparking occurring at the main contacts. Circuit breakers are fitted with "free" handles, making it impossible to close or hold them closed on an overload or reverse current.

Fuses of the cartridge, self-quenching type are provided to protect the batteries against short circuits on the main discharge cables. These are mounted as close as practicable to the battery, and are designed to operate with a current slightly in excess of the one-hour discharge rate of the battery.

(c) For installations with a peak drain of not more than 600 amps a hand-operated rotary type discharge switch is mounted on the power board. The important points of design are:—

(i) The switch to be of the make before break type to enable either 23 or 26 cells of either of two batteries to be connected to the discharge busbars without opening the battery circuit.

(ii) The design of the parts to be such as to provide for reliable operation and the construction to be robust to obviate trouble due to wear of the component parts.

(iii) The make before break feature is provided by an auxiliary blade which is connected to the main blade through a low resistance to prevent short circuiting the end cells during the travel of the switch. The value of the resistance and the current carrying capacity to be such that it will not affect adversely the operation of the exchange equipment and will not burn out when the switch is operated in the normal manner with the peak load current flowing.

(iv) The cross-sectional area of the moving blade and fixed contacts to be such that they will carry the peak load current at a current density not greater than 500 amps per square inch.

(v) The current density over contact surfaces to be not more than 100 amps per square inch.

(vi) The potential drop across contact surfaces to be not more than 15 millivolts.

(vii) The insulation resistance between parts not in electrical connection to be not less than 5 megohms when tested with a 500-volt megger.

In exchanges with a peak discharge current in excess of 600 amps, the discharge switch is power operated, but the above design points apply.

**Q. 2.—In an automatic exchange—**
**(a) Why is the battery earthed?**
**(b) Which side of the battery is earthed, and why that side in preference to the other side?**

A.—(a) The battery is earthed for reasons similar to those which caused earth to be retained on one side of the common battery in manual systems.

Earth return was used for early telephone lines and although metallic circuits were introduced during the progress of common battery development, an earth connection was necessary on the central battery during the transition stage, to enable mixed circuits to be dealt with, although it had been found desirable for other reasons. A few early systems did not use earth, but later its use became standard, owing to its advantages, which are:—

(i) The level of crosstalk and other noise disturbances is reduced because the earth, being of negligible resistance, shunts out currents caused by the difference of potential due to "out-of-balance." The latter is the difference in distribution of capacity and insulation, etc., along the two sides of each line and is unavoidable owing to practical maintenance conditions and to necessary tolerances in electrical characteristics of the materials of which the lines are composed.

(ii) A return circuit is provided for signalling over junctions and special circuits, also for supervisory circuit functions in various parts of the system. This enables much of the system to be simplified and the amount of wiring to be reduced.

(iii) A return circuit of negligible resistance is provided for battery supply to P.B.X.'s and the current over a single pair of wires is supplied over the two wires in parallel so that its value is four times the amount that it would be if supplied over a metallic circuit. A saving in cable pairs is thereby effected.

(iv) The exchange power distribution and protection system is simplified and economised, because some power switches are simplified, some return power cables are eliminated and the number of fuses is reduced. At a number of points smaller power cables can be used than would be the case with metallic circuit, as the circuit resistance is halved due to the negligible resistance of the earth. At some points, where a return conductor on the earth side is necessary, it may be uninsulated.

(v) Faulty insulation of any part of the system is, in many cases, promptly indicated, due to the earthed battery and, in many cases, the location of the fault is generally indicated by fuse, relay or alarm operations.

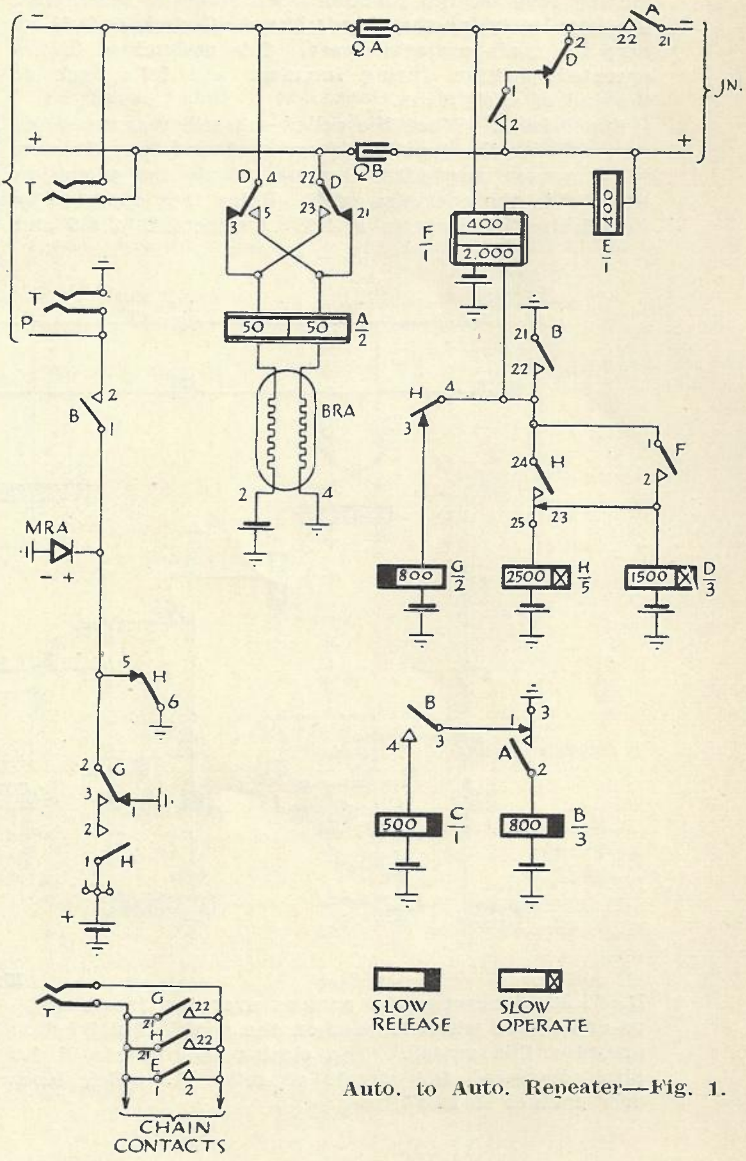
(vi) Identification of each wire of the line is facilitated, at various points in the exchange, and on the outside plant, because a simple test identifies the insulated leg and the earthed leg, while continuity and insulation tests are simplified.

(b) The positive side of the battery is earthed. This side is preferable to the other side because—

(i) The direction of current in circuit is from positive to negative. Leakage current between live side and the ground side, which includes relays, cords, frames, etc., is, therefore, in the direction from the frame towards the conductors. Consequently, the effect of electrolytic corrosion is to deposit metal from the frame to the conductors, which means that the effect of such corrosion is infinitesimal, because the deposit is being taken from a very large mass. Had the direction of the current been reversed, by grounding the negative, the deposit would be taken from the conductors, which are of small mass.

(ii) Partial earth faults show up more definitely on tests when the conductor is negative to the grounded side of the frame. If the negative pole were earthed, the conductor would be positive to the grounded side and there would be a liability of partial faults sealing through the formation of an oxide coat.

**Q. 3.—Figure 1 is the schematic diagram of the auto.-auto. repeaters which are now being delivered. Explain the circuit operation.**



Auto. to Auto. Repeater—Fig. 1.

**A.—Seizure.** The circuit is picked up from a selector, the absence of earth on the P wire indicating the free condition. A loop is then extended on the line wires and relay A operates over the ballast resistance BRA and contacts D 3. 4 and D 21.22 close the junction the circuit for relay B and A 21.22 close the junction loop over F 400 and E 400. The operation of contacts B 1.2 earths the P wire to mark the switch busy and B21.22 close the circuit of relay G over contacts H 3.4 and the polarising winding of the shunt field or electro-polarised relay F. G operates, but F does not, because the direction of the current over the junction in the 400 ohm winding magnetises the core in the same sense as the 2000 ohm coil. The chain contacts are closed at E 1.2 and G 21.22 to prevent search if all repeaters are engaged.

**Impulsing.** The incoming impulses are received on relay A (with N.1 sleeves to make it high impedance). On the first fall back of A 1.3 the circuit of relay C is completed over contacts B 3.4. The opening of A 21.22 in the junction loop sends the first impulse to the distant exchange and contact C 1.2 short circuits E 400 and F 400 to give a low impedance impulsing loop on the junction. Although E beats with the impulse trains the circuit is not affected, as G 21.22 keep the chain contacts closed. C is maintained in the operated position during impulses and falls back at the end of each train.

**Supervision.** When the called subscriber answers the current over the junction is reversed and the 400 ohm winding now magnetises the core to aid the polarising winding in the operation of F. Relay D is operated by the closing of contacts F 1.2. Contacts D. 3.4.5 and D. 21.22.23 reverse the current over the incoming + ve and — ve wires to pass on the signal if a junction precedes this switch. The closing of contacts F 1.2 also completed the circuit of relay H, which locks over contact H 24.25.

**Registration.** Contact H 5.6 removes earth from the incoming P wire and at H 1.2 replaces it with positive battery. The subscriber's register is connected in series with a rectifier which allows operation when + ve battery is connected to the P wire. The rectifier MRA prevents this battery being short circuited, but ensures that the test relays of preceding switches are retained in the operated position.

When H operated the circuit of G was opened at contact H 3.4, but G retains for the slow release period of about 300 milli-secs, after which time at contact G 2.3 it opens the registering battery and re-earths the P wire on its back contact.

**Release.** If the called subscriber releases first, the battery on the junction will restore to its original direction and F will release and pass on the reversal over the incoming line wires. When the calling subscriber releases the A relay drops out and releases relay B. Contact A 21.22 opens the loop and B 21.22 releases H while the circuit is made free to searching selectors by opening of B 1.2. The circuit, therefore, restores to normal.

**Q. 4.—Figure 2 is the schematic diagram of a switch. Say what switch it is, describe four necessary corrections to the diagram and explain briefly the necessity for each correction.**

A.—The switch is a Final Selector, 100 outlet, booster battery type.

Any four of the following irregularities:—

1. Ringer to be connected to earth. F is to be tripped by a loop and ringing return is via battery.

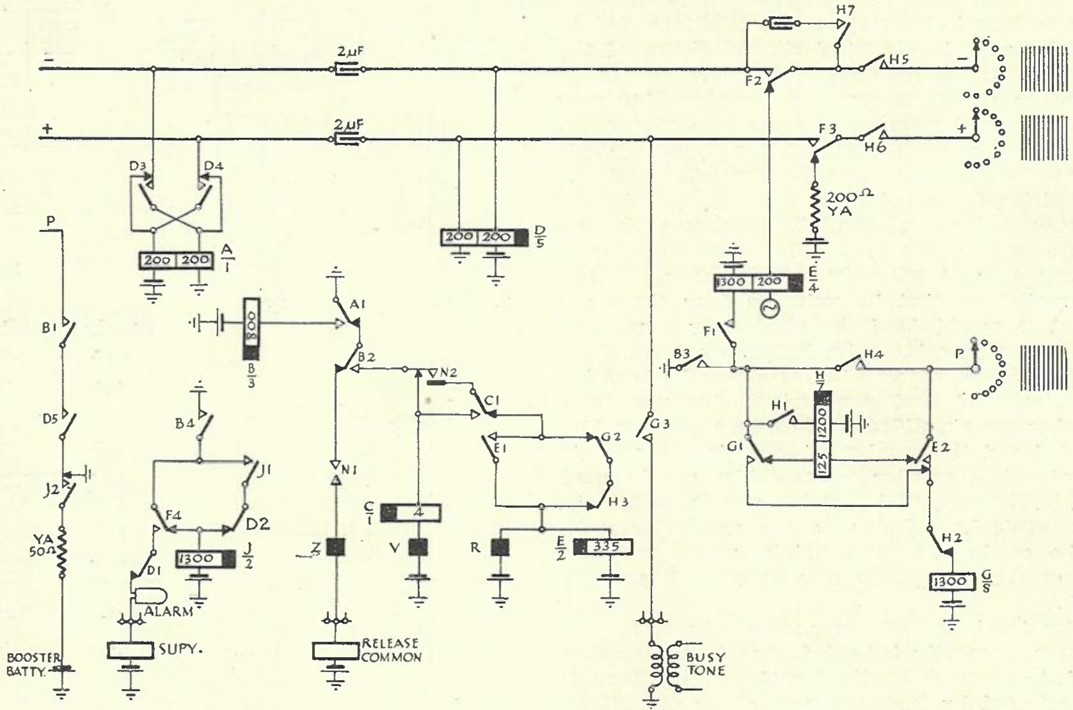


Fig. 2.

2. D relay must not be slugged, as it would be low impedance to speech currents, and battery feed relays must be high impedance.

3. The booster battery is reversed. In order to get the high voltage across the register it is necessary to

connect the positive pole to the P wire and negative to earth.

4. There should be a common shown on the booster battery lead, as such battery will not be individual to each switch.

5. There should be an earth normally made at contact D5 and this contact should be make before break. When B operates, the closing of contact B 1 applies an earth to the P wire from the back of contact D 5, and when D operates the make before break ensures that the P wire is continously earthed.

**Q. 5.—For an automatic exchange of ultimate capacity 5,000 lines, the following data is given:—**

**Traffic—**

| | |
|---|---|
| **Local 5 digit calling** | **30A** |
| **To other main exchanges trunked from 1st selectors via junction finders** | **120A** |
| **To a branch exchange from second selectors via junction finders** | **10A** |
| **Incoming to second selectors** | **140A** |

**Busy Hour—**

**Ratio busy hour to daily traffic .... 1 : 8**

**Battery Consumption, per switch per traffic unit, A.**

| | |
|---|---|
| **Preselector** | **.113830** |
| **1st Selector** | **.032410** |
| **2nd Selector** | **.032410** |
| **3rd Selector** | **.032410** |
| **Final Selector** | **.325846** |
| **Repeater Auto-auto** | **.263469** |
| **Junction Finder** | **.110080** |
| **Preselector B.C.O.R.** | **.04** |

**Battery Consumption (General).**

**Magnet operating, 2.5 A.H. per 100 lines per day**

**Ringing machines and miscellaneous total per day of 24 hours .... 336 A.H.**

**Emergency margin, 10 per cent.**

**(a) Derive the 24-hour load. Show your working.**

**(b) State the ultimate capacity of battery tanks to provide 2 sets of batteries, each set to carry the exchange for 12 hours.**

**(c) Determine the cross sectional area of the charge and discharge leads at the usual current rating which you are to state.**

**A.**—The details of the computation of the battery consumption basis on the traffic data are given in Table I.

| | |
|---|---|
| From this the traffic consumption for 24 hours | 1,164 |
| Magnet operating 2.5 × 50 | 125 |
| Ringing machines and miscellaneous | 336 |
| | 1,625 |
| 10 per cent. emergency | 162 |
| Total 24-hour load | 1,787 |

(b) Capacity of battery tanks $\frac{1{,}787}{2} = 893.5$ — say, 900 A.H. capacity.

(c) The combined output of the generators should be $\frac{1787}{8} = 223$ amps—say, 225 amps.

The charging cables will ultimately be required to carry 225 amps. The current rating is 1,000 amps. per square inch. The cross-sectional area will be $\frac{225}{1000} = 0.225$ square inch.

Discharge cables to be capable of taking the ultimate peak load at a rate of 500 amps/square inch. Peak load obtained from Busy Hour load with allowance in this case—15 per cent.

| | |
|---|---|
| Busy Hour load | 225 amps. |
| Allowance for peaks (15 per cent.) | 33.75 amps. |
| Peak Load | 258.75 |

Cross-sect. area at 500 amps/sq. in. $= \frac{258.75}{500} = 0.5175$

**TABLE I.**

| | Battery Consumption | Local Call | Call to Main Exchange | Call to Branch Exchange | Incoming Calls |
|---|---|---|---|---|---|
| Preselector | .113830 | .113830 | .113830 | .113830 | — |
| First selector | .032410 | .032410 | .032410 | .032410 | — |
| Second selector | .032410 | .032410 | — | .032410 | .032410 |
| Third selector | .032410 | .032410 | — | — | .032410 |
| Final selector | .325846 | .325846 | — | — | .325846 |
| Auto. to auto. repeater | .263469 | — | .263469 | .263469 | — |
| Junction finder | .110080 | — | .110080 | .110080 | — |
| Preselector B.C.O.R. | .04 | .04 | — | — | .04 |
| Additions | — | .576906 | .519789 | .552199 | .430666 |
| Traffic units | — | 30 | 120 | 10 | 140 |
| Product | — | 17.30718 | 62.37468 | 5.522 | 60.29324 |

| | |
|---|---|
| Total amps. per busy hour | 145.497 |
| Ratio of daily to busy hour calls | 8 : 1 |
| A.H. per 24 hours | 1,163.976 |

(To be continued.)

## EXAMINATION 2050.—LINE CONSTRUCTION.

*C. J. GRIFFITHS, M.E.E., A.M.I E.E.*

**Q. 1.—Frequent interruptions have been occurring on a trunk route during the winter months, principally due to broken wires. Discuss briefly the conditions likely to cause such troubles, state the points to which you would pay particular attention whilst inspecting the route and set out the corrective measures you would apply.**

A.—The initial step is to analyse fault records over as extensive a period as possible, particular attention being paid to—

(1) Section of route concerned.
(2) Date of occurrence.
(3) Size of wire.
(4) Location.

(1) By plotting the faults on a plan of the route it may be found that one particular section gives rise to most of the trouble experienced. This may be due to faulty construction, severe exposure to wind or a section of very poor holding ground.

(2) An examination of the date of occurrence of the faults will indicate whether the failures occur regularly throughout the winter months or at each cold spell. The proportional increase during the winter months over the remainder of the year will also be indicated. Occurrence of the failures principally during the winter months suggests attention particularly to—

Over-tensioning of wires.
Wires incorrectly tied and terminated.
Burnt soldered joints and overheating of wire.
Irregular regulation of the wires.
Faulty joints and damaged wire.

The increased strain arising from the contraction of the wires is associated with the decreased stress limit due to one or more of the above factors. Depending upon the geographical location of the route, the severity of winter conditions, including the presence of snow and ice, will have an important bearing on the analysis.

(3) Due to the lower tensile strength and smaller diameter, failures on 100 lb. per mile wire are normally more extensive than on 200 lb. per mile. A higher proportion of failures on the 200 lb. wires indicates a condition existing mainly on the latter. Such conditions might be associated with over-tensioning, faulty terminations, secondhand wire, re-transpositioning work which has introduced additional joints, particular types of transpositions, etc., as distinct from poor staying condition, pole marching, etc., which generally affects all wires similarly.

(4) A knowledge of the location of the fault will assist considerably in subsequently determining the exact nature of the cause. A full fault record should also show whether the fault occurred at a sleeve, at an insulator tie, at a termination, at the centre of a span, adjacent to the pole or at a transposition.

During the actual inspection the points to which particular attention should be paid are:—

(1) The condition of the poles, whether wood or steel beam, and length of spans. Poles may be marching due to poor holding nature of ground, whilst excessive spans make it difficult to provide stable route conditions. Grading of wires.

(2) The extent of the staying, with particular attention to exposure of the line to prevailing winds.

(3) The condition of the arms, whether braces or combiners are providing sufficient rigidity. Movement of the arms will be extended to the insulators with consequent breaking of the wires.

(4) Cracked insulators leading to abrasion of the line wire.

(5) Wire conditions. As the exact reason for the breaking of a wire is not generally apparent from superficial observation, particular care must be taken with the examination of the wires. This examination must not be restricted to ground observation, but must cover climbing of the poles, examination of broken ends under a microscope and other necessary laboratory tests. Summarised briefly, the more important points to be observed and checked are:—

(i) Correct sag, with adjustment for temperature.

(ii) Fitting of tapes and binding wire.

(iii) Effect of wind vibration. Wire which has been subject to fatigue and ageing has generally a lower tensile strength.

(iv) Sleeve incorrectly made—

(a) Twisted with ordinary pliers.
(b) Insufficient turns allowing wire to pull out.
(c) Too many turns, causing stressing of the wire.
(d) Sleeves bent.
(e) Incorrect size of sleeve.
(f) Sleeve gripped by clamps too close to end.
(g) Sleeve twisted from one end only.

(v) Wire damaged in transport or during erection.

Corrective measures to be applied.

(1) Ensure stability of pole route by adequate staying and reduction of excessive spans. Particular attention to be paid to angles.

(2) Provide grading of wires to prevent abrupt changes of direction.

(3) Properly brace and combine the arms to ensure even regulation of wire.

(4) Correctly tension all wires, slackening off stays where necessary.

(5) Re-run spans of wire in poor condition or containing poorly made joints.

(6) Provide for tree clearance (as far as practicable) where wires are broken due to flying branches.

(7) Consideration of improved methods of tieing wires and making joints.

**Q. 2.—Discuss briefly the conditions which are likely to cause electrolytic corrosion of underground cables. Describe the protective measures usually adopted and give the reasons for their effectiveness.**

**A.—Causes.**

The conditions likely to give rise to electrolytic corrosion of underground cables are:—

(1) D.C. Traction systems.
(2) A.C. Traction or Supply systems.
(3) "Galvanic" currents.
(4) D.C. Supply systems.
(5) Exchange currents.
(6) "Earth" currents.

(1) **D.C. Traction Systems.** This cause is by far the most important of the six listed. It is general practice to use the rail of the tramway or railway system as one conductor of the current supply to the traction motors. It is also general practice for the rail conductor (or uninsulated return) to be connected at the sub-station to the negative terminal of the generator. With a potential gradient along the uninsulated rail from the terminus to the sub-station portions of the return current take the parallel path through the earth. The adjacent cables pick-up current towards the terminus (cathodic areas) and discharge it at the sub-station (anodic areas). It follows that in the cathodic areas the cables are negative to the surrounding ground, and in the anodic areas, positive. In the anodic areas the lead of the cable sheath is disintegrated by the passage of the current.

(2) **A.C. Traction or Supply Systems.** The electrolysis effect of an alternating current is appreciably less than that of a direct current equivalent to the r.m.s. value. The percentage effect is less than 1 per cent., and its influence can normally be neglected.

(3) **"Galvanic" Currents.** This general designation includes the following causes:—

(a) Different metals forming a cell in the soil which acts as the electrolyte, e.g., lead and iron pipe.

(b) The same metal in soil (or electrolyte) of different concentration or characteristics, e.g., salty water and limestone conditions.

(c) Condition of stress between different parts of the lead sheath.

(d) Variation in oxygen concentration at different parts of the lead sheath.

(e) Local cells set up by impurities in the lead.

Such currents are normally steady in character, as contrasted with the rapidly fluctuating traction currents, and in general cause only a small proportion of the corrosion attributed to "electrolytic" causes.

(4) **D.C. Supply Systems.** Under the Statutory Regulations only one point on the supply system is permitted to be earthed; consequently any appreciable leakage represents a fault condition.

(5) **Exchange Currents.** For P.B.X. operation and certain conditions of signalling very small exchange currents may be present on the cable. This cause is negligible in comparison with (1).

(6) **"Earth" Currents.** The presence in the earth of current arising from—

(a) Terrestrial causes such as tidal friction, evaporation of sea water, etc.;

(b) Extra terrestrial causes such as sun spots, cosmic rays, etc.,

has also a negligible influence in comparison with (1).

**Protective Measures.**

The principal measures for minimising electrolytic corrosion are detailed below:—

(1) **Traction System.** The protective measures should pay attention to:—

(a) Adequate track maintenance.

Continuity of rail bonds—these should be tested at least once every 12 months.

Track leakage resistance—this should be as high as practicable, consistent with economic considerations and engineering construction methods. Involves strict attention to track construction and ballasting.

(b) Re-arrangement of loading and existing feeders to provide best operation conditions from a current leakage point of view.

(c) Provision of additional sub-stations and negative feeders.

(2) **Telephone Cable System.**

(a) The maintenance of good underground plant construction involving well-drained ducts and manholes, with the object of providing as high a contact resistance between the cable sheath and source of stray current as is economically practicable.

(b) The use of iron pipe—this conflicts to some extent with the provisions of paragraph (a). For the smaller sized cables iron pipe is an economical form of construction, and at the same time provides protection for the cable against stray current discharge.

(c) Zinc plates—to transfer the discharge of current from the cable to the plate—assisted by the high electro-chemical potential between lead and zinc.

(d) Insulating joints—are found suitable in only a small number of cases.

(e) Connections through of two discontinuous cable sheaths between which stray current is interchanging. Such work must, of course, be consistent with an economical cable distribution scheme.

(f) Armoured Cable. The use of such cable must also be consistent with an economical cable scheme.

(g) Boosted Drainage. Using an externally applied e.m.f. (battery or rectified A.C.), a cell is formed with the cable negative to an earth plate. The cable is then always in a "picking-up" and never in a discharging condition.

(3) **Drainage Bonding.** A drainage bond in its simplest form is a direct metallic connection from the cable sheath at its anodic points to the rail or negative feeders of the traction system. A metallic path for the stray current is provided in lieu of the path through the earth. To provide for the wide variation in conditions met with in practice, a number of different arrangements have been developed. The principal types are:—

(a) Directly connected to sub-station busbar with relay switch operating off main circuit breaker.

(b) Connected to rail or negative feeder through copper oxide rectifier (Fig. 1).

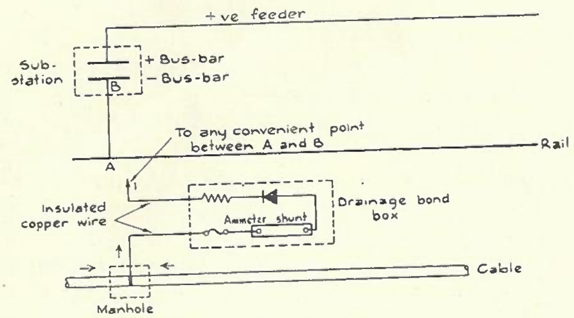


**Fig. 1.**

(c) Connected to rail or negative feeder through a reverse current relay.

(d) The booster type (Fig. 2).

Types (b) and (d) are the more general.

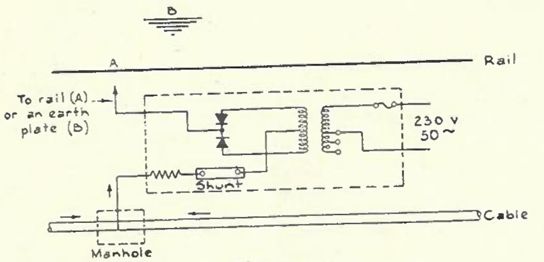


**Fig. 2.**

**Q. 3.—Describe the method you would adopt to test a subscriber's cable tapering from 800 pairs to 50 pairs in which 100 pairs have been reported faulty. State what instruments you would use and show how you would calculate the distance to the fault.**

**A.—Method of Test.**

(1) First obtain advice from the exchange giving full details of the services reported faulty, including the type of fault, time of occurrence, etc. With 100 pairs out of order the type of fault is likely to be either low I.R. or partly open circuit and partly short circuit.

(2) The details obtained should then be checked against cable plans, jointing records and multipling plans, and in this way an idea of the general location of the failure obtained. For example:—

(a) The combination of open circuit and short circuit on the 100 pairs will point to the fault being in the 100-pair section of the route.

(b) If tests show comparatively high resistance to earth fault may be in outer layers of a section greater than 100-pair capacity.

(c) If all the pairs are "flat out" the failure is more likely to be in the 100-pair section.

In case (b) it is important for a continual watch to be maintained on the behaviour of the other pairs in the cable.

(3) Simultaneously with the checking up of cable plans, etc., location tests should be carried out from the exchange to provide a check on the deduced location referred to in paragraph (2). The extent of the exchange tests will be determined by—

(a) The type of fault—open and short circuit or low I.R.

(b) The availability of "good" pairs in the faulty or other cables.

(c) The degree of accuracy with which the location has been deduced from cable plans, etc.

In many cases (c) is sufficient to enable the location testing to be transferred to a point closer to the fault with a consequently greater accuracy in locating.

(4) In the present instance the fault will be assumed to be due to low I.R. For this form of fault the Varley loop test, using the Wheatstone Bridge connections, is the most convenient. The bridge may be the ordinary type using a battery or the bridge megger —the latter is generally the more suitable for cable fault location.

**Instruments Used.**

The Varley loop test using the bridge megger will be described:—

Figs. 1 and 2 show the circuit conditions for the Varley test. The testing procedure is:

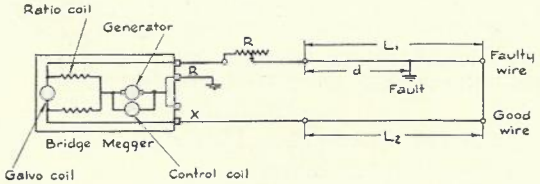


**Fig. 1.**

(a) Check accuracy of bridge megger by short-circuiting R terminals and X terminals. On turning handle, pointer should read infinity on scale.

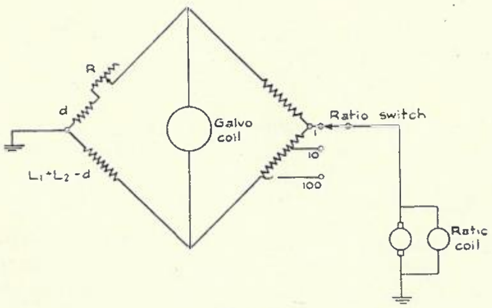


**Fig. 2.**

(b) Measure total resistance of loop of good and faulty wire by connecting Resistance box to R terminals and $L_1$ and $L_2$ to the X terminals. Let the value obtained be $(L_1 + L_2)$ ohms.

(c) Connect as in Fig. 1.

(d) Set ratio switch. Ratios of A/B = 1, 10 and 100 are provided. The unity ratio should be used for all normal measurements. For lines of low resistance the 10 or 100 ratio is used. For lines of high resistance the connection to the R and X terminals should be reversed and the 10 or 100 ratio used. As a general rule the same ratio should be used for the Varley Test as was found most suitable for the Loop Test.

(e) Set all resistance box dials to zero.

(f) Turn handle and raise R until pointer reads infinity on scale.

(g) The distance to the fault is obtained as follows:

$(R + d)/(L_1 + L_2 - d) = A/B$;
or if $A/B = 1$
$d = 1/2\ (L_1 + L_2 - R)$ expressed in ohms.

From a knowledge of the conductor resistances of wires involved in the test, d can be expressed as a distance.

**Method of Calculation.**

Assume that a good wire in a 20-lb. cable has been obtained for test. With the faulty and good wires looped at the far end the loop resistance measures:

$$L_1 + L_2 = 264 \text{ ohms.}$$

On the Varley test with ratio $A/B = 1$

$$R = 64 \text{ ohms;}$$

$$\text{then} = 1/2\ (264 - 64) = 100 \text{ ohms.}$$

Resistance of 10-lb. cable = 88 ohms per mile.

Distance to fault = 100/88 = 1.136 miles.

**Q. 4.—It is desired to make an economic study to determine the method to be adopted to provide additional trunk circuits between two towns.**

**There is an existing aerial route and consideration is to be given to the provision from time to time of additional aerial wires and to the alternative of providing an underground cable.**

**State what information you would require and show the manner in which you would make the economic comparison.**

**A.—The information required** can be divided broadly into the three headings:—

(1) Factors not directly associated with either method of circuit provision.
(2) Aerial route conditions.
(3) Underground cable conditions.

(1) Under this heading are:

(a) Traffic development—Telephone, Telegraph, Broadcasting.

(b) Any contemplated changes in operating conditions of circuits such as magneto signalling to dialling, including V.F. dialling.

(c) Changes in transmission conditions such as reduction of zone to zone limits to zero equivalent.

(d) Period over which comparison is to be considered. The period of 20 years is an arbitrary choice generally adopted as representing a limit beyond which the estimating of traffic development and methods of circuit provision becomes indefinite.

(2) For Aerial Route Conditions the important details required are:

(a) Age of pole route and whether reconstruction is essential.

(b) The cost of the reconstruction work and the period to which development will be provided. As far as practicable the method of provision should be outlined, namely—

Telephone = V.F. physical; V.F. phantom; Single channel carriers; Three channel carriers.
Telegraph = Physical wires; Composite; Cailho; Carrier.
Broadcast = Physical wires; Carrier.

Both capital and maintenance costs differ appreciably, depending upon whether wire circuits or superposed equipment are concerned.

(c) Estimated costs of providing for development on the basis of the information provided in (b).

(d) Maintenance costs on the aerial route and on the office equipment. These details are obtainable from costing records, due allowance being made for any variation in the present case from average conditions.

(e) Depreciation costs on the aerial route and office equipment obtained from records of the average life of the various items of plant, with allowance for obsolescence.

(f) Cost of dismantling aerial route and value of material which would be recovered.

(g) The cost of either additional aerial construction or underground cable to provide for the full 20-year period of development. For the purpose of the present comparison, aerial plant will be considered over the 20-year period.

(3) For Underground Cable Conditions the important details are:

(a) The capital cost of the cable, including installation, to provide for the 20-year development. This may be in one amount initially or in two amounts, one initially and the other at some stage between 8-14 years' development. To determine which arrangement is the more economical will require a separate examination apart from the main economic comparison. For the purpose of the latter, cable provision initially for the 20-year period has been assumed.

(b) Capital cost of loading and office equipment initially and at various stages of development.

(c) Capital cost of associated duct provision.

(d) Maintenance costs obtained from costing records.

(e) Depreciation costs from the estimated life of underground plant.

**Method of Making Economic Comparison.**

To illustrate the method, an example providing for the replacement of an existing aerial route by underground cable will be considered. An aerial route five miles long and carrying 20 wires 40 lb. C.C. is in need of reconstruction. The rate of development is two circuits per annum, and it is assumed that all circuits, both aerial and cable, are provided by physical wires. A further assumption is made that no financial provision has in the past been made for depreciation on the aerial plant.

## OMEGA SUBSCRIBERS' ROUTE.

## COMPARISON OF COSTS.

| Provision of Underground Cable. | | Retention of Aerial Route. | |
|---|---|---|---|
| **Capital Costs:** | | **Capital Costs:** | |
| **Cable,** 54 pair/10 lb., 5 miles at £300 | £1,500 | Value of existing aerial plant, 5 × 20 (wire miles) × £15 | £1,500 |
| **Conduit,** 1" dia. B.I. + manholes, 5 miles at £250 | 1,250 | **Provision for Development:** | |
| | | 20 wire miles per annum at £10 = £200; | |
| | | Present value over 20 years, £200 × 12.5 | 2,500 |
| TOTAL CAPITAL COSTS | £2,750 | TOTAL CAPITAL COSTS | £4,000 |
| **Annual Charges:** | | **Annual Charges:** | |
| Interest, 5 per cent. on £2,750 | £138 | Interest, 5 per cent. on £4,000 | £200 |
| Maintenance— | | Maintenance— | |
| **Cable,** 540 wire miles at 1/- | 27 | From now to 20th year, 100 wire miles at 20/- | 100 |
| **Conduit,** 5 miles at £2 | 10 | Development throughout 20 years, 20 wire miles per annum at 20/- (20 × 111 = £2,220). | |
| Depreciation— | | Depreciation— | |
| **Cable,** 25 years' life—£1,500 × .021 | 32 | Average life, 15 years—£4,000 × .046 | £184 |
| **Conduit,** 25 years' life—£1,250 × .021 | 26 | | |
| **Present Value of Annual Charges:** | | **Present Value of Annual Charges:** | |
| Interest, Maintenance, Depreciation—233 × 12.46 | £2,900 | Interest. 12.46 × 200 | £2,492 |
| Loss on demolished asset represented by existing aerial plant | 1,200 | Maintenance— | |
| Cost of demolition | 200 | From now to 20th year—12.46 × 100 | £1,246 |
| Total Present Value of Annual Charges | £4,300 | Development through 20 years—111 × 20 | 2,220 |
| Amount in favour of Underground Cable | £4,948 | Depreciation—12.46 × 184 | 2,290 |
| | | Reconstruction of existing route required immediately | 1,000 |
| | £9,248 | Total Present Value of Annual Charges | £9,248 |

(To be continued.)

ERRATUM: Journal No. 4, Page 177, Question 4, Fig. 1— In this figure the wires leading into the right-hand lessee's premises should be reversed.

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