The
Telecommunication Journal of Australia

No. 6 — Registered at the General Post Office, Melbourne, for transmission by post as a periodical. — DECEMBER, 1937

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THE POSTAL ELECTRICAL SOCIETY OF VICTORIA

The
Telecommunication Journal
of Australia

No. 6. DECEMBER, 1937

INTERCOMMUNICATION TELEPHONES. TYPES A5 AND A10

A. Brookes (Ericsson Telephones Ltd., Beeston, Nottingham, England).

Prior to the introduction of this system, the needs of small subscribers were met chiefly by cordless P.B.X's. or a cordless P.B.X. and an internal intercommunication system. From the viewpoint of a subscriber, both alternatives suffer from disadvantages which this system is designed to overcome.

Facilities:

A summary of the facilities offered follows:—

Local Intercommunication Calls:

(1) Direct calling between all internal extension stations on the system.
(2) No secrecy is provided on local intercommunication calls.
(3) An engaged test is given if the called extension is engaged on an exchange call.
(4) Direct calling of an external extension from all internal extensions.
(5) An external extension obtains connection to an internal extension via the main station. The main station requests the desired internal extension to call the external extension, i.e., the call is reverted.
(6) Conference facilities—i.e., facilities for speaking from any station to all or any number of stations on the system simultaneously are provided.

Exchange Calls:

(1) Direct connection from any internal extension to the public exchange system over any exchange line connected to the installation.
(2) Direct outgoing exchange calls may be barred to chosen extensions. These extensions may originate exchange calls via the main station at the discretion of the main station operator.
(3) Connection (via the main station) of an external extension to the public exchange system over any exchange line connected to the installation.
(4) Incoming exchange calls may be answered at any predetermined station. This extension is known as the main station, and is provided with special unit equipment. Arrangements can be made also for equipping any one of the internal extensions as a second choice main station. On such installations the functions of the first choice main station can be transferred to the second choice main station when desired by the operation of a key or keys at the first choice main station. As an alternative to the second choice main station any internal extension with full facilities may be equipped with an extension bell or bells to enable incoming exchange or external extension calls to be answered at this point.
(5) An incoming or originated exchange call (with the exception of directly dialled calls originated by the external extension) may be transferred from any station to any other station connected to the installation without breaking down the exchange connection. On installations with two exchange lines, an internal extension may hold a call on one exchange line while transferring a call incoming on the second exchange line. If an exchange call is to be transferred to an internal extension which is barred exchange facilities or to an external extension the transfer must be carried out indirectly, i.e., via the main station.
(6) Any internal extension may hold an exchange call whilst making a call with any other station on the system. While the exchange line is being held the outside subscriber is unable to overhear the conversation between the station to which he is connected and the party called by the same station. Also, on installations with two exchange lines any station not barred exchange facilities may hold one exchange line whilst making a call on the second line.
(7) On engaged exchange lines, an audible test is given on pressing the exchange line button. It is unnecessary to remove the handset from rest while making this test—the test is operative whether the handset is lifted or not.
(8) Secrecy is given on exchange connections. Monitoring facilities may be allowed at main stations or any of the internal extensions if desired.

As constant mention will later be made of the fundamental parts constituting the system, a general definition of such equipment is desirable.

An Internal Extension Station is any station served by the standard intercom. telephone instrument having the full complement of local and exchange push keys.

A Main Station is an internal extension station specially predetermined and allocated to handle the incoming and in certain cases the outgoing exchange traffic. In normal circumstances only one such main station is desired per installation, but (as on P.B.X. working) provision is made for extending night service to other extensions by means of a second master station. It is thus possible to transfer at will the supervision and distribution of exchange calls to this "second choice main station." The main stations have in addition to the standard instrument an Auxiliary Apparatus Unit in which is housed the necessary exchange line and transfer equipment, together with an audible alarm.

An External Extension Station is a station equipped with a standard C.B. or auto telephone and is connected to the main cabling by means of a 2-wire cable. This station can be rung by all instruments but can only make calls to internal extensions via the main station, at which special auxiliary apparatus is fitted according to the number and type of lines equipped. This facility of incorporating an external extension is of great value since it affords a means of communication to a point some distance from the main installation where the cost of installing standard multiple cable would be unduly expensive.

The equipment is available in two sizes for accommodating:—

(a) One exchange line and five internal stations (A5) system.

(b) Two exchange lines and ten internal stations (A10) system.

While these will normally cater for the usual requirements, in exceptional cases the provision of a sixth station on a five line system, or an eleventh station on a ten line system is desirable. This is accommodated by utilising the "home" button on each instrument for calling the additional station. On either size of installation one external extension station may be fitted in lieu of an internal extension.

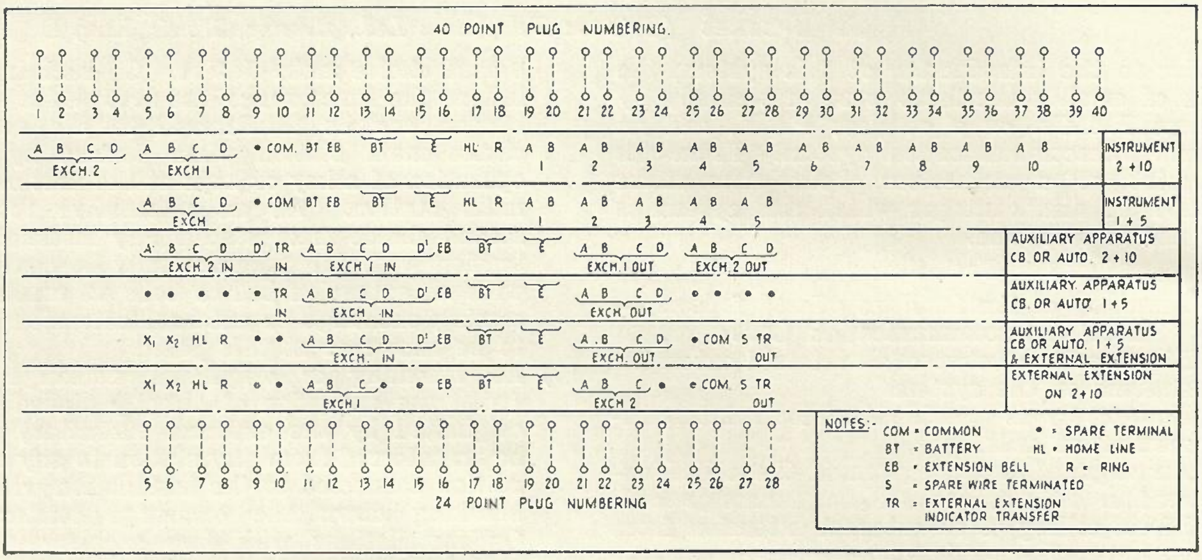

Fig. 1—Connections of Plugs and Jacks of the Instruments and Auxiliary Units.

In order to facilitate initial installation and subsequent maintenance, both the instruments and units are equipped with plugs and cords, the incoming cables being terminated on jacks.

Fig. 2—The A10 Instrument.

The jacks are standardised so that it is possible to plug in the smaller equipped instrument into an installation wired for a capacity of 2 exchange lines and 10 extensions. Similarly if it is desired to add an external extension at any point, the appropriate auxiliary unit may be jacked in to replace the standard exchange line auxiliary unit. This interchangeability can readily be appreciated by reference to figure 1 showing the plug point connections.

Extension bells wired from the jacks may be provided. This provision, for extending the exchange line or external extension alarm bell, enables incoming calls to be answered at other points should the main station operator be absent. On installations having two exchange lines a common alarm bell serves both exchange indicators, so that when the alarm circuit is extended it becomes necessary to test both lines at the normal internal extension. A similar test is necessary when the main station unit caters for one exchange line and one external extension.

The A 10 size Instrument consists of the push-button mechanism enclosed in a moulded bakelite case as shown in figure 2, the exchange keys numbered 1 and 2 being coloured red and the local keys 1 to 10 black. The mechanical arrangement of the key movement is such that under normal circumstances the depression of any key automatically restores any previously operated local key. If an exchange key is in the operated position the depression of a second exchange or local key will partially restore the first exchange key which takes up the "hold" position leaving a 600Ω hold coil across the exchange line. A special green conference key is included which renders the normal tripping mechanism inoperative when it is desired to set up a conference call. Two special triggers are provided above the exchange buttons on the (A 10) instruments in order to allow the complete release of either exchange button when "holding" both exchange lines. The necessity of such a provision becomes apparent when it is realised that the whole of the exchange key spring-set can otherwise only be restored to normal by replacing the handset. Should both exchange lines be in use the result of replacing the handset would be to clear both exchange lines, hence the provision of individual releasing triggers. Slip-in paper labels are provided at the side of the keys for designation purposes. A diversion from the standard practice has been made in mounting the buzzer externally on the instrument plug. This allows any adjustments to be carried out without interfering with the casework of the instrument. A standard size of case is used for both the 5 and 10 line instruments.

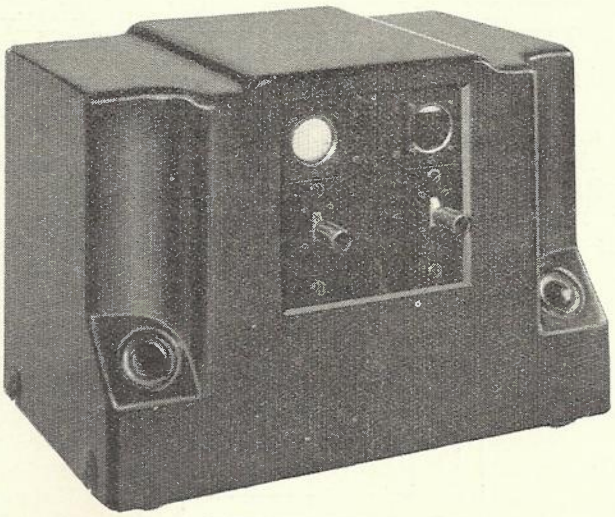

Fig. 3—A Typical Auxiliary Unit.

The A5 telephone Intercom. No. 1 is similar to the A 10, but equipped with keys for 1 exchange and 5 extension lines only.

The special auxiliary or transfer units are also housed in a standard bakelite case as in figure 3, the equipment varying according to the particular use of the unit.

Unit, Transfer, Intercom. No. 1 is used on 1st and 2nd choice main stations on systems having one exchange line and up to 10 extensions, but not an external extension station. They may however be used on 2nd choice master stations, on an installation which includes one external extension, by the addition of a standard eyeball indicator in place of the dummy normally fitted.

Unit, Transfer, Intercom. No. 1A caters for the first choice main stations on installations having one exchange line, one external extension and up to 4 internal extensions.

Unit, Transfer, Intercom. No. 2 is for use as a first or second choice unit on installations having 2 exchange lines and 10 internal extensions. They may also be modified by the addition of a standard eyeball indicator for use as second choice main stations when an external extension is incorporated in the system.

Unit, Transfer, Intercom. No. 3 is purely an external extension unit for use in conjunction with Unit, Transfer, Intercom. No. 2, for 1st choice main station working on systems having 2 exchange lines, 1 external extension and 9 internal extensions; or in conjunction with unit, Transfer, Intercom. No. 1, when more than 5 internal extensions are required on a system including one exchange line and one external extension.

Owing to the comparatively small number of standardized units, minor modifications become necessary when certain of the special facilities are desired at any particular station. This has been catered for in so simplified a form that modifications can readily be carried out on site to suit any particular requirement.

Units, Transfer Intercom. Nos. 1 and 2 are fitted with a "dummy indicator" which is replaced by the standard indicator when required for external extensions. Provision has been made in the local cable form for this additional indicator which should be wired as shown in figure 4.

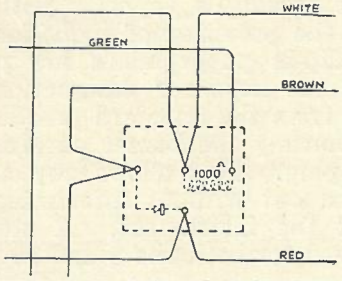

Fig. 4—Wiring for External Extension Indicator.

When a second choice main station is fitted, the exchange lines and the external extension indicator circuit can be transferred to this station, by throwing the appropriate keys of the first choice main station auxiliary unit or units. To provide for this facility it is necessary to remove the strap connections on the first choice units, as detailed in the following table:—

UNIT.	Straps to be Removed.
Transfer Unit No. 1	T_1 T_2 T_3 T_4
,, ,, No. 1A	T_1 T_2 T_3 T_4 T_5
,, ,, No. 2	{Exch. 1. $T_1T_2T_3T_4$} {Exch. 2. $T_1T_2T_3T_4$}
,, ,, No. 3	T_1

These straps are clearly shown in figure 5, which illustrate the terminal block of a transfer

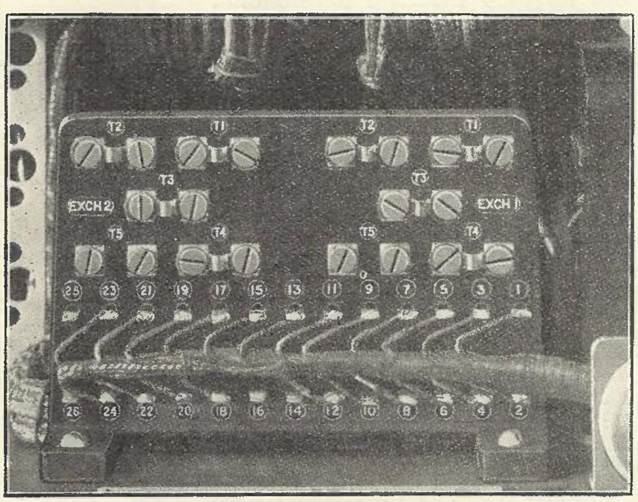

Fig. 5—Transfer Unit (No. 2) Terminal Block.

unit with 2 exchange lines. Certain of the transfer unit key labels which are engraved both sides should also be reversed to indicate the transfer position.

While one of the main features of the system is that all exchange calls are normally secret, it may be desirable and advantageous for one or more instruments to have monitory or supervisory facilities: e.g., for trunk offering pur-

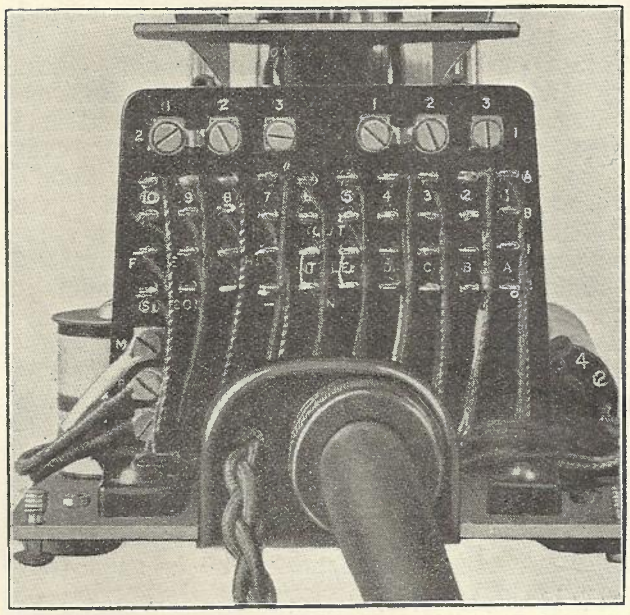

Fig. 6—Terminal Block of an AIO Instrument.

poses. Straps are provided on the terminal block of each instrument as shown in figure 6. When supervision facilities are required strap 1-2 is removed and strap 2-3 substituted. This permits the operation of the exchange line instrument relay over a local circuit irrespective of the condition of the exchange line. Normally this relay can only operate and access be obtained to an exchange line, when the exchange line is disengaged.

An automatic dial is normally supplied with each instrument for automatic working, but should automatic facilities not be required at the outset, the dial can be omitted and supplied as and when required. The dial can be

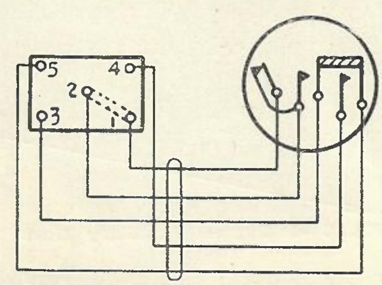

Fig. 7—Cord Connections when a Dial is fitted. Strap 1-2 removed.

connected on site by means of a flexible cord as shown in figure 7.

At this stage, it might be mentioned that for the present, it is not proposed to install these telephones in magneto areas.

In common with the instruments and units, special type junction boxes have been designed, giving excellent facilities for cross connecting the various cables. These boxes are made up in two sizes, 30-way and 48-way, the former being used throughout the five line system and also as an auxiliary box when required on the ten line system, which is normally served by the larger size. The pleasing external appearance of the moulded bakelite cases is shown in figures 8 and 9. Provision for the termination of four multiple cables is provided and the lids of the boxes have thin bakelite "break-ins" which may readily be removed to permit the entry of the cable at either end of the box. A further deviation from standard multiple boxes of the past has been incorporated, in that the cables are terminated on individual terminal strips and the necessary commoning done by means of special square-section bare wire supplied with the boxes. When jumper connections are required they are carried out in switchboard wire, a typical example of a completed box being shown in figure 8. Each of the four terminal strips may be individually removed from the moulded base and if desired the cable can be connected to the underside prior to being cleated down. Cable bonding clamps on the underside of the strips are connected by means of the bonding strip (figure 8 and 9) on the upper side, and where the cables are led in at opposite ends of the box the two bonding strips should be connected by suitable switchboard wire. Three point fixing of the base plate is standardized and together with the three rubber feet allows the mounting of the box on uneven surfaces without any undue strain on the bakelite moulding. Separate cellastoid labels are supplied as required for designating the various cables.

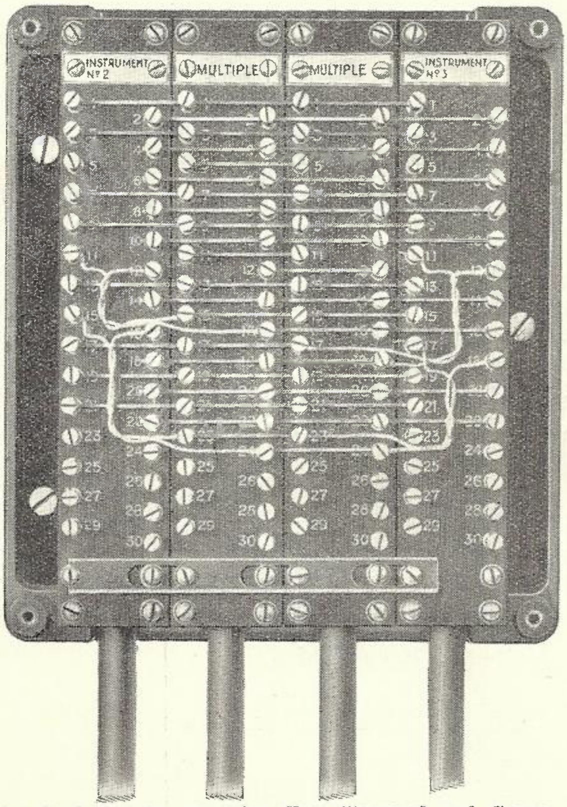

Fig. 8—A 30-way Junction Box Strapped and Cross-connected for Instruments Nos. 2 and 3 in Fig. 12. See also Fig. 13.

Cable, switchboard L/C. 12 pr. 10 enam. is used for installations using Telephone, Intercom. No. 1 and for connection between the Unit Jacks and Junction Box on installations using Telephone Intercom. No. 2. For multiple and instrument wiring for installations using Telephone, Intercom. No. 2, cable switchboard, L/C 20 pr. 10 enam. is required. When the smaller size cable is led into the larger size box it is necessary to pack the cable with a thin lead strip in order to obtain a satisfactory bonding grip.

The layout of an installation will naturally depend to a great extent on the particular design of the establishment, and this should be given careful consideration with a view to obtaining the most economical cable runs, etc. If a system is not fully equipped in the first instance, provision should be made for extending the multiple to further junction boxes. Two typical layouts for 5 and 10-line systems are shown in figures 10 and 11.

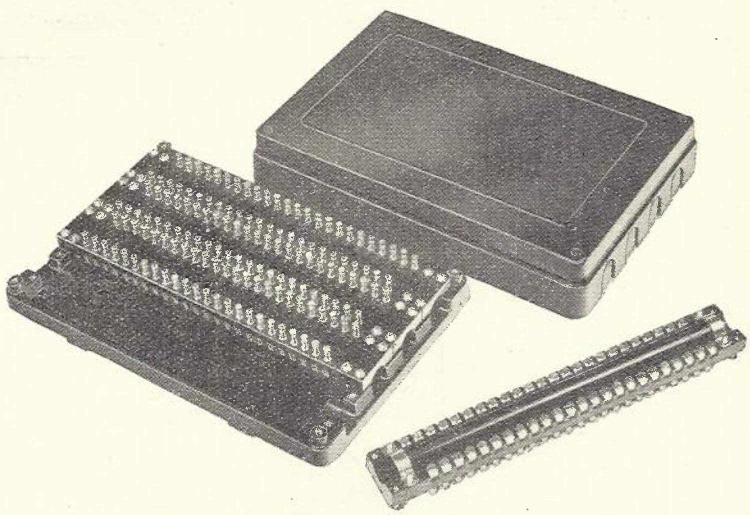

Fig. 9—A 48-way Junction Box with Cover and One Strip removed.

In order to illustrate how the details necessary for the cross connections of the junction boxes are obtained, a pictorial diagram of a 5-line system comprising 5 internal extensions and 1 external extension (No. 5) is given in figure 12, the junction boxes being designated with the figure numbers described hereafter. Figure 13 shows in detail the cross connections necessary to serve instruments Nos. 2 and 3 (see also figure 8). In both cases terminals Nos. 11 and 12 (HL and R) on the instrument strips are connected to the multiple pairs corresponding to these particular instruments, i.e. No. 2 to 15 and 16, and No. 3 to 17 and 18. Thus it can be seen that on a normal 5 and 10-line installation the A and B terminals on the instrument strip, corresponding to the station's own number, would be disconnected from the main cabling. When a 6th or 11th station is fitted this particular pair of terminals is connected by switchboard wire to the 12th or 20th pair of the multiple cable, and the terminal strip serving the additional station has its HL and R terminals (Nos. 11 and 12) strapped to the 12th or 20th pair as shown in figure 14. The main station junction box is represented by figure 15. In addition to the multiple and instrument cables this box feeds the auxiliary unit and, if desired, a second choice master station auxiliary unit as shown dotted in figure 12. An external extension is included in the layout in lieu of No. 5 internal station and is connected to terminals 29 and 30 of the auxiliary unit strip. The HL and R of this auxiliary unit (terminals Nos. 11 and 12) are strap connected to No. 5 pair of the multiple cable. Normally an internal extension is rung by the application of an earth to the 'B' line at the calling station, thus operating the D.C. buzzer of the instrument. In the case of the external extension, which is fitted with a polarized bell, it is necessary to convert the application of the earth into a suitable ringing current. This is done by the external apparatus unit which, as far as the cross connecting for HL and R is concerned, becomes equivalent to No. 5 instrument. The exchange line is also terminated on the main junction box.

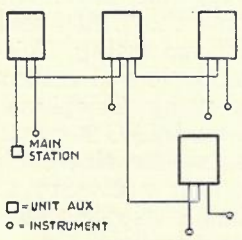

Fig. 10—Typical Layout of a 5-line System.

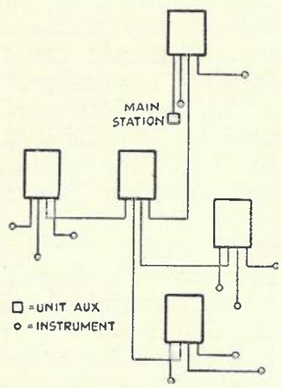

Fig. 11—Typical Layout of a 10-line System.

When certain special facilities are required at any particular station, modifications are made to the junction box strappings.

Any station may be "barred direct access" to the exchange lines (except at the discretion of the master station) by a modification of the strap connections on the junction box serving the multiple to the barred station. By reference to the instrument circuit figure 16 it will be seen that the operation of the instrument line relay depends upon an earth being supplied over the D wire. To prevent the operation of this relay in order to bar direct access to the exchange line, it is only necessary to remove the earth from the "D" line of the particular instrument in question. The 'D' line of the instrument is strapped on the junction box to the 'D₁" line, to which an earth may be applied

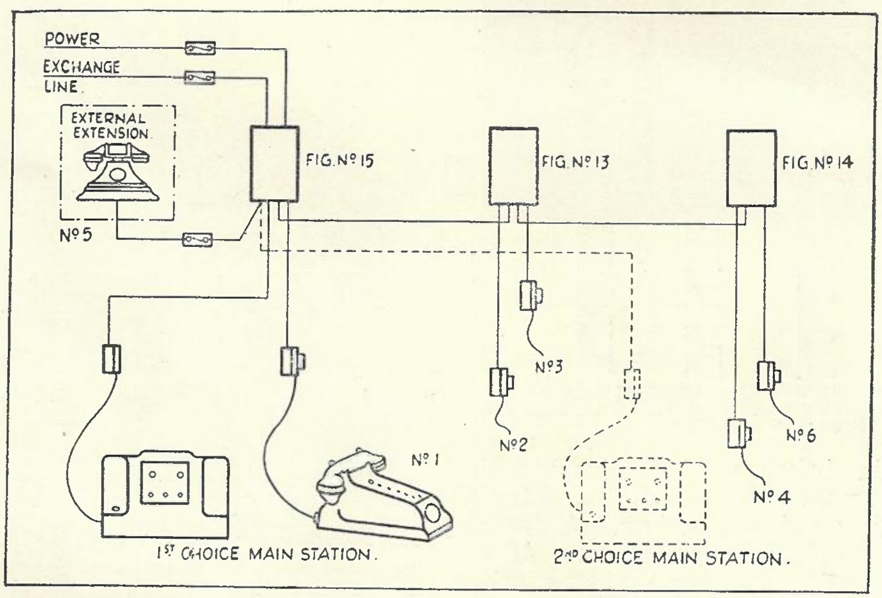

Fig. 12—Pictorial Diagram of a 5-line System with One External Extension.

at the discretion of the main station by depressing the push button provided on the main station auxiliary unit. This junction box connection is shown in figure 17.

When it is desired to completely bar a station from the exchange service the multiple wires C, D and D_1 are not cross connected to the multiple strip and the C wire of the instrument is permanently strapped to earth as shown in figure 18. This has the effect of giving the normal engaged signal if the exchange button is pressed in error. A similar earth strap is required on the second exchange line 'C' wire on an AIO system when only one exchange line is connected to the system.

The cross connecting of an AIO system follows the same principle as that of the 5-line, except that, at the main station it may be necessary to fit a 30-way auxiliary junction box in addition to the 48-way main box, owing to the number of cables to be accommodated. Such a case is illustrated in figure 19 where two auxiliary apparatus units are required in addition to the instrument. It will be noticed that the instrument cable is taken from the main box and the units from the auxiliary

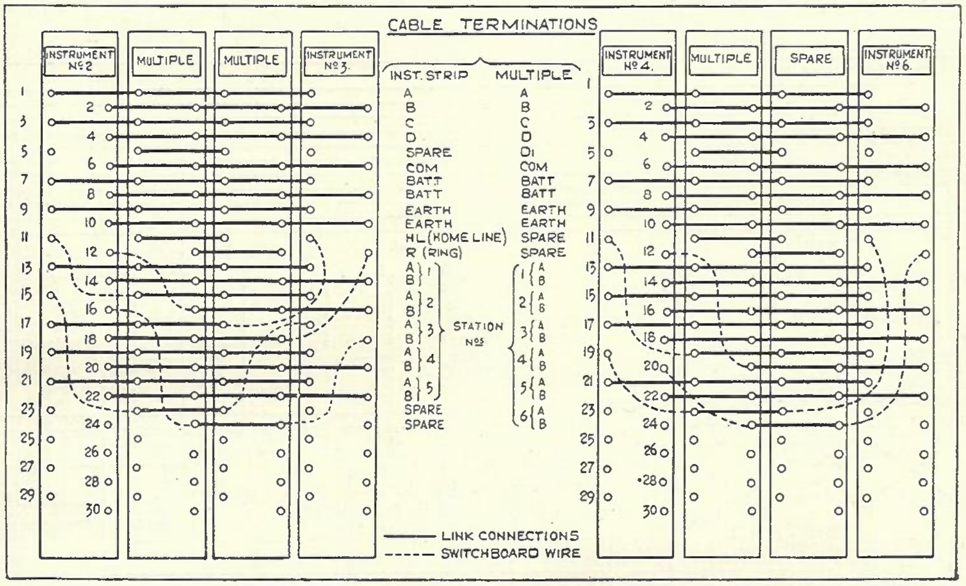

Fig. 13—Commoning of Terminal Block for Instruments 2 and 3 in Fig. 12. See also Fig. 8.

Fig. 14—Commoning of Terminal Block for Instruments 4 and 6 in Fig. 12.

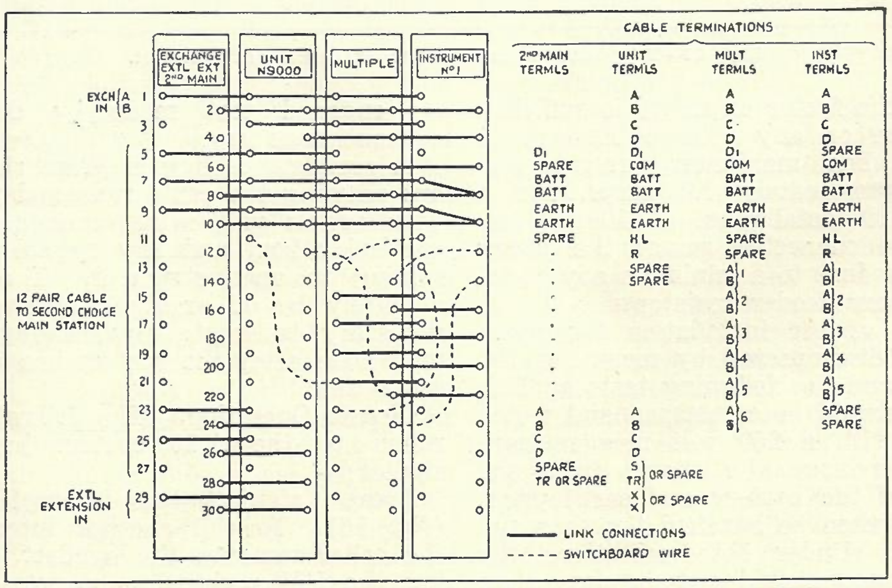

Fig. 15—Commoning of Terminal Block for the Main Station in Fig. 12.

box. By this method the smaller type box can be used and connected by means of a 12-pair cable, the necessary cross connections being as shown in figure 20.

The power is normally obtained over a power lead from the public exchange but where this is not available a battery of primary cells or a trickle-charged accumulator set may be employed. The system is designed to operate

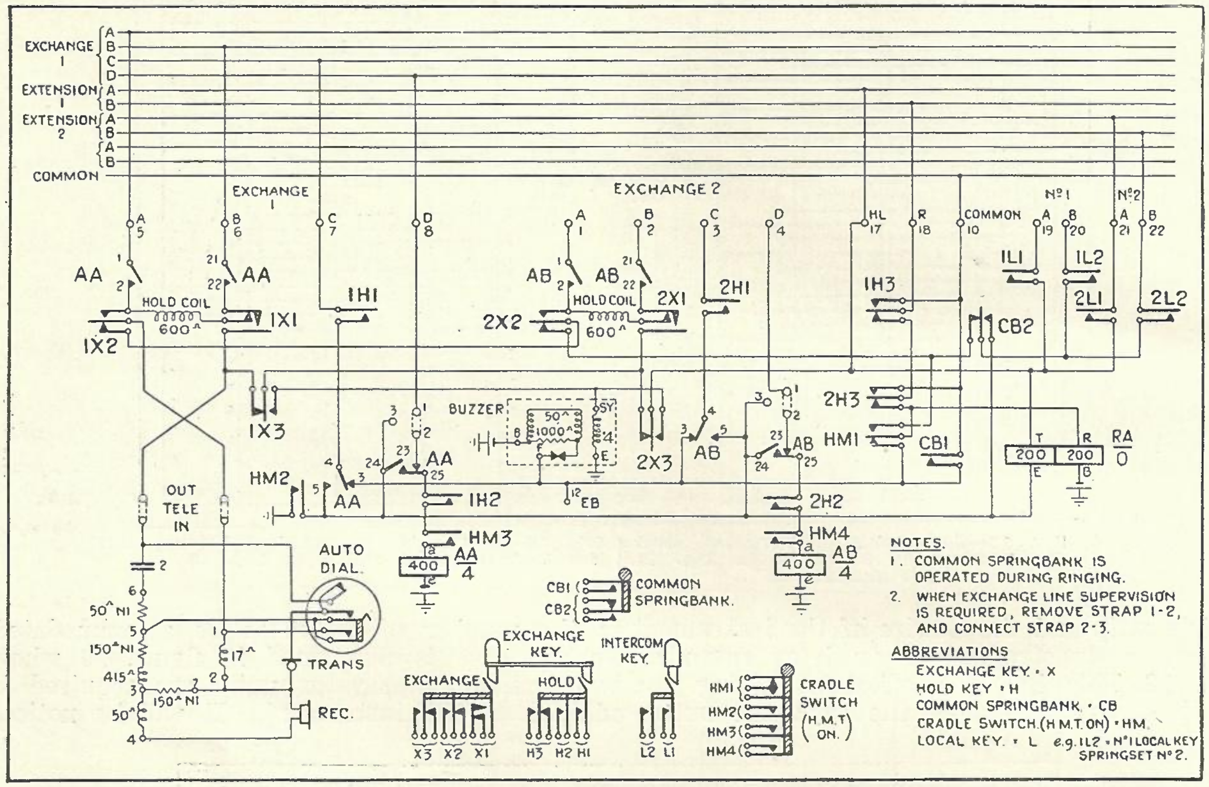

Fig. 16—Telephone Intercom. (No. 2). Schematic Circuit.

on 24 volts but the factor of safety is sufficient to permit its use on any voltage between 18 and 28 volts. The maximum current consumption is approximately 1.3 amps. for a fully equipped AIO installation. A 10 mF condenser should be connected across the power lead in order to reduce to a minimum any cross-talk due to battery feeder resistance.

On completion of the installation the apparatus should be disconnected by means of the plugs and jacks and the following tests applied. All the A lines should be commoned and tested to the B lines with a 250 volt megger, care being taken to remove the straps from the A and B lines of the battery and earth pairs. The pairs should then be bunched together and tested to earth. Under both conditions the insulation resistance should not be less than 1 megohm. Continuity of the cables should be tested and also the efficiency of the bonding clamps to earth.

After jacking in the apparatus the following tests should be made at each instrument:—

(1) An exchange call to be made on each exchange line at each station.
(2) A local call to be made to each station on the system.
(3) A conference call to be made to include all instruments.
(4) The exchange lines to be 'busied' and an engaged test made by depressing each exchange key.

A complete cabling diagram should be drawn out showing the cable runs and junction boxes, with details of the instruments fed from each particular box, and any special feature appertaining to an instrument. The diagram will definitely be of great assistance should it be necessary to locate any cabling faults which may arise after the system has been in service some time.

Circuit Operation. The following description refers to the A 10 system but the A 5 is similar:—

Local Call between Internal Extensions.—(fig. 16). To call another internal extension, the caller removes the handset, thereby allowing the HM springs to operate, and fully depresses the local key adjacent to the number of the required extension. Springs CB and L are thereby operated. Earth is extended via

HM2, CB2 and the appropriate L2 springs to the B-line of the called extension. HM1 and HM2 prepare a circuit for the transmission bridge. CB1 extends the buzzer to the common wire. HM3 and HM4 have no function at this stage.

If the called extension is free, the earth placed on the B-line is extended to the R-wire of the called extension circuit and thence via 1H3, 2H3, HM1 and the buzzer to battery. (Note:—At each instrument the A and B common wires in the multiple cable are jumpered to

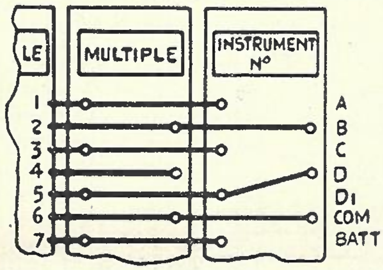

Fig. 17—Connections of Instrument Terminal Strip to Bar Direct Access to Exchange Lines.

the HL and R terminals respectively). The called extension's buzzer is actuated for the period during which the caller has the appropriate local button fully depressed.

The called extension answers by removing the handset from its rest. The HM springs then operate and the telephone circuit is connected to the HL and R wires via 1X3, 2X3, and 1X2, 2X2, HM1, 2H3 and 1H3 respectively. Battery and earth are fed to the line through the transmission bridge RA.

When the caller's finger is removed from the local key, the latter partially restores to the "speaking" position. The L springs remain operated in this position, but the common spring bank CB is released. The telephone circuit and the transmission bridge are connected to the A- and B-lines via the appropriate L1 and L2 springs and so to the called extension's telephone. Transmission bridges, consisting of battery and earth fed through the two 200-ohm coils of the retardation coil RA, are provided at both stations on this type of call.

If the called extension is engaged on a call to another extension, the earth on the R-wire incoming from the calling extension will not operate the buzzer at the called extension as the buzzer circuit is disconnected at HM1. When the local key on the calling extension's telephone set restores to the "speaking" position however, the telephone circuit is connected to the A- and B-wires. A caller is thus able to break into a connexion between the two other extensions.

If the called extension is engaged on an exchange call, the hold (H) springs on the appropriate exchange key will be operated and, at 1H3 or 2H3, the R-wire will be connected to the common. When the caller fully depresses the appropriate local key, the earth placed on the R-wire of the called extension is extended to the common. This earth is returned to the calling extension on the common wire and operates the caller's buzzer via CB1. This serves as an engaged signal indicating that the distant extension is engaged on an exchange call.

At the termination of a call both extensions replace their handsets on the rests, which action

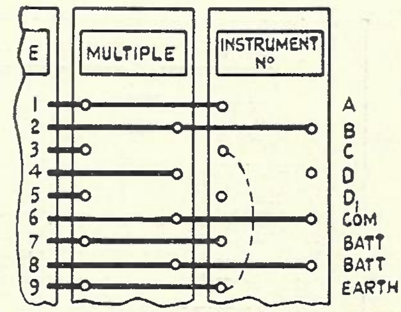

Fig. 18—Connections of Instrument Terminal Strip to Totally Bar Exchange Service.

mechanically restores all operated keys to normal.

Internal Extension Calling External Extension.—(Fig. 21). When the calling extension removes the handset from its rest, and fully depresses the appropriate local key, an earth is extended to the B-line. This earth is received on the R-wire of the external extension circuit and thence via 2X4, 1X4, L2, BZ3y, coil of relay BZ to battery, with a parallel circuit via coil of relay H to battery. Relays H and BZ operate. H1 short-circuits the 2 mF condenser and relay Q, while H2 and H3 prepare for the extension of the A- and B-lines. H4 disconnects the external extension calling indicator.

Ringing current is placed on the external extension line in the following manner. Relay BZ in operating, breaks its own circuit at BZ3y and, consequently, releases after its slow-release period, whereupon it immediately commences to reoperate. Relay BZ thus alternately operates and releases during the time that the local key at the calling extension is fully depressed. The contacts of relay BZ make and break with a frequency of approximately 16-20 per second, and the resultant reversals of potential sent to line via BZ1 and BZ2 ring the magneto bell at the external extension station. The path of the current with relay BZ operated is: earth, YA, BZ1, coil of relay L, 2X2, 1X2, H1 to X2 (B-line); battery, YB, BZ2, coil of relay L, 2X1 and 1X1 to X1 (A-line). During the ringing period, the two 0.5 m F condensers act as a spark-quench to the contacts BZ1 and BZ2. Relay L does not operate while ringing current is being applied to the line. When the earth is removed from the

R-wire, relay H holds from earth, 1X3, 2X3, coil of relay H, HL-wire, calling extension telephone loop, R-wire, 2X4, 1X4 and coil of relay H to battery. Relay BZ releases, as it will not hold in parallel with H under these conditions. BZ1 and BZ2 extend earth and battery respectively via the coils of relay L, to prepare the transmission bridge for the external extension.

The external extension answers by removing the handset from the rest, and the telephone loop thus provided operates relay L. L1 and L2 extend the A- and B-wires from the caller's telephone circuit to the called telephone. L3 serves no purpose at this stage. Relay BZ is disconnected at L2.

If the external extension is engaged on a call with another extension, relays H and L will be operated and, consequently, when a caller depresses the local key appropriate to the external extension number, relay BZ does not operate. When the local key restores to the "speaking" position, the caller breaks into the local connexion.

If the external extension is engaged on an exchange call, key springs 1X4 or 2X4 will be operated, thereby connecting the R-wire to the common. Therefore, when a caller fully depresses the local key adjacent to the external extension number, his own buzzer will operate. At the termination of a call, both extensions replace their handsets. Relays H and L release and the circuits are restored to normal.

External Extension Calling Internal Extension —(Figs. 16 & 21). The external extension has not the facility of direct access to internal extensions and must obtain all such calls via the main station.

The main station is called by the action of removing the handset from the rest. Relays L and Q operate via earth, YA, BZ1, coil of relay L, 2X1, 1X1, external extension telephone loop, coil of relay Q, 1X2, 2X2, coil of relay L, BZ2 and YB to battery. Q1 operates relay QR, the contact of which has no function at this stage. L1 and L2 prepare the HL and R-wire circuits respectively, L3 extends an earth to operate the eyeball indicator via earth, L3, H4, T1, 1NS1, 2NS1, and indicator coil to battery. An audible alarm is given by a bell, which is actuated by earth from the calling indicator contact via CO1.

The main station answers by removing the handset and depressing the local key corresponding to the external extension number on the telephone set, thereby connecting the telephone circuit to the A- and B-multiple wires of the external extension station as follows: A-wire appropriate L1 springs, 2X3, 1X3, telephone circuit, 1X2, 2X2, CB2 and appropriate L2 springs to the B-line. The transmission bridge is provided from earth, HM2, 200 ohms coil of RA and appropriate L1 springs to the A-line, and battery via 200 ohms coil of RA, HM1, CB2 and appropriate L2 springs to the B-line. HM3 and HM4 have no function at this stage. The A- and B-wires are connected via the multiple to the HL- and R-wires respectively of the external extension station. The main station telephone loop applied to the HL- and R-wires completes a circuit for the operation of relay H via 2X4, 1X4 and 2X3, 1X3. H1 short-circuits relay Q, H2 and H3 extend the HL- and R-wires to the external extension telephone, and H4 disconnects the indicator circuit. The relays L and

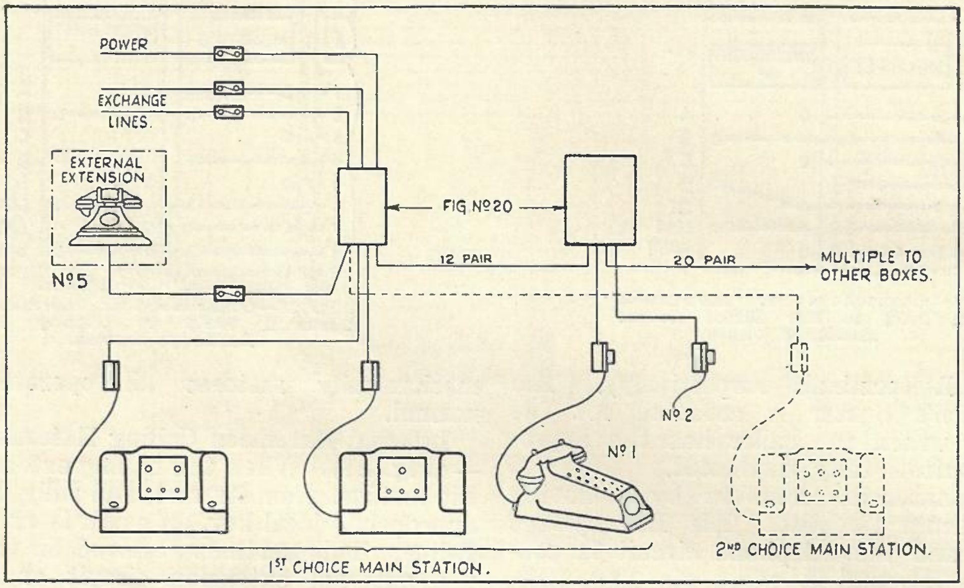

Fig. 19—Pictorial Diagram of an AIO System showing the use of Two Junction Boxes for the Main Station.

H together with the retard coil RA provide the necessary transmission bridges.

The caller now informs the main station of the number of the internal extension with which he requires to communicate. The main station then calls the required extension, the circuit operation being similar to that described previously. The called extension, upon answering, is requested by the main station operator to call the external extension; the main station operator then replaces the handset. The operarelay G at the exchange-line termination. AA4 provides a locking circuit for relay AA via HM3, 1H2, AA4 and HM2 to earth. At the exchange-line termination, relay G in operating removes the earth from the D-wire at G1 in order to avoid intrusion. G2 removes the exchange indicator and 2mF condenser from the speaking circuit. If an automatic exchange is concerned, the caller receives dialling tone and may proceed to set up the connexion.

At the termination of a call, the calling exten-

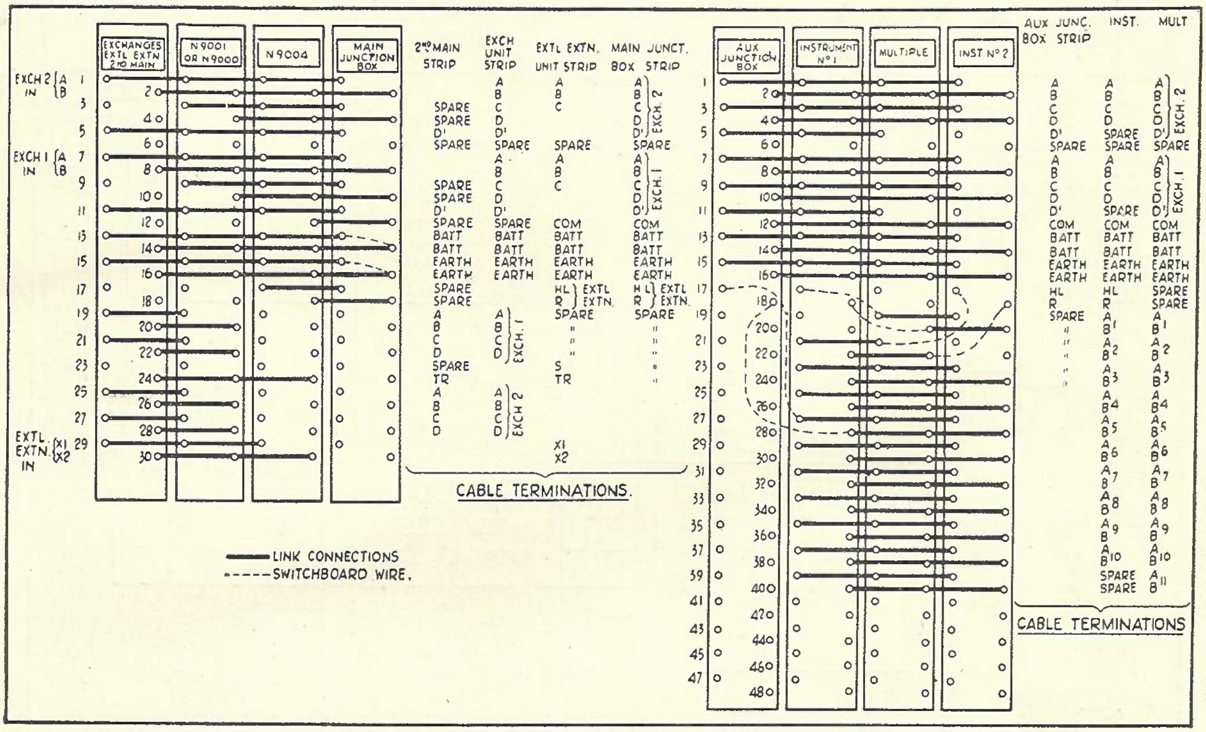

Fig. 20—Commoning of Terminal Blocks for the Main Station Junction Boxes in Fig. 19.

tion of the internal extension calling the external extension has been described.

Internal Extension with Full Facilities Calling the Exchange.—(Figs. 16 & 22). To call the public exchange, the internal extension station removes the handset thereby operating the HM contacts, and depresses (say) Exchange Key No. 1 thus operating the X and H springs. 1X1 and 1X2 remove the hold coil and prepare to connect the telephone to the exchange line. 1X2 and 1X3 also disconnect the local side of the circuit. 1H1 prepares an engaged test circuit. 1H2 prepares an operate circuit for relay AA. 1H3 connects the R- and common-wires to provide an engaged test to calling extensions.

If the exchange line is disengaged, relay AA operates from battery, coil of AA, HM3, 1H2, AA4 and D-wire to earth at G1 on the exchange-line termination. (fig. 22). AA1 and AA3 extend the telephone circuit to the A- and B-wires and thence to the exchange line. AA2 extends the earth via HM2 and 1H1 to the C-wire, to operate sion replaces the handset, thereby restoring the HM, X and H spring banks. Relays AA and G release, to restore the circuits to normal, when a clear is given to the exchange.

When the key of an engaged exchange line is depressed (with the handset on or off the rest), the caller's buzzer will operate from battery, coil of buzzer, AA2, 1H1, and the C-wire to an earth applied by the HM2 contacts of the engaging extension. The caller's AA relay will not operate, due to the absence of earth on the D-wire of an engaged exchange line, and secrecy on exchange calls is thus provided.

External Extension Calling Exchange-Day Service.—(Fig. 21). To gain access to a public exchange, the external extension must first call the main station. The main station, having ascertained that the external extension requires an exchange call, proceeds to test an exchange line by depressing the exchange line key on the telephone set. When a free line is found, it is switched to the external extension line by throwing the appropriate EXTENSION TO EXCHANGE key on the main station unit. The main station then replaces the handset. Extension to Exchange key contacts function as follows:—X1 and X2 connect the external extension to the A- and B-wires of the exchange line. X3 extends an earth via 2NS2, 1NS2 and X5 to the C-wire, to operate relay G and place engaged-test conditions on the exchange line. X4 disconnects relay BZ from the R-wire and connects the R-wire to the common, in order to busy the extension against incoming local calls. X6 has no function at this stage. Relay Q operates from the public ex-

Incoming Exchange Call. (Fig. 22.) All incoming exchange calls are received on indicators fitted in the Unit., Transfer, Intercom. at the main station. The eyeball indicators, operate to rectified ringing current from the public exchange via the A-line, T1, coil of indicator, 2mF condenser, G2 and T2 to the B-line. The indicator when operated extends an earth via CO1, to operate the alarm bell.

The main station answers all exchange calls by removing the handset and depressing the appropriate exchange key on the telephone set. The circuit operation is then similar to that described previously.

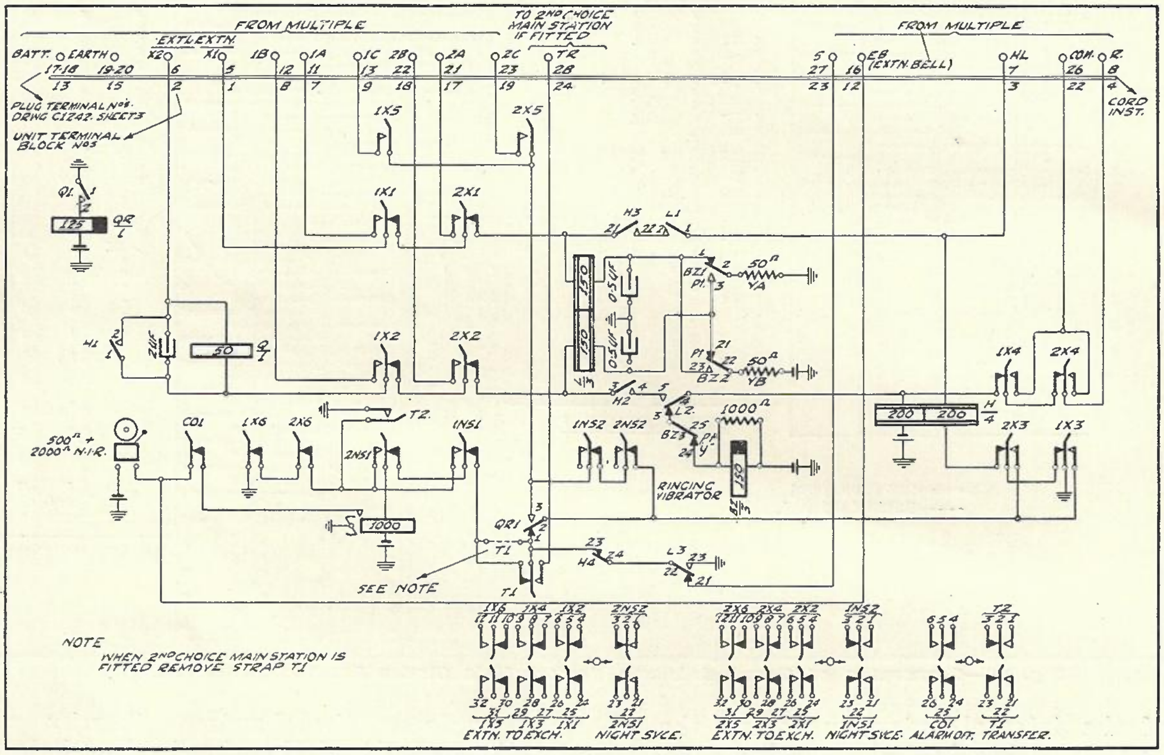

Fig. 21.—Unit Transfer No. 3: Schematic Circuit.

change battery to the extension station's telephone loop and at Q1 operates relay QR. QR1 disconnects the indicator circuit. If the public exchange is of the automatic type, relay Q responds to the impulses dialled from the extension, relay QR however, being slow-to-release, remains operated during the dialling operation. At the termination of a call, the external extension station replaces the handset, to give a through clear to the public exchange. Relay Q releases, followed by relay QR. QR1 now extends earth from X3, to operate the clearing indicator via T1, 1NS1, and 2NS1.

The operation of the clearing indicator places an earth via CO1 to the bell associated with the main station unit, to provide an audible clear. The main station now restores the EXTENSION TO EXCHANGE key, to re-establish normal conditions.

Call for Internal Extension. (Fig. 16).—Incoming exchange calls for an internal extension are first received by the main station. Upon ascertaining the number of the extension required, the main station fully depresses the local key corresponding to this number. This operation mechanically restores the exchange line key to the "hold" position. In this position the H springs remain operated but the X springs are released, and the exchange line is now held by a circuit from the A-line, AA1, 600-ohm resistance coil, 1X1, AA3, to the B-line. The main station telephone circuit is disconnected from the exchange line at springs 1X1 and 1X2, and, when pressure is released from the local key, the telephone is switched to the A- and B-lines of the called extension via the appropriate L1 springs, 2X3, 1X3, telephone loop, 1X2, 2X2, CB2, and the appropriate L2 springs.

The called extension is then requested to "pick up" the exchange line on which the call is being held. To do this, the distant extension depresses the appropriate exchange key, whereupon the buzzer at that station will operate. Buzzer tone is passed back to the main station from earth, 0.4 ohm coil of the buzzer, 1X3, 2X3 to the HL-wire and thence at the main station via A-wire, appropriate L1 springs, 2X3 and 1X3 to the telephone circuit. On receipt of tone, the main station replaces the handset on the rest, and the call now proceeds as detailed previously.

Transference and Holding of Exchange Calls.—(Figs. 16 & 22). Internal extension to internal extension.—If an extension, after speaking on an exchange line, desires to transfer the exchange call to the main station or to another extension having full facilities, the operations are similar to those described for a main station transference.

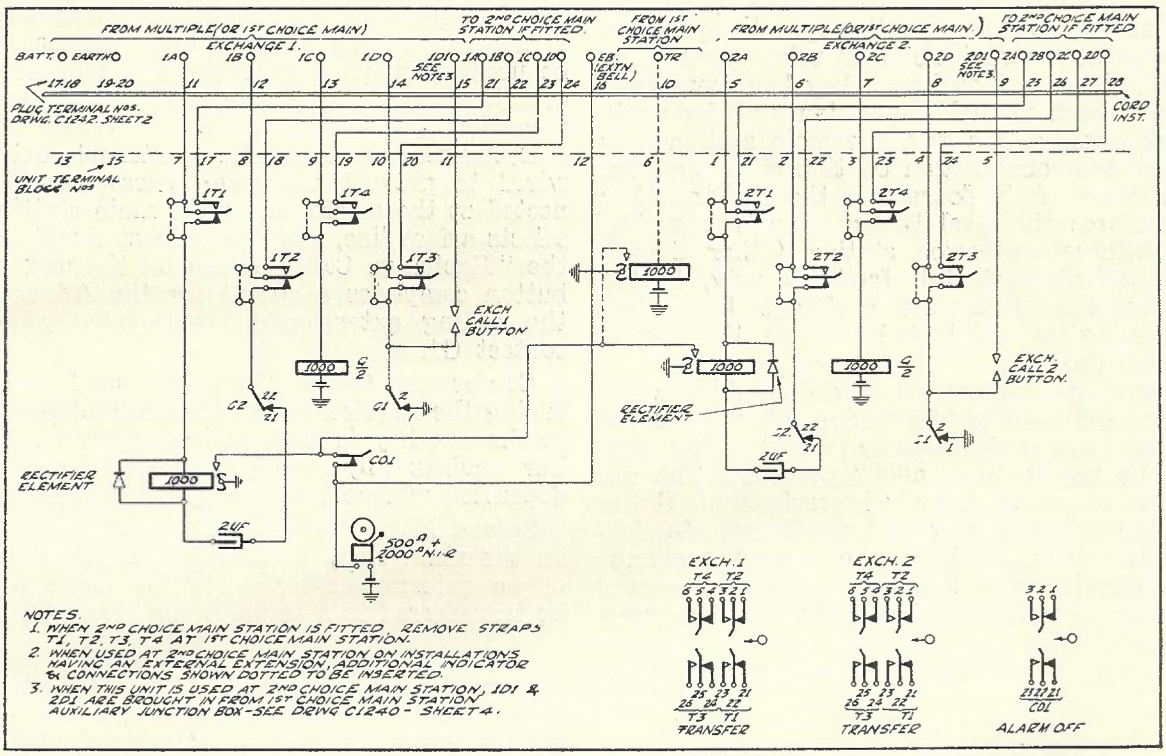

Fig. 22.—Unit Transfer No. 2: Schematic Circuit.

station replaces the handset on its rest; this restores all keys to normal, and removes the busy condition from the C- and D-wires. The AA or AB relay at the extension station is then allowed to operate to earth on the D-wire and so connect this extension to the calling exchange line.

If the required extension is engaged on a local call, the main station is enabled to break in on the connexion, and offer the exchange call to the extension concerned. If the required extension is engaged on an exchange call the main station can break in on the connexion only if provided with monitoring facilities.

Upon ascertaining that the external extension is required, the main station calls the external extension by depressing the appropriate local key, the exchange line being held mean-while. The external extension is advised that an exchange call is waiting, and the main station then throws the appropriate EXTENSION TO EXCHANGE key on the main station unit. The

Internal extension to external extension—An exchange call cannot be transferred direct from an internal extension to the external extension but must be transferred via the main station.

External extension to internal extension—By "flashing" the main station operator it is possible for exchange calls to be transferred from the external extension to any other extension via the main station. In automatic areas, directly-dialled calls originated by the external extension cannot be transferred.

Holding one exchange line while transferring a call on the other.—If on an installation with two exchange lines, the main station is talking on one line and a call is received on the second line, the main station may temporarily abandon the call on the first line and, by depressing the second exchange key (which automatically restores the first exchange key to the "hold" position), may accept the call. The main station then depresses the local key corresponding to the number of the extension to which it is desired to transfer the call. This causes the second exchange line key to restore to the "hold" position.

If the call is for the external extension, it is transferred. If the call is to be transferred to an internal extension, the procedure is as described earlier except that, on receipt of buzzer tone, the main station releases the second exchange line from the instrument by operating the associated "trigger key." This causes the "hold" springs associated with the second line to restore, while leaving the "hold" springs on the first exchange key in the operated position. The distant extension's AA relay may then operate. The first exchange key has meanwhile remained in the "hold" position and, by again fully depressing this key, the main station may continue the conversation on this exchange line. The action of fully depressing the exchange key also restores the local key previously operated.

An internal extension station (other than a main station) with full facilities may, in the same manner, hold one exchange line while transferring an originated call on the second exchange line.

Holding one exchange line while making a call on the other.—The depression of the second exchange key automatically restores the first exchange key to the "hold" position. The call is then set up as described previously. Either exchange call may now be transferred. On termination of the call on the second exchange line, connexion with the first exchange line may then be re-established by again fully depressing the first exchange key, and operation, of the associated trigger key releases the second line from the instrument.

MISCELLANEOUS FACILITIES.

It is not practicable to give an extensive outline of the circuit operations involved in the provision of miscellaneous facilities, but the four principal features are:—

External Extension—Night Service: The external extension is switched to an exchange line by the operation of 2 keys on the main unit. When the exchange line concerned is free, it may be used by internal extensions, but under these conditions, calls are non-secret to the external extension.

Restricted Access:—Any internal extension wired to prevent exchange access can be connected at the discretion of the main station who selects a free line, tells the extension and presses the "Exchange Call" button on the unit. This button completes a circuit for the AA relay of the calling extension to earth at the normal contact G1.

Conference Calls:—They are made by first calling the required extensions individually. The conference key is then depressed and a locking bar enables any number of local keys to be depressed and held in the operated position.

Second Main Station:—By throwing the keys on the main unit, all facilities except switching of an external extension to the Exchange can be transferred to a second main station.

Editor's Note:—The telephones described in this article will be available in Australia early in 1938. On page 253, the reference to the non-installation of these telephones in magneto areas, applies only to Australian practice. If a suitable power supply is available and a special unit to give correct call and clear conditions is installed at a magneto exchange, the telephones will function with L.B. exchange equipment.

Recent Improvement In Handset Telephones

T. T. Lowe

During the past few years many changes have taken place in the Telephone Instrument, and further interesting modifications are pending. Such changes have a wide interest, and the present article attempts to set out the main features of the Handset Telephone which will be supplied on current orders. Automatic, C.B. and Magneto Wall and Table Handset Telephones No 232, which will be supplied on Schedule C.1715, should be available early in 1938. The instruments will differ considerably from 566 Type Handset Telephones previously supplied.

Both wall and table telephones will be delivered and held in stock as complete units, i.e., with the bellset connected to the handset portion of the instrument both electrically and mechanically. Each table telephone will be provided with 4 rubber feet screwed to the metal base plate of the bellset, a 3 conductor cord 6 feet long (No. 3600), and a moulded 4 terminal strip (Strip No. 1.). The wall telephone, instead of 4 rubber feet, a 6 ft. cord and a terminal strip, will have a black enamelled steel wall bracket screwed to the metal base plate of the bellset for securing the telephone to a wall or other fixture, the holes in the metal bellset base plate used in the table instrument for fitting the rubber feet being utilised for securing the wall bracket to the bellset. The moulded base which, on Telephone 566, carries 4 rubber feet and is screwed to the bottom of the bellset, will not be supplied.

On the 566 Type Telephone previously supplied, a 3 conductor braided cord 9 in. long (No. 3009) connects the bellset to the handset portion of the instrument. As this cord is run externally to the case it does not improve the appearance of the instrument, the unsightly length of cord being necessary in order that maintenance adjustments may be performed without disconnecting the cord when the bellset and handset telephone case are disconnected mechanically. On handset type telephones which will be supplied on current orders a small hole 0.193 in. in diameter is provided in one corner of the moulded bellset cover through which the cord connecting the bellset to the handset portion of the instrument passes internally, thus presenting a more pleasing appearance. A lighter 3 conductor cord is used, having only 19 strands of 42 S.W.G. conductor, instead of the usual 55 strands and without external braiding over the three conductors. The cord is of sufficient length to enable the internal equipment to be inspected and adjusted without disconnecting the cord.

The supply of handset telephones as complete units avoids mounting the bellset separately from the handset portion of the instrument, and ensures far greater stability of the set when dialling and when removing or replacing the handset on the cradle switch, thus reducing the liability of false impulses and broken cradles, handset bodies, etc. Previously the handset telephone and its associated equipment was purchased as a separate unit due to the necessity for using up the accumulated stocks of Bellset No. 1, a condition not now existing. If, however, a subscriber desires a bellset to be mounted separately from the handset telephone, as for example in a position previously occupied by a Bellset No. 1 or to cover a wall disfigurement, he may be supplied with a Telephone 566. If a Telephone 566 is not available, the bellset of a 232 Type Telephone may be mounted separately from the handset portion of the instrument, as the small hole in the bellset cover is scarcely noticeable and is in no way a disadvantage, but a separate moulded base must be provided for the handset telephone case and will no doubt be stocked if necessary for this purpose.

The magneto handset telephone when used on a straight line service will be associated with a 3 magnet hand generator No. 4CN mounted in a wood case (formerly known as hand generator No. 3). The output of this generator is about 45 milliamperes on a 750 ohm load and is ample for straight line services. On other services, such as party lines, trunk line stations, etc., where a generator having a greater output may be required, a 4 magnet hand generator No. 1 mounted in a black lacquered wood case will be used.

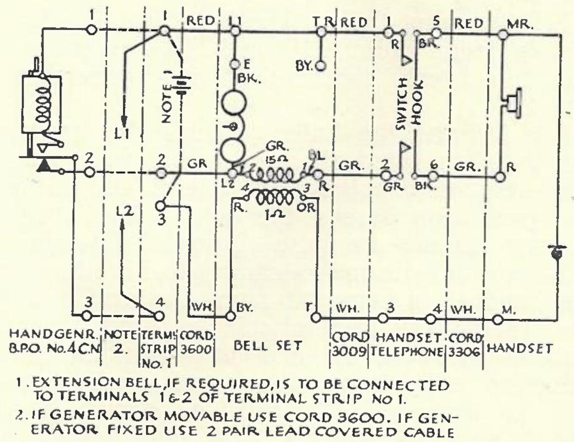

Fig. 1.—Magneto Table Telephone 232 (C 1256/1).

Magneto table and wall telephones will be wired to Sheets 1 and 2 of Drawing C.1256 (See Figures 1 and 2) which indicate also the cord connections between the handset, the handset telephone, the bellset, terminal strip and the hand generator No. 4CN. The magneto telephone is equipped with a 1 ohm plus 15 ohm induction coil which is mounted in the bellset. In special cases, when the subscriber desires the bellset mounted in a fixed position separately from the handset telephone, the cord connections are as shown in Fig. 2 for a wall telephone except that Cord 3009 (9 in. long) between the bellset and the handset portion of the instrument, is replaced by Cord 3600 (6 ft. long). If the subscriber desires the bellset to be fixed and the hand generator to be movable, the generator will be connected to Terminal Strip No. 1 by a Cord 3600 (6 ft. long), one pair L.C. cable being used between the terminal strip and the fixed bellset. The line will be connected to the terminal strip and the battery to the bellset.

The following is a brief description of the circuit of the magneto handset telephone. (See Figures 1 and 2).

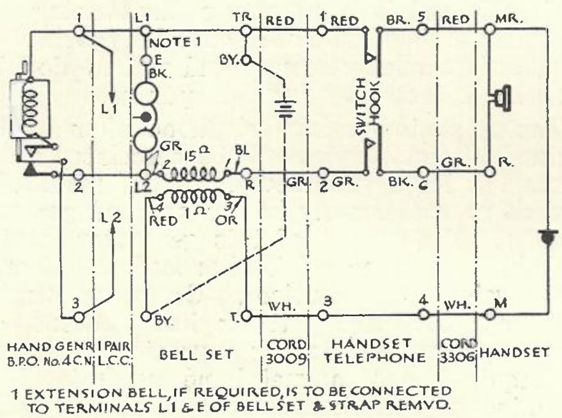

Fig. 2.—Magneto Wall Telephone 232 (C 1256/2).

(a) **Incoming Calls.** The incoming ringing circuit is from Line 1 through the magneto bell and the break contacts of the generator to Line 2.

(b) **Originating Calls.** When the generator handle is operated the generator springset disconnects the telephone at Line 2 and connects the generator across the line. The outgoing ringing circuit is from Line 1 through the generator and its make contact to Line 2. When the handset is removed from the cradle switch the transmitter local circuit is completed from battery through the one ohm winding of the induction coil, transmitter and cradle switch, back to battery. The receiver circuit is completed also from Line 1 through the cradle switch, receiver, cradle switch, 15 ohm winding of induction coil, break contacts of generator to Line 2.

C.B. and automatic wall and table telephones will be wired to drawing C.1255 (see Fig. 3). The drawing indicates also the cord connections between the several parts, i.e., between the handset, handset telephone, bellset and terminal strip. When the bellset is mounted as a separate unit the cord connections are as shown for the wall telephone except that a cord 3600 (6 ft. long) is required between the handset portion of the instrument and the bellset instead of the cord 3009 (9in. long). On wall telephones terminals L1 and E of the bellset are strapped unless an extension bell is required. The equipment in the bellset consists of a bell and condenser only, as the anti-sidetone induction coil is mounted in the telephone case. In the C.B. telephone the dial and dial cords are omitted and terminals 3 and 4 of the handset telephone are strapped. A dial dummy replaces the dial on both the C.B. and magneto types. The dial provided on the automatic telephone is the latest B.P.O. No. 10 type fitted with a stainless steel (Staybrite) finger plate and chromium plated case, label frame, securing ring and finger stop. Fig. 4 indicates the dialling circuit.

The following is a brief circuit description and description of the operation of the C.B. and Automatic Handset Telephone No. 232. (See Figures 3, 4 and 7).

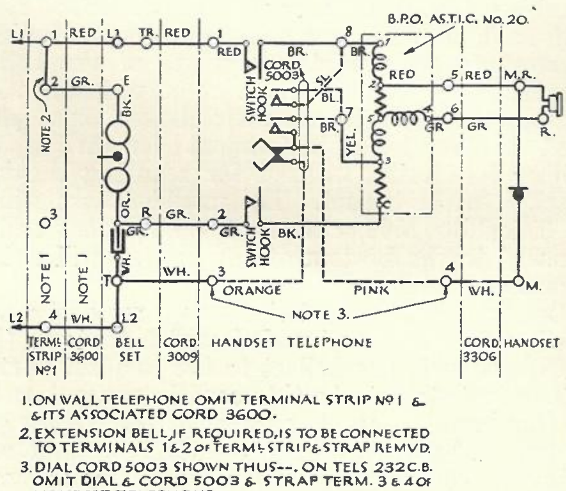

Fig. 3.—C.B. and Automatic Table and Wall Telephones 232 (C 1255).

(1) **Incoming Calls.** (Fig. 3). The ringing circuit is from Line 1 through the magneto bell and 2mF condenser to Line 2.

(2) **Originating Calls:**

(a) **Impulsing Circuit.** (Figs. 3 & 4). The impulsing circuit is from Line 1 through the cradle switch, dial off normal springs, dial impulse springs to Line 2. A shunt circuit as follows is provided across the dial impulse springs to prevent high voltage surges and correct impulse distortion. From Line 1 through magneto bell and 30 ohm non-inductive winding 3-C of induction coil in parallel through the 2mF condenser back to Line 2.

(b) **Transmitter Feed Current Circuit.** (Fig. 3). The transmitter is supplied with current from the exchange battery feeding bridge. The feed current circuit is from Line 1 through the cradle switch, induction coil winding 1-2, transmitter, dial impulse springs to Line 2. The transmitter may be regarded as a variable resistance through which a constant direct current is passing, resulting in a variable E.M.F. This variable E.M.F. may be resolved into two components:

(i) A fixed potential due to the constant feed current.

(ii) A superimposed alternating potential proportional to the variation in resistance brought about by the sound waves impinging on the diaphragm of the transmitter.

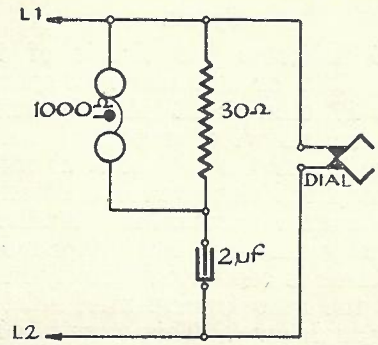

Fig. 4.—Dialling Circuit, Automatic Telephone 232.

(It will readily be seen that in the inductor condenser types of battery feeding bridge which are now almost exclusively used, the high impedance offered by the battery feed inductors to any changes at voice frequency in the value of the direct current enable the transmitter feed current to be considered as constant).

The transmitter may therefore be considered as an A.C. generator.

(c) **Sending Circuit.** (Figs. 3 and 7). Considering the transmitter as an A.C. generator, the transmitter current divides, the major portion passing from the transmitter through induction coil windings 2-5, 5-3, and 3-C, cradle switch, 2mF condenser, and dial impulse springs back to the transmitter, the remainder flowing through winding 2-1 to Line 1 and back through Line 2 and the dial impulse springs to the transmitter. As the current in winding 5-3 produces a greater magnetic flux in the core than winding 1-2, winding 5-3 acts as the primary of a step-up auto-transformer in which windings 1-2 and 5-3 together form the secondary. The transmitter is therefore approximately matched to the impedance of the line with a resulting increase in line current compared to a telephone without an induction coil. This increase in current is sometimes referred to as the "booster" effect. The anti-sidetone features of this telephone are discussed later.

(d) **Receiving Circuit.** (Figs. 3 & 7). In the receiving condition the majority of the voice frequency current passes from Line 1 through cradle switch, induction coil, winding 1-2, transmitter, dial impulse springs, back to Line 2 due to the low impedance of the transmitter compared to its parallel circuit formed by the induction coil windings 2-5, 5-3 and 3-C, cradle switch and 2mF condenser. The flux due to the current through the induction coil winding 1-2 induces a potential in winding 4-5 which drives the current through a local circuit consisting of the receiver and induction coil winding 2-5. The small current from the line passing through winding 5-3 tends to assist the current passing through winding 1-2.

A dial cord having 5 conductors is provided (Figure 3) in order to enable the dial and its spring contacts to be readily tested from the cord terminals when assembled in the telephone, and to provide flexibility when circuit changes are necessary for special services.

Appropriate circuit diagrams to Drawings C.1256 and C.1255 (Figures 1, 2 and 3) are attached to the under-side of the moulded bellset cover of each 232 type telephone. The diagrams have been simplified on the detached contact principle and serve both as schematic and wiring diagrams.

The Anti-sidetone Induction Coil.

As indicated previously, the C.B. and automatic handset telephones No. 232 are provided with an anti-sidetone induction coil (B.P.O. A.S.T.I.C. No. 20) instead of the standard induction coil 17 ohms + 33 ohms (B.P.O. No. 18) mounted in the bellset and the anti-sidetone transformer No. 35A mounted in the telephone case. The A.S.T.I.C. No. 20 is mounted in the telephone case in the position occupied by the anti-sidetone transformer No. 35A in telephone 566. A number of the automatic telephones supplied on Schedule C.1715 may be provided with B.P.O. A.S.T.I.C.'s No. 22 or No. 24, but the circuit arrangements and the operation will be the same as for the B.P.O. No. 20 coil.

Sidetone.

When speaking into the transmitter of a telephone a proportion of the voice frequency current generated passes through the local telephone receiver, the remainder traversing the line circuit. Also when listening in the receiver the listener's transmitter picks up any noise in the neighbourhood and reproduces it in the receiver. Sidetone is the name given to sound reproduced in this manner in the local telephone receiver. Noise may be regarded as unwanted sound.

With sidetone at a high level, reception may be considerably degraded. The listener's transmitter picks up any extraneous noise which may be present with the result that a mixture of speech from the distant telephone and local noise is reproduced in the listener's receiver. The effect of the local noise, particularly when it is at a high level, is to cause an apparent reduction in the level of the received speech.

The ideal level of "sending" sidetone would be such that the speaker would hear his own voice through the receiver at approximately the same level as he would hear it through the air. When sidetone is reproduced at a higher level the effect upon the speaker is that he appears to "shout in his own ear" and it may cause him to lower his voice or avoid speaking directly into the transmitter. In this manner a serious transmitting loss may be experienced due to the psychological effect upon the speaker of excessive sidetone.

Unless sidetone is properly controlled the use of a second receiver is of little value as a mixture of speech and noise will be reproduced in both receivers. When using a telephone which properly controls sidetone, the listener does not experience any difficulty in differentiating between sounds heard in the receiver and those heard in the free ear, as the brain appears to be capable of isolating sounds heard in one ear from those heard in the other. The complete elimination of sidetone, even if this were practicable, is unnecessary and undesirable, however, as if no response is present uncertainty is produced in the mind of the speaker as to the efficiency of the instrument.

It is well-known that the noise level in city shops, offices, factories and even in suburban residential areas is at a much higher level nowa-

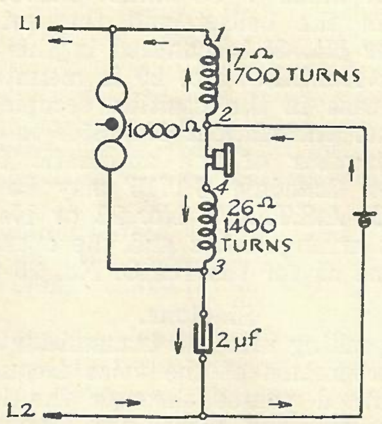

Fig. 5.—Fixed Transmitter Tube. C.B. or Automatic Telephone.

days than formerly, thus increasing the need for proper sidetone control. It is exceedingly difficult to effect appreciable reduction in noise level, although in the construction of modern buildings for offices, factories, etc., increasing attention is being given to the need for a considerable reduction in noise and reverberation.

As modern balanced and relatively noise-free telephone lines and exchange equipment having high transmission efficiency are available, it is particularly desirable that the telephones in use at each terminal are such as will, as far as possible, allow the users to conduct a normal conversation without interference from extraneous noise.

Need for Sidetone Control when Using Handset Telephones.

In the earlier types of C.B. and automatic telephone in use before the introduction of handsets, the need for sidetone reduction was not so apparent, due to the inefficient transmitters and receivers which reproduced sidetone at a relatively low level.

Sidetone in Telephones other than Handset Types.

Figure 5 indicates the circuit of the fixed transmitter C.B. or automatic telephones provided with 17 ohm + 26 ohm induction coils. These instruments were in general use prior to the introduction of the handset. It will be seen that this telephone circuit resolves itself into an auto transformer connection in a similar manner to that already described for Telephone No. 232. As the receiver is connected directly in the local winding of the auto transformer, sidetone is at a relatively high level. This circuit is known as a "booster" circuit.

Method of Sidetone Control in the 566 Type C.B. and Automatic Handset Telephones.

The 566 type C.B. and automatic handset telephones are provided with a standard C.B. Induction coil (17 ohm + 33 ohm) and an anti-sidetone transformer No. 35A, one winding of which is connected across the receiver and the other across the transmitter. (See Figure 6). The similarity of this circuit to Figure 5 will be appreciated. Sidetone is reduced because the current induced in the receiver circuit through the anti-sidetone transformer is in opposition to that caused by the direct connection of the transmitter as indicated in Figure 5 and discussed in the previous paragraph. The connec-

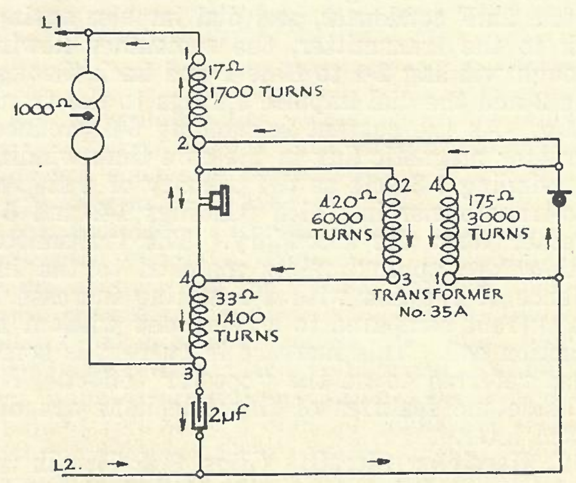

Fig. 6.—C.B. and Automatic Telephones 566.

tion of the anti-sidetone transformer in the circuit causes some reduction in sending efficiency when compared with the circuit indicated in Fig. 5, due to the direct current shunting effect of winding 1-4 which is connected across the transmitter.

The arrangement does not provide for a large reduction in sidetone. When this circuit was introduced sidetone suppression to a greater degree was thought to be inadvisable, and it was considered that the public had learned to regard sidetone as a measure of the efficiency of the telephone. Experience, however, has shown that this is not so, and that a much greater reduction of sidetone than that provided for in the 566 type telephone is greatly appreciated by the user and is of definite advantage.

It should be remembered also that when handset telephones were introduced in 1932 it was necessary to use up the excess stocks of bellset No. 1 provided with 17 ohm + 26 ohm induction coils. This precluded the use of a complete instrument (combined bellset and handset telephone) and made it necessary to utilise some form of sidetone suppressor fitted in the handset telephone case, thus leading to the adoption of the anti-sidetone transformer No. 35A, which is mounted in the handset telephone case of C.B. and automatic handset telephones 566. No such limitations, however, are imposed when telephones are supplied as complete units, and anti-sidetone induction coils are fitted in 232 C.B. and automatic handset telephones, thus providing a more economical and efficient arrangement.

Sidetone Control in 232 Type C.B. and Automatic Handset Telephones.

Reference has already been made to the action of the B.P.O. A.S.T.I.C. No. 20 in 232 type telephones under sending and receiving conditions. As stated previously, the flux produced in the core of the induction coil by current from the transmitter is the resultant of the opposing effects of windings 1-2 and 3-5. This flux induces an E.M.F. in the winding 4-5 and would produce sidetone current in the receiver. One method of reducing this sidetone current would be to increase the ampere turns of 1-2 until they were approximately equal to those of 3-5. This would, however, destroy the auto-transformer or "booster" effect. To retain this effect and at the same time reduce the sidetone, the non-inductive winding 2-5 is included in the local circuit of the receiver and for normal line impedances the potential across this winding opposes the E.M.F. induced in winding 4-5. Since the resultant flux from windings 1-2 and 3-5 depends upon the current in 1-2, which is controlled by the impedance of the line, the amount of sidetone is influenced by the line conditions. The coil is designed to give minimum sidetone under average line impedances. Figure 7 indicates the connections.

A.S.T.I.C. No. 20.

The core of the anti-sidetone induction coil is of the "open" type. The three inductive windings and two non-inductive windings are wound on a black moulded bobbin. Figure 8 indicates the direction of the windings and the connections.

A small label indicating the resistance of each winding and the number of turns is gummed on

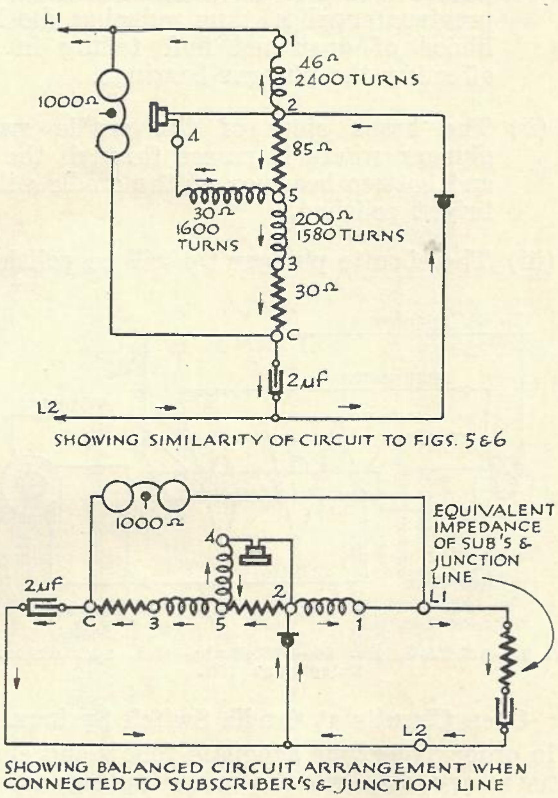

Fig. 7.—C.B. and Automatic Telephone 232, with A.S.T.I.C., No. 20.

the outside of each induction coil. The A.S.T.I.C. is mounted in the telephone case on metal supports.

Principal Faults on Handset Type Telephones.

The principal faults which are experienced in service on 566 type handset telephones are:—

(i) Cradle switch plungers sticking;

(ii) Open circuits at cradle switch springs;

(iii) Defective transmitter insets;

(iv) Broken plungers and cradles.

Plungers Sticking.

This fault may be due to any of the following causes:—

(i) Dust or fluff entering the top of the hole in the cradle through which the plunger stem passes and causing the plunger to bind.

(ii) Serrations or dirt on the brass plunger stem where it passes through the cradle.

(iii) Dirt on the ebonite plunger tip.

In the 232 handset telephone which will be supplied on current contracts these faults should be reduced considerably due to the following:—

(i) The top of the hole in the telephone cradle through which the plunger stem passes will not be counter-sunk as on previous supplies, thus reducing the likelihood of dust and fluff falling in and affecting the plunger bearings.

(ii) The brass stem of the cradle switch plunger where it passes through the top and bottom bearings of the cradle will be bright polished.

(iii) The ebonite plunger tip will be polished.

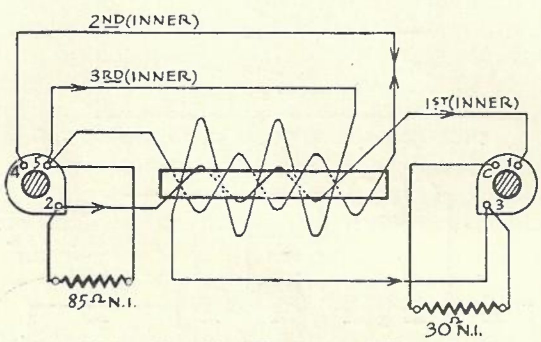

Fig. 8.—A.S.T.I.C. No. 20.—Windings—C.B. and Automatic Telephones 232.

Open Circuits at Cradle Switch Springs.

In order to provide adequate follow and ensure satisfactory contact, the inner springs of the cradle switch spring assembly are set away from the centre spacing insulator, the space between each spring and the centre spacing piece being from 2 mils minimum to 7 mils maximum. In addition the pressure of the tension springs on the inner contact springs is from 40 to 50 grams. This adjustment should ensure a good rubbing contact and reduce the likelihood of open circuits at the spring contacts.

Defective Transmitter Insets.

If practicable the transmitter insets provided on handset telephones supplied on current contracts will be the No. 13 type instead of No. 10 which are not entirely satisfactory in service. The No. 13 inset incorporates the following improvements:—

(i) The oiled silk membrane is omitted. This membrane frequently adheres to the front metal guard in the No. 10 type, causing a serious transmission loss. The diaphragm is protected by a coating of enamel.

(ii) The liability of corrosion of the diaphragm at the edges which occurs frequently on No. 10 insets in service should be considerably reduced by a cement seal provided at the point of contact between the duralumin diaphragm and the brass case and clamping ring.

(iii) The escape of granular carbon is rendered more difficult by stiffening with mica washers the silk washers which seal the carbon chamber.

(iv) A breathing hole is provided in the center of the back electrode, the escape of carbon being prevented by a felt disc which covers the hole.

These improvements should overcome the principal faults experienced on No. 10 insets in service, i.e., escape of granular carbon, corrosion of diaphragms and sticking of the oiled silk membranes to the metal guards.

Transmitter Insets for Local Battery Telephones.

The Specification for transmitter insets indicates that neither the talking nor quiet resistance of the transmitter when measured in parallel with the primary of the anti-sidetone transformer shall exceed 60 ohms. As the resistance of the primary of the anti-sidetone transformer is 175 ohms ± 15 ohms, transmitter insets of up to 96 ohms resistance comply with the Specification. A transmitter resistance of over 90 ohms is much too high for satisfactory transmission under local battery conditions using two dry cells due to the high feeding current loss which results. Arrangements have been made therefore for low resistance insets having resistance values if possible not in excess of 60 ohms to be provided on magneto handset telephones which are being supplied on current orders.

Broken Cradles.

In order to carry out service trials a number of cradles and plungers moulded from moulding material having a cellulose acetate base has been purchased. This is a thermo-plastic and the likelihood of fracture of the moulded parts when subjected to sudden knocks of the type experienced in service is greatly reduced. Although the handset telephones supplied on Schedule C.1715 will be provided with phenolic cradles and plungers, if trials are satisfactory cradles and plungers supplied in future will probably be of cellulose acetate.

Sending and Receiving Efficiency and Sidetone Reduction.

The transmission (sending and receiving) efficiency of Magneto C.B. and Automatic Telephones No. 232 will be about equal to the equivalent 566 type telephone, but for automatic and C.B. types the sidetone will be from 4 to 10 d.b. less than for the 566 types, depending upon line conditions.

THE AUTOMATIC PUBLIC TELEPHONE

M. Bowden

The Automatic Public Telephone is familiar to many, and Maintenance Circulars have been issued for the guidance of area mechanics. To a large number of readers, however, whose duties do not bring them into contact with the Automatic Public Telephone, a brief description of its operation may be of interest. During recent years a number of circuit and mechanical alterations has been made, and a few comments regarding these may be worthy of mention.

Unlike the manual public telephone which consists of a magneto or a C.B. telephone with a separate coin attachment, the Automatic Public Telephone is a self-contained unit, and consists of two compartments divided by a 1-8th in. steel plate. The upper compartment is of pressed sheet steel, and of rectangular section, while the lower compartment is of circular section and constructed of wrought iron pipe. The telephone apparatus and coin collecting mechanism are housed in the upper compartment and the coin tin in the lower, the tin being secured in its compartment by a malleable breech block locked in position by a cylinder lock.

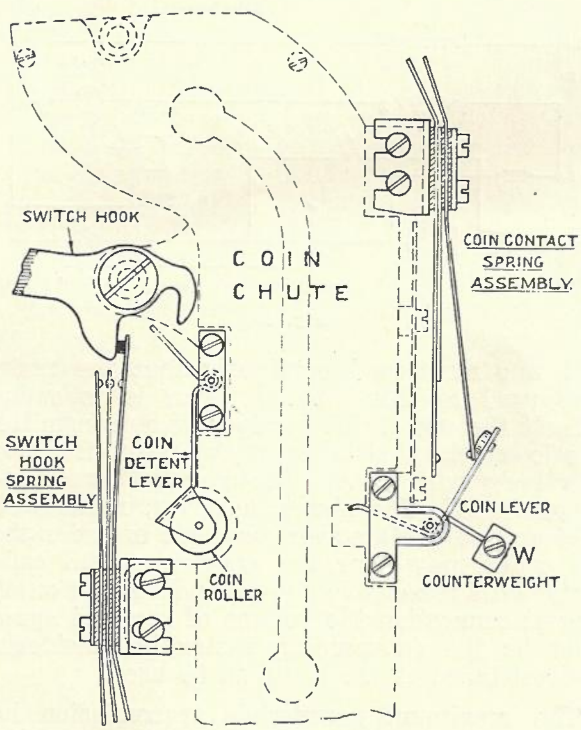

Fig. 1.

The coin collecting mechanism with the telephone normal, i.e., with the receiver on the hook, is shown at Fig. 1. It will be observed that the coin contact springs are not making and that there is considerable clearance between the switch hook extension and the end of the coin detent lever. Under this condition the coin roller and lever can be deflected to the left about the lever pivot. Fig. 2 illustrates the condition with the receiver raised and two pennies in the chute. The switch hook extension has been lowered by the lifting of the receiver and is now practically in contact with the detent lever. The roller is thus locked in the position shown and any coins inserted in the chute are arrested by the coin roller at the left and the coin lever at

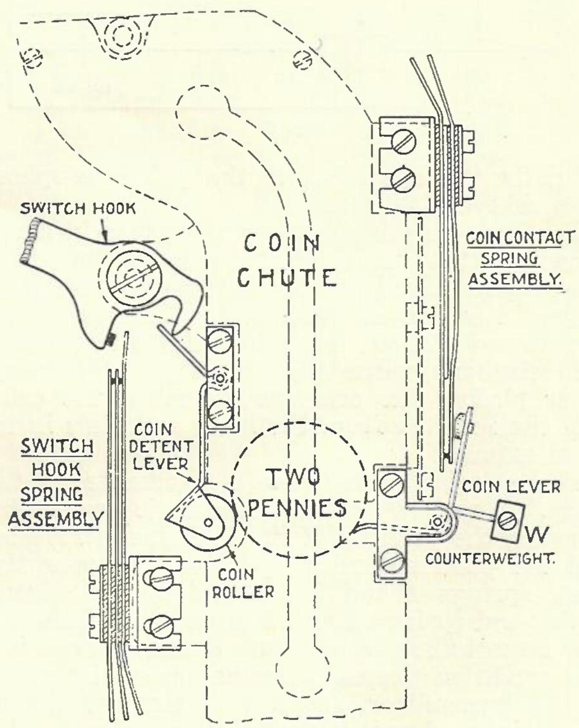

Fig. 2.

the right of the chute. The weight of two pennies resting on the coin lever causes the coin contacts to close, as indicated. The contacts should not close under the weight of one penny, and the correct adjustment is obtained by regulating the position of the counterweight W. When the receiver is replaced on the hook on completion of a conversation, the switch hook extension and the detent lever disengage, the coin roller is deflected by the coins which pass freely to the coin tin. The mechanism then restores to the normal position.

A schematic diagram of the telephone in general use until June, 1934, is shown in Fig. 3. At that time circuit changes were made and further reference to these will be made later. The circuit arrangement illustrated is that of the standard automatic telephone (fixed transmitter type) with the addition of a polarised relay PR. The polarised relay as its name implies operates only when the potential applied to its terminals is of the correct polarity. It is designed to operate with a current of 27 m.a. flowing through its coil in the correct direction and not to operate with 250 m.a. in the reverse direction.

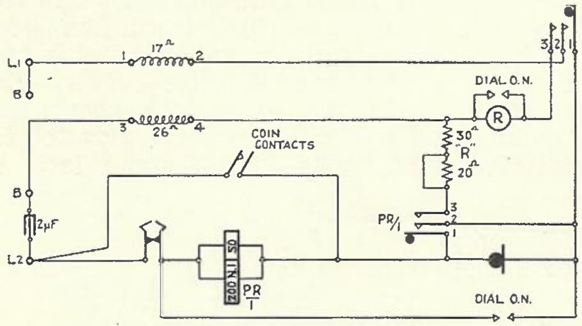

Fig. 3.

Briefly the operation of the public telephone is as follows:—

Two pennies are placed by the caller in a rest known as the "coin head" mounted on top of the telephone, and are so held that by the pressing of a button in the coin head the coins may be released without delay into the coin chute of the telephone when the called party answers. After placing the coins as indicated, the caller lifts the receiver from the hook and dials in the usual manner.

The polarised relay does not operate at this stage. When a called automatic subscriber answers, the polarity of the P.T. line is reversed and the polarised relay operates. In operating relay springs 1 and 2 short circuit the transmitter and springs 2 and 3 cause a non-inductive resistance to be placed across the receiver. Under this condition the caller cannot speak by means of the transmitter, and speech through the receiver is rendered difficult by the shunt. The receiver shunt does not prevent the caller from hearing, and when the called party answers, the caller presses the coin head button. The pennies pass into the chute, come to rest as shown in Fig. 2, and cause the contacts of the coin springs to close. The coin springs short circuit the polarised relay which releases, and the transmitter and receiver circuits are restored to normal, when conversation may proceed. At the end of the conversation the receiver is replaced on the hook and the pennies pass into the coin tin. In the event of the caller dialling a manual exchange or an information desk, the polarity of the P.T. line is not reversed when the telephonist answers, the polarised relay does not operate and the caller may converse with the telephonist without the insertion of coins. After the manual telephonist establishes a connection, however, the polarised relay in the Public Telephone operates and conversation with the wanted subscriber cannot take place until the normal fee is deposited.

During the last few years large numbers of public telephones have been installed on subscribers' premises and these are used to receive as well as to originate calls. When the receiver of a telephone is raised to answer an incoming call the line battery to the called subscriber is not reversed, and if the telephone called be a Public Telephone the polarised relay does not operate. As the relay does not operate, it is not necessary to deposit coins when an incoming call is answered. The relay therefore is not short circuited and speech takes place through the relay. Although the operating winding of the relay is shunted by a non-inductive resistance, the relay when connected as shown in Fig. 3 introduces quite an appreciable loss into the receiving circuit and complaints of faint reception on incoming calls are not infrequent, if the relay be connected as shown. To overcome the trouble, the circuit has been modified as shown in Fig. 4, the alteration consisting of removing the relay from the "booster" circuit of the telephone to a position directly in the line. The change has resulted in a gain of approximately 3.5 db. in receiving efficiency when the relay is in circuit, compared with the condition shown in Fig. 3.

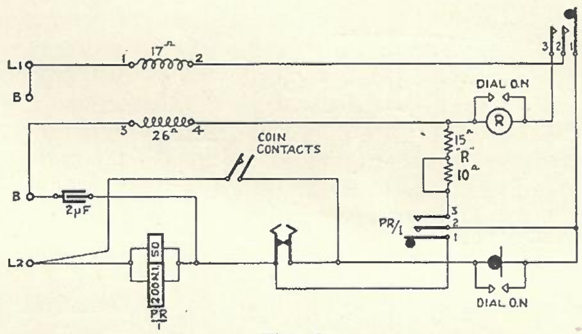

Fig. 4.

It was mentioned previously that the resistance used to shunt the receiver is to render difficult the use of the receiver as a transmitter. The lower the resistance of the shunt the more effectively will speech through the transmitter be prevented. The shunt, however, reduces the efficiency of the receiver also and in order that the caller may hear the answer of the called party with reasonable clarity and volume on the longest connection the volume of received speech must be the determining factor in considering the resistance of the shunt to be used.

The maximum permissible transmission loss between any two subscribers has been specified as 47 db and in the Metropolitan network the total permissible loss for a connection between two subscribers connected by a junction line of maximum attenuation is 33 db. The maximum loop resistance of each subscriber's line should not exceed 450 ohms if solid back transmitter telephones be used.

Calls from a standard automatic public telephone are dialled only into the Metropolitan network, and therefore in the extreme case the overall attenuation of received speech may be increased from 33 db to 47 db without exceeding the permissible limit. This means that the resistance used to shunt the receiver in an endeavour to restrict speech through the receiver should not increase the receiving loss by more than 14 db. When the public telephone line loop is 450 ohms the resistance of the shunt required for a P.T. in accordance with Fig. 4 is 25 ohms. As the resistance of the exchange line is reduced the efficiency of the receiver, both for receiving and transmitting speech is increased and to obtain the maximum benefit of the shunt in restricting the use of the receiver as a transmitter the resistance of the shunt should be reduced progressively as the telephone is taken closer to the exchange. This is not practicable however, and satisfactory results may be obtained by using two resistances, one for use on short lines and a higher resistance for long lines. The resistances are wound on one spool and one winding is bridged by a strap of copper wire when the telephone is being assembled. As issued from stock the P.T. is suitable for installation on an exchange line of resistance not exceeding 200 ohms, and under this condition the receiver is shunted by 15 ohms. Should the resistance of the exchange line exceed 200 ohms the bridge piece should be cut by the installing mechanic to increase the resistance of the shunt to 25 ohms. For a public telephone wired in accordance with Fig. 3 the relative resistances are 30 ohms and 50 ohms.

In addition to the circuit changes mentioned, alterations have been made to the coin chute in the mechanism compartment and to the coin tin. Originally the coin chute was constructed with a small recess or pocket in the back wall just above the coin roller. The normal depth of the chute was sufficient to pass two but not three pennies. The pocket had an advantage in that the greater depth of chute immediately above the roller reduced the possibility of two coins "riding" in the chute and ensured that in practically every instance the pennies would come to rest side by side on the roller and the coin lever to provide reliable operation of the coin contact springs. Investigations into the causes of chute blockages indicated that a large number was due to three pennies becoming jammed in the pocket owing to the greater depth at this location compared with the depth of the chute below the roller. It was decided to modify the chute by eliminating the pocket and increasing the depth to pass three coins. The greater depth permits the pennies to come to rest at the roller with little danger of the coins riding and should three pennies enter the chute a blockage is not likely to follow. It might be mentioned that it was at first suspected and later verified that some callers were inserting three pennies for a call and it is fairly apparent that a number of blockages were due to this cause.

The alteration to the coin tin consists of the fitting of an external hopper to increase the effective height of the tin and to widen the slot. Consideration was given to the question of increasing the height of the tin itself, but the construction and location of the chute in the tin rendered this course undesirable. The alteration adopted was introduced to overcome the tendency in some installations for pennies when passing from the chute in the telephone to come to rest on the edge of the coin tin. The trouble mentioned was due largely to the different clearances found to exist between the bottom of the chute and the top of the coin tin in consequence of the manufacturing tolerances allowable for the P.T. case and the tin respectively. Where a tin of minimum length was associated with a case of the maximum length the trouble was most pronounced.

Large numbers of public telephones and coin tins in which the alterations discussed have been incorporated are now in use and the adoption of the modifications has resulted in a marked reduction in the number of coin blockages. Consideration is being given to the desirability of modifying telephones of the earlier type in situ to conform to the present standard.

TELECOMMUNICATION SERVICES FOR CIVIL AVIATION

R. M. Badenach, B.Sc., A.M.I.E. Aust.

Introduction.

As a modern system of fast moving transportation, civil aviation demands organised telecommunication services for its successful operation. To achieve success in its operations an air transport organisation must build up regular and punctual traffic schedules for the transport of passengers, mail, and goods. The greatest deterrent to regularity and punctuality is adverse weather, and it is under such weather conditions that telecommunication facilities are most essential. The prime underlying reason, however, for the development of such services is economic in that no system of transportation can hope to develop successfully unless it gains the confidence of the public from the viewpoint of consistent and reliable operation.

The telecommunication services that are required may be summarised as follow:—

(a) Radio aids to aerial navigation;
(b) Aeronautical radio services (communication between ground and aircraft and vice versa);
(c) Point to point communication on the ground between terminal and intermediate airports;
(d) Airport control radio services; and
(e) Radio broadcasting of weather conditions.

Unless otherwise stated, these services will be discussed from the viewpoint of the design of telecommunication systems for the operation of commercial aircraft over large land masses such as the continent of Australia.

Radio Aids to Aerial Navigation.

Radio aids to aerial navigation are necessary to overcome the practice of "contact flying", i.e., directing the course of an aircraft by the recognition by the pilot of familiar landmarks. Such a method of navigation obviously breaks down during adverse weather conditions and at night. Moreover, it does not permit an aircraft to fly at those heights at which winds may be most favourable, an important factor when the running costs of modern high-powered, fast-moving machines are considered.

Radio aids to aerial navigation take many forms, but herein will be described briefly the following:—

1. Ground direction finding systems (D.F. systems);
2. Radio compass or homing device; and
3. Equi-signal radio beam systems (radio range systems).

Ground Direction Finding Systems.

In the ground direction finding system of navigational aid, use is made of the directive property of a loop aerial capable of rotating in the electro-magnetic field of a radio transmitter, as illustrated in Fig. 1. As the loop is rotated in the field an electromotive force is induced in it proportional to the cosine of the angle between the vertical plane of the loop and direction of the transmitter, so that if, as in practice, the loop is turned until a minimum signal is received, then its plane is at right angles to the direction of the emission.

Since the rotation of a simple loop will produce, as shown in Fig. 1, two positions 180

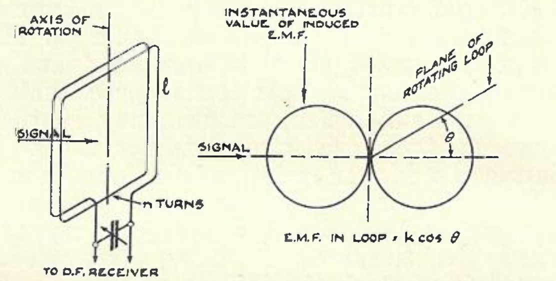

Fig. 1.—Electromotive Force Induced in Rotating Loop.

degrees apart where the induced signal is a minimum, such a device will give the direction of an emitter only. In order to obtain the sense of this direction, a loop is used in conjunction with a vertical aerial, as shown in Fig. 2.

The receptive properties of a vertical aerial are omnidirectional, and when the signal induced in it is combined in the receiver with that induced in the loop, the phasing of the respective induced currents is such that for 180 degrees of rotation of the loop the signals in the vertical and loop aerials are in phase and for the other 180 degrees they are in anti-phase. By a suitable balancing of the e.m.f.'s induced in the two

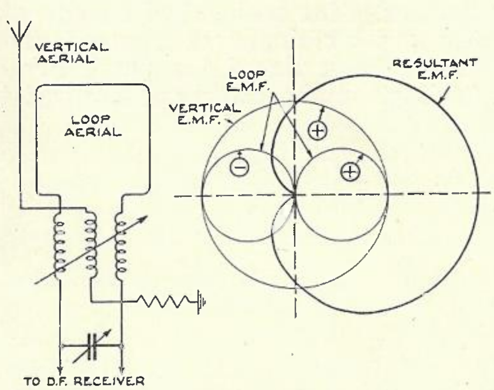

Fig. 2.—Heart Field Pattern for Obtaining Sense of Signal.

aerials it will be seen (Fig. 2) that in one direction the signals will assist and cause a high maximum output in the direction finding re-

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ceiver, while in the other direction they will be opposed and cause a definite minimum, thus producing a resultant heart-shaped diagram, and thereby permitting the sense of a signal from a transmitter to be given, so that an aircraft in flight emitting such a signal may be given a bearing.

"Fixes" of aircraft in space are obtained by a process of triangulation by two or more ground direction finding stations, each determining the bearing of an incoming radio signal and then plotting the results on a map in order to determine the intersection of the directions obtained. One of the ground stations is usually nominated as a control station, and the subsidiary stations forward the results of their bearings to this control station which, in turn, after plotting all the bearings, transmits the resultant fix by radio to the inquiring aircraft.

A rotating loop is restricted necessarily in its dimensions so that its ability to pick up radio signals is limited. In order to improve sensitivity the Bellini-Tosi System of ground direction finding is used. In this system the rotating loop is replaced by two large fixed loop aerials placed at right angles. These aerials are fed to a radiogoniometer, a device which may be compared to an alternator in that it consists of an armature rotating in the field produced by two stator windings. These fixed field windings are placed at right angles, and are connected respectively by radio frequency transmission lines to the fixed aerial loops. The rotating armature consists of a winding which, in turn, is connected by a slip ring device to the direction finder receiver. It may be shown that an incoming radio signal inducing e.m.f.'s in the aerial loops sets up a resultant field via the fixed coils of the radiogoniometer, the direction of which resultant field is the same as that of the field incident upon the aerials. The armature of the radiogoniometer is now rotated just as a rotating loop would be rotated until a minimum signal is received, and the direction of the incoming signal is read off from a calibrated dial.

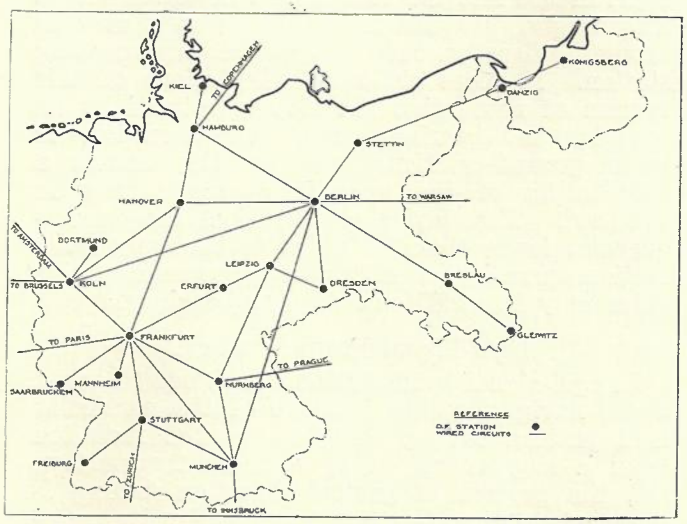


Fig. 3.—Application of Ground Direction Finding System in Germany.

The application of the ground direction finding system of giving navigational aids to aircraft in flight is well illustrated in Fig. 3, which shows radio direction finding stations in Germany. It will be noted that these stations are so placed that an aircraft in flight over almost any portion of the country may be given information regarding its location by the process of taking bearings from two or more stations.

One of the big disadvantages of loop type ground direction finding systems is that bearings are subjected to the so-called night effect, as a result of which varying and false readings are obtained. These false readings have been proved to be due to that part of the radiated field of a transmitter which is reflected from the ionosphere, that is, the so-called indirect ray. As for the radio frequencies used such reflected fields only reach an appreciable magnitude between the hours of sunset and sunrise, it will be seen how the term "night effect" has been introduced. During daylight hours receiving aerials are influenced only by the direct radiation from an emitter and, generally speaking, this direct radiation, except for an aircraft directly overhead, is vertically polarised, that is, adopting the usual convention, the magnetic vector of the electro-magnetic wave is horizontal and the electric vector vertical so that the e.m.f. induced in a loop may be regarded as being due to the cutting of the vertical sections of the loop by the magnetic vector. No e.m.f. would be induced in the horizontal portions of the loop as the magnetic vector would be parallel to such portions. After sunset, however, when the down-coming ray from the ionosphere is received, the plane of polarisation is invariably rotated to a greater or lesser extent, i.e., the magnetic vector, instead of remaining horizontal, has components in the vertical plane. These components act upon the horizontal members of a rotating loop and produce e.m.f.'s giving false bearings. To overcome the phenomenon of night effect, the Adcock Aerial System was developed. Such a system is shown diagrammatically in Fig. 4.

It will be noted that the fixed loops of the Bellini-Tosi System have been replaced by two U-shaped aerials each consisting of two vertical wires spaced diagonally, the wires being connected to the receiving hut by screened or balanced radio frequency transmission lines. By this construction there are no horizontal members of the receiving system that are capable of picking up any appreciable signal, so that the receiving system is sensitive only to the direct normally polarised ray and insensitive to any abnormally polarised radiation that may be down-coming from the ionosphere.

The radio carrier frequencies (wave-lengths) that have been used almost universally until

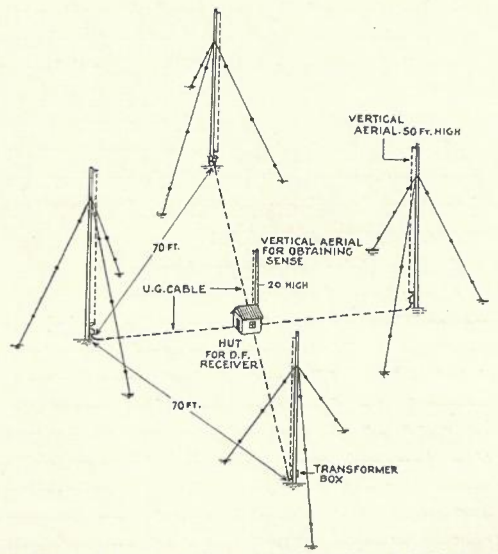


Fig. 4.—Typical Adcock Ground Direction Finding Station.

quite recently for ground direction finding were of the order of 300 kc. (1,000 metres), the whole of the ground direction finding system of the Continent of Europe having been built up by using frequencies of this order. Propagation of these frequencies is good, giving bearings from 150 to 300 miles, although a system is rarely expected to work at distances greater than 100 miles because the design of a ground network is such that for reasons apart from radio propagation direction finding stations must be placed at distances not exceeding approximately 200 miles. However, even over short distances, the big disadvantage of these medium frequencies is that under conditions of high atmospheric disturbances reception becomes extremely difficult and at times impracticable, so that the giving of bearings is impossible. In recent years, therefore, attention has been given to the design of direction finding systems using intermediate and high radio frequencies extending from two to 20 megacycles (150 to 15 metres). The noise level on this frequency band is considerably less and propagation characteristics are such that good signals may be obtained over great distances. The radiation of the frequencies, however, is subject to extreme abnormal polarisation so that the use of receiving aerials of the Adcock type is essential and all the equipment must be carefully balanced and screened.

The use of intermediate and high radio frequencies is simplified considerably by replacing the headphones of the direction finding receiver by a cathode ray tube so that incoming signals may be viewed as a trace on the screen of the tube, i.e., the direction is obtained by using the sense of sight rather than the sense of hearing. Moreover, as the screen of the tube is calibrated in 360 degrees, the bearing is given instantaneously, a great improvement over the comparatively tedious method of tuning a radio receiver until a minimum signal is received in a pair of headphones. Furthermore, the trace of an incoming wave stands out vividly against a background of even high atmospheric interference.

A further interesting development that is being undertaken in the design of direction finding systems in order to overcome the effects of abnormal polarisation is the making use of an adaptation of the experimental methods that have been used for conducting research regarding the extent of the various regions of the ionosphere. An electro-magnetic pulse having a duration of a small fraction of a second is sent out from a transmitter and, because of the fact that an indirect ray reflected from the ionosphere must travel a greater distance than the direct ground ray, the latter reaches the receiver first. This received signal may be so applied as to give error-free bearings.

Radio Compass or Homing Device.

The use of the radio compass or homing device as an aid to aerial navigation may be regarded as a reversal of the ground direction finding system previously described, in that the transmitter is on the ground and the rotating loop on the aircraft. When used as a simple homing device the loop is fixed in a definite relation to the centre line of the aircraft, and it is connected through a radio receiver to a centre zero meter on the instrument board. The circuit arrangements are such that when the aircraft is directed exactly at a transmitting station, the meter reads zero. If the aircraft deflects to the right or the left the centre zero indicator moves accordingly. By this means an aircraft may be brought directly over a ground transmitting station. In more elaborate adaptations of this system of navigation the loop is rotated by an operator and bearings are obtained on two or more ground stations, and by this means a definite fix of the aircraft in space may be obtained. The device usually operates on frequencies lower than 1,000 kc. so that any radio station operating on a frequency lower than this value may be used for obtaining bearings.

Equi-Signal Beam Systems.

In equi-signal beam systems designed to assist aerial navigation, use is made of the particular field pattern set up in space by the radiation from a loop energised by a radio transmitter, i.e., the process of ground direction finding is reversed, in that the loop is used for transmitting and not for receiving. In practice, two large crossed loops are used, the loops being energised alternately. The system may be explained by reference to Fig. 5, where the two full circles represent the field pattern produced in space by one vertical transmitting loop, and the two broken circles represent the field pattern produced by the second loop placed at right angles to the first one.

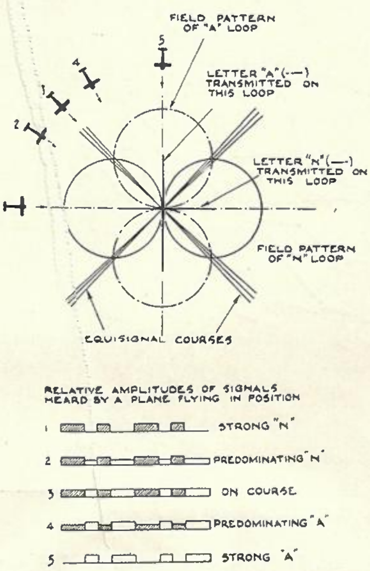


Fig. 5.—Production of Equi-Signal Courses or Beams Using Medium Radio Frequencies.

If the loops be energised alternately it will be noted that there are four directions in space where the circles intersect and where the signal would always be received by an aircraft in flight. In practice, the energy fed to the loops is keyed, and Fig. 5 is illustrative of the so-called "A" and "N" System. One loop is keyed to send out a modulated signal representative of the Morse symbol for the letter "N"; the other loop transmits the letter "A". If the spacing between the dots and the dashes of the "A's" and the "N's" is so arranged that the two signals interlock, then an aircraft flying in the "N" zone will receive such a signal on a radio receiver tuned to the transmitter; if flying in the "A" zone he will receive the letter "A"; and if flying in the zones covered by both the "A" and the "N" signals then a constant tone is received. This is made clear in the lower portion of the figure, where five positions of an aircraft are shown, and the signal received in the aircraft is indicated. This figure also illustrates how the "A's" and the "N's" are so spaced as to interlock and so give rise to the continuous signal that is received when an aircraft is flying on course. The system may be so designed and adjusted that the equi-signal zones providing the continuous signals have a spread of approximately three degrees.

In Fig. 5 the courses are spaced at 90 degrees but by again making use of the omni-directional field set up by a vertical radiator in conjunction with the field produced by the crossed loops, and by adjusting the value and phasing of the currents in the respective radiators, individual courses may be bent over angles from 45 degrees to 135 degrees so that, by this means, the one beam transmitting station may be used for setting up courses over a wide range of the points of the magnetic compass.

The crossed loop system of transmitting equi-signal beams is subjected to the same errors from night effect as the ground direction finding receiving loops. To overcome this disadvantage crossed loops are replaced by vertical radiating systems after the principle shown in Fig. 4. Since the system is used for transmitting, however, the whole of the equipment must be of a much heavier design. The vertical aerials consist of four self-supporting steel towers each 125 ft. high and spaced on 600 ft. diagonals. Each tower is furnished with an extensive earth system, and must be illuminated with aircraft warning lamps. The towers are connected by underground radio frequency transmission lines to a transmitting station situated in the centre of the site, from which point also 50-cycle power is supplied by cables to each tower for lighting purposes. It will be realised that such an installation is fairly costly, and necessitates a high capital outlay when a continental-wide service is under consideration.

The equi-signal radio beam system has been developed extensively in the United States of America where it forms the main radio navigational aid to what must be one of the largest commercial aviation organisations in the world. Altogether, serving the domestic airlines within the boundaries of this country, there are some 140 beam stations varying in rated power from 15 to 2,000 watts. The application of the system particularly from the viewpoint of delineating definite air routes, is shown in Fig. 6.

A close study of the medium frequency radio beam system shows that, notwithstanding its acknowledged success, it has, from the viewpoint of the radio engineer, certain disadvantages. In stating these disadvantages it should be remembered that the commencement of the installation of the American system was made approximately 10 years ago, and that it has been constantly developed since that date until now some millions of dollars of capital have been expended upon it. Developments in the science of the propagation of radio signals since the commencement of the design of this system have been extensive so that, in considering the application of an equi-signal radio beam system to another continent, it was only natural that these developments should be taken into account, with a view to determining in what way the American system should be modified.

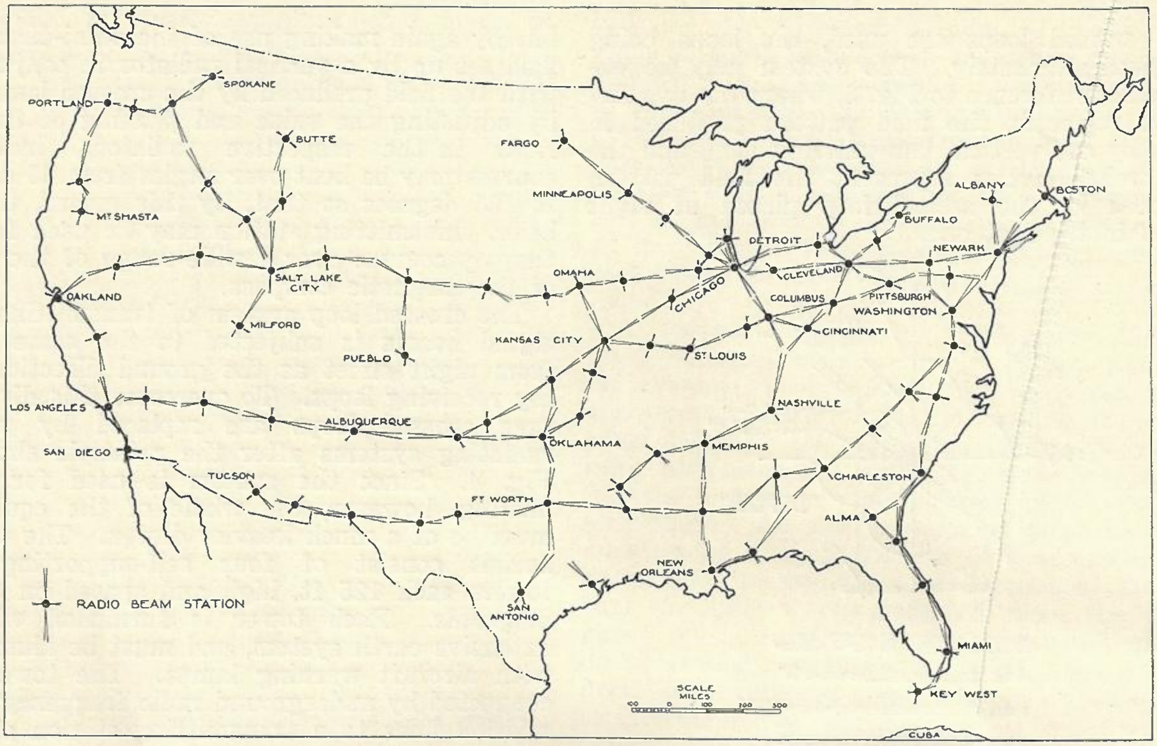


Fig. 6.—Application of Radio Beam System in the United States of America.

The equi-signal radio beam systems in the United States of America operate on radio frequencies between 200 and 400 kc. (1,500 to 750 metres), and practice has shown that mainly because of this fact the following difficulties are experienced:—

1. Interference from electromagnetic disturbances set up by thunderstorms and by rain, dust, and snowstorms is at times severe.
2. Night effects limit the range of stations to approximately 30 miles.
3. Because of the comparatively long wave-lengths used, the costs of radiating systems to reduce night effects are high.
4. Reflections from the ground of the propagated waves, particularly in broken country, cause the equi-signal beams to become split or, in other words, multiple courses are set up, i.e., instead of there being only the one equi-signal course in a particular direction there may be several courses, all of which but one would be false. These multiple courses vary with distance from the station, and also with the height at which an aircraft is flying.
5. Because of the extensive earthing system which enters into the radiation circuit of a beam station, variations in soil conditions immediately below the aerial cause the courses to shift by as much as 15 degrees, i.e., variation of vegetation, snowfalls, and alteration of conditions brought about by seasonal effects do, unless particular care be taken, cause a beam to be deflected from the course for which it was originally set.
6. The propagation characteristics of the radio frequencies are such that there is a comparatively high indirect ray reflected from the ionosphere. This ray may be received at some distance from the station and so cause a severe limitation of the extent to which the already limited number of frequencies that are available may be used by more than one beam station.

Ultra High Frequency Equi-Signal Radio Beam Systems.

Many of the difficulties outlined above would be overcome if, instead of using that portion of the frequency spectrum between 200 and 400 kc., ultra high frequencies in excess of 30 megacycles were used for transmitting the equi-signal beams. The concentrated research upon these frequencies during the past few years has shown that satisfactory reception utilising them is possible for a short distance beyond the so-called optical range between the transmitting and receiving points. The optical range for various heights above the surface of the earth is shown in Table I, the heights listed being the sum of the heights of the transmitters and receivers.

TABLE I.

Height in feet.	Range in miles.
500	27
1,000	39
1,500	47
2,500	61
5,000	87
6,667	100
10,000	122

The spacing on the ground of equi-signal radio beam stations is determined to a large extent by the characteristics of the air route. For instance, a beam station should be located at all important intermediate and terminal airports and, in practice, it is found that stations are required at the most at distances from 150 to 200 miles. Preferably, they should be located at much closer intervals, and so act as markers for as many intermediate landing fields as is possible, and at the same time provide a wider margin of safety in the event of a temporary equipment failure at one station for, in the event of such failure, the gap temporarily without a radio navigational aid would be considerably reduced. In other words, a comparatively large number of small-powered beam stations is to be preferred to a smaller number of higher-powered equipments. It will be realised, therefore, that even if ultra high frequencies be propagated only over optical distances, the ranges shown in Table I. are quite adequate to permit their use for radio beam purposes, particularly when it is remembered that by governmental regulation aircraft must fly at a height in excess of 1,500 ft. and in normal daily operation fly at heights from 5,000 to 10,000 ft.

Prior to 1935 an ultra high frequency equi-signal radio beam system had been developed by C. Lorenz, of Berlin, primarily for use as an approach beam and low ceiling landing aid for use in conjunction with ground direction finding systems. The radiating system of this radio beam equipment is particularly simple, and is illustrated diagrammatically in Fig. 7.

The radiating elements consist of three half-wave dipoles supported upon a wooden framework and represented in (a) of the figure. The centre dipole is coupled at the mid-point to the beam transmitter. The outside dipoles are broken at the mid-point, but they may be converted to a resonant condition for the operating frequency by a connection across the mid-points introduced by the operation of a relay. In Fig. 7 (a) the dipole R_1 is shown in the resonant condition so that it becomes energised parasitically by the radiation from the centre dipole. Dipole R_1 then also radiates and the phase relationship between the two radiations is such that the circular field pattern of the centre dipole radiating alone becomes elliptical as shown in the left-hand portion of (c), i.e., radiation in the direction from S to R_1 is reduced, whilst in the direction of R_1 to S it is increased. If, now, the connection across the centre point of dipole R_1 is opened and that across R_2 is completed, R_2 becomes parasitically energised, causing a maximum resultant field in the direction of R_2 to S and a minimum field in the direction of S to R_2 as shown in the right-hand portion of (c). Thus, the operation of the relays produces an alternating field, and where the two fields overlap, as shown in (c), a continuous field is set up. This continuous field forms an equi-signal beam. If now, the relays are arranged by a keying system to produce dots and dashes, the timing of which is such that the dots fill the space between the dashes, then an aircraft flying in the field of one

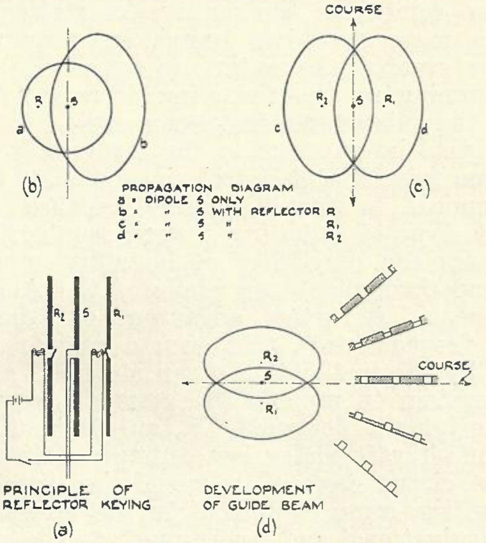


Fig. 7.—Production of Equi-Signal Courses or Beams Using Ultra High Radio Frequencies.
Electrical Communication, Vol. 15, No. 3, Jan., 1937.

ellipse would receive dots, in the field of the other ellipse dashes would be heard, whilst when on course a continuous signal would be experienced. This is made clearer by reference to (d) of Fig. 7. In practice, an aural signal is used supplementary to a visual indication given on a centre zero meter which is located on the instrument board of the aircraft. When an aircraft is flying on course this instrument reads zero, when off course in either direction the centre zero instrument reads accordingly.

The comparative simplicity of the Lorenz System is appealing and, although it had not been used for any purpose other than a low ceiling landing aid, its apparent advantages were such that tests were conducted in Australia to determine its suitability for long distance radio beam work. These tests have shown that for this purpose it is quite satisfactory, giving reliable reception in aircraft not particularly well screened or bonded to distances beyond 100 miles without any indication of multiple courses or interference from atmospheric disturbances. This latter factor alone is a tremendous advantage when one considers the large portions of Australia where it would have been quite impracticable to have considered the use of beam systems operating on frequencies between 200 and 400 kc.

In (c) of Fig. 7 two courses are shown from a transmitter, each 180 degrees apart. No difficulty is anticipated in bending these courses to at least 22½ degrees. For the production of more than two courses it is probable that an additional transmitter operating from a separate radiating system and utilising a different carrier frequency will be required. Such an arrangement will have distinct operating advantages in that there will be a marked differentiation in the pairs of beams emanating from any one particular station. In any case, under existing Australian conditions the number of stations from which more than two beams are required will not be great for some time to come.

Summing up the foregoing, it may be stated that the ultra high frequency system has been proved to be superior to the medium frequency scheme from the electrical view-point, it is more economical to install mainly because of the simple type of radiating system required, and it provides the possibility of installing a uniform scheme throughout the whole of the Australian continent. A further advantage of using ultra high frequencies is that such a system may be used by the installation of an alternative radiating system to provide the service for which it was originally designed, i.e., an aid to the landing of aircraft under low ceiling conditions. In these circumstances it would be possible to utilise the same equipment in the aircraft both for navigational and landing purposes, a simplification having advantages from the viewpoints of cost, weight, instrument panel layout, and ease and simplicity in operation.

Discussion on Radio Aids to Aerial Navigation.

The principal characteristics of the radio navigational aids that have been mentioned in the first part of this paper may be summarised as follow:—

Equi-Signal Radio Beam Systems.

Equi-signal radio beam systems provide a continuous signal to an aircraft in flight, so that as long as a pilot is on his course he has a definite indication to that effect. This receipt of a constant signal has a very favourable psychological reaction upon the pilot. An equi-signal beam indicates the shortest distance between two points, thus tending to fast, economical operation, an important factor when the running costs of high-powered, costly modern transport aircraft are considered. The pilot is the only individual entering into the navigation so that the possibility of errors due to the human factor is reduced to a minimum. The equipment required in the aircraft is a simple receiver which is light in weight and costs little to install. The complicated costly portion of the service is on the ground, and consists of relatively few stations staffed by expert technicians. The fact that the aircraft equipment is so simple permits of its being used by private fliers not necessarily engaged in commercial transport. In other words, the cost of the radio navigational equipment is comparatively negligible as compared with the cost of even the cheapest type of aircraft. Subject to limitations regarding the height and speed at which aircraft must fly, and these limitations are only necessary on the busier routes, there is no limit to the number of aircraft that an equi-signal beam system may handle. Furthermore, when a route is marked by an equi-signal radio beam there is little, if any, need to install light beacons, a very important economical factor in laying out an organised air route. Disadvantages of the beam system are that it gives direction only and the fact that any one particular beam station provides only a limited number of courses.

Ground Direction Finding Systems.

With ground direction finding systems a fix is given in space to an aircraft in flight subject to the time that it takes for the co-operating ground stations to determine the necessary bearings. This time may in certain cases be as great as three minutes, so that with a modern aircraft travelling at 180 miles per hour the aircraft would have travelled nine miles from the time the signals on which the measurements were taken were sent out. Aircraft may be brought to the airport from any point of the compass although experience in Europe indicates that for the final 20 or 30 miles an approach equi-signal radio beam system should be used to supplement the ground direction finding station. Fixes from ground direction finding stations are usually given at, say, 15-minute intervals, and between these intervals it is quite possible for an aircraft to drift dangerously. In any case, this drifting causes unnecessary flying time and, therefore, higher running costs for the aircraft. The responsibility of operating the radio aid to navigation is dependent upon operating personnel in the aircraft and on the ground so that the possibility of error due to the human element is high. Furthermore, on larger aircraft the increased attention that must be given to the operation of the radio equipment necessitates in general the employment of a third member in the aircraft crew, thus further increasing running costs and reducing payload. The aircraft equipment required is comparatively complicated, costly and heavy, and cannot be regarded as being suitable for lighter type of aircraft which it is hoped will be used more and more extensively by private fliers. The system in operation has shown that there is a definite limit to the number of aircraft in flight which a ground station may handle, and in certain busy European airports when climatic conditions become unfavourable to flying this factor places a serious limitation upon the effectiveness of the system. In order to reduce the drift between fixes to a minimum the question of the installation of comparatively costly light beacon systems on the flying routes between airports cannot be altogether disregarded.

Radio Compass or Homing Device.

The radio compass will bring an aircraft in from any point of the magnetic compass and, subject to the distance that is covered during the time taken to make observations, a fix is given in space. The sole responsibility of navigation is upon a member of the aircraft personnel. The radio compass may make use of any ground radio transmitting station operating on frequencies lower than, say, 1,000 kc., but when flying in heavy cross winds the course taken by an aircraft would be parabolic, i.e., it would not be the shortest path between two points, so that unnecessary flying time would be occupied with its consequent increase in running costs. Moreover, this deflection from a straight course may introduce flying hazards into the actual course taken. The aircraft equipment is complicated, costly and heavy, and does not lend itself to the installation of dual navigational equipment which should be provided to ensure service in the event of failure of one equipment, particularly when the apparatus is comparatively complicated. Perhaps the main use of the radio compass is for military flying purposes, and on large commercial aircraft as an adjunct to one or other of the other two systems discussed.

In considering the application of one or other of the above systems to Australian conditions, where ground stations may be spaced over wide areas at intervals not exceeding 150 to 200 miles, it may be concluded that the equi-signal radio beam system has definite advantages. In arriving at this conclusion, it is to be remembered that in 1935 the radio aids to aerial navigation of any type that were in existence were negligible, and it was not necessary, therefore, to consider the possibility of any wastage being incurred due to the scrapping of existing systems. Important flying routes within the Commonwealth of Australia are restricted to definite courses between the larger centres of population so that the limitation of the beam system from the viewpoint of a restricted number of courses is not a serious disadvantage. The fact that, by using ultra high frequencies, a system for the whole of the continent, subject to the limitations imposed by the Commonwealth of Australia Constitution Act, may be designed on the basis of unified control is important, both from the viewpoint of introducing a uniform system and in the allocation of the radio frequencies required. It is difficult to stress the tremendous advantage that Australia has in these matters when compared with a continent like Europe where the conflicting interests of the various nations make unanimity almost impossible. Ultimately, with equi-signal beam systems installed throughout the whole of the Australian continent, any aircraft equipped with a simple type of receiver could fly any route, and the expenditure incurred in installing the necessary navigational aid apparatus would be small. Finally, economic studies indicate that, from the viewpoint of the ground equipment alone, radio beam systems are more economical to operate. If the simplified type of aircraft equipment that is required for the beam systems be taken into consideration, these economies become greater, particularly in the future when the number of aircraft in constant use must increase tremendously over that at present licensed.

Aeronautical Radio Services.

It is essential that aircraft in flight should be able to conduct regular two-way communication with ground radio stations. Such communication services are referred to as aeronautical radio services, and are necessary to permit an aircraft to furnish regular reports, say at 15-minute intervals, regarding its position and progress on its flying schedule; to give details of flying conditions, particularly in regard to weather, for such information is an important adjunct to the data received for weather forecasting purposes; to receive from the ground details of weather conditions over the portions of the route yet to be flown; to receive instructions regarding landing; and to handle service messages regarding bookings, luggage, passengers, meals, etc. Furthermore, in some countries passengers are permitted to transmit private messages whilst the aircraft is in flight.

It is important to decide whether two-way radio communication with aircraft should employ telegraphic or telephonic means of communication. Telegraphy is commercially possible on radio field strengths of considerably less value than those required for telephony. For instance, in the frequency band from two to six megacycles it has been stated that reliable commercial telegraphy may be worked on field strengths as low as five microvolts per meter, whereas for corresponding conditions, to obtain the same degree of intelligence on telephony, field strengths as high as 50 microvolts per meter are required. Telephone modulated equipment is much heavier than correspondingly powered equipment necessary for telegraphy. It is generally admitted, however, that for a modern transport aircraft two men are required solely for the operation and navigation of the aircraft in flight, and that telegraphic communication demands the attention of a third member of the crew skilled in morse operation. Telephonic messages, however, can be readily handled by a pilot or his assistant. It will, therefore, be seen that on this basis, for telegraphic operation, a third man is required thus reducing considerably the paying load of the aircraft and at the same time increasing running costs. Generally, it may be concluded that the use of telephony is justified for intracontinental services over populous routes where, for other reasons as well as for communication with aircraft, ground stations must be placed at fairly regular intervals. On intercontinental routes employing larger aircraft, and where ground stations frequently must necessarily be spaced at greater distances, the use of telegraphy is the standard practice. Furthermore, aircraft of the type employed on these routes are such that the carrying of a third man in the crew for the operation of the aeronautical and air navigation radio services is fully justified, remembering that the latter type of service must be of the ground direction finding system type, necessitating considerably more work in the aircraft than is required for equi-signal radio beam operation.

In Europe the practice has been to use radio frequencies of the order of 300 kc. (1,000 metres) for aeronautical radio services. The propagation characteristics of these frequencies are well-known but, as mentioned previously, they suffer from a very serious drawback in that the noise level on them from atmospheric interference is particularly high. In other countries attention has, therefore, been given to the use of that portion of the radio spectrum between two and six megacycles, and in the United States of America and the Union of Soviet Socialist Republics extensive aeronautical services have been built up employing these frequencies; in fact, the whole of the intricate structure of the organisation for such services in the former country is based solely upon the use of them. Their advantages are that atmospherics are less troublesome, radiating systems may be constructed more efficiently because of the shorter wave-lengths (this applies particularly on the aircraft), and the aircraft transmitting and receiving equipment is much more compact. Furthermore, experience in operating these frequencies in point to point radio services on the ground cannot be translated directly in order to determine their suitability for effecting communication between the ground and aircraft in flight, particularly in so far as the phenomenon of skip distance is concerned. There is undoubtedly evidence to state that, in communicating with aircraft, the skip distance effect so well-known in point to point operation on the ground is not extensively experienced. The propagation characteristics of the band are such that dual frequency operation is required, one frequency towards the lower portion of the band being used for night operation and another towards the upper end of the band for day working. Once a system has been developed utilising these frequencies there is every evidence to indicate that it will operate more satisfactorily than a system utilising the lower frequencies around 300 kc.

The ground stations for intracontinental aeronautical radio services should be spaced from 100 to 200 miles apart, depending upon the routes flown and the traffic conditions pertaining on the routes. They should be operated on the "Watch" principle, i.e., any one particular route extending say, across a continent, would have allocated to it one set of operating frequencies, for use at all stations both on the ground and in the aircraft, and a continuous watch would be kept on these frequencies by all ground stations. The powers of the ground transmitters should be from 150 to 1,000 watts unmodulated carrier in the aerial, the figure of 400 watts being normal. Although telephone modulated signals are normally transmitted, the equipment should be designed to permit of operation in case of emergency on continuous waves and modulated continuous waves. As stated previously, particularly when intermediate radio frequencies are used, the radio stations should be capable of operation on at least two frequencies, preferably three, and should be designed for remote control, including remotely operated facilities, for changing the carrier frequency. From this it will be inferred that there is no need to have a technical staff in constant attendance at the transmitters. Crystal control of the carrier frequency is almost if not absolutely essential, whilst modern practice demands that all apparatus should be operated direct from alternating current supply mains, i.e., the use of rotating machinery is avoided as much as possible.

Aircraft transmitting sets (aircraft stations), should be capable of operating on at least two, and preferably three, carrier frequencies. To permit the equipment being placed in suitable locations apart from the pilot's cabin, and yet retain within that cabin all essential operating facilities, all equipment should be designed for remote control. Carrier frequency stability should be determined by piezo-electric crystals and, as stated previously, for intracontinental routes the equipment should be telephone modulated and capable of delivering an output of 50 watts of unmodulated carrier to the aerial. An important feature in the mechanical design of the transmitting sets is that they should be readily demountable from the aircraft to permit of maintenance, spare sets being installed whilst the overhaul is proceeding.

Aircraft receiving sets should be of the superheterodyne type with the oscillators crystal-controlled, and designed to receive at least two radio carrier frequencies. As for the transmitter, receiving apparatus should be designed to permit of mounting in convenient positions apart from the pilot's cabin, operation by the pilot being completed remotely either by control wires or electromagnetic switching, this remote operation to include frequency changing. All equipment should be designed to permit of rapid detachment from the aircraft to allow regular maintenance.

Illustrative of the design of a telecommunication net-work for aeronautical radio services is the development within the United States of America where the various airway companies operate some 140 stations, whilst in addition the governmental authority controlling civil flying owns and operates a further 68 radio stations capable of communicating with aircraft in flight.

Point to Point Ground Communication.

An organised system of air transport necessitates constant and reliable communication between ground stations at airports and between landing fields and weather reporting stations along a scheduled flying route. This communication channel is required for the transmission of meteorological information, notices regarding the despatch and arrival of aircraft, information relative to conditions of aerodromes and any such emergency intelligence as it may be necessary to transmit from point to point in order to ensure added safety to air navigation. In certain instances, communications of the governmental authority controlling air services are transmitted, particularly in relation to accidents and the transfer of material and spare parts such as are required to ensure reliable and safe flying operations. Furthermore, terminal and intermediate airports must have ready means of being kept informed regarding passenger reservations and cancellations.

At first glance it would seem that this communication traffic could be handled by the aeronautical radio stations and to a certain extent such is the case, but experience in many parts of the world has shown that, where the number of scheduled air flights along a route reaches any magnitude at all, land wired circuits must be employed. In other words radio communication, which at any time is a poor substitute for wired communication, should be reserved for those services for which its use is absolutely necessary, i.e., for communication between ground and aircraft in flight. As indicative of the application of this principle, a map of Germany showing the wired circuits employed solely for point to point ground communication relative to air services is shown in Fig. 3. In the United States of America the governmental authority controlling the airways operates a wide wire network, used mainly for weather reporting purposes, having a total length as at June, 1936, of 13,151 miles. In addition, in that country, the various airways operating companies have private wires to the extent of some thousands of miles, apart from the use they make of the teletypewriter exchange service. On these wire circuits it is the practice, both in Europe and in the United States of America, to utilise machine telegraph systems employing teleprinters.

Airport Control Radio Services.

At airports where traffic reaches any reasonable dimensions it is necessary that facilities be provided for directing, from an airport control tower, the arrival and despatch of aircraft. Such direction is required to prevent the landing field being employed simultaneously by more than one machine, to give instructions regarding the runway that should be used in taking off or landing, and to give directions regarding the gate of the airport to which the aircraft should be taxied after landing. A certain amount of this traffic may be handled by semaphore methods, but for giving directions regarding landing, which directions may be necessary when an aircraft is some 20 or 30 miles away from an airport, radio communication must be used.

Frequently, small transmitters of limited range are installed in the control tower of an airport, these transmitters operating on a frequency which can be tuned in on the aircraft receivers that are used for either air navigational or aeronautical radio purposes, preferably the latter.

Radio Broadcasting of Weather Conditions.

Experience has shown the necessity of the personnel of an aircraft being kept informed regarding the weather conditions to be met on the route ahead of the aircraft during the progress of a flight. This communication service may be provided by first designing a ground system to collect weather data at selected reporting stations along the course of the aircraft, and then arranging for the broadcasting of these reports from radio stations placed along the route. A weather report for aviation purposes should supply details regarding the height of flying ceiling, extent of cloud, visibility, weather, obstructions to vision, temperature, dew point, wind, barometric pressure, and field observations. At each reporting station these observations are made hourly, and are communicated to the appropriate radio station for immediate broadcasting. A working system may best be described by explaining the conditions that existed at Los Angeles, U.S.A., in May, 1935. This city is the junction of four scheduled air routes and receives hourly weather reports from stations along all these routes. These reports were broadcast hourly as follows:—

On the hour .... six reports on route No. 1;
At 10 min. past the hour .... six reports on route No. 2;
At 15 min. past the hour .... three reports on route No. 3;
At 30 min. past the hour .... the report for Los Angeles;
At 50 min. past the hour .... ten reports on route No. 4.

In addition, at five min. past the hour the upper air reports obtained by pilot balloon observations at Los Angeles were broadcast, and at a stated time four times daily the airway weather forecasts for each of the four airways previously mentioned were also radiated. By this means the personnel of any aircraft within the range of the broadcasting station would be kept informed regarding the weather ahead including upper air conditions and, in the event of the receipt of adverse reports, would have ample warning to take such steps as are necessary—such as landing at an intermediate airport —in order to ensure safety.

Weather radio broadcasting service has been given in many countries over the same communication channel as the radio navigational aid. With the growth of air transport, this method has serious disadvantages in that the interruption to the navigational aid causes considerable inconvenience and at times a hazard to aircraft in flight. If the aeronautical radio stations be used solely for communication with aircraft, that is, if all point to point service on the ground be conducted by telegraphy over wired circuits, then it is thought that a communication traffic study would show that, for Australian conditions for some considerable time to come, all weather reports to aircraft in flight could be handled by the aeronautical stations. By this means the provision of special weather broadcasting stations could be avoided with a consequent reduction in the cost of establishing the radio ground organisation, and aircraft radio equipment would be simplified, thus resulting in even further economies.

Conclusion.

As an example of the application of the services outlined in this paper, there is shown in Fig. 8 the ground organisation that existed in March, 1935, for the provision of telecommunication facilities on the airway between San Francisco (Oakland), and San Diego, California, U.S.A.

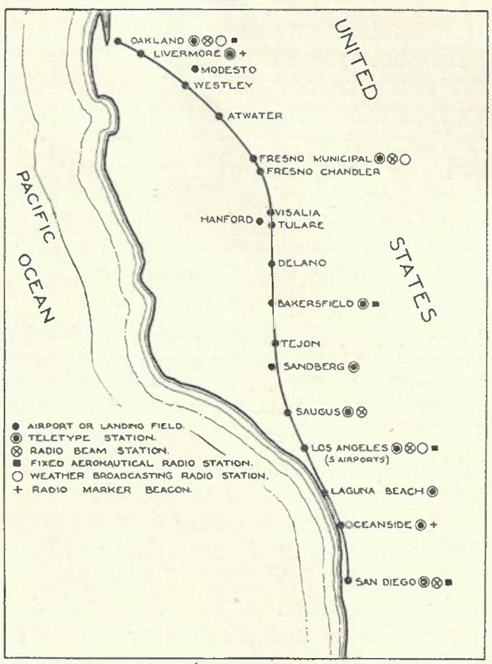


Fig. 8.—Communication Services on Typical American Air Route.

A study of this figure will indicate that on this route of approximately 460 air miles there are some 20 landing fields, 10 teletype stations for reporting weather conditions and conducting other point to point communication services, five equi-signal radio beam stations of various powers, two radio marker beacons, three radio telephone stations for broadcasting weather conditions and four aeronautical radio stations.

As further evidence of the extent to which communication services are considered necessary in the organisation of commercial air routes, the following statistics relating to the services controlled within the United States of America by the Bureau of Air Commerce as at June, 1936, are furnished:—

Combined weather broadcast and equi-signal radio beam stations (full power)	56
Weather broadcast stations (full power)	16
Equi-signal radio beam stations (full power)	32
Equi-signal radio beam stations (medium power)	41
Equi-signal radio beam stations (low power)	11
Non-directional radio marker beacons	56
Point to point radio telegraph stations (employed chiefly on routes where wired communication circuits are not available)	68
Teleprinter stations for weather reporting	210
Radio operators employed	580
Airway keepers employed	296
Teletype wire circuit mileage	13,151
Teletype circuit rentals paid to the American Telegraph and Telephone Co. per annum	$374,488
Cost of maintenance and operation of telecommunication services, exclusive of foregoing teletype circuit rental	$2,145,713
Cost of telecommunications per mile of scheduled airway	$93
Gross cost of telecommunication services per passenger mile for scheduled air lines	$0.015

The foregoing figures do not include the costs relating to some 245 aeronautical, point to point and airport radio stations owned and operated by the various commercial air transport companies.

This paper summarises briefly the conclusions relative to the subject matter discussed herein of an overseas investigation made by the author in 1935. The investigation was made in conjunction with Squadron-Leader C. S. Wiggins, of the Royal Australian Air Force, but Mr. Wiggins has not been consulted in the preparation of the paper and is, therefore, in no way responsible for the views expressed in it. The author is sure, however, that he is in complete agreement in acknowledging the unlimited assistance that was given during the inquiry by radio engineers in many overseas administrations, particularly in the British and German Air Ministries, but especially in the Air Navigation Division of the Bureau of Air Commerce of the United States of America.

Acknowledgments.

The author is indebted to Mr. R. Lawson, M.I.E.Aust., for his permission to publish this paper and to Mr. R. A. Turner for the preparation of the illustrations.

AN INTERESTING DELAYED ACTION CIRCUIT

C. L. Hosking

Time delay devices have almost universal application in the field of electrical science. Flashing signs, automatic lifts, railway and road signal operation, power station switching apparatus and circuit breaking appliances, all have features requiring some form of timing control; and these are but a few of examples which may be called to mind in allied engineering sections. In this diverse range of application it is evident that many and varied principles of physics have been exploited to evolve successful deferred action contrivances, each possibly the most suited to its particular need.

It is probable that automatic telephony has created the greatest demand for such devices, and an outstanding development of modern telephony has been the evolution and almost general adoption of one of the simplest and most reliable timing arrangements yet devised—the slow acting relay. This relay is ubiquitous in modern circuit design because of the multitudinous needs which are met by its induced field's action of retarding its operation and/or release. Whilst admirable for the purpose of bridging short intervals of time such as those which occur in the circuit operation of automatic telephone switches, the slow acting relay is still only capable of time delays of the magnitude of a fraction of a second, and as there are conditions in automatic exchange operation which require timing apparatus covering seconds or minutes of sustained action, other types of apparatus must be adopted to meet this need.

One instance is the necessity for some contrivance which will indicate the failure of a bimotional switch to release after operation. The release of a selector involves a mechanical movement which normally occupies but an instant, and a faulty return movement will tend to sustain the release circuit condition for an undue period of time. The release circuits of a group of switches therefore, include a deferred action alarm device which will not operate if a switch or a succession of switches behave normally in their release action, but if any fails in its restoring movement the alarm will function, to attract attention, at the expiration of the delay period.

In Strowger type exchanges the so called "dashpot" relay has been installed to produce the necessary time delay, and this relay will provide a deferred circuit closing action which will barely respond to the short pulse caused by the release motion of any selector which it serves, but the sustained closure of a faulty release circuit will prolong the "dashpot" relay's action until it reaches its limit, when an alarm circuit will be established. The dashpot consists of a solenoid operated piston moving in a cylinder of oil. The piston, in its upward movement under the influence of the solenoid, forces oil through a small opening, and may take some seconds to reach its final operated position, where it closes contacts to establish the alarm circuit. When the solenoid circuit is opened gravity restores the piston to its normal position, its fall being comparatively rapid, as the oil is now returned through a valve opening providing a relatively low fluid resistance. This arrangement is slow to fully operate but is much quicker in its restoring movement. One disadvantage of the "dashpot" relay is that the time of piston movement is dependent on the viscosity of the oil used and this may vary with temperature.

Another method is often used to obtain the necessary delay period for release alarms, this method is also used for signals indicating that receivers are not properly restored to switchhooks after use, or that permanent fault conditions exist on subscribers' lines. A switch of the uniselector type is operated step by step from a pulse action generated by cam movement on the exchange ringing or other rotary machine, alternatively the pulse may be produced by interacting relays. If the pulse has a periodicity of say 1.5 seconds then the time taken to step 20 contacts is 30 seconds, and if a relay initially operated at the 1st contact and then locked electrically to the starting circuit, is still retained in this position at the 20th step an alarm circuit may be established having a delayed action of at least 30 seconds. By utilising this 30 seconds pulse in a similar stepping action of a 2nd switch the delay period may be multiplied as desired. A detailed description of this system may be obtained by a perusal of the article by Mr. Draper, in Telecommunication Journal, No. 5, of June, 1937, Page 196.

A thermal operated device is sometimes used employing a bimetallic strip, which, when heated by a resistor, is distorted by unequal expansion of the two metals, and these slowly move to finally establish an alarm circuit. This design needs a comparatively long period to recover fully after operation, and is limited in this respect for general adoption.

A scheme, the subject of this article, has recently been evolved which may prove to have advantages over previous methods, and, apart from other considerations, attracts attention by the ease of its assembly and the absence of specially constructed equipment. Its operation introduces a principle which, it is believed, is new to telephone work.

The new design was developed after considera-

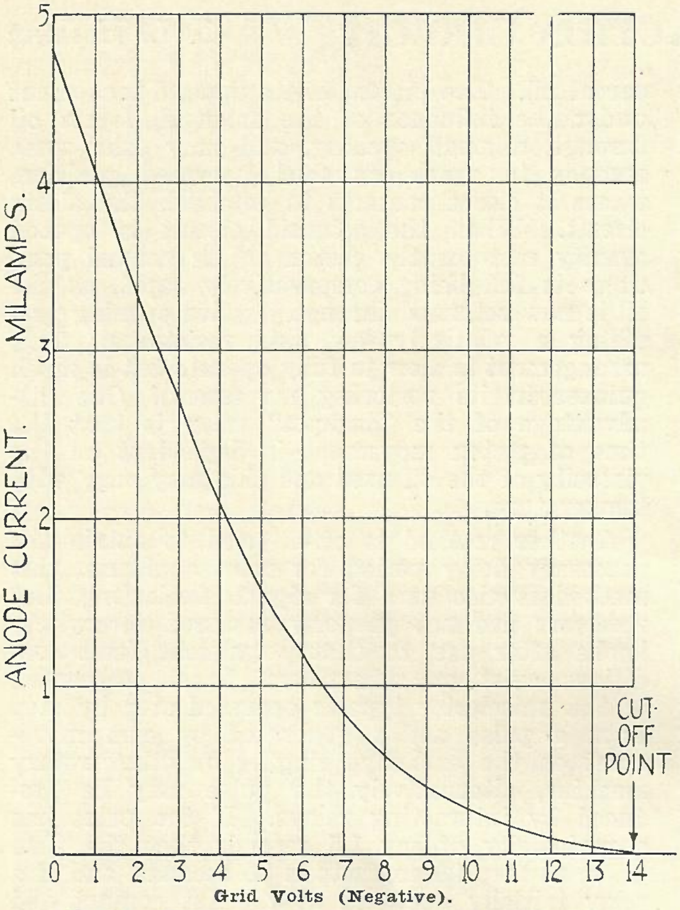


Fig. 1.—Relationship between anode current and grid potential of typical triode amplifying tube.

tion of the behavior of the ordinary triode electron tube when subjected to grid control. This is illustrated in the familiar characteristic graph shown in Fig. 1 which indicates the behavior of a tube used in trials of the new circuit. This graph depicts the effect of the application of gradual increases of negative or bias potential to the grid of a tube, this varying bias causing a decline in the anode current until the so called "cut off" point is reached, where the current falls to zero, and remains at zero with any further increase in negative grid potential. It will be seen by reference to the graph that, whilst at all grid potentials exceeding the cut off point of 14V negative no anode current flows, at lower negative values the current increases at progressively greater rates until, at zero grid potential, the value of 4.8 milliamps is reached.

The actual timing element of the new device is a charged condenser connected to a charge dissipating resistor, the time of discharge being dependent on the respective values of the quantity of charge held, and the resistance used. By suitably choosing different capacity values of the condenser, and making a corresponding selection of the discharge resistor, a wide range of discharge times is available from commercial types of condensers and resistors, at any one potential value.

The scheme associates a triode tube with the condenser unit so that, if the condenser is charged and afterwards connected to the resistor, the charge on the condenser maintains a negative potential to the grid of the tube, so preventing anode current flow. As the condenser discharge progresses, the grid potential decreases accordingly, the potential across the condenser being proportional to the charge held, and thus the falling condenser potential, and correspondingly the grid bias, will eventually reach the point at which anode current is permitted to flow, and later, to reach that value which will operate an alarm relay forming part of the anode circuit.

The time occupied in discharging the condenser from the initial full charge potential to the point at which the relay operates is, of course, the delay function desired, and some idea of the period of time occupied in this action may be obtained from the result of one experimental trial which showed that with the circuit details as described hereafter, a delay of 4 to 5 seconds may be anticipated with a 2 mF condenser combined with a 1 megohm resistor, whilst 100 to 125 seconds delay should result from the use of 10 mF condenser and a 5 megohm resistor, the delay being directly proportionate to the value of the capacity and of the resistance. It should be noted, however, that the delay period will also depend on the type of tube used.

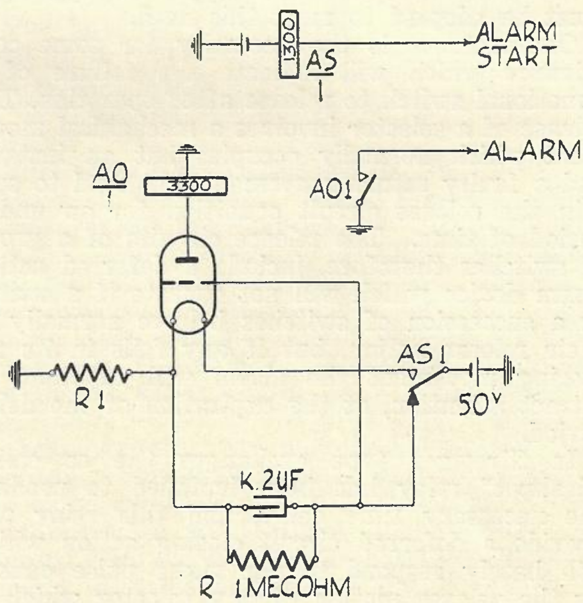


Fig. 2.—Delayed alarm circuit for selector release operation.

The circuit as arranged for selector release alarm operation is shown in Fig. 2. Here the start relay at AS1 normally connects negative battery to the condenser K which, in this case, is of 2 mF capacity. The condenser is thus fully charged, and is retained at the potential of the exchange battery (50v.). When AS operates, due to a selector's release action, battery is disconnected from the condenser, and is switched to the filament circuit which includes the resistance R1, provided to maintain the filament current at the correct value. The anode of the tube is connected through the relay AO to earth and the latter, being positive to the filament by the value of the potential drop across R1, represents the anode battery supply. The grid of the tube is connected to the negative pole of the previously charged condenser and therefore, at the instant of operation of relay AS, is at 50V negative, a value which is greatly in excess of that needed to prevent anode current flow. While AS is held operated, the condenser charge dissipates through R, and gradually reduces the grid negative voltage until, if the relay is retained for the full delay period (in this case about 5 seconds), anode current will finally build up to operate relay AO, and in turn the alarm signal will function. It will be noted that, on the release of AS, K will recharge almost instantaneously, as the resistance in the charging circuit (that of R1) is of relatively low value, this means that the resetting time of the device is exceedingly small, a desirable feature for the purpose for which it is used in this alarm circuit. The start and alarm operating details of the circuit may, of course, be varied to suit any particular existing requirement, thus if relay AS is provided with an additional winding of low value, AO when operated may be arranged to connect this winding in shunt with the 1300 ohms winding, and so amplify the current over the start wire, the latter will then serve also in lieu of the alarm wire by the operation of a marginal relay included in the start circuit.

The projected scheme utilises apparatus of a standard which is perhaps not generally required in telephone practice, and of course reliable performance must be assured from these components before they can be accepted. It is confidently expected that, largely as the result of radio development, apparatus is now procurable which will prove quite satisfactory and reliable. The type of tube needed for use with the circuit is a power amplifier, having a directly heated filament, and there are a variety of makes which are suitable. These tubes are designed to function with anode voltages up to 150V but, when used in the delayed action circuit, the anode voltage may be but 50 or less; under these conditions very long life may be expected from the tube used.

The developments due to radio advancement probably have had influence in the recent marked improvements in the manufacture of paper insulated condensers. These are now, by departmental specification, not acceptable unless they withstand 400 volts DC and have an insulation resistance such that the product of the capacity and the insulation resistance is not less than 300, thus the ordinary 2 mF condenser must be not less than 150 megohms, and it is a tribute to the modern manufacturer that 2 mF condensers of 1000 megohms and over quite frequently appear in acceptance test figures.

The resistor which it is suggested should be used in the circuit is definitely a product of radio development. It is of the carbonised pattern (1 watt type), and is designed to give accurate and consistent results even in the ultra-high resistance values required.

The relationship between discharging time and the decrement in potential of a discharging con-

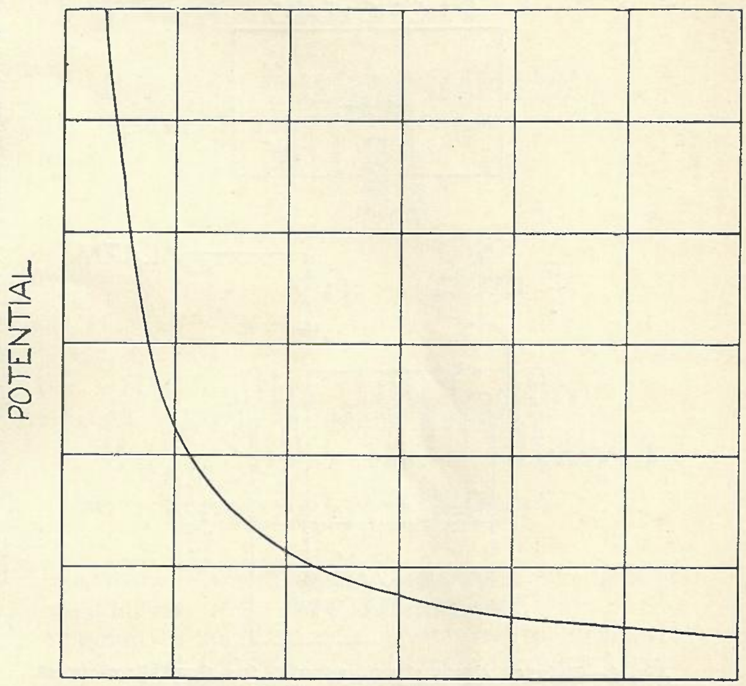


Fig. 3.—Characteristic graph of discharging condenser.

denser is indicated in the graph fig. 3, and an examination shows that the fall in potential is at first rapid but that this initial rate progressively declines until, at the final stage, very small differences in voltage are indicated over comparatively long intervals of time. This feature of the graph suggests that if it is desired that the greatest degree of delay action is to be obtained from the circuit, it is advisable to provide a high initial voltage for condenser charging, and to select a tube having a characteristic which prevents anode current until a relatively low negative grid value is reached, or in other words the selected tube should have a low value cut off point. Such a tube is the Osram P2 which, incidentally, has other properties which make it very suited to the needs of the circuit. However, practically any triode which will provide sufficient anode current value to satisfactorily operate a relay, should function in the circuit, the selection of the tube being merely a matter of the efficiency of the circuit, in respect of the delay period desired, and the resources which may be available for alternative choice of tubes.

Many modifications of the circuit will no doubt be possible, applying it to other conditions requiring deferred circuit action. One instance, which has interesting possibilities, is that of its adaptation to a ringing failure alarm, in which a ringing supply of the usual periodically interrupted type is so supervised that the omission of one ringing period is sufficient to cause the alarm to operate. The circuit arrangement is indicated in Fig. 4. Relay R is shunted by a copper oxide rectifier to provide a very satisfactory unit for operation by ringing current; this unit is connected to the ringing supply via the condenser K. R. will therefore be held operated during the ringing period of say 1 second, and will be released during the silent period of 2 seconds. With R released, the filament circuit of the tube is complete and, in the absence of any negative grid potential, the plate current would operate relay P, provided to close the alarm circuit. However, the condenser K1 is charged during the ringing period by the application of battery at R1, this charge being afterwards dissipated through X and Y during the silent period. The time constant of the discharging circuit is so arranged by the values of K1 and of X and Y that at no time with normal ringing conditions is the grid potential permitted to fall below the limit controlling anode current. Should, however, one or more ringing periods be omitted, due to fault development, R will remain inoperative sufficiently long (say 4 secs.) to enable K1 to discharge to a point at which the grid control is relaxed, P operates accordingly and the alarm will function. The charging of K1 is influenced by the presence of the resistor Y which so retards the time of charging as to make it necessary for R to be operated for a definite time to enable the condenser to fully charge, and only if this charge is complete will the maximum delay action be obtained. Thus the fleeting operation of R by a faulty or incomplete ringing period will produce only partial charging of K1, and subsequent operation of the alarm may ensue by the consequential early discharge of the condenser. Other values for K1 and for X and Y may be selected to cater for different periods of ringing cycle.

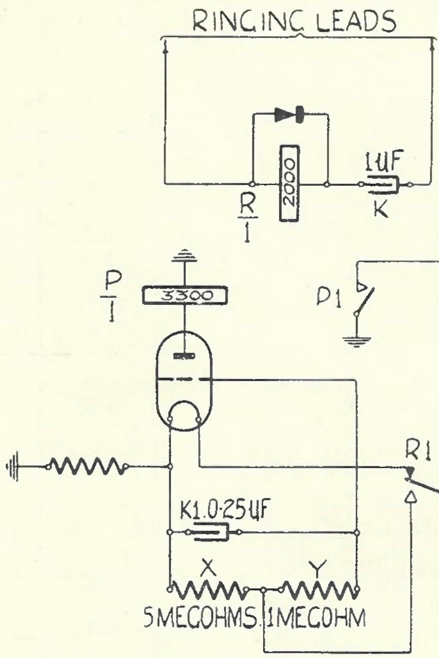


Fig. 4.—Delayed alarm circuit adapted for ring failure signal.

The future of the new scheme will no doubt be dependent on the result of practical trials but very promising results have been obtained from tests to date. Apart from the interesting principles involved in its operation the arrangement will no doubt make an appeal by the fact that it can be made up of components which are readily available, and it should be easy to exploit its possibilities in any circuit or circumstance requiring a delayed action function.

ERRATA, JOURNAL No. 5.

PAGES 201 AND 202.—The titles of Figures 8 and 9 should be transposed.

PAGE 232, Q. 2b.—The last two lines of the answer should read:

$$\frac{dy}{dx} = \tfrac{1}{2}x^{-\frac{1}{2}}\left((a - x^{\frac{1}{2}}) + (a + x^{\frac{1}{2}})\right) / (a - x^{\frac{1}{2}})^2.$$

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

PAGE 232, Q. 4a.—The last equation should read:

$$\text{Sinh } u = u\left(1 + \frac{u^2}{3!} + \ldots \text{ higher powers of } u\right).$$

TRANSMISSION PRACTICE. PART 3.

AN ELEMENTARY EXPLANATION OF THE RADIATION AND RECEPTION OF RADIO WAVES

S. O. Jones

Author's Note: The following article is an attempt to explain in an elementary and qualitative manner the various phenomena associated with the radiation and reception of radio signals. The explanation and analogies contained herein have appeared in several authoritative text books, but at best are very elementary and may be in some ways misleading unless the reader fully appreciates the limitations necessarily associated with any attempt to explain in physical terms phenomena which can only be interpreted accurately mathematically. Nevertheless, it is a point of view which many students have found helpful and it is, in this spirit, offered.

Readers who desire an accurate explanation are recommended to study electromagnetic field theory, with the added warning that this involves the use of advanced mathematical analysis.

Electrical energy that has been transmitted into space exists in the form of electromagnetic waves. These waves, which are commonly called radio waves, travel with the velocity of light and consist of electrostatic and magnetic fields at right angles to each other and also at right angles to the direction of travel.

The essential properties of a radio wave are frequency, intensity, direction of travel and plane of polarization. The radio waves produced by an alternating current will vary in intensity at the frequency of the current, and will therefore be alternately positive and negative. The distance occupied by one complete cycle of such an alternating wave is equal to the velocity of the wave divided by the number of cycles which are sent out each second, and is called the wave-length. The relation between the wave-length in metres and the frequency in cycles per second is therefore:—

$$\text{Wave-length} = \frac{300{,}000{,}000}{\text{(cycles per second).}}$$

where 300,000,000 is the velocity of light in metres per second.

The intensity of a radio wave is measured in terms of the voltage stress produced in space by the electrostatic field of the wave and is usually expressed in millivolts per metre.

The direction of travel is merely the path along which the waves move from their source.

The direction of the electrostatic lines of flux is called the direction of polarization of the wave. If the electrostatic flux lines or the lines of electric stress are vertical, the wave is vertically polarized, or if these lines are horizontal the wave is said to be horizontally polarized. The radio waves due to the ground ray, received at any distance from a broadcasting station are usually vertically polarized.

The transmission of speech or music by radio waves requires that some means be used to control the radio waves by the speech or music frequencies (audio-frequencies) to be transmitted. This is done by modulating the radio waves with the audio-frequencies, that is, by varying the amplitude of the radio waves at the frequency and amplitude of the audio-frequency signals. This is accomplished by means of a modulator, usually a vacuum tube, in which the audio-frequency signal controls the amplitude of the radio frequency signal, resulting in the production of a number of different frequencies referred to as "products of modulation." The main products of modulation are three frequencies, viz., the original radio-frequency (referred to normally as the carrier) the original radio-frequency plus the audio-frequency (referred to as the upper side-band), and the original radio-frequency minus the audio-frequency (referred to as the lower side-band). Fig. 1 shows graphically a radio-frequency wave modulated with an audio-frequency signal, such a wave being termed a modulated wave. For transmission the modulated waves are fed into some form of radiating system from which they are radiated into space in the form of electromagnetic waves.

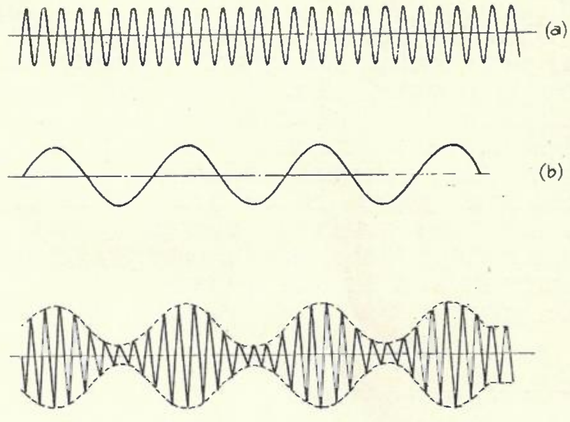


Fig. 1.—Radio frequency wave (a) modulated by an audio-frequency signal (b).

In order to obtain a physical conception of what occurs in and around a radiating system, consider a simple type of oscillatory circuit as shown in Fig. 2. This consists of two condenser plates joined together by an inductance, in the centre of which is a generator supplying alternating current.

At the commencement of the cycle let the condenser plates be charged to maximum potential so that the upper plate is positive and the lower one is negative. There is then an electrostatic field between the two plates, the lines of force being as shown in Fig. 2.

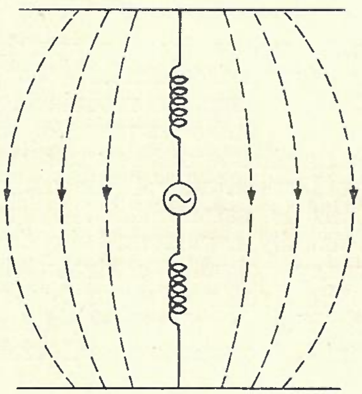


Fig. 2.

When the instant of maximum potential on the plates has passed current will commence to flow downwards. The electric field starts to collapse, and this effect may be represented by Fig. 3. The current continues to flow after the potential difference across the condenser plates is reduced to zero, and in so doing starts to charge up the condenser plates to the opposite polarity, giving rise to new lines of force in the opposite direction to the previous field. Due to the fact that the

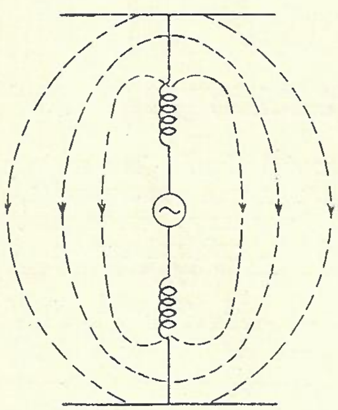


Fig. 3.

velocity of lines of electric stress in space has a definite numerical value (300,000,000 metres per second), collapse of the initial field lags a little on the changes in potential which caused it to take place, and the new electric field commences to build up before the first one has completely disappeared, as shown in Fig. 4. Now, lines of force are a physical conception that is devoid of meaning unless the lines are imagined to exist either between points of different electrical potential, or else as closed loops. In this case the lines most distant from the oscillatory system have not time to collapse entirely, therefore they become closed loops and are forced outwards in this form by the new electric field, the direction of the lines in the inner sur-

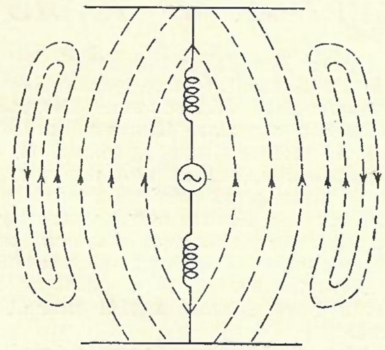


Fig. 4.

face of the first group of loops being the same as that of those on the outer surface of the second group. As the current oscillates in the circuit a series of these closed loops is sent off into space radially from the oscillatory system, each set repelling its predecessors.

This type of oscillation is produced by an oscillating system excited in the centre, such as that illustrated in Fig. 2. In most of the radiating systems used at National broadcasting stations the earth is the bottom plate of the condenser and the radio-frequency power is fed in at the lower end of the radiator so that it can be regarded as the upper half of the symmetrical type of oscillating system excited at the centre which has been discussed so far. This assumes that the capacity is concentrated at the upper end of the radiator which is, in fact, not quite so; but for purposes of analysis this approxima-

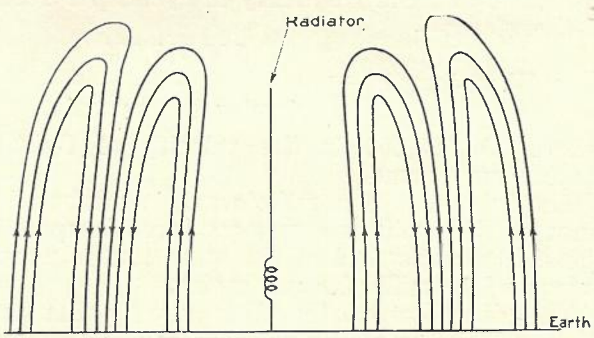


Fig. 5.

tion can be accepted. Fig. 5 illustrates schematically how the electric field spreads out in the form of annular loops of ever-increasing height but constant width (wave-length). These loops are accompanied by horizontal loops of magnetic flux spreading out from the aerial with the electric loops.

There are two conditions, however, associated with this phenomenon which should be mentioned. These are radiation and induction.

It was stated above that the lines of electric stress most distant from the oscillating system had not time to collapse entirely before the next group of lines was set up. Some of the lines of stress do collapse on the system which gave rise to them however. Therefore, it will be seen that there are two different fields to consider. The first is that caused by the lines of electric stress which are prevented from collapsing and are, therefore, radiated into space. The second is that caused by the lines of electric stress which are built up and which do have time to collapse. The first field is called the radiation field, and is the one upon which service from a broadcasting station depends. The second is referred to as the induction field, and because it occurs only in the vicinity of the radiating system, it has no influence upon the broadcasting station's service area.

Close to the radiating system the induction field is stronger than the radiation field, whereas at an appreciable distance the reverse is the case. Actually the intensity of the radiation field over a perfectly conducting surface varies inversely as the distance from the radiator, while the intensity of the induction field varies inversely as the square of the distance. At one-sixth of a wave-length distance from the radiator the two fields have the same intensity, while at a distance of five wave-lengths the intensity of the induction field is approximately one-thirtieth of that of the radiation field.

When carrying out field intensity measurements with the object of determining the efficiency of a radiator, it will be clear, therefore, that such measurements should not be made too close in to the radiator. If close in measurements are made, they will be affected by the induction field and will, therefore, be misleading. In practice it is considered that the intensity of the induction field is negligible, so far as such measurements are concerned, at a distance of one wave-length from the radiator.

The types of radiators employed at National broadcasting stations can be divided generally into two classes. They are quarter-wave and half-wave types grounded through a coupling coil at the lower end. By tuning the radiator to resonance with frequency to be radiated, the impedance of the system is reduced to a minimum so that a relatively small applied voltage produces a large current and hence a high radiated energy.

A quarter-wave radiator usually consists of a vertical wire attached to, and supported at the upper end by, a cage of wires held between two masts. The physical length of the vertical wire is less than a quarter the wave-length of the frequency to be radiated, but the cage of wires at the top (flat top) represents a capacity to ground which has the effect of increasing the electrical length of the radiator, while at the lower end of the vertical wire a sufficient amount of inductance is inserted to again increase the electrical length to exactly a quarter wave-length. When energy is fed into such a radiator it behaves as a transmission line a quarter wave-length long and open at the distant end. The result is that the radio-frequency alternating current fed in at the base flows along the vertical wire to the upper end and is reflected back again. At the lower end the reflected current is in phase with the current fed in at that end, and standing waves appear in such a manner that at earth the current measured is a maximum, while at the extreme ends of the flat top the current is zero. In effect, the current distribution over the whole radiator, when plotted, appears approximately as a quarter sine wave as shown in Fig. 6. The only portion of such a radiator which radiates energy effectively is the

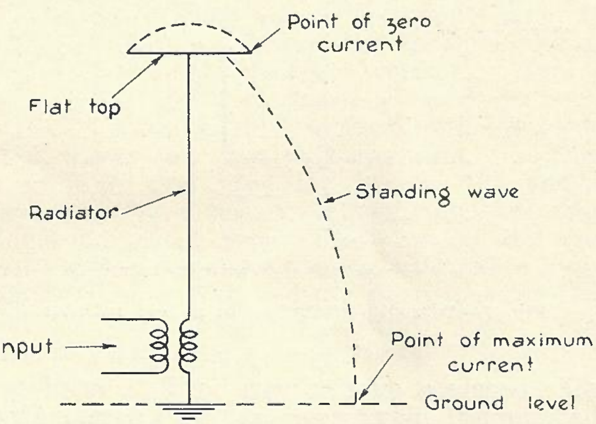


Fig. 6.—Current distribution in ¼ wave radiator.

vertical wire because the tuning coil at the lower end is usually screened while the direction of the current flowing in the flat top is such that any radiation from one half of it is cancelled by that from the other half.

A half-wave radiator consists of a vertical steel mast slightly greater than half a wave-length in height or, in some cases, a steel mast considerably less than a half wave-length high but loaded at the upper end with an inductance and circular steel armature so that the "electrical" length of the structure is slightly more than half wave (1). In order to resonate such a radiator an inductance coil is inserted at the base and adjusted so that the overall "electrical" length becomes three-quarters of a wave-length. When energy is fed into such a radiator it behaves as a transmission line three-quarters of a wave-length long and open at the distant end. When fed with radio-frequency

(1) See "Developments in Broadcasting Aerials," A. J. McKenzie, "Telecommunication Journal," No. 3, June, 1936.

A.C. at the base the current is reflected back from the open end and again standing waves appear in such a manner that at earth the current measured is a maximum while at the top (or at the periphery of the armature in the case of a top-loaded structure) the current is zero. As the complete structure is electrically three-quarters of a wave in length, however, the current distribution is different from that in a quarter-wave radiator. In this case, the half-wave radiator, the current distribution is approximately as shown in Fig. 7. It will be seen that along the steel mast the standing wave appears as slightly more than half a sine wave

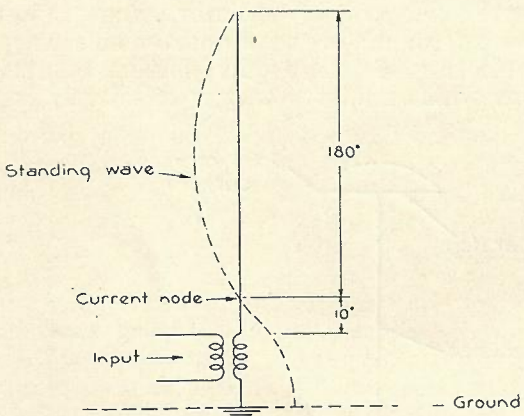


Fig. 7.—Current distribution in a 190° radiator.

while nearly a quarter-wave is distributed over the tuning inductance at the base. Above ground level there is a point at which the current is shown as zero (a current node). Actually the current at this point is not zero, due to slight irregularities in the construction of the mast, and due also to losses which occur in the radiator on account of resistance, etc., but the current does fall to a very low value at the node point. In a radiator of this type, which is correctly tuned and lined up, the current node occurs at a point such that the phase difference between the current at the top of the tuning coil and the node is 10 degrees. Regarding the standing half-wave as being distributed over 180 degrees (i.e., half a complete sine wave) the electrical distance between the top of the tuning coil and the top of the mast (or, in the case of a top-loaded structure, between the top of the tuning coil and the periphery of the armature) is 190 degrees. Such a radiator, although it is commonly referred to as a half-wave radiator, is in fact a "190 degrees radiator."

A quarter-wave radiator is a useful type of radiating system and, until comparatively recently, it was in almost universal use for medium frequency broadcasting stations. In recent years, however, a considerable amount of investigation was carried out with a view to increasing the night range of broadcasting stations. This could be achieved most readily by reducing the amount of energy radiated upwards into the Heaviside layer. This energy is reflected back to earth, and where it returns at sufficient strength it interferes with the energy radiated horizontally along the earth and causes distortion and fading at that point. It was found that the ratio of horizontal radiation to high angle radiation increased as the point of maximum current in the radiator was moved higher up, and the maximum ratio between the two directions of radiation was found to occur with a radiator which was approximately 190 degrees high electrically. It is for this reason mainly that 190 degrees radiators are now used in preference to the quarter-wave type, although even during daylight hours when reflection from the Heaviside layer does not occur at medium frequencies, the former is the more efficient.

Figs. 8 (a) and (b) show "vertical polar diagrams" of a quarter-wave and a 190 degrees radiator respectively. These vertical polar diagrams show graphically the directional characteristics of the two types of radiator in the vertical plane, and it will be seen that the diagram of a quarter-wave structure is a semicircle in any direction. The ratio of the length of the line A-B drawn at 45 degrees to the horizontal to the length of the line A-C drawn in the horizontal is actually the ratio of the energy radiated at an angle of 45 degrees to that radiated horizontally. In the case of the 190 degrees radiator the vertical polar diagram is a flatter figure and the ratio of the length of the line A-D drawn at 45 degrees to the horizontal to the length of the line A-E in the horizontal is again the ratio of the energy radiated at an angle of 45 degrees to that radiated horizontally. This ratio is smaller for the 190 degrees radiator than for the quarter-wave one, and for each kilowatt of power the 190 degrees structure radiates more energy in the horizontal plane than the quarter-wave structure does, while for each kilowatt of power it radiates less energy

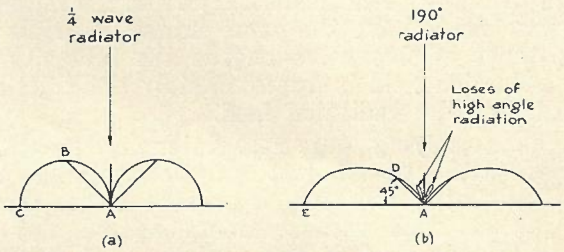


Fig. 8.—Vertical polar diagrams of ¼ wave and 190° radiators.

at high angles than the quarter-wave structure.

It will be noticed that in the diagram for the 190 degrees radiator there are small lobes denoting the existence of some high angle radiation. These lobes are so small, that they are negligible.

The advantage of the 190 degrees radiator, therefore, is the higher ratio of horizontal radiation (ground ray) to high angle radiation (indirect ray) because this means that not only is the signal radiated horizontally from it of greater intensity than from the quarter-wave type, but also the distance in any direction between the radiator and the point at which the indirect ray begins to interfere with the ground ray is increased by using the higher structure.

In the reception of radio signals it is first necessary to extract energy from the radio waves passing the receiving point. After this has been done the receiving device must first separate the desired signal from all other radio signals which may be present. Then the original audio-frequencies must be reproduced from the modulated wave and fed into some electro-acoustical device such as a telephone receiver or loud speaker.

The energy is extracted from the passing waves by merely placing some form of conductor in their path. Such a conductor is referred to as a receiving antenna, and as the passing waves of electric and magnetic stress cut it a voltage appears across it which is directly proportional to the intensity of waves, and which alternates at the frequency of the waves.

At any point a receiving antenna will be in the path of a large number of waves of different frequencies emitted from different transmitting stations. Therefore, many voltages of different frequency will appear across it. The desired frequency, however, is selected by means of a tuned circuit or band pass filter located in the receiving device.

After the desired frequency has been selected it is amplified in a series of vacuum tube amplifiers, and then it is fed into some form of demodulator (or detector). An analysis of the process of demodulation is beyond the scope of this paper, but the function of a demodulator is to reproduce from the modulated wave the original audio-frequency signal which modulated the radio-frequency wave at the transmitting station. Any device which exhibits a non-linear impedance characteristic can be used as a demodulator. For instance, a vacuum tube biassed to the upper or lower band of its Grid-voltage v. Anode-current characteristic curve exhibits a non-linear impedance characteristic and this is probably the most common type of demodulator at present in use. Such items as copper-oxide rectifiers. carborundum and galena crystals, also exhibit a non-linear characteristic and are consequently suitable for use as demodulators.

Actually, when a modulated wave is fed into a demodulator the carrier and the side-bands are heterodyned, i.e., they are mixed together, and in the output of the demodulator there appear a number of frequencies which are termed "products of demodulation." The main products of demodulation are three frequencies, viz., the original radio-frequency; the original radio-frequency minus the lower sideband; and the upper sideband minus the radio-frequency. It will be seen that the two latter products are each equal to the original audio-frequency, and if they appear in phase there is no interference between them, so that when fed into a telephone receiver or loud speaker, they reproduce the sounds which give rise to them at the transmitting station.

As radio waves are always passing through space it is reasonable to assume that any conductor in their path will have induced in it voltages at the frequency of the passing waves. This is so in fact, and in telephone lines, for instance, there will always be found a number of different radio-frequency voltages. This is not serious, providing there is no demodulator in the telephone circuit, because, until the modulated waves are demodulated, their frequency is so high that they are beyond the audible band. If, in a telephone line, however, there should be placed some device having the non-linear impedance characteristic referred to above, demodulation occurs, and the subscriber can then hear in his telephone receiver the audio-frequency products of the demodulation.

Devices are not deliberately placed in telephone circuits for the purpose of demodulation, but such items as carbon transmitters, dirty lightning arrester carbons, dry joints, and, in some cases, faulty condensers, frequently exhibit a non-linear impedance characteristic, and so perform as demodulators. Troubles of this nature are not uncommon. It frequently occurs that telephone subscribers whose lines pass within the intense induction field of the radiator of a broadcasting station are enabled to hear the station's programme in their telephone receivers. Also, due to faulty joints or dirty carbon arresters, trunk lines are subjected to interference from broadcasting stations. In a subscriber's line the usual method of suppressing such interference is to connect a low capacity condenser—say, .005 microfarad—across the carbon transmitter. The condenser offers a low impedance shunt path to the radio frequency currents and so, in effect, short circuits the carbon transmitter at radio-frequency, thus preventing the entry of radio-frequency to the transmitter and so preventing demodulation from occurring. Where such interference occurs in a trunk line the faulty arrester or wire joint is located and made good.

CABLE JOINTING. PART 2

G. O. Newton

This is the second of a series of articles on the various operations performed by a Cable Jointer. The previous article discussed the construction of the different types of subscribers' P.I.L.C. cable in common use, the method of numbering pairs and quads in P.I.L.C. cable and the preliminary precautions and operations associated with the jointing of conductors.

CONDUCTOR JOINTING.

Straight Joints in P.I.L.C. Cable Conductors:

The first conductors to be jointed together should be the marker pairs or quads of the centre core, and the order of jointing continued by proceeding in rotation on each side according to the numbers of the pairs as indicated by the numbering rule (Fig. 4, Part I.), taking care in the case of star quad cable, that the wires in each quad with the similar identification marks are jointed together. This procedure must be followed strictly to ensure that pairs with the same number are jointed together, or the value of the numbering will be lost. Every care must be taken to avoid split pairs or quads as shown

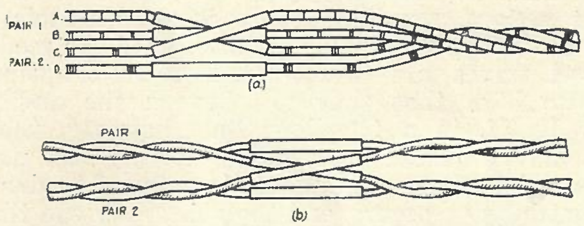


Fig. 6.—Showing splitting of quads and pairs. [Note: The joining of A to B, and B to A, or C to D, and D to C, does not split the quad, but reverses the legs of the pairs.]

in Fig. 6. Such errors give rise to crosstalk and other inductive noises, and their location and removal at a later date are difficult and expensive. **It should also be borne in mind that the insertion of a reverse split at a nearby joint does not rectify the trouble.** The correct fanning out of the conductors in their layers and the retention of the twist in the pairs and quads will materially help to avoid splits. This particularly applies to the old type of twin cable built up of pairs with mostly red and white insulation in which the mixing of the conductors of similar colour on adjacent pairs can very easily occur if the twist of the pairs is lost or the wires of the layers mixed. In the case of star quad cable, owing to the whippings around the quads there should be little danger of a split between one quad and another so long as the whippings are not removed or allowed to become unravelled.

The best joint in the wire is one consisting of two complete and comparatively loose twists with the paper left on, followed by about $\frac{3}{4}$ inch of twist in the bare conductor, made in such a way that the twists gradually get tighter towards the end, with the tip consisting of very close tight twists, as shown in Fig. 7. Such a wire joint provides sufficient length of wire tightly bedded together to give satisfactory

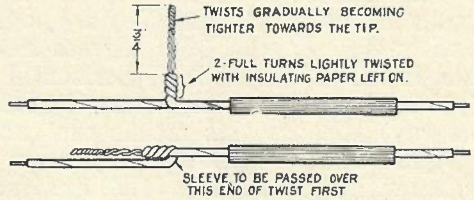


Fig. 7.—Showing correct method of making joints in cable conductors.

electrical contact, and ensures the least strain in the wire when it is bent back for sleeving. The initial paper covered twists are made by gripping each wire in the opposite hand (i.e. wire from the left in the right hand and vice versa) with the thumb and forefinger close up to the point of twist and with only a light tension on the wires, evenly twisting them together with the loose ends held at a close angle to the through wires. Care must be taken not to hold the wires too tightly, otherwise the paper insulation will break. The remainder of the joint can be made by the "crankhandle" method by holding the bare conductors firmly with left thumb and forefinger about one inch from the initial twists in the paper covered portion, and allowing the twists to run back towards this insulated portion as they are made by cranking with the right thumb and forefinger. If the grip with the fingers of the left hand is too loose, the twists are likely to become crowded together and tight at the paper covered portion, with the consequent danger of a fractured wire at this point (See Fig. 8 (f)). In such cases it will also be found more difficult to fit

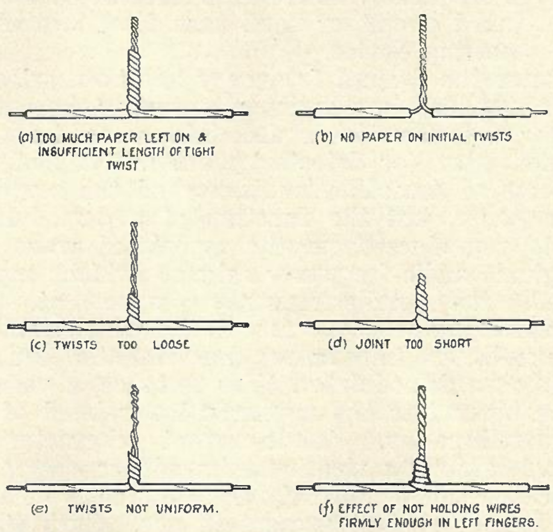


Fig. 8.—Showing incorrect methods of making joints in cable conductors.

the correct size of paper sleeve over the joint owing to the increased bulk at the paper covered portion of the twist. The same difficulty will be encountered where the paper covered twists are irregular. This trouble is usually due to the fact that the two conductors are not held at regular and even angles to the cable whilst these twists are being made.

The correct type of joint can also be made by holding the initial paper covered twists very firmly with the left thumb and forefinger, and inserting two complete loose twists in the bare wire by cranking at a wide angle, then slipping the grip to these turns and tightly twisting together for the remaining length by cranking at right angles and without letting any of the twists run back through the finger grip as in the former method. The initial twists with the paper left on ensure that the paper insulation does not become unravelled, thus exposing the conductor to possible contact with other conductors. The removal of the paper insulation from the conductor after the initial twists should be performed by using the right thumb and forefinger, the face of which should be coated with powdered resin to ensure a grip on the paper. This is simpler and safer than using the pliers since it not only saves the time occupied in the movements necessary for getting the pliers into position in the hand and away again, but obviates all possibility of a nick in the wire which may result in a broken wire when the joint is bent back ready for sleeving. In the case of star quad cable, the whipping of each quad after being cut to free the conductors for jointing shou'd be tied each side of the joint to prevent the twist of the wires being unravelled any more than is necessary and to assist in the future identification of the wires forming the quad. If the whipping is made off by three (3) half hitches around the quad, then three (3) around one conductor, it will lock and avoid any slipping back. The tie should be about three (3) inches from the joint on the sleeving side and two (2) inches on the other side.

A defect which can give rise to a very considerable amount of trouble, and which is extremely difficult to locate, is one where small additional resistances are introduced into the conductors. Such additional resistances are mostly due to badly made joints which do not provide sufficient firm and clean metallic contact between the wires. The effect if the trouble occurs on both conductors of a pair is to still further weaken the already weak alternating voice currents, and where they occur more in one conductor of a pair than another, they unbalance the circuit, causing crossta'k and other inductive troubles similar to that caused by split pairs. The conductors should therefore be clean when jointed, and loose and other defective types of joints as shown in Fig. 8 should be carefully avoided.

The tension on the conductors as they are jointed requires to be watched. This should be even throughout and just loose enough to allow of the fingers penetrating among the conductors. If the tension is too loose or uneven, it will cause trouble when the joint is being finally tied up. The consequential bending of the conductors may break them or cause them to break through the insulation and contact with other pairs, and where faults do not occur immediately, it provides the conditions for causing faults during any subsequent handling of the joint. There is also a danger of the paper sleeves shifting and exposing the wire joints. Excess tension may give rise to broken wires and insulation and prevents access to inner pairs in the joint unless slack can be obtained by movement of the cable in the manhole.

The joints in the two wires of a pair in twin cable and four wires of a quad in star quad cable should be made opposite each other so that the conductors forming each pair or quad can be readily located on future occasions, and the joints of consecutive pairs or quads should be staggered up and down the cable joint so as to keep its bulk even and as small as possible. The staggered groups of sleeves of the consecutive pairs or quads should butt and not overlap. This assists to prevent sleeves slipping off wire joints and to reduce the bulk of the joint. To further guard against movement of paper sleeves on the joints, care should be taken to use the correct size of paper sleeve. The paper sleeve should always be in a central position on the wire joint.

Multiple Joints in Conductors: These should be made in a similar manner to straight joints except that three and on some occasions four conductors instead of two are twisted together in one operation. Such a joint will require a larger size of paper sleeve than the standard one for the particular gauge of cable. Where three conductors of the same gauge are involved, the next larger size of paper sleeve will normally suffice.

When connecting a branch or lateral cable to the through cable, consideration should be given to the possibility that it may be necessary to transfer it over to another cable at a later date or rearrange it on the existing cable. To assist in obtaining sufficient length of conductor for rejointing, the tendency should be to group the mu.tiple conductor joints more towards the opposite end to that at which the branch or lateral cable enters. In cases where small laterals are being connected to large main cables the whole of the multiple joints can be grouped at the end opposite to that at which the lateral cab'e enters the joint, but where the branch cable compares with the through cable in size the grouping of joints towards one end can only be carried out to a limited extent.

Insulating Conductors: When it is necessary to insulate the ends of any conductors, as is the case when they terminate in a joint or at the end of a cable, this must be done in such a way that the ends are not likely to contact with each other or with other conductors or the sheathing. Such insulated conductors should be left sufficiently long to permit of them being correctly jointed through if it becomes necessary to do so at a later date. A suitable method of insulating each pair in twin cable is to first lightly twist the conductors with the paper insulation intact by the crank handle method for about three complete twists, and then cleanly cut each conductor with the paper insulation still intact,

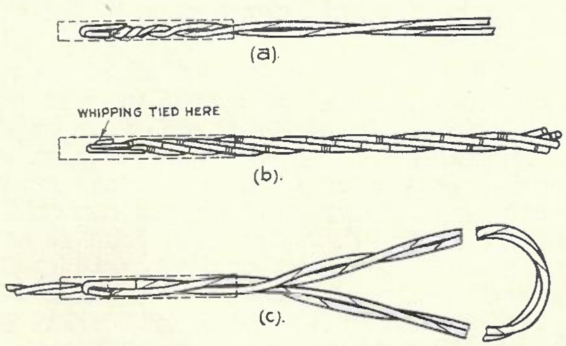


Fig. 9.—Showing methods of insulating ends of cable conductors.

one about one quarter ($\frac{1}{4}$) inch and the other about one half ($\frac{1}{2}$) inch beyond the twists, after which each end is bent back along the twist on opposite sides, as shown in Fig. 9 (a). A paper sleeve of tight fit is then slipped over the end so as to leave it at least one quarter ($\frac{1}{4}$) inch inside the paper sleeve. In the case of star quad cable the quad whipping should be carefully tied about one inch back from the end, the conductors of the quad cleanly cut with the ends staggered and bent back along the quad clear of each other (See Fig. 9 (b)), and a paper sleeve of tight fit then slipped over the whole so as to keep the ends at least one quarter inch inside the paper sleeve. Alternatively, after tying the quad whipping about two inches back from the point where it is desired to insulate the ends, the pairs can be separated and dealt with as in twin cable. Another method which assists to give a longer length of conductor for future jointing and is probably the most satisfactory where a limited number of pairs are to be insulated inside a joint is to slip a paper sleeve of suitable size over the pair or quad, cleanly cut and bend back the conductors with the ends staggered and the paper intact, and then loop them back inside the paper sleeve as shown in Fig. 9 (c).

Faulty Pairs: Should it be known as a result of testing or from the factory test sheets of the cable drum concerned, that any pairs within a section of cable being jointed are faulty, use should be made of the extra pairs, when provided, to enable the nominal size of the cable to be retained. This can be done by transposing the faulty pair with one of the extra pairs on the section in which the fault occurs, in the manner shown in Fig. 10. The fact that use has

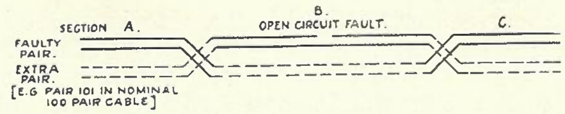


Fig. 10.—Showing method of substituting an extra pair for a faulty pair.

been made of the extra pair and the numbering order slightly disarranged will be noticed if the joint is opened subsequently by the fact that an inner pair on each side has been connected to an outer pair on the opposite side. The arrangement has the advantage that, if there are several faulty pairs, each on different sections, only one pair is lost throughout the cable since on each section where a fault occurs continuity of good pairs is given by substituting the extra pair. Where there are more faulty pairs than spare pairs, all reasonable steps should be taken to clear as many of them as possible. If any of the excess faulty pairs are not cleared, it will of course be necessary to joint them to their corresponding pairs. The loss of such pairs, however, means reduced circuit carrying capacity for the cable with consequential loss of revenue or the necessity for earlier expenditure for relief arrangements.

Reversed Pairs: In many exchange areas it is necessary that care be taken to avoid reversals of the legs of cable pairs on certain classes of circuits such as Junction, P.A.B.X., Public Telephone and Party Lines in automatic exchange areas, and Party and Key Control Lines in C.B. exchange areas. For this reason in such areas the A and B legs of each pair on each M.D.F. should correspond in the case of junction cables and the A and B legs of each pair on the M.D.F. should correspond to A and B legs respectively on the cable terminal box or cross-connecting facility in the case of subscribers' cable. In each case the A leg is the top or left terminal, and the B leg the lower or right terminal of the pair according to the type of termination (fuse strip, terminal block, distribution box, cable terminal box, etc.). This can be arranged by specially marking A legs (e.g. turn down end or place pair number tag on A leg of pair and twist B leg to it) when numbering or identifying on each side before the final joint of an installation or an alteration is made. In the case of S.Q. cable, the markings of the four wires of each quad should readily enable the continuity of each leg to be retained without any possibility of reversing. In those cases where it is necessary to insert crosses between the legs of pairs on account of capacity unbalance causing crosstalk, action should be taken to bring the wires back into line at a suitable joint at the end of the cable.

Soldering of Wire Joints: Normally there is no need to solder properly made twist joints in light gauge conductors. Wire joints should, however, be soldered in the following instances:

(i) All joints between paper insulated conductors and silk and enamel insulated conductors or between conductors solely of the latter type, for the purpose of avoiding possible high resistance joints due to the presence of the wax and particles of enamel and to permit of less tightly twisted joints and so minimise breaks due to slight nicks or cuts in the wire caused when scraping enamel off it.

(ii) All joints between conductors 40 lb. or over in weight owing to the difficulty of making satisfactory tight well-bedded twists in cable conductors of such weight.

(iii) All joints between conductors of cables which are to be balanced with a view to specially minimising inductive troubles. In such cases it is necessary to take every precaution to guard against possible causes of even very small unbalances in the electrical characteristics of the circuits. Normally this only applies to trunk cables with conductors 20 lb. and over in weight.

The method of soldering such joints is to apply the solder with a light or medium iron to about a quarter of an inch of the twist at the tip, using resin cored solder. To avoid waste of time, groups of conductors (say 20 at a time) should be soldered in one operation. Resin is used as a flux since it is chemically inactive. If a chemically active flux were used, any small quantities of it which might remain after the soldering would set up corrosive action inside the joint. Any remaining traces of the flux on the completed wire joint should always be wiped off while the joint is still hot to permit of the soldering being examined to make certain that it is satisfactory.

Closing of Joint: Before tying up a completed joint, and especially where jointing has been performed under damp conditions or the cable has been open for a considerable period, it should be thoroughly dried out so that there will be no trace of moisture in the insulation. As there is a tendency for moisture to be absorbed in the paper insulation at the ends of the sheathing, this is liable to be driven inside the sheathing if drying out is commenced on the centre of the joint. This would result in low insulation resistance, possibly rendering the pairs unsuitable for use on working circuits. Drying-out should therefore be commenced by warming the sheathing a short distance back from each end with the flame of a blow lamp and working towards the end so as to drive out any moisture which may have collected at this point. Where cables have only been open for a short period under very dry conditions, this warming of the ends of the sheathing together with the drying out which will be obtained as a result of the plumbing operation, should normally suffice, but in other cases the joint itself should be dried out by one of the methods to be described. One suitable and reasonably safe method is to play the blowlamp flame on the under surface of a sheet of light gauge iron held around the joint in the shape of a U (See Fig. 11 (a)). Another method is to arrange a sheet of canvas or other suitable material over the joint, and so set the blow lamp at a safe distance from the joint that

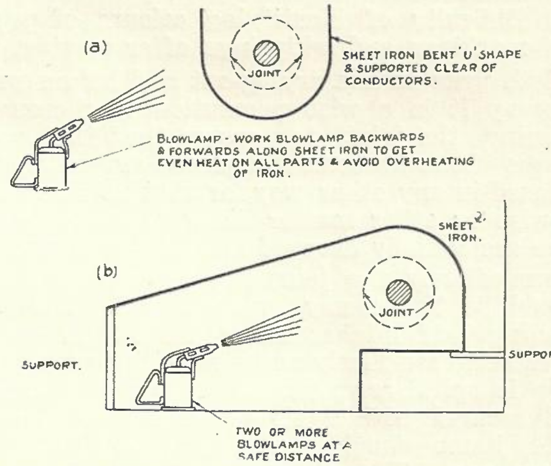


Fig. 11.—Showing methods of drying out joints.

the warm air collects around the joint underneath the sheet. If any evaporated moisture cannot readily escape at the ends of the sheet, a vent hole should be provided at the highest point, usually the centre. Another very satisfactory method is an arrangement of sheets of iron with the heat from blowlamps, as shown in Fig. 11 (b). This allows the heated air to circulate all around the joint, finally escaping with any evaporated moisture at the ends. The drying-out should be continued until the paper at all parts of the joint, including the centre, is in a crisp condition. To permit of the centre of the joint being reached by the heat it is necessary that the conductors be kept reasonably loose.

The application of excessive heat, either by over-heating the sheet iron where it is in proximity to the conductors or by playing the flame of the blowlamp directly towards and/or close to the conductors, should be strictly avoided owing to the very serious danger of damage to the insulation by charring or burning. In some cases such charring is not readily apparent to the eye and is only noticeable by the fact that the paper becomes brittle and readily breaks when handled. The use of a moderate heat for a relatively longer period not only removes this danger but ensures a sufficient time interval to allow of the heat penetrating to the centre of a joint. Paraffin wax should only be used for drying joints in exceptional circumstances, and then with every care to ensure that the wax is not too hot. The objections to the use of wax are:—

(i) Reduction in insulation resistance of the cable when the wax is warm or hot.
(ii) Danger of damage to the insulation when the wax is too hot. (In such cases it is possible to entirely destroy the paper).
(iii) Brittleness of waxed paper insulation when cold, making subsequent handling of the joint difficult and giving rise to faults on conductors.
(iv) Difficulty of identifying colours of paper, markings and whippings after waxing.

Both prior to the drying-out and before wrapping up it is a wise precaution to thoroughly examine the joint to ensure that no paper sleeves have become displaced or conductors exposed in any other way, or that no short ends of wire or other matter likely to cause trouble have accidentally dropped among the conductors.

Immediately the joint has been dried out, it should be tied firmly by a doubled thread, by running half hitches along the length of the joint, and then firmly wrapped with brown paper strip in spiral arrangement with a good overlap and secured with a tie of thread at the end. Both items should be thoroughly dried out before use. The whole should then be sealed within the lead sleeve as quickly as possible so that there is no further opportunity for the absorption of moisture.

CABLE TERMINATIONS.

Record and Rotation Cable Pair Numbers: The numbers of the cable pairs as used for record purposes are obtained directly or indirectly from the numbers of the terminations or fuse strips on the line side of the exchange M.D.F. in the case of main cables and from the terminations on the subscribers' side of the cross-connecting device in the case of secondary cables. These numbers may not, however, be identical with the numbers of the cable pairs as obtained by counting in rotation in accordance with Fig. 4, Part I. To avoid confusion, the former will be referred to as the **"Record Cable Pair Numbers"** and the latter as the **"Rotation Cable Pair Numbers."** It should be the object in all cable jointing work to make these numbers correspond or to bring them into corresponding order, and the methods of doing this will be explained.

Terminating Cables on M.D.F.'s, Cross-Connecting Frames, Cable Distribution Boxes, etc., and Jointing P.I.L.C. Cable to S.I.L.C. Cable.

The usual method of terminating subscribers' cables on Main Distributing Frames and other cross-connecting devices (except those provided with a sealing chamber for terminating P.I.L.C. cable direct as in pole type boxes, one type of pillar terminal, etc.) is by means of a short length of enamel and silk insulated beeswaxed, lead-covered cable called S.I.L.C. cable for short.

In S.I.L.C. cable the outside cotton covering is variously coloured to form a conductor identification scheme usually referred to as the colour code. The colour code and lay up of this type of cable is set out in Tables 2 and 3 of Departmental Specification No. 610C, and it is desirable that cable jointers become familiar with it. All S.I.L.C. cable should be fanned out and terminated according to the colour code, i.e., the numbers of the fuse or terminal tags of the M.D.F. or other cross-connecting device should correspond with the S.I.L.C. cable pair numbers according to the colour code. It is also very desirable that the same rules for order of jointing apply to the joint between the S.I.L.C. and the P.I.L.C. cables as for P.I.L.C. to P.I.L.C. cable joints. To meet these requirements the order of the colour code in the S.I.L.C. cable when looking at the end where the joint with the P.I.L.C. cable is to be made, should be clockwise in the case of exchange M.D.F. and secondary cable terminations, and anticlockwise in the case of main cable terminations at cross-connecting devices or

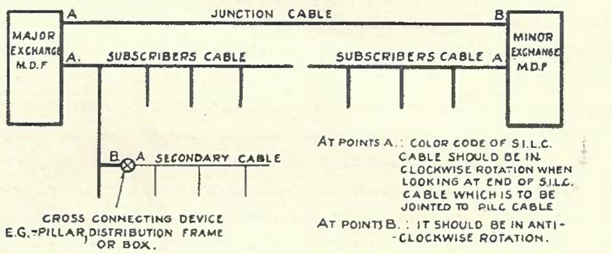


Fig. 12.—Showing order of S.I.L.C. cable pairs at various points in cable system.

at the smaller exchange in the case of junction cables (See Fig. 12). Any other arrangement, i.e., colour code in reverse order or S.I.L.C. not terminated in order of colour code, will result in a badly interlaced joint at this point. The most suitable and neatest arrangement when, as is usually the case, the cable is connected from below, is when the numbering on the M.D.F. or cross-connecting device is from the top downwards. This permits of the S.I.L.C. cable form being neatly made with the lower numbered pairs in the centre connecting to the top fuse or terminal strips and the higher numbered pairs in the outer layers connecting to the lower strips. If the numbering of the M.D.F., etc., is from bottom to top and the most desirable order of pairs at the joint is to be retained, it necessitates the inner group of 20 pairs being brought out of the cable on to the lowest fuse strip whilst the outside group is taken to the top of the M.D.F. after all the inner groups have been fanned out on to lower strips. Apart from this practical consideration, numbering from top to bottom has the advantage that it conforms to the direction of reading adopted in most matters of general usage. The importance of this joint at exchange M.D.F.'s needs stressing since by it the "record cable pair numbers" given to the cable at the M.D.F. are transferred to the P.I.L.C. cable in the street, and are made to correspond with the "rotation cable pair numbers" of the latter. If this is not done it will necessitate two sets of numbers being recorded where one will suffice, or else add considerable difficulty to future identification work. In some areas M.D.F. bays are given letter designations and the terminating tags or fuses are numbered similarly on each bay. In such cases it is very desirable that the record cable pair and M.D.F. numbers be linked together in some simple order. Taking the case of an 800 pr. cable where the M.D.F. bays are 200 high on the line side, each 200 pair of the 800 pair should be connected in order to consecutive bays of the M.D.F., e.g. pairs 1-200 in the 800 pair cable would be connected to, say, strips 1-200A, pairs 201-400 to 1-200B, pairs 401-600 to 1-200C and so on.

The joint between the two types of conductors is made similarly to ordinary P.I.L.C. cable conductor joints except that all the enamel must be carefully removed in addition to removing the silk and cotton covering after the initial twists have been made. A small scraping tool which is a standard item readily removes both of these, and minimises the risk of cuts and nicks in the wire which if not carefully avoided are liable to give rise to open circuit faults. Since such wire joints are soldered they need not be twisted quite so tightly and this will help to avoid broken wires should any slight nicks be accidentally made in the conductors when cleaning them.

Cable Terminations by P.I.L.C. Cable: Where the type of cross-connecting facility (pole type cable boxes, etc.) permits of the P.I.L.C. cable being directly connected to the terminal tags, the pairs should be connected in order of rotation cable pair numbers, these being counted clockwise in the case of main cable pairs and anticlockwise in the case of secondary cable pairs. As in the case of S.I.L.C. cable terminations, the most satisfactory arrangement for fanning out is to take the inner pairs with the lower numbers to the top (assuming the cable enters from the bottom in every case) and to connect the higher numbered pairs on the outer layers to the bottom terminal tags. To meet this requirement the terminating tags should be numbered from top to bottom. Where they are numbered in the reverse direction it necessitates a departure from the ideal fanning out arrangement. It is essential in this type of termination that the work be checked out before sealing with compound owing to the difficulty of correcting faults afterwards. Care should also be taken when filling the sealing chamber with compound to ensure that all conductors are completely covered and no further faults are caused.

THE DESIGN OF PORCELAIN "EGG" TYPE INSULATORS

K. R. Thompson

Introduction.

The growing demand for both A.C. power and telephone requirements has resulted in considerable increase in the provision of transmission lines of both services; with increase of proximity of these lines the problem of protection to human life and stock has to be considered. In localities where power lines and telephone aerial routes cross, or run parallel in close proximity, it is necessary to protect the telephone stay wires from the high voltage that might be impressed on them in the case of accident to, or failure of, the high tension lines. The choice among existing insulators for use in the stay wires has been somewhat limited, and the P.M.G. Research Laboratories were requested to investigate the types available, and if necessary to design a suitable insulator.

After preliminary investigation it was decided to design two "egg" type insulators for use with light and heavy stay wires respectively.

The two essential characteristics of this type of insulator are mechanical strength and resistance to electrical discharge between conductors. This type of insulator has been made in many different forms, the reason for some designs being rather obscure.

Mechanical Considerations.

In Fig. 1 are illustrated some insulators at present on the market, together with drawings of their cross-sections. The photograph of G6AP shows the remains of an actual test specimen after straining in tension; it will be noticed that the core, in the centre foreground, is still intact, while the fins have burst sideways.

In Fig. 2, Curve 1, we see the relation between their breaking loads and cross-sectional areas. The departure from the usual curve that would be expected from metals is not so astounding as it appears; it is the result of the peculiar behaviour of porcelain under stress which is also probably one reason why so few investigations have been carried out on this increasingly important material, and why literature on it is so scarce.

Of much interest are the tests of Navias[1] on the strengths of porcelain. Under ideal conditions of test he found that in compression the height of a specimen was an important variable, and there were two forms of failure "Initial" and "Ultimate." On test specimens $1\frac{1}{8}''$ dia. x $1\frac{1}{8}''$ high, the initial failing occurred at 47% of the ultimate increasing to 49%, 54%, 71%, for values of height/diameter of 1.04, 1.57, 2.07, the ultimate failure decreasing proportionately, and the initial failure remaining reasonably constant at a stress of 12 ton/sq. in. In tension he found, that as the area of cross-section increases, the tensile strength decreases rapidly; for a specimen $1\frac{1}{8}''$ dia. the ultimate stress was $3\frac{1}{4}$ tons/sq. in. For a specimen $2\frac{1}{4}''$ dia. the stress was 0.5 tons/sq. in. No results were given for porcelain in shear.

Porcelain is weak in shear having an ultimate stress of about 500 lbs./sq. in. No definite results of tests are available. The physical properties of porcelain are dependent upon the batch composition, the methods of working in the plastic state, and upon firing; any changes in these processes are reflected in the physical properties.

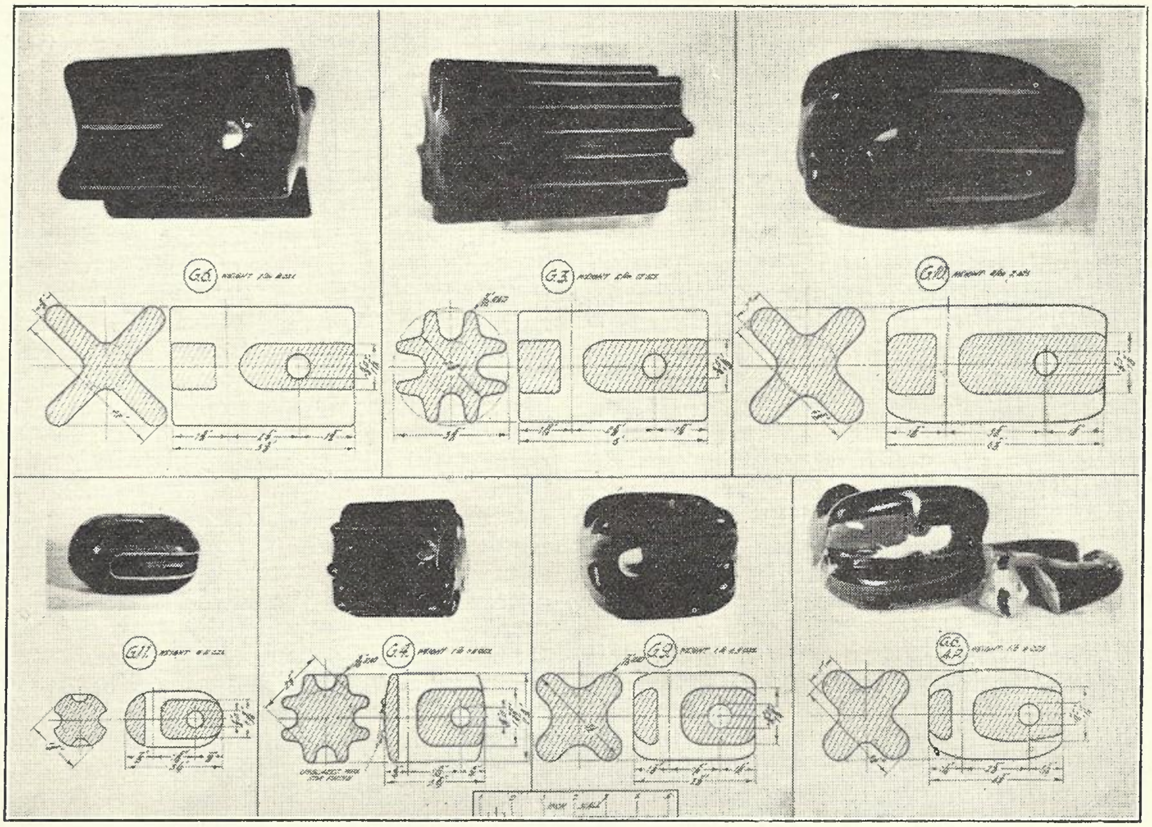


Fig. 1.—Typical commercial strain insulators.

Mechanical Design.

No attempt has been made to calculate the actual strength in tension of an egg type insulator from first principles, but consideration has been given to the behaviour of that part of the insulator, which is under compression, disregarding portions under other stresses.

In an attempt to observe the stress distribution in the core of an insulator under strain, it was decided to experiment with rubber cubes and right prisms of the same cross-sectional areas. By applying compressive loads in the centre of the square faces it was seen, that the rubber tends to burst out normal to the line of application of the load, the cube being stronger than the prism. Similarly, if compressive loads are applied at two points on each of the square faces, and in planes normal to one another it was found that the cube was much stronger, and did not tend to burst out so much as in the previous test; the cube was also stronger than the right prism. It will be seen, therefore, that when two points of application of the load are provided at each end (i.e., when four points of application are provided) of the rubber cube, we have a much stronger condition

[1] American Ceramic Society, Jour. 1926, page, 501.

for withstanding a load. These investigations showed that it was desirable to incorporate the idea of four point loads on a cubical core in the construction of the insulators.

Definitions.

Core diameter. This is the diameter of the largest circle that can be inscribed on a plane

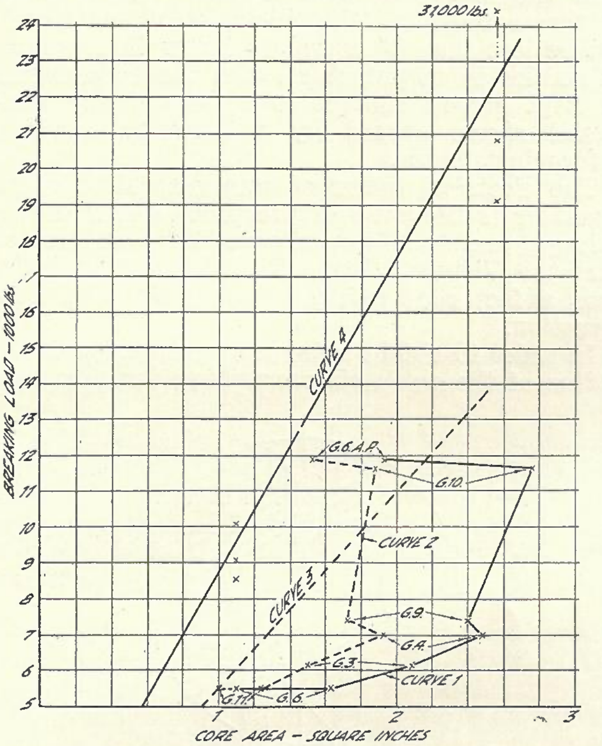


Fig. 2.—Mechanical characteristics of strain insulators.

normal to the longitudinal axis of the insulator without crossing the grooves.

Core Area. This is the area enclosed by the above circle. Turning to Fig. 2, Curve 1, we see that G.6.A.P., G.10 and G.11 are the strongest. The important features of G.10 and G.11 are the provision of a straight Portion A (slightly curved in G.6.A.P.), where the wire passes the centre line of the insulator. This causes the load to be distributed more heavily on the curved portions B, thus providing by the holes in combination 4 points of application of the load instead of 2 when the holes are continuously curved over the portion A as in G.6. When 4 point loads are applied, the compressive stress on the porcelain is concentrated more towards the centre of the cross-section, and therefore to some extent tends to delay bursting in direction C (which is the normal means of failure).

It would seem of advantage to provide a curve in the surface of the groove as at D which would help to delay bursting in direction C. It is, therefore, important that the porcelain in the core be in the form of a cube; this result will be obtained if the core diameter is equal to the length between holes. Thus insulator G.10 could be improved by lessening this distance. The improvement that might be obtained in the insulators under review by designing for a cubical core is shown in Curve 2, Fig. 2, and has been obtained by dividing the core area by the percentage difference of lengths between holes and core diameter; where the distance between holes is less than the core diameter, the percentage was calculated on the shortest distance. Curve 3 represents the average stress of Curve 2.

Consideration of the relation between the diameter of hole and core diameter shows, that a nice balance is obtained if the diameter of

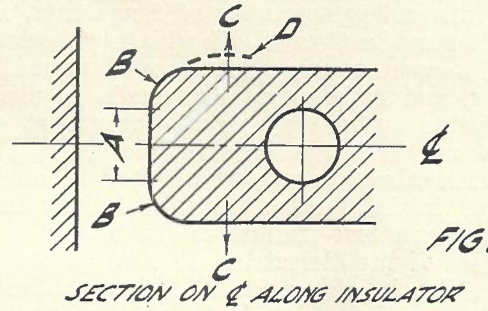


Fig. 3.—Portion of the cross-section of insulators G10 & G11.

the core is 2.3 times the hole diameter. In practice it will be found unnecessary to calculate the diameter of hole other than by the method outlined above. The relation between the diameter of wire used, and the diameter of the hole should, nevertheless, be considered. To prevent any chance of tensile stress or shear being impressed on the ends of the insulator, or at the sides of the hole, it is essential that no pressure be exerted on the unstressed side of the hole; this means that if the wire is allowed to flatten out, no metal would be above the centre-line at the sides of the hole, so that the total cross-

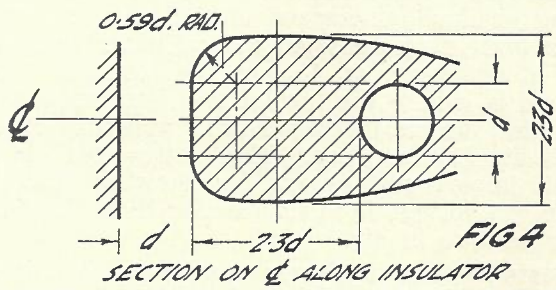


Fig. 4.—Portion of the cross-section of improved insulator.

sectional area of the individual strands of the wire must not be greater than half the cross-sectional area of the hole. Calculations show that this will not occur if the diameter of the hole is 1.5 times the diameter of the wire. Fig. 4 shows the desirable proportions of core design.

The outer dimensions of the insulator are dependent on the flashover voltage requirements, with the following exceptions:—The groove should be deep enough to prevent the wire from pulling out sideways, and should slope towards the end of the insulator conforming to the shape of the guy or wire eye. Of six insulators designed on the above principles, the average stress being derived from Curve 3, test results far exceeded the expected breaking loads, the average stress being double that of the best insulators shown in Fig. 2, Curve 1, being 3.9 tons/sq. in. with a variation of +37% and —15% shown by Curve 4.

It is dangerous to observe porcelain under compression as failure occurs suddenly by breaking up into a large number of fragments, some of which may be thrown off with high velocity; for this reason a bag was wrapped around the insulator, and no attempt was made to observe initial failure, which apparently occurs at some value above half the breaking load. A sharp click is sometimes heard, which may be an indication of initial failure. Initial failure means partial mechanical failure sufficient to cause breakdown of the dielectric. In view of the variation in the breaking loads, it seems that an insulator should be rated at half its calculated breaking load; this would also cover the possibility of initial failure. In design therefore the average breaking load should be twice the breaking load of the wire used. The factor of safety of the insulator would then be twice that of the wire, and would also allow sufficient margin on initial failure.

Electrical Considerations.

There are two common types of standard electrical tests applied to insulators. The first is, where the insulator is suspended in air and connected between the output terminals of a step-up transformer fed through a variable transformer from the A.C. supply, the voltage being gradually increased until flashover occurs. This test is also carried out with water spraying at an angle of 45° on the insulator. The second is, where the insulator is immersed in oil and the voltage increased until puncture of the porcelain takes place. This latter test is of small importance, except for showing that the puncture voltage is much greater than the flashover voltage in air.

Tests for dry flashover vary with the atmospheric conditions; as the humidity rises the results are correspondingly reduced. The average relation of wet to dry flashover voltages is about 60%. It is important when testing for flashover voltage, that the wires by which the insulator is suspended should conform in size to the wires that will normally be used with the insulator.

Electrical Design.

The fins and ends of an "egg" type insulator should be so designed, that the flashover distance, which is the shortest air gap measurement, is the same both across the fins and in the direction of the ends. It is necessary to provide sufficient porcelain in the ends to provide the same flashover distance at the ends as across the fins. The thickness of end should not be less than $\frac{3}{8}''$ as values below this present difficulties in manufacture, also the ends should be kept strong enough to withstand any accidental stress caused by a blow or handling before installation.

The electrical factor of safety required of an insulator is the ratio of the proof wet flashover voltage, and the line voltage. It is understood that the Victorian State Electricity Commission uses a factor of safety of 4, in electrical construction.

In order to obtain an approximate value of the radius of the circle circumscribing the fins, (see

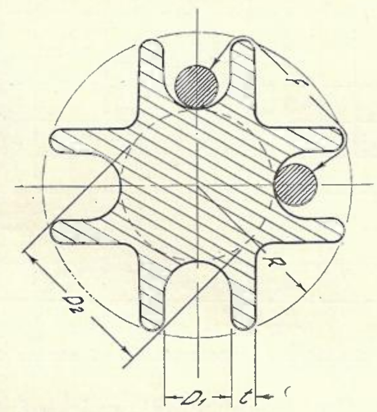


Fig. 5.—Illustrating the electrical design.

Fig. 5), the following formula was developed:—

$$R = \frac{F + D_2}{3.57} + .7D_1$$

where R = radius of circumscribing circle.
F = flashover distance.
D_2 = core diameter.
D_1 = diameter of hole.

From this formula a circle can be drawn, the types of fins inserted, and the flashover distance checked. In order to keep the weight of an insulator down, the thickness "t" of the fins may be kept quite small without affecting the flashover distance.

The thickness of the ends is obtained by a trial and error method, keeping the maximum permissible height consistent with finished appearance, while the thickness is increased until sufficient flashover distance is obtained.

Provision should be made for supporting the insulator during firing. When the glaze is continuous, it will be found that the insulator adheres to the saggar in which it is fired, and has to be broken out tending to make an unsightly end. This is avoided by the addition of four unglazed pips on one end of the insulator (see G.4), on which it may be stood during firing.

Conclusion.

It seems desirable to point out what has been achieved by comparing some of the insulators in Fig. 1, with an insulator designed in accordance with the principles outlined herein.

Let us consider G.4 and G.9; these insulators are reasonably well designed electrically, but have the distance between holes too short, resulting in reduced strength. In G.9 the distance between the holes is half the core diameter.

The design of G.6 is not good mechanically as it has only two points for application of the load; electrically the flashover distance is 7/8" longer across the fins than at the ends, corresponding to a difference of 11 kV in flashover voltage. An insulator designed to have the same performance could be made having only half its weight, for instance, G.11 has the same breaking load. G.3 is of a similar design and has the same characteristics with the exception of added strength. The sample to hand seems to have suffered by buckling which has occurred in the plastic state owing to its length being so much out of proportion to its overall diameter, and being stood on one end whilst drying and firing.

Insulator G.10 is a typical example of excessive waste of porcelain, weighing over 4 lbs. and having little extra flashover voltage than one half its size. It seems that the designer has relied on overall increase in weight to provide a little added strength.

The characteristics of two insulators designed on the principles described are shown in Table 1.

Type No.	Average Breaking Load lbs.	Dry Flashover Voltage.	Core Diameter.	Weight ozs.	For use with Stay Wires.
1	9,200	28 kV.	1-3/16"	9	Light
2	23,700	55 kV.	1-13/16"	41	Heavy

TABLE 1.—Characteristics of P.M.G. Standard Strain Insulators.

The details of these insulators, which have been adopted as standard by the Department, are shown in Fig. 6.

For a good comparison with the research that has been made in this design, it is of interest to note that the larger insulator in Fig. 6 has a higher flashover voltage than any of the insulators under review, and it has approximately twice the breaking load of the strongest of them; its weight is 2 lbs. 9 ozs.

As this article can by no means be regarded as a complete account of the design of strain insulators, it is important to point out several aspects affecting the design which require further research. They are:—

(a) Initial failure.

(b) The variation of the ratio of initial to ultimate failure with variation in core diameter.

(c) Variation of the stress curve (Fig. 2, Curve 4), with increase of core diameter.

(d) Methods of manufacturing insulators with large cores.

Thanks are due to the Sunshine Porcelain Potteries Pty. Ltd., for their co-operation in manufacturing sample insulators and in the testing of them.

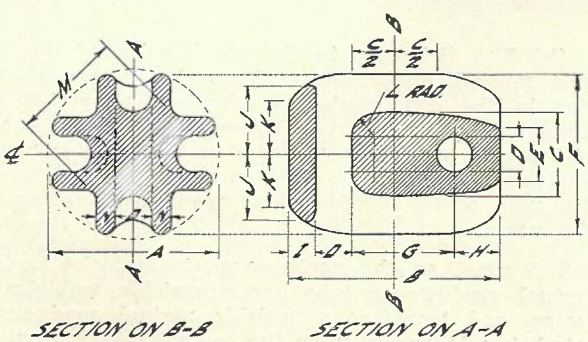


TABLE OF DIMENSIONS—IN INCHES

INSULATOR TYPE No	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	2 3/8	2 15/16	1 7/16	1/2	3/4	2 1/4	1 7/16	5/8	5/8	15/16	3/4	5/16	1 9/16	1/4
2	3 15/16	4 15/16	1 13/16	3/4	1 1/4	3 3/4	2 3/16	1 1/8	3/4	1 3/4	1 1/2	1/2	2 5/16	3/8

Fig. 6.—Standard strain insulatcrs.

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. 2071.—SENIOR MECHANIC.—RESEARCH.

J. D. CAMPBELL

Q. 1.—(a) What is the meaning of the following terms:—

Amplification Factor,
Plate characteristic,
Mutual conductance.

(b) From the anode current—grid voltage characteristics of two thermionic electron tubes A and B it is seen that the curves in the two cases have the same slope, but in the case of tube A the curves of the several values of anode voltage are closer together than in the case of B. Which tube has the greater

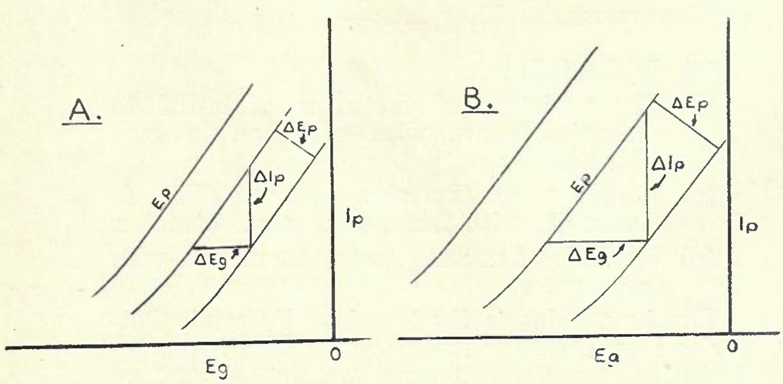
Amplification Factor
Plate resistance?

A.—(a) The "amplification factor" of an electron tube is expressed as the ratio of a small change in plate voltage $\triangle E_p$, which is necessary to change the plate current a given amount $\triangle I_p$, to the small change in grid voltage $\triangle E_g$ which will produce the same change in plate current.

$$\text{Thus } \mu = \frac{\triangle E_p}{\triangle E_g}$$

where μ = amplification factor.

Plate characteristics is the term used to describe the relations existing between the plate voltage and the plate current of an electron tube, when the grid voltage is held constant at a fixed value. The plate characteristics are usually presented in the form of a graph in which the values of plate current are plotted against plate voltage for various fixed values of grid



voltage. Such a set of curves is known as "family" of plate characteristic curves.

Mutual conductance is the ratio of the change in plate current I_p, to the small change in grid voltage E_g producing it, when the plate voltage is held constant. The unit is the mho but is usually expressed in micromhos or milliamperes per volt.

$$\text{The mutual conductance } Gm = \frac{\triangle I_p}{\triangle E_g}$$

(b) The amplification factor is given by $\dfrac{\triangle E_p}{\triangle E_g}$ and the plate resistance by $\dfrac{\triangle E_p}{\triangle I_p}$ assuming $\triangle E_p$ to be the same in both cases, then in the case of tube A $\triangle E_g$ and $\triangle I_p$ are smaller than in the case of tube B. This can be seen from the diagrams A and B. Thus A has the greater amplification factor and the greater plate resistance.

Q. 2.—(a) What are the functions performed by the various electrodes in a screened grid thermionic electron tube?

(b) How does the variable mutual conductance screen grid tube differ in construction and performance from the normal type of tube?

A.—(a) The electrodes of a screened grid tube are:—

1. The cathode,
2. The control grid,
3. The screen grid,
4. The plate.

The cathode, which may be a filament or a cathode heated by a filament, provides a source of electrons which pass through the control grid to the screen grid and plate, a positive potential being applied to both these electrodes. The screen grid attracts and accelerates the electrons towards it, but the majority pass through it to strike the plate and set up the plate current in the external circuit. Thus the screen grid acts as an accelerating device to accelerate the electrons towards the plate and also to shield those electrons near the cathode from the influence of the plate potential. The plate current depends to a great extent on the screen potential, and very little on the plate potential over the normal working range.

The voltage to be amplified is applied between the control grid and cathode, the control grid serving to control the electron stream flowing to the plate. The screen grid is placed at earth potential to alternating currents, and so acts as an electrostatic screen between control grid and plate. This reduces the control grid plate capacity to a very small value. This capacity causes instability in radio-frequency amplifiers, and its reduction means a substantial increase in amplification from the circuit.

(b) The difference in the construction of the variable mutual conductance tube and the normal tube lies in the construction of the control grid. In a normal tube the spacing between turns of the wire of the grid is regular, whereas in the variable mutual conductance tube the spacing varies, being close at the ends of the winding and open in the centre, or vice versa.

The effect on the performance is that the variable mutual conductance tube has a variable amplification factor, and therefore a variable mutual conductance, this being dependent upon the control grid voltage and the plate current. Also as relatively high bias is needed to reduce the plate current to zero and the cut-off value is reached very gradually, cross modulation is reduced considerably as the tube will handle both weak and strong signals equally well.

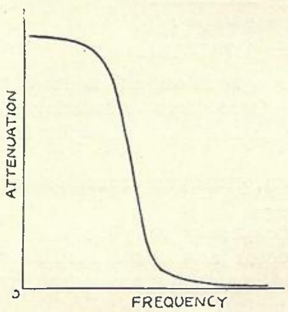
Q. 3.—What is an electric wave filter? Give typical attenuation—frequency curves for high pass, low pass, and band pass filters. What is the difference between an actual " filter " and an " ideal " filter?

A.—An electric wave filter is a network of coils and condensers, so designed that currents of certain frequencies are transmitted readily while currents of frequencies outside the desired range are attenuated to a greater extent.

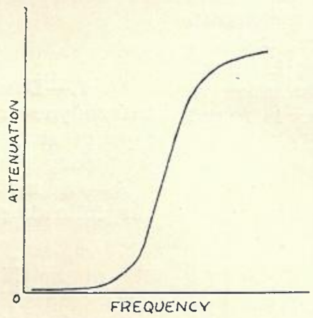
Wave filters may be divided into four general classes:—

1. Low pass filters, which cut off all frequencies above a certain value.
2. High pass filters, which cut off all frequencies below a certain value.
3. Band pass filters, which pass a band of selected frequencies and attenuate all others.
4. Band stop filters, which attenuate a certain band of frequencies and pass freely all others.

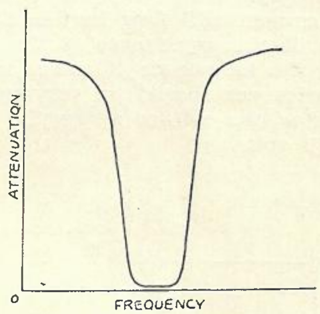
A filter may consist of a single network or section or may be rendered more effective, if two or more sections are connected in series. Typical curves of simple high pass, low pass and band pass filters are given.



HIGH PASS FILTER



LOW PASS FILTER



BAND PASS FILTER

An ideal filter would have pure reactance elements, and would offer zero attenuation to the desired band of frequencies, and a finite attenuation to all other frequencies. As it is impossible to obtain inductors and condensers without resistance, some attenuation must occur for the band of wanted frequencies, and the undesired frequencies will be attenuated by a finite amount, the ratio of these values of attenuation and the sharpness of cut-off being determined by economics.

Q. 4.—(a). What do you understand by the term " Radio Field Intensity," and in what unit is the electric field intensity of a radio transmitter usually expressed?

(b) What is the meaning of the term " Signal to Noise ratio "?

A.—(a) By definition, field strength or field intensity is equal to the space rate of change of electric potential. In practical units then field intensity can be expressed in volts per centimetre or any multiple or sub-multiple of this.

Where the electric field being dealt with is that from a radio transmitter, the field intensity is alternating at radio frequency, and in this case it is the R.M.S. value of the field intensity which is spoken of, as the " Radio Field Intensity."

Convenient units are the millivolt per metre and the microvolt per metre.

An explanation of the unit volt per metre, may be had by consideration of the field of a charged condenser. In a charged condenser consisting of two plates one metre apart, charged to a voltage of 1 volt the electric field has an intensity of 1 volt per metre. As a further illustration, an aerial may have an effective height of two metres, and if this is acted upon by a radio wave having a field intensity of one millivolt per metre in the vertical direction, then the voltage induced in the aerial will be two millivolts.

(b) The term signal to noise ratio is a measure of the " clearness of reception." It is the ratio at a point in a communication system of the intensity of the signal to the intensity of residual noise at that particular point. This ratio is usually expressed as a voltage ratio, or as a power ratio.

Radio signals which are received are sometimes marred by noises caused by static, set noises " man made " interference, etc., and the greater the noise, the greater the signal necessary for communication.

The field strength of a station may be quite adequate for satisfactory reception in country districts where the noise level is low, but for reception in city areas, where the noise level is high, the same field strength may be far too low, and to give satisfactory reception either the field strength must be increased or the noise reduced. Thus the signal to noise ratio at receiving points really determines the service area of broadcasting stations.

Q. 5.—The apparent resistance of wires and coils to the flow of alternating currents at high frequencies differs from that for direct current. What is the term used to express this resistance to distinguish it from the direct current resistance, and explain fully why the apparent resistance varies with frequency?

A.—The term used to express the resistance to the flow of alternating current at high frequencies is "effective resistance."

Effective resistance is the term which takes into account all the effects which cause power to be absorbed in the circuit, that is, the D.C. resistance and the A.C. resistance. Under the term A.C. resistance are grouped all the effects causing loss of power which are peculiar to alternating currents. The most prominent of these effects on wires and coils are " eddy current loss " and " skin effect." The " eddy current loss " occurs when the coil or part of the coil is placed near other metallic objects, such as screening, boxes, etc., so that currents are induced in the metallic objects by the varying magnetic field of the coil. Power is absorbed due to the resistance of the metal and the resistance of joints in the metal.

The effect varies with frequency because the eddy currents which cause it are set up by the change in flux cutting the conductor and increase with an increase in frequency of the current, or rate of change of the flux.

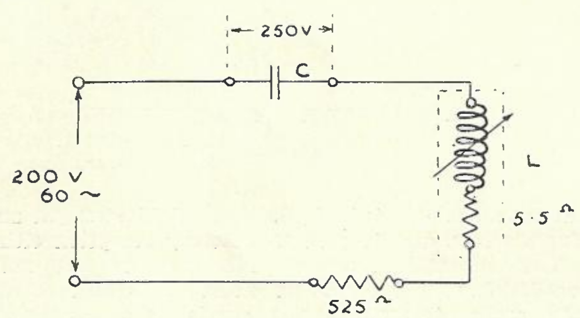
"Skin effect," is due to the eddy currents in the wire itself. The eddy currents flow in opposition to the inducing current in the wire, the effect being greatest in the centre of the wire, and there is a decreasing current density from the surface to the centre of the wire. As a result at the higher frequencies the current flows in the skin only.

If the wire is wound in a coil, the losses are greatly increased as there is further reaction between turns of the coil.

Q. 6.—A series circuit consisting of a condenser of negligible effective resistance, a non-reactive resistance of 525 ohms and a variable inductor having a constant resistance of 5.5 ohms, and negligible capacitance are connected to a 200 volt 60 cycle alternating current supply.

What current will flow in the circuit at resonance, and what is the capacitance of the condenser, and the value of the inductance if, when the circuit is tuned to 60 cycles per second by varying the inductance of the inductor, the voltage across the condenser is found to be 250 volts.

A.—



At resonance $I = \dfrac{E}{R}$

where I = current in amperes,
E = applied voltage,
R = total effective resistance,

$$I = \frac{200}{530.5}$$

$= 0.377$ amps.

Also at resonance

$$2\pi f L = \frac{1}{2\pi f C}$$

where f = frequency in cycles per second,
L = inductance in henries,
C = capacity in farads,

$$\frac{1}{2\pi f C} = \frac{Ec}{C}$$

where Ec = voltage across condenser.

$$\frac{1}{2\pi f C} = \frac{200}{0.377} = Xc,$$

Xc = 663.1 ohms,

$$C = \frac{1}{2\pi \times 60 \times 663.1}$$

= 4 microfarads,

and $2\pi L$ = 663.1 ohms,

$$L = \frac{663.1}{2\pi \times 60}$$

= 1.765 henries.

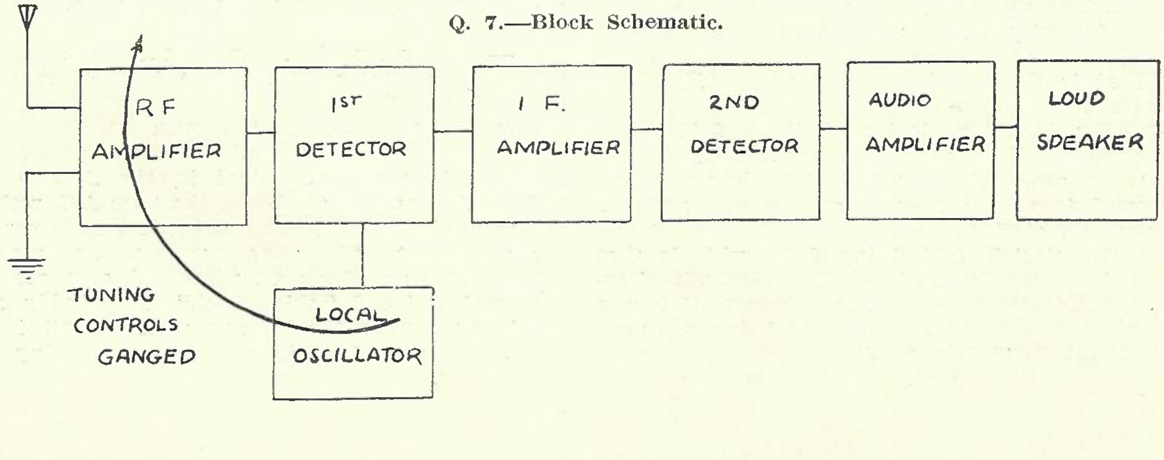
Q. 7.—Describe the operation of a modern superheterodyne receiver. Give two advantages of this type of receiver compared with a straight tuned radio frequency amplifier?

A.—A modern superhetrodyne receiver consists of the following stages:—

1. Radio frequency amplifier.
2. 1st detector and local oscillator.
3. Intermediate frequency amplifier.
4. 2nd detector.
5. Audio frequency amplifier and loudspeaker.

In the radio frequency amplifier the signal is selected, amplified and passed to the 1st detector. There the signal is mixed with a local oscillator current of higher frequency than the signal. In the anode circuit of the 1st detector are various currents of the sum and difference frequencies, of the oscillator and signal frequencies, but usually the difference frequency is selected and amplified by the intermediate frequency amplifier. If the signal is modulated, the intermediate frequency currents will also be modulated and the 2nd detector is used to produce these modulation frequencies which are ampli-

Q. 7.—Block Schematic.



fied by the audio amplifier and operate a loud speaker.

The radio frequency amplifier is necessary in order to amplify weak signals to a value suitable for the efficient working of the 1st detector and also to minimise cross modulation and spurious beat effects. Efficient selection of the signal prior to the 1st detector is necessary, as a signal of higher frequency than the oscillator will also produce a difference frequency corresponding to the intermediate frequency.

The intermediate frequency provides the necessary selectivity and amplification of the receiver, as, the frequency being fixed, these can be secured with ease.

At the second detector, there is developed a negative D.C. voltage, which is proportional to the signal. This voltage is applied as bias to the radio frequency, and intermediate frequency amplifiers, and acts as an automatic volume control, the gain of the receiver varying with the applied signal.

The advantages of this type of receiver over a straight tuned radio frequency receiver are:—

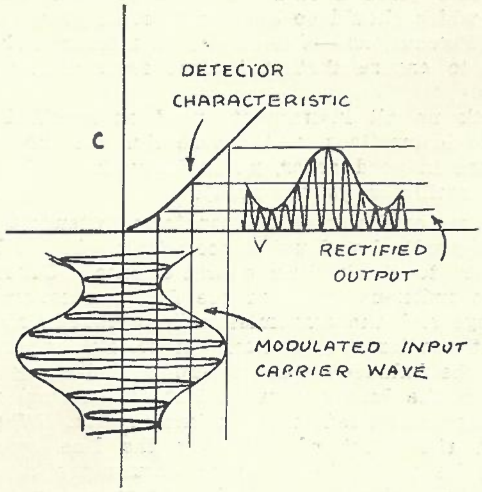
1. Greater and more constant selectivity which also may be varied at will.
2. Higher overall amplification with fewer stages.

Q. 8.—(a) Why is a detector necessary for the reception of radio broadcasting signals?

(b) Name three types of detector operation. In a receiver which would you use in each of the following cases:—

(1.) To receive weak signals.
(2.) To ensure freedom from distortion?

A.—(a) A detector is necessary for the reception of radio signals in order that the signals may be heard in a telephone receiver or loud speaker. The signals are radiated from the radio station in the form of a varying carrier wave of a frequency which is higher than the highest audible frequency. The amplitude of the carrier wave is varied in accordance with the speech or music being transmitted. The detector is used to transform the varying carrier wave currents into a pulsating direct current. This con-



sists of three components, a radio frequency current, a direct current, and an audio frequency current. The audio frequency current should be an exact replica of the speech or music originally impressed on the carrier in all respects except amplitude.

(b) Three types of detector operation are:—

1. Diode detector,
2. Grid leak detector,
3. Anode bend detector.

To receive weak signals the grid leak detector is the one commonly used. This type delivers more output from a given signal voltage, particularly when the signal is small. The audio output is dependent upon the rate of change of the slope of the grid-current grid-voltage curve, and the output current is therefore proportional to the square of the input voltage.

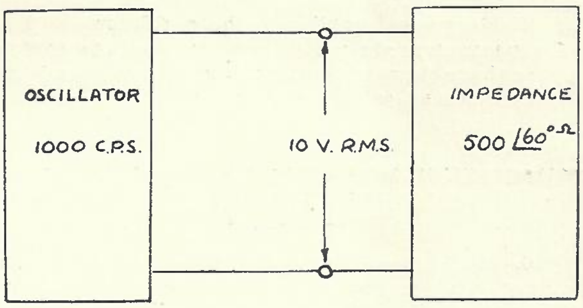
To ensure freedom from distortion a diode detector should be used as this detector is essentially linear in its operation, the audio output being proportional to the variations of the carrier; except in extreme cases of deep modulation, or weak signals.

Q. 9.—A circuit having an impedance of $500\angle 60°$ ohms is connected to an oscillator which is delivering power to the circuit. When the oscillator is set at 1000 cycles per second the voltage applied across the terminals of the circuit is found to be 10 volts R.M.S.

(a) What is the true power absorbed by the circuit under these conditions?

(b) What is the effective resistance of the circuit (Tan 60° = 1.732).

A.—



(b) $Z = \sqrt{R^2 + X^2}$

where R = effective resistance in ohms.
X = reactance of the circuit in ohms.

$500 = \sqrt{R^2 + X^2}$

Also $\tan 60° = \frac{X}{R} = 1.732$

$X = 1.732\ R$

inserting this in the equation for Z

$500 = \sqrt{R^2 + (1.732\ R)^2}$

$500 = \sqrt{R^2 + 3R^2}$

$500 = \sqrt{4R^2}$

$500 = 2\ R$

$R = 250$ ohms.

(a) Power $= I^2 R$ watts.

and $I = E/Z$

where I = Current through the circuit.

$I = 10/500.$

$= .02$ amps.

Power $= (.02)^2 \times 250.$

$= 100$ milliwatts.

Q. 10.—Why is a high degree of frequency stability necessary in a radio broadcasting transmitter. Discuss the main causes of frequency instability and the methods of minimising these variations.

A.—Frequency stability is necessary in a radio transmitter for the following reasons:—

1. To ensure that stations will not interfere with one another.
2. In order that the most economic use be made of the channels available.
3. To minimise distortion due to frequency modulation.

The main causes of frequency instability are:—

1. Incorrect design of the transmitter such as the aerial coupled directly to the oscillator, and modulating the oscillator directly.
2. Using coils and condensers which are mechanically unstable or can be greatly affected by temperature.
3. Large fluctuations to the power supply to the oscillator valve.
4. The use of a quartz crystal, which can be greatly affected by temperature, or which may oscillate at other frequencies than the desired frequency.

To minimise frequency variations it is usual to have:—

1. The oscillator circuit coupled to a fixed load to which it delivers a relatively small amount of power.
2. The oscillator operating at low power.
3. Coils and condensers, which are mechanically stable, and which are not greatly affected by temperatures.
4. Stable power supplies to the oscillator.
5. Quartz crystals which are temperature controlled or have low temperature co-efficients and which oscillate at only one frequency.

EXAMINATION 2050.—TRANSMISSION, TELEPHONE AND TELEGRAPH.

(Continued.)

Q. 5.—It is desired to determine by measurement the characteristic impedance, at several frequencies in the carrier range, of an open wire line. How would you carry out the measurement?

State—

(a) The instruments required (not to be described in detail).

(b) The manner in which the instruments would be arranged.

(c) Any precautions to be taken to prevent errors in measurements.

(d) The method of computing the characteristic impedance from the measurements made.

A.—The characteristic impedance (Z_0) of the line is calculated from the formula:—

$Z_0 = \sqrt{Z_c Z_f}$ when

Z_c is the measured impedance looking into the line when the distant end is short circuited, and

Z_f is the measured impedance when the distant end is open circuit.

(a) **Instruments.**—The method of measuring the impedances Z_c and Z_f involves the use of the following instruments:—

(i) 4A Bridge, i.e., a Hybrid Coil type High Frequency Impedance Bridge.

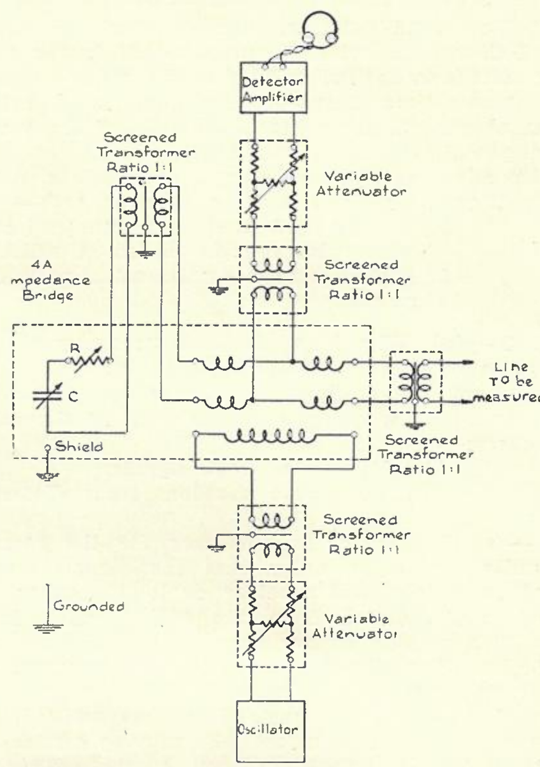
(ii) 4-1 : 1 ratio Screened Transformers suitable for use with frequencies up to 50 kC.

(iii) An Oscillator capable of operation over the range of frequencies desired. The output should be reasonably free of harmonics.

(iv) 2 Variable Attenuators.

(v) A Detector Amplifier to give an audible or visible indication of the presence of the high frequency testing current.

(b) **Layout of Instruments.**—The instruments would be arranged as shown.



Twisted pairs should be used for the connecting leads, which should be kept as short as possible.

(c) **Precautions.**—The line to be measured should be tested to ensure that it is free from abnormal conditions.

Check up all instruments used as specified in the relative instructions, and ensure that all the batteries used are in good order, particularly the grid batteries of the oscillator (where used).

The use of the screened transformers tends to reduce the longitudinal and unbalance effects. It is advisable, however, to check their characteristics. Generally, it will be sufficient to check the D.C. resistances of the windings and the transmission loss introduced by the coil at carrier frequencies. It is also advisable to check the balance of the set-up by balancing a resistance in the known arm against an external variable resistance connected to the unknown arm. When measuring, the effect of reversing the line connections should be tested in order to ensure the absence of longitudinal effects. The effect of reversing the leads to the oscillator, detector amplifier and the variable elements of the bridge should be tried also.

Method of Measurement.—Generally, the reactance of an open wire line at carrier frequencies will be negative. In this case the impedance of the line may be balanced by connecting the resistance and capacity standards of the bridge in series as the known arm, the line being connected as the unknown arm. The resistance and capacity standards are adjusted until the best possible balance is obtained.

For very accurate measurements the residual error caused by unbalances in the hybrid coil, wiring, etc., may be eliminated in the following manner:—

Having balanced the bridge as described above, substitute for the line a variable standard resistance in series with a variable standard condenser. These are adjusted until the bridge is again balanced and their values used for calculating the impedance of the line. Measurements should be made with the far end of the line short circuited, and again with the far end open circuit.

(d) **Method of Computation.**—Let R represent reading of bridge variable resistance, and C represent reading of bridge variable capacitance, then for lines with negative reactance—

$$Z_c = R - \frac{j}{wC} = \sqrt{R^2 + \left(\frac{1}{wC}\right)^2}$$

and Z_f may be calculated similarly.

Then—

$$Z_o = \sqrt{Z_c \times Z_f}.$$

Measurements of both Z_c and Z_f should be made at each of the carrier frequencies for which it is desired to determine Z_o.

Q. 6.—Thermionic tubes are in use in the following conditions:—

(a) A diode as a detector.

(b) A triode as an anode-bend detector.

Give a diagram of the circuit arrangements for each case and describe the manner in which the tubes operate as detectors.

A.—The circuit arrangements for the diode as a detector and the triode as an anode-bend detector are as shown in Figures 1 and 2 respectively.

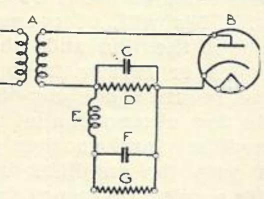


Fig. 1.

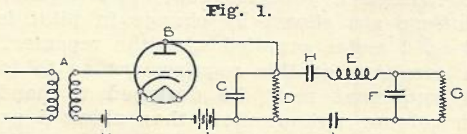


Fig. 2.

In both diagrams the lettered elements have the following significance:—

A. Transformer or Tuned circuit transmitting the modulated signal.

B. Fig. 1: The Diode. Fig. 2: The Triode.

C. & F. Condensers having low impedance to the carrier frequency and a high impedance to the modulation frequency. F is sometimes omitted.

D. Loading resistance.

E. Blocking inductance for carrier frequency.

G. Loading resistance or grid feed for next stage in an amplifier.

In Fig. 2.

H. & I. Blocking condensers for D.C. In practice I may be omitted by returning load circuit directly to the cathode.

J. Anode battery.

K. Bias battery: must be sufficient to bias back B nearly to cut off.

The manner in which these tubes operate as detectors is shown with the help of Figure 3.

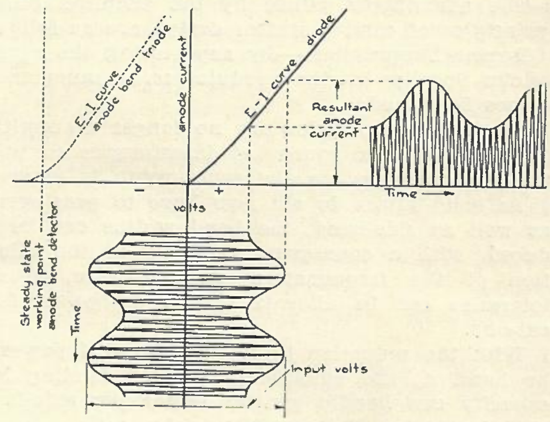


Fig. 3.

The e-i section of Figure 3 gives the relation between the current i in the anode-cathode circuit of the detector and the impressed voltage across the input to the detector.

The lower curve represents the impressed voltage plotted against the time for a modulated carrier. The right-hand curve represents the resultant current in the anode-cathode circuit also plotted against the time.

The effect of the detector is to produce a current which is certainly composed of a D.C. component plus a component having the modulation frequency plus other components having the carrier frequencies, etc. If proof of this statement is required, the following method might be used:—

Assume that no modulation exists. In this case the output current will clearly be a direct current component plus the carrier frequency. Now introduce a small degree of modulation. The output will now consist of the carrier frequency plus a direct current component which rises and falls with each modulation peak and valley, but this rising and falling is the equivalent of a superposed signal having the modulation frequency. Thus, a component having the modulation frequency must exist in the output current.

The above discussion relates equally well to the diode and anode bend detector since the e-i curve for each is similar, but in the case of the anode bend detector the steady state working point, as represented by the axis of the modulated carrier diagram, is at a negative voltage and the e-i curve is displaced to the left.

The elements C, D, E and F are necessary in a detector to separate the wanted component (modulation frequency) from the carrier and other unwanted products of detection. They also react on the detector in a manner which usually increases the efficiency of the detector. The filter shown is of a form suitable for use where large differences exist between the carrier and modulation frequencies, such as radio and audio frequencies.

Q. 7.—The later types of Carrier Telephone Systems in use in Australia incorporate in their design—

(i) Carrier Suppression.

(ii) Single side band transmission.

(iii) Grouped frequencies for each direction of transmission.

(iv) Differing carrier frequencies for systems to be used on parallel open wire lines, e.g., CN, CS, and CT systems.

Explain briefly the advantages gained by the adoption of these principles.

A.—The advantages gained by the adoption of the four principles of carrier system design are as follows:

(i) **Carrier Suppression.**—By suppressing the carrier frequencies locally in the modulators, a number of advantages is gained:

(a) As these frequencies are no longer transmitted over the line, a source of interference to other systems operating on the same route is removed.

(b) As band filters do not now have to pass carrier as well as side-band, the band widths can be reduced, with a consequent economy in the allocation of the frequency spectrum. Also, greater tolerance can be allowed in the design of filter cut-offs.

(c) With the reduction in total sources of power to be handled, the amplifiers at their existing load capacity can handle greater power per side-band, thus improving the speech to noise ratio.

(d) With carrier suppression a more stable overall equivalent is possible. The audio output of a channel is proportional to the product of the amplitudes of carrier and side-band at the demodulator. In a carrier suppressed system the side-band component only is affected by variations in line attenuation.

(ii) **Single Side-band Transmission.**—The advantages of suppressing the unwanted side-band are similar to those gained by suppressing the carrier frequency, particularly in regard to—

(a) Removal of a further source of interference to other systems.

(b) Economy of the available frequency range.

(c) Reduction in power to be handled by amplifiers.

(iii) **Grouped Frequencies.**—The grouping of frequencies for transmission in either direction—

(a) Greatly simplifies the arrangements for filtering and amplification at common amplifier points. With the standard arrangement for 3-channel systems the three "low" frequencies are used A-B and the three "high" frequencies B-A. They can be separated by "directional" filters consisting of high and low pass filters only. The relative amplifiers need only be designed for a frequency range covering three adjacent side-bands.

(b) The "grouped" or directional frequency scheme (two frequencies per channel) provides the equivalent of four-wire working, thus allowing the desirable higher gains due to improved "singing point" conditions.

(c) By using similar groups of frequencies in the same direction on adjacent systems, the levels of frequencies most likely to cause cross-talk rise and fall together over the various sections. Cross-talk problems are thus limited to far end troubles, and design of transposition schemes can be less strict.

(iv) **Differing Carrier Frequencies for Parallel Systems.**—By "staggering" the frequencies of one system with respect to those of another system operating on the same pole route the possibility of cross-talk is greatly reduced as the points of maximum power produced in the channels of, say, the "normal" system occur at frequencies which lie between the band filters of the "staggered" system. The conditions for the line transposition layout are consequently less exacting.

Q. 8.—(a) Give briefly the requirements to be met by a long-distance channel to be used for the transmission of programmes for broadcasting.

(b) Describe how these requirements have been met on any channel in use in Australia.

A.—(a) The ideal to be aimed at in the provision of a programme channel over trunk circuits is the transmission of music without distortion or interference. The programme circuit must, likewise, not interfere with other lines on the route.

It is found that music is little affected if a frequency band 35 to 8000 cycles per second only is transmitted, and that very fair results are obtained with a band of 50 to 5000 cycles. Within this band, the attenuation plotted against frequency graph should be substantially flat (say, within ± 2 db of the 1000 cycle value) and phase distortion must be negligible.

In an open wire physical circuit, phase distortion causes no trouble, and to obtain a satisfactory band, carrier systems must work above the upper frequency limit, composite sets must be removed, and discontinuities, such as lengths of cable, eliminated as far as practicable. An equaliser will be required to compensate for the attenuation frequency characteristic of the line. In carrier systems, the transmitted band is taken care of in the design of the system, but the line should be free of discontinuities and will require equalising.

Considering interference, experience shows that a programme is satisfactory if the volume range is confined to 40 db (although many musical programmes actually cover a much greater range) and, therefore, the level at any point along the line must be such that maximum volume will not cause cross-talk into adjoining lines, and that 40 db below this level the received cross-talk and other noise will be negligible. This requires that noise shall be about 55 db below average programme level. This will, of course, depend on the physical condition of the line and whether the circuit is provided at voice or carrier frequency. Amplifiers will, therefore, be required on long-distance lines.

(i) To provide for observation of physical circuits, a monitoring amplifier, loud speaker and level indicator are supplied with the amplifier installation; while on carrier circuits a pilot frequency is transmitted and line variations are shown by change in pilot level as indicated on a meter supplied with the repeater.

(ii) A corollary of this requirement as to levels is that the equipment must be designed to handle the maximum volume without more than about 5 per cent. distortion due to overloading.

(iii) The location of and power transmitted by these installations will be co-ordinated with ordinary voice frequency repeaters and carrier repeaters, to ensure that the difference between low level and high level circuits (i.e., at the receiving and transmitting ends of a repeater section respectively) shall not be such as to cause cross-talk. Where possible all such equipment will be installed in the same building and use the same batteries.

Consider the case of the permanent programme line —Melbourne to 3GI, Sale. The distance in this case is approximately 130 miles, the trunk lines consisting of an unloaded entrance cable of 12 miles and then open wire lines. Examination of the wires available showed that a physical circuit free of composite sets and carrier equipment giving a 35 to 8000 cycle band could be provided much more economically than a carrier system. In order to obtain a flat attenuation versus frequency characteristic, equalisation of cable and open wire sections was necessary, and the equivalents were then 35 db and 22 db respectively.

The average level at the sending end is limited by the apparatus to zero (= 6 mW), this figure being in turn decided from economic considerations governed by number and power handling capacity of repeaters necessary for satisfactory telephone conversation. (Note that average level can be taken as 10 db below maximum level.)

As the received level at Sale would thus be —55 db, an amplifier and associated equipment was installed in the exchange at the end of the cable to avoid cross-talk. This amplifier lifts the received level to approximately —22 db, and after careful balancing and transposing the line this was satisfactory from the point of view of noise and cross-talk, but too low for introduction into the transmitter; this was overcome by the use of an additional amplifier at the station.

EXAMINATION 2050.—TELEGRAPH EQUIPMENT.

(Continued.)

B. E. EDWARDS

Q. 5.—(a) It is desired to utilise double current transmission over the connecting channel, but the transmitting machine is only adapted for single current operation. Explain with the aid of a sketch the arrangements you would make.

(b) What is meant by "Bias" on a telegraph relay and what effect does bias have on the reception in a machine system?

A.—(a) In machine working the differential properties of the polarised telegraph relay are generally utilised for this purpose. Figure 1 shows the connections.

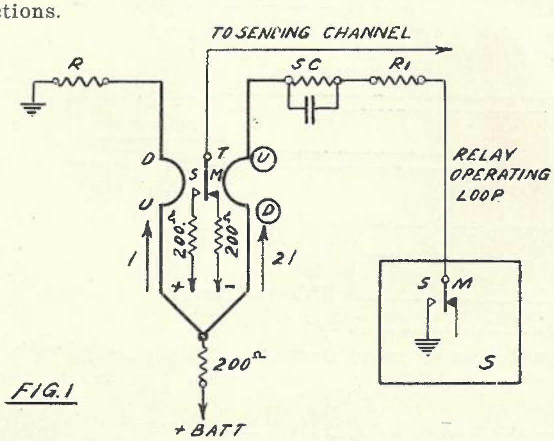


FIG. 1

Winding U̇–Ḋ is arranged as a biasing winding to move the tongue T to the marking contact when winding Ḋ–U̇ is unenergised.

R limits the current to some value I suitable for the relay in use. With a Creed relay 15 mA's would be a suitable value.

S is the sender. As shown, it represents a teleprinter, but it may be the distributor of a morkrum teletype. In the latter eventuality, since the morkrum distributor has marking contacts, but no spacing contacts, the directions of the relay windings would be reversed.

R_1 and the resistance of SC limit the operating current through Ḋ–U̇ to a value = 2I. When the sender is operated to spacing the predominance of current in the winding Ḋ–U̇ moves the relay tongue to the spacing contact.

SC is a shunted condenser inserted to neutralise the inductance of winding Ḋ–U̇. With a Creed relay the values are 2000 ohms/2 mF. SC preserves the signal shape in the operating winding and tends to overcome the bias that is inherent in this kind of relay operation.

T is the relay tongue connected to the sending channel; e.g., carrier or V.F. send loop, split of duplex equipment, etc.

The battery resistances are shown as 200 ohms each.

Figure 2 indicates the corresponding currents in the operating loop and the sending channel.

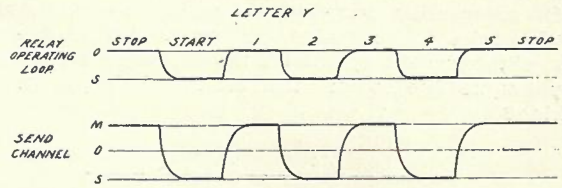


FIG. 2.

(b) Bias on a telegraph relay is a condition by virtue of which the relay responds more readily to currents of one polarity than to those of the opposite polarity. In a relay working under double current conditions, it would generally be due to a marked inequality in the distribution of the magnetic field from the armature to the pole pieces on either side. Defective centring of the contacts or unequal adjustment of the pole pieces (in certain types of relay) are usual causes of relay bias.

In machine systems, where reception depends upon the correct spacing of the code elements on a time basis, relay bias may cause errors by distorting this spacing beyond the operating margins of the receiving machine. Figure 3 shows the possible effect on reception of marking bias in the receiving relay of a teleprinter circuit.

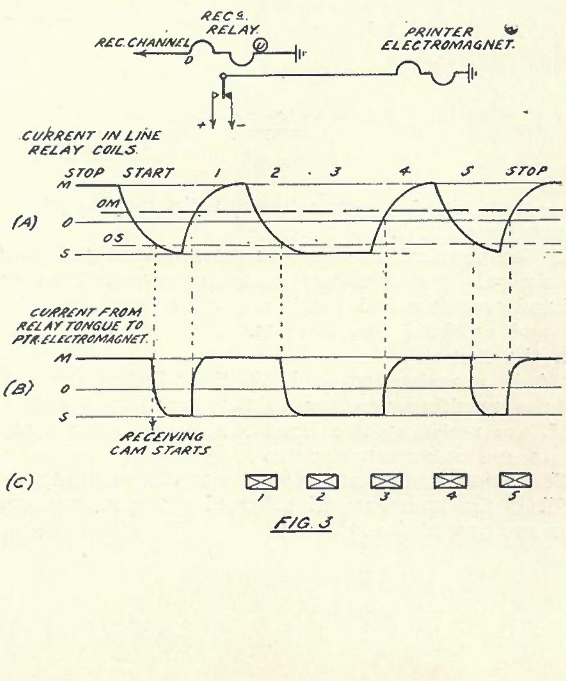


FIG. 3

The circuit shows the generalised arrangement.

Curve A is the received signal train for the letter D as it appears in the windings of the receiving relay.

OM and OS are the mark and space values that the current must attain in order to operate the relay. Marking bias is evident.

Curve B is the distorted output from the relay tongue. This curve may also be assumed to show the movements of the printer electromagnet.

Curve C shows (relative to the operation of the electromagnet armature in curve B) the periods during which the striker blade is moved towards the selector fingers. If the electromagnet armature is to "marking" at these times a finger will be selected. Therefore elements 3 and 5, which were spacing in the original transmission, may appear as marking in the reception.

Q. 6.—Draw a schematic diagram of the connexions of a long-distance leased teleprinter, including the C.T.O. observation teleprinter facilities to enable the leased service to be tested and supervised as desired. What effect has the spasmodic movement of a receiving relay tongue due to an incorrect line balance, on the working?

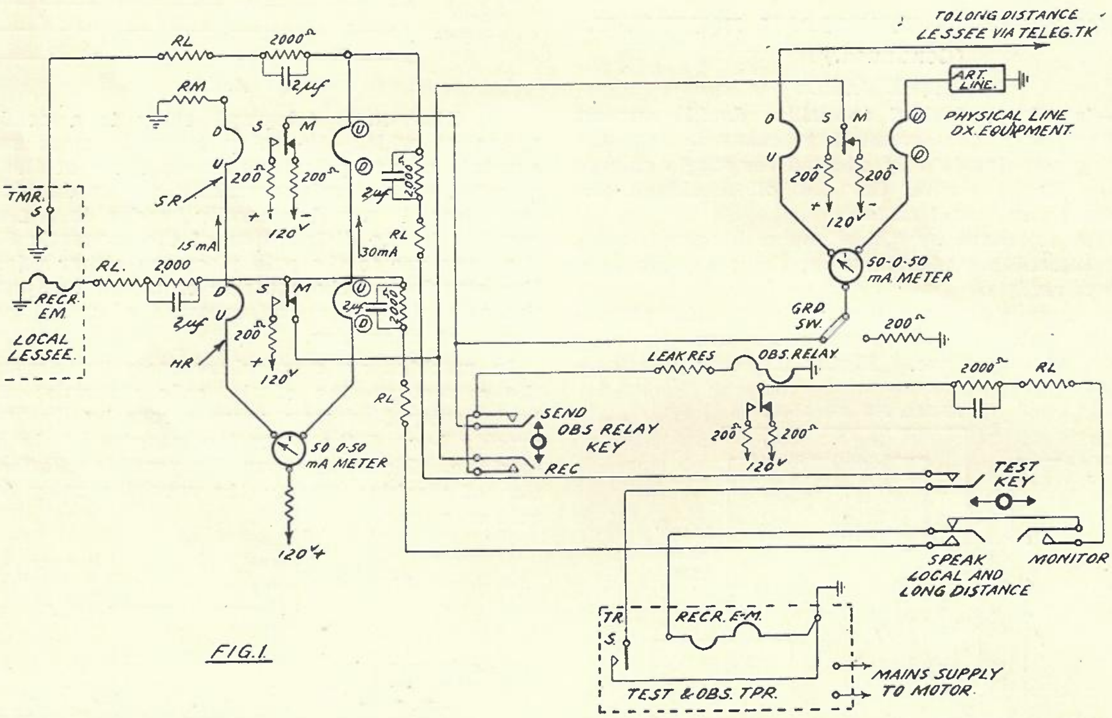


FIG. 1.

A.—(a) Fig. 1 shows schematically the long-distance teleprinter point to point service.

At the physical line duplex terminal only essentials are shown. Switches are generally provided to allow of hand working and hand balancing, and for opening line and artificial line circuits.

In the figure:

RM is a resistance to limit the biasing current in the marking winding of the auxiliary relays.

RL are resistances to limit the steady state currents in the operating circuits.

SR is the sending relay of the auxiliary group.

HR is the home record relay of the auxiliary group.

Keys are provided to allow:

(i) The test teleprinter to monitor on either the outgoing or incoming transmission.

(ii) The test teleprinter to be connected as a second "local" station and therefore to "speak" to either lessee.

(b) Fig. 1 shows that the marking battery on the contact of the home record relay is supplied through the tongue of the receiving relay. In order that the home record may be received during outward transmission, the receiving relay must be held on the marking side by the stop signal from the distant end. If the position of the receiving relay tongue is disturbed due to faulty balance conditions, the home record at the sending station will be mutilated. Transmission to the distant station will not be adversely affected.

Q. 7.—At a country centre a number of morse simplex channels and one manual duplex system are terminated. A 24-volt secondary battery and a commercial A.C. power supply of 200-400 volts are available and it is proposed to utilise these for main and local telegraph power requirements. Explain fully, with the aid of a sketch, the arrangements you would make.

A.—As shown in Fig. 1, "double current" potentials for the duplex circuit would be provided by the use of two rectifier bridge arrangements. Morse lines terminating at the office would be connected to either of the two duplex potentials available, to the 24V bus bar, or to earth, depending upon the conditions at the distant end.

The value of the duplex potentials would be chosen after consideration of all line conditions, but the 120 volts shown would meet general requirements, as local resistance could be inserted in those lines for which

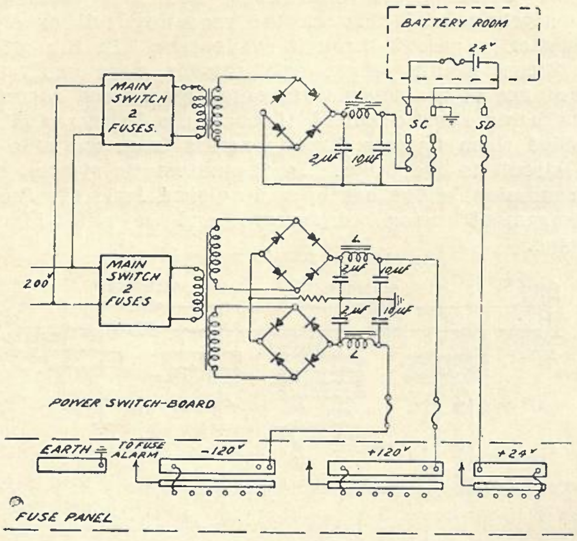


FIG I

24 volts would be too low, and 120 volts too high if connected direct. Besides any short morse lines, the 24 volts would supply current for the locals of both the duplex and simplex sets. Since the office is comparatively small no battery IDF or resistance panel would be provided. The sets would be wired direct to the fuse panel, and resistances where necessary would be mounted at the set.

In the figure, SC is the 24-volt charging switch which connects the rectifier to the battery for charging. Since the battery may be floated, a filter is included in the charging circuit to prevent ripple from the rectifier interfering with telephone channels on the same routes as the telegraph lines. This filter would not be necessary if the 24-volt battery were used for locals only.

SD is the 24-volt discharge switch.

The 120 volts positive and negative are obtained from two rectifier bridges in order to obtain good voltage regulation. Both leads are filtered as these potentials are intended for line voltages.

L may be a 4001A repeating coil connected as a choke coil.

Q. 8.—Draw a schematic diagram of a Fast Speed repeater installation suitable for use on a long physical channel, multiplex being operated between the two terminal stations. Assuming the repeater relays are operated on the Gulstad principle, explain how you would satisfy yourself that they are in correct adjustment.

A.—At a repeater station where no multiplex apparatus is installed the Wheatstone receiver must be used to test the operation of the Gulstad relays. Although the record of reversals received thereon may be interpreted as being satisfactory or not, signals of varying length cannot be so treated unless the combinations of transmitted signals are known. It is usual for test purposes, therefore, to send pre-arranged groups of signals from the terminals so that the reception at the repeater station may be interpreted. These would include the equivalents of dots, dashes and spaces.

The operation of the Gulstad relays may be taken as satisfactory if the speed of free vibration, and the control are correct. By control is meant the current

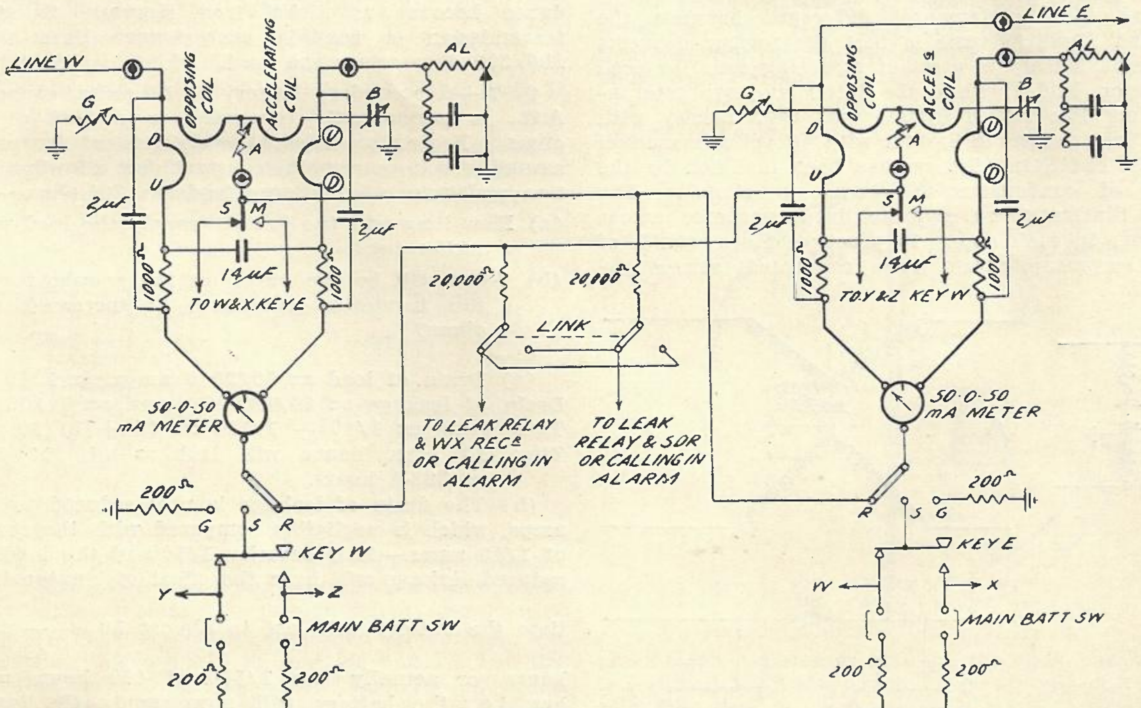


FIG. 1.

value at which the signal predominates over the effect of the current in the opposing coil.

Test for speed:

(a) Receive reversals from the multiplex terminal concerned and record them on the tape of the Wheatstone receiver.

(b) Open main battery switch and line switch of repeater terminal concerned. Record free vibrations of Gulstad relay on the Wheatstone receiver tape.

(c) Compare the records and verify that the free vibrations are about 10 per cent. slower than the incoming reversals.

Test for control:

(a) Receive pre-arranged test signals from multiplex terminal with Gulstad relay circuit operating. Record these signals on the Wheatstone tape, and examine them to verify that there are no mutilations such as—

Dashes split.
Signals or spaces between signals clipped.
Extra dots.

(b) Verify that some margin exists in the control by ascertaining that G may be increased and decreased about equally on each side of the set value before failure occurs.

If the Gulstad relays pass this test, their adjustment may be regarded as satisfactory.

EXAMINATION 2050.—TELEPHONE EQUIPMENT.

(Continued.)

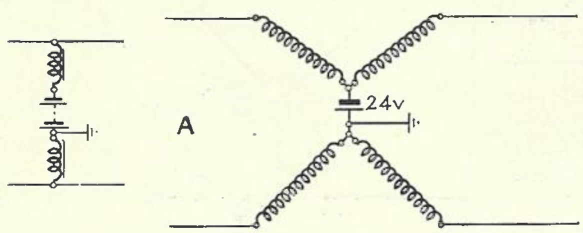
J. A. KLINE, B.Sc., A.M.I.E.E.

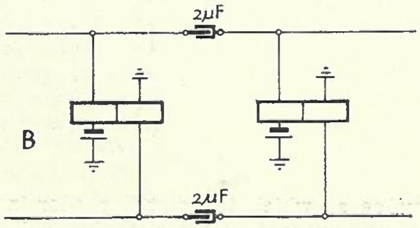
Q. 6.—(a) Show schematically the "Stone" and "Hayes" feeding bridges. Comment briefly on the essential points of difference.

(b) From Figure 1 and Figure 2 extract and draw the feeding bridges as a combined schematic diagram. Intermediate switches may be omitted.

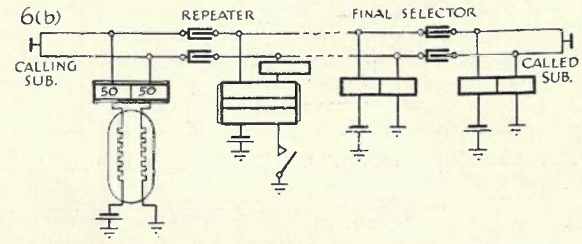
(c) What is the effect of the ballast resistance shown in Figure 1?

A.—(a) The fundamental difference between the Hayes and Stone Systems is that the former connects the common battery to a set of repeating coils for each transmission bridge, while the latter employs retardation coils. The Hayes System was used mostly with 22 volts and the Stone System with 40 volts in manual working. The Stone System has been modified by the addition of condensers as shown in sketch. The sketches illustrate two separate lines connected across the battery in each case. In practice, there would, of course, be many more lines connected across the battery.





In each of the arrangements shown, direct current is supplied to the sub-station transmitter in series with the two coils, whether they be retards or repeaters. Speech currents are alternating and are, therefore, inductively passed through the repeating coil or electrostatically passed through condensers. In the original Stone circuit, where only retards were used, the impedance of the retards prevented the speech currents from being short-circuited through the battery and so enabled them to pass directly across from one side of the circuit to the other. In the automatic system, the transmission bridge has been developed from the Stone arrangement using condensers and a still higher voltage.



(c) The ballast lamp is included to regulate the current flowing in the calling subscriber's transmitter. The characteristic of this unit is to increase the resistance with increase of current; therefore on short loops the line current will be limited to 100 milliamperes, but as the line increases in resistance and the current decreases, the resistance of the ballast lamp falls. Even on long lines the transmitter current is always kept comparatively high. The battery feed relays, although of 50/50 ohms resistance, have high impedance because of nickel iron sleeves. Satisfactory transmission is possible over longer lines than if 200/200 ohm relays are used.

Q. 7.—A secondary battery of 50 volts, capacity 10 A.H., is permanently connected to a load of 2,000 ohms. Neglecting internal resistance of battery and assuming voltage remains constant, but allowing insulation resistance of discharge leads as 10^4 ohms—

(a) How long will the battery supply the load without recharging?

(b) What will be the effect on the answer to (a) if the insulation resistance is increased to 10^6 ohms?

A.—

(a) Drain of load = 50/2000 amps. = 1/40 amps.
Drain of leakage = 50/10,000 amps. = 1/200 amps.
Total drain = 1/40 + 1/200 = (5 + 1)/200 amps.
Time 10 amp. hours will last = (10 × 200)/6 = 333-⅓ hours.

(b) The drain of leakage is now reduced to $50/10^6$ amps, which is negligible compared with the real load of 1/40 amps.—it is actually 1/500 of the load. The reduced leakage will have the effect of lengthening the time the battery will last to almost $10 \div \frac{1}{40} = 400$ hours, or actually less 1/500 of 400 hours = 4/5 hrs, i.e., the battery will now supply the load for 399-⅕ hours.

Q. 8.—(a) Explain the essential differences between Siemens No. 16 system and the regular Strowger automatic system, for five figures.

(b) In a network equipped with No. 16 type, what special arrangements would be required to establish a new branch exchange, using Strowger equipment?

A.—(a)

	Siemens No. 16.	Strowger.
1. Feeding Bridge	In first selector	In final selector.
2. Voltage	60v.	50v.
3. Rotary Motion of Switches	By current impulses from interrupter	Self-interruption of each switch.
4. Engaged Test on Bank Contacts	(a) Selectors and 2nd preselector-battery on C wire is free condition	Absence of earth is free condition.
	(b) First preselector free when C wire earthed	Battery is free condition.
5. Call Registration	Reduction of resistance in C wire circuit	Increase of potential on C wire.
6. Preselector	10-point 1st and 2nd	24-point homing.
7. Impulsing	Repetition from 1st selector over one leg	Loop dialling straight through to successive switches.

(b) The special arrangements would affect only the junction circuits between the main and the branch exchange.

(i) Junctions from Strowger branch to Siemens 16 main exchange. Normally the outgoing repeater or Switching Selector Repeater of the Strowger equipment will provide a loop for calling and accept reversal for supervision; whilst the incoming selector at the Siemens exchange is normally impulsed by applying battery over one leg to an earthed relay and extends supervision by applying battery over the other leg back to an earthed relay at the branch exchange. Three possibilities would permit inter-working:—

(a) Alteration of outgoing repeater or S.S.R.
(b) Alteration of incoming selector.
(c) Interposing a special repeater at either end of the junction.

Since the network has Siemens main exchanges, alternative (a) would probably be the best, and the repeaters would be modified from the principle shown in Fig. 1 to those shown in Fig. 2.

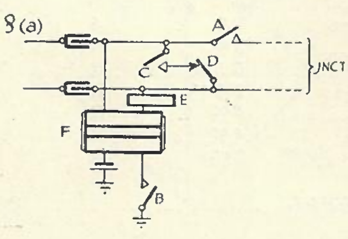


Fig. 1.

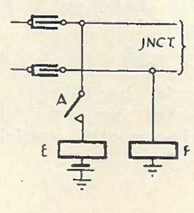


Fig. 2.

(ii) Junctions from Siemens main to the Strowger branch. There is no outgoing repeater normally necessary with the Siemens No. 16 equipment, the P wire terminating in a resistance connected to battery, but the outgoing impulses will be sent via one leg and the supervision received on the other leg. The incoming selector or final selector at the Strowger branch required a loop circuit and would transmit supervision by reversal. The alternatives available are:—

(a) To alter the circuit of all the first selectors in the main exchange, making the calling side similar to Fig. 1.
(b) To alter the circuit of all the switches which can receive impulses from the junction so that the impulse relay is connected to one leg and supervisory signals are transmitted back over the other leg.
(c) The use of special repeaters at either end of the junction.

If the branch has final selectors only, on the incoming junctions, (b) will probably prove the most economical, otherwise (c) might prove the best arrangement.

Q. 9.—(a) Sketch the essential parts of one type of moving iron ammeter used for A.C. measurements. Explain the principle of operation and damping.

(b) If its resistance is 2,000 ohms and 20 milliamperes gives full scale deflection, how would you adapt this instrument to measure 500 volts direct current? Show your working.

A.—(a) The moving system consists of a light soft iron plate which is pivoted as shown. Attached to the

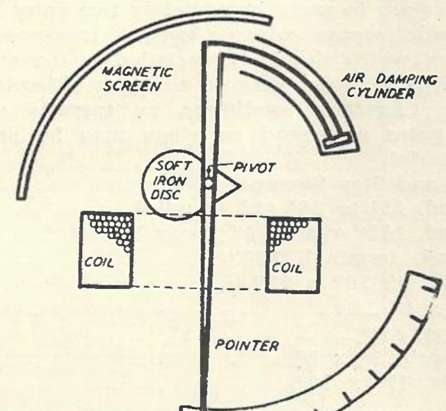


plate is an aluminium pointer, the back end of which is terminated by the piston in an air-damping cylinder. The fixed coil is wound on a short cylindrical former and is located in relation to the moving system as shown. When a current is passed through the fixed coil, a magnetic field is set up which embraces the soft iron plate. The force of this field on the plate tends to move the plate into the strongest field, i.e., at the centre of the coil, irrespective of the direction in which the current is flowing. Owing to the eccentricity of the pivot, this force is converted to a turning moment and the pointer moves over the scale until the turning moment of the field balances the restoring moment provided either gravitationally or by means of hair springs. (The restoring system is not shown on the sketch.)

The air-damping device is necessary to avoid vibration of the needle which would otherwise occur due to the small inertia of the moving system. The damping device is particularly important when the instrument is used on alternating current. In this case it is necessary to maintain the needle steady, although the current and magnetic field are varying in intensity and direction at a very rapid rate.

(b) In order that the instrument should measure 500 volts with a full scale deflection, it is necessary to add resistance in series with the meter so that the current is 20 milliamperes when a pressure of 500 volts is applied. The value of this series resistance can be calculated from Ohms law:—

Total resistance of circuit = V/I

$$= 500 \div \frac{20}{1000} = 25{,}000 \text{ ohms;}$$

where V = volts applied and I = current (amperes). But, 2000 ohms of this resistance are already provided by the meter itself. Therefore series resistance to be added

$$= 25{,}000 - 2{,}000 = 23{,}000 \text{ ohms.}$$

EXAMINATION 2050.—LINE CONSTRUCTION.

(Continued.)

C. J. GRIFFITHS, M.E.E, A.M.I.E.E.

Q. 5.—Prepare a detailed estimate showing quantities of material and man-hours of labour, but no prices for the erection of a pole line five miles in length along a country road where the conditions are such that the poles cannot be erected within less than 6 feet from the fence line.

The poles are to carry immediately two pairs of 200-lb. per mile copper wires phantom transposed, the provision of which should be included in the estimate. The pole line is to be designed to carry ultimately two crossarms. Average conditions as regards sinking, clearing, gates and road crossings may be assumed.

A.—Material.

(1) Poles and Stay Stores.

Poles, wood, 20′ to 26′ (32 to mile)	161
Arms, wood, 108″ x 3″ x 3″ 8-way W.S. & S.S.	159
Arms, wood, terminal, 108″	2
Bolts, ⅝″ x 9″, 10″ x 11″	161
,, ⅜″ x 4″	322
Braces, arm, 41″	322
Screws, coach, 3″ x ⅜″	161
Roofs, pole, 17″ x 12″	161
Nails, S.H.	15 lb.
Stayrods, 6′ x ⅝″ (2 transverse ¼ and ¾ mile points, 2 longitudinal at ½ mile points and say 10 angles)	48
Stayrods, 8′ x ¾″ (2 terminal stays)	2
Plates, steel stay, 12″ x 12″	48
,, ,, ,, 15″ x 15″	2
Eyebolts, bent, 9″ or 10″ x ⅝″	29
,, ,, ,, ¾″	2
Detachable eyes, ⅝″	19
Stayguards (saplings or timber)	50
Wire, steel, 7/14	125 lb.
,, ,, 7/12	10 lb.
,, G.I., 400 lb.	100 lb.
Staples, G.I.	6 lb.
Creosote	160 galls.

The number of each size of pole will vary with nature of country, number of road crossings and gates and number of extra-sized poles required for grading.

(2) Wire Stores.

Wire, H.D.C., 200 lb.	4100 lbs.
Insulators, Trunk P	600
,, ,, Terminal (Pothead)	80
(Assumes 9 Phantom Transpositions—and for terminating.)	
Spindles, Trunk, Wood	520
,, ,, Steel, ⅝″	40
,, Tl., J	80
,, Tr., Double	20
(Assumes 20 non-phantom Transpositions.)	
Bands, terminal, ⅝″	72
Bolts, 4″ x ½″ (for bands)	36
,, 4½″ x ½″ (for Double Spindles)	20
Screws, coach, 2½″ x ⅜″	20
Cable, P.I.L.C., 1 wire/.044	80 yds.
1 pair/.044	12 yds.
Compound, sealing	5 to 6 lbs.
Wire, soft copper, 50 lb.	25 lbs.
Tapes, copper, 100/200	604
Sleeves, 200 C.	100
Clips, cable	200
Sundry items, solder, etc.	

Labour.

Description.	Avge. Adopted.	Qty.	Man-hours.
Erect poles, soil	4	120	480
Erect poles, rock	7	41	287
Lay out poles	1	161	161
Fit poles	1	161	161
Fit arms	.5	161	80
Fit braces	.25	161	40
Stays soil	4	38	152
Stays rock	6	12	72
Creosote poles	.33	161	54
Erect wire	15	20	300
Transpositions	1	20	20
Pothead transpositions	3	9	27
Bridle leads on T poles	.5	4	2
Supervision	3%	R	66
Travelling	5.5%	R	121
Clerical	2.5%	R	55
Material handling	4%	R	88
Material lay out	4%	R	88
Driving motor vehicle	2%	R	44
TOTAL			**2210**

Incidentals.

Incidentals will include allowance for the following: —Cartage, Freight, Truck Hire, Local Purchases, Plant Upkeep.

Q. 6.—Describe the method you would adopt to capacity balance a trunk cable, and state what instruments you would require for the work.

What are the reasons for doing this work?

A.—The procedure adopted in capacity balancing a trunk cable is as follows:—

(1) The drum lengths of cable are drawn into ducts or laid in the ground, as the case may be, gas pressure tested and I.R. check tests made.

(2) The capacity balancing is carried out over loading coil lengths, and in the preliminary layout of the

drum lengths the loading section must be divided into 16, 12, 10, 8 reasonably equal lengths.

(3) The number of test lengths selected will be dependent firstly on the loading section layout as referred to in (2), and secondly on the final limiting capacity unbalance conditions. The more stringent the capacity unbalance conditions (and consequently crosstalk) the greater the number of sections required. Normally 8 or 10 test and selection points in a loading section of 2000 yards will be satisfactory. Fig. 1 illustrates an 8-length section.

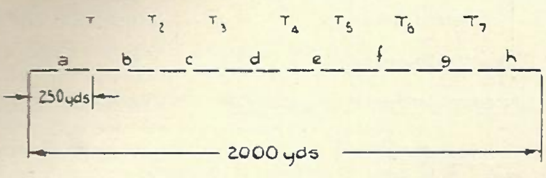


FIG 1

(4) The preliminary jointing together of the intermediate lengths (a case where the cable is laid in ducts—with armoured cable a full 200 or 250 yard length will probably be laid in one section) at a, b, c . . . . should be made by selection from factory test sheets of capacity unbalance.

(5) Capacity unbalance tests on quads are now carried out at points T_1, T_2 . . . . on an A.C. bridge termed a "capacity unbalance set." Two types of set are in general use—the "double bridge" and the "single bridge." The latter does not provide for separate measurement of wire to wire capacities independent of earth unbalances, but is sufficiently accurate for all normal cable balancing work and has the advantage of greater speed in operation. The "single bridge" will be considered in the present instance.

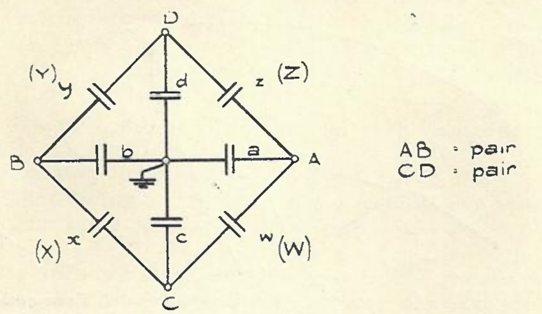


FIG. 2

(6) The capacities concerned in the network formed by the four wires of a quad are as shown in Fig. 2.

The resultant wire to wire capacities are designated W, X, Y, Z, and the "side" to "side" and "phantom" to "side" capacity unbalances as measured by the single bridge by:

$$P + Q = W - X + Z - Y$$
$$R + S = W - Z + X - Y$$

for phantom to side unbalance, and

$$P - Q = W - X - Z + Y$$
$$\text{or } R - S = W - X - Z + Y$$

for side to side unbalance where:

$$P = W - X$$
$$Q = Z - Y$$
$$R = W - Z$$
$$S = X - Y.$$

For no crosstalk, the following conditions apply:

$$P + Q = W - X + Z - Y = 0$$
$$R + S = W - Z + X - Y = 0$$
$$R - S = P - Q = W - X - Z + Y = 0$$
$$\text{whence } W = X = Y = Z.$$

(7) The schematic circuits of the "single bridge" for measurement of side to side and phantom to side capacity unbalance are illustrated in Figs. 3a and 3b respectively.

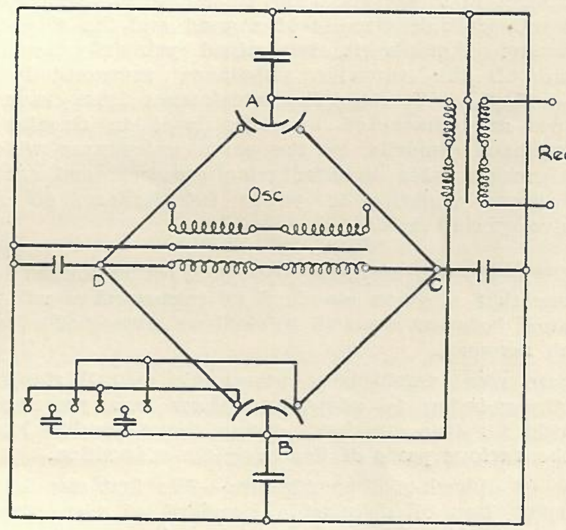


FIG. 3A Side to side

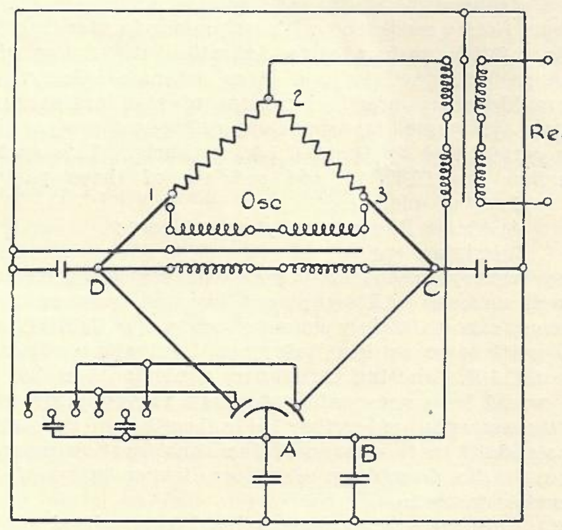


FIG 3B. Phantom to side

Apart from the bridge an oscillator, screened connecting lead and a Megger will be required.

(8) After measurement of the capacity unbalances at points T_1, T_3, T_5 and T_7 (Fig. 1), a careful selection of quads is made to reduce the resultant as near as practicable to the above ideal. By joining the conductors of the two quads together in an appropriate manner, any one of the three unbalances in one quad may

be made to subtract from the similar unbalances in the other quad. After completion of tests at T_1, T_3, T_5 and T_7 a similar test and selection is made at T_2 and T_6 and finally at T_3.

(9) After the final jointing up crosstalk tests should be made to check the results of the capacity balancing. Check tests should also be made of earth unbalances —these can be measured by a suitable modification of the "single bridge."

The principal object of capacity balancing testing is the reduction of crosstalk and interference. The crosstalk between side circuits of a quad and the side circuits and phantom is determined primarily by the extent of the capacity unbalance represented by W — X, Z — Y, etc. The interference from external sources as represented by noise level on circuits is determined primarily by the earth unbalances which, with present cable manufacturing processes and except for severe exposure to power interference, do not require special tests.

Q. 7.—State briefly the principles to be followed to ensure that a given standard of transmission will be attained between any two subscribers connected over a trunk network.

State what would be a reasonable overall standard of transmission to adopt and show how you would provide for this standard, giving the allowable losses in the various parts of the complete connection.

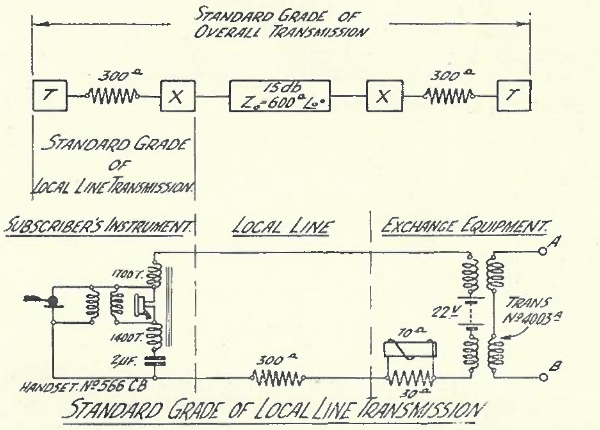
A.—Standard of Transmission:—The first step is the determination of a suitable standard of transmission for conversation between any two subscribers, remembering that such a standard must necessarily be a limiting rather than an average condition. In broad terms, transmission is satisfactory when two subscribers can converse without misunderstanding or strain. With such a wide definition the fixing of a particular standard is to a large extent arbitrary, and to provide some practical system of standardisation a master telephone transmission reference system has been established by the C.C.I.F. in Paris. This system is called the SFERT, and consists of three parts—

Sending end;
Artificial line normally set at zero;
Receiving end.

Comparison between sending system, receiving systems, as well as lines and equipment inserted between these systems, can ultimately be referred to the SFERT. and a figure known as the Reference Equivalent obtained. The C.C.I.F. limiting reference equivalent is 30 db. and would be a reasonable standard to adopt for overall transmission subscriber to subscriber. In setting the standard in this manner, due consideration must be given to the degrading effects on transmission of the following factors:—

(1) Limitation of frequency band transmitted.
(2) Circuit noises.
(3) Room noises, both at speaker's and at listener's end.
(4) Variations in speech power delivered to transmitter.
(5) Transient phenomena.

In the case of a trunk connection the distribution of the standard equivalent between the trunk portion of the circuit and the subscriber's portion is determined primarily by the economics of trunk and subscriber's circuit provision. A reasonable subdivision on this basis provides for a 15 db. allowance for line and equipment in the trunk connection. The remainder of the allowance is taken up in the subscriber's connection, which is defined by the circuit conditions shown in Fig. 1.



Transmission Layout.

Trunk Network:—With an allowable limit of 15 db. on the trunk portion of the connection the next step is to provide for the limits to be applied to the various links making up this trunk connection. Arising out of the variety of connections which may be set up, it is necessary to divide up the network into zones served by an important trunk exchange, called the zone centre, to which the other exchanges, called terminal exchanges, are connected. See Fig. 2. The terminal exchange may be a country exchange or a branch or main exchange of a multi-exchange network.

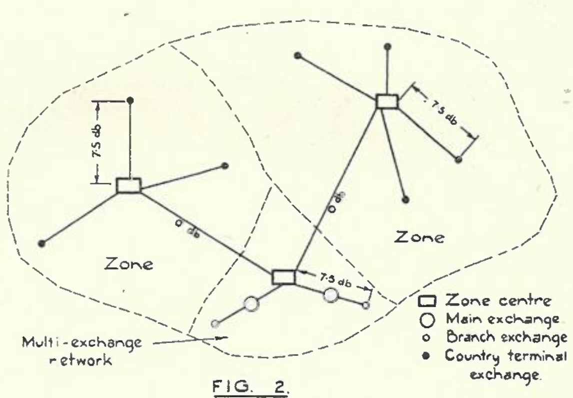


FIG. 2.

The arrangement illustrated provides for the whole of the available equivalent to be associated with the zone centre to terminal exchange link. This necessarily means the provision of zero loss circuits between zone centres and permits the connection of more than one such link in tandem without exceeding the allowable limit.

Subscribers' Network:—As the efficiency of the transmitting and receiving conditions varies appreciably with the telephone circuit and battery feeding bridge arrangements, it is necessary to relate the limiting subscribers' loop conditions with any variation of these from the standard shown in Fig. 1. For example, with the C.B. No. 1 solid back transmitter and 200 ohm/200 ohm 48 volt battery the limit is 300 ohms; with No. 10 inset transmitter, 200 ohm/200 ohm 48 volt battery feed the limit is 440 ohms, while with a No. 10 inset transmitter 50 ohm/50 ohm 48 volt ballast resistor the limit is 540 ohms. Extending this principle, limits are derived for P.B.X. conditions, magneto exchange services, and other forms of subscribers' services.

The principles to be followed are:—

1. Trunk Network.

(a) Between zone centres requiring zero loss, 4-wire circuits will be necessary. On aerial routes these will generally be provided by 3-channel or single channel carrier systems, and on underground cable routes by physical pairs, single channel carrier, 4-channel carrier or 12-channel carrier systems.

(b) For zone centre to terminal exchanges, two-wire circuits will be suitable, the use of heavier conductors on aerial circuits and heavier conductors and improved loading on underground cable circuits in comparison with light gauge conductors and repeaters, will be necessary.

(c) Establishment of a system of routine transmission tests on the trunk network.

2. Subscribers' Network.

(a) Design of subscribers' line distribution to provide suitable loop resistance conditions.

(b) Consideration of existing and new subscribers' telephone equipment in relation to standard transmission requirements. This particularly applies to the transmitter, requiring considerations of solid back and inset type transmitters, pedestal type telephone and handset type, etc.

(c) Consideration of new or alteration to existing equipment involving ballast resistors, feeding bridges and local battery telephones with two or three cells as alternatives to heavy conductor cables and bunched pairs, in the provision of cable.

(d) Maintenance of equipment in such a manner as to retain standard conditions.

(e) Loading of subscribers' circuits in cable.

(f) Consideration of room noise conditions, circuit noises and other similar interference.

Q. 8.—State what information you would require and show how you would proceed to prepare a transposition scheme for an aerial trunk route.

Is any alteration in transposition design desirable when it is proposed to use a number of carrier systems on an aerial route?

If so, what is the general nature of the alteration and what is the reason for it?

A.—The essential information required for the preparation of a transposition scheme falls under the following headings:—

(1) Traffic development—Telephone; Telegraph; Broadcasting.

(2) Method of provision of traffic requirements—Voice frequency: Physical; Phantom. Carrier frequency: Single channel; Three-channel; Broadcast; Telegraph.

(3) Details of pole spacing, long spans and sections of intermediate cable and location of transpositions on an existing route. In the case of an existing route consideration must be given to existing pole locations and existing transpositions insofar as a compromise may be necessary between the theoretically desired pole and transposition layout and existing conditions. In the case of a new route, it is important to know details of the pole spacing, taking into account the extent of irregularities introduced by being unable to locate poles in their theoretical position, e.g., the centre of a roadway, river crossings, etc., sections of intermediate cable and long spans.

(4) Details of power parallels, including type of circuit separation, transformers, branch lines, or other form of impedance change, transpositions and configuration of wires.

The preparation of a transposition scheme would involve the following:—

(a) Preparation of development plan showing the method of provision of circuits over the life of the pole route, including a tentative allocation of carrier systems. From this information would be determined the number of arms to be provided at 14″ vertical and 14″ horizontal spacing and at 28″ vertical and 9″-18″-9″ horizontal carrier spacing.

(b) Layout of transposition sections along the route co-ordinating the section length with the discontinuities determined by telephone circuit conditions and associated power parallels. The transposition section lengths will be determined on nominal span combinations of—256, 128, 64 or 16 spans, for which a nominal span length of 55 yards has been assumed in the estimation of crosstalk conditions, preference being given to the longer sections.

(c) Having laid out the route in transposition sections, it is now necessary to design the transposition pattern for the required carrier and V.F. crosstalk conditions, taking into consideration the effect of variations from nominal span lengths, irregularities in transposition location, etc. The normal crosstalk design limit for aerial line circuits is 60 db., due regard being paid to power levels and staggering advantages.

Carrier Transpositions.

There is an essential difference in the transposition requirements for V.F. and for carrier conditions. For V.F. work the limiting frequency to be considered can be taken as 3 Kc., whereas for single channel carrier the limiting frequency becomes 10 Kc. and for three channel systems 30 Kc. Over this range of frequency the crosstalk between two aerial line circuits increases appreciably with increase in frequency. In consequence, a high standard of crosstalk, involving reduction of coupling coefficients by variation of wire and arm spacing, and in the transposition design an increase in the number of relative transpositions between circuits is necessary for carrier operation. Apart from the increase in transpositions, it is necessary to give consideration to the characteristics of the carrier systems, such as the staggering advantage between systems, orientation of systems so that similar bands of frequencies transmit in the same direction, suppression or transmission of the carrier frequency, etc. Decreased coupling coefficients are obtained by providing 9″ horizontal spacing between wires of a pair, 18″ between the nearest wires of adjacent pairs and 28″ spacing between arms. An increase in the relative transpositions between circuits is obtained by increasing the number of transposition poles.

For average conditions the provision on a pole route for carrier operation as compared with V.F. operation represents, apart from variation in transposition patterns, increases in transposition poles of the following order:—

	V.F.	Carrier.
256 span section	32 (may require 64 for more than 4 arms)	64 (may require 128 for severe conditions)
128 span section	16	32
64 span section	8	16
16 span section	4	8

Q. 9.—Prepare a detailed estimate showing quantities of material and manhours of labour, but no prices for the provision in a suitable pipe of a cable to serve a newly opened dead-end street.

Twenty houses occupying the whole of the available land are in course of erection, ten on each side of the street. Each house may be considered a telephone possibility. The street is 220 yards long and no Departmental plant exists in it.

A.—The arrangement of conduit and cable plant assumed for the purpose of the estimate is shown in Fig. 1.

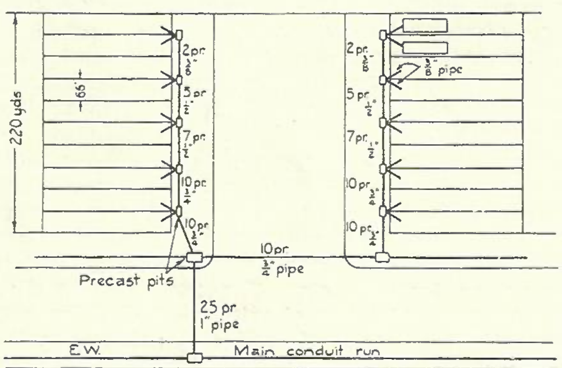


FIG. 1

Material.

(1) **Conduit.**

Item.	Quantity.
Pits, jointing, 18" x 9" x 9"	10
,, ,, 18" x 9" x 18"	2
Pipe, G.I., 1"	66'
,, ,, 3/4"	440'
,, ,, 1/2"	528'
,, ,, 3/8"	924'
Bushes, Pipe, 1"	2
,, ,, 3/4"	10
,, ,, 1/2"	8
,, ,, 3/8"	44
Clips and Sundries.	

(2) **Cable.**

Cable, P.I.L.C., 25 pr./10	28 yds.
,, ,, 10 pr./10	116 yds.
,, ,, 7 pr./10	92 yds.
,, ,, 5 pr./10	92 yds.
,, ,, 2 pr./10	92 yds.
Cable, E. & C.C., 1 pr./10	440 yds.
Lead, sheet, 4 lb.	3 to 4 lbs.
,, sheathing (10" x 1" and 10" x 3/4" internal),	10 pieces
Solder, 50/50	4 lbs.
,, 66/34 (wiping metal)	2 to 3 lbs.
Sleeves, paper, No. 3	200
,, ,, No. 2	50
Paper, brown strip	10 yds.
Thread	1 reel
Kerosene or petrol	2 qts.
Sundries, resin, stearine or tallow, etc.	

Labour.

Conduit.

Description.	Qty.	Average used.	Manhrs.
Excavation soil	40	3.0	120
Filling in	40	1	40
Reinstatement	20	.75	15
Lay iron pipe	1958	.03	59
Lay precast pits	12	2	24
Alter manhole	1	2	2
Recording units	—	15% approx.	40
Supervision, travelling, records, clerical and lay-out material.			
			300

Cable.

Description.	Qty.	Average used.	Manhrs.
Draw in cable	680	.05	34
Test cable	1	1	1
Test and number	60	.06	4
Identify	25	.17	4
Joint	100	.08	8
Plumbing	13	1	13
Take off sleeve	1	1	1
Test circuits	20	.25	5
Erect cable on walls	220	.10	22
Recording units	—	15% approx.	20
Supervision, travelling, records, clerical material, lay-out, etc.			
			112

Total Manhours likely to be anything from 400 to 600, according to local conditions.

Reinstatement might be several times higher, depending upon type of surface to be restored.

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All remittances should be made payable to "The Postal Electrical Society of Victoria," and not negotiable.

Ruskin Press Pty. Ltd.
123 Latrobe Street
Melbourne